AN ANALYSIS OF ROADS, TRAILS, AND ROADLESS AREAS ON THE SUPERIOR NATIONAL FOREST, MINNESOTA

Pacific Biodiversity Institute

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The Superior National Forest provided most of the data used in this analysis. Kendall Cikanek, GIS Coordinator for the Forest, was extremely helpful in responding to requests for GIS data and spent considerable time providing detailed responses to questions we had regarding the Forest's GIS and other data. We made extensive use of 2003 color orthophotos obtained online from the USDA Farm Service Agency. We also obtained land use-land cover data from the Minnesota Department of Natural Resources' Internet site and used this in our roadless area mapping.

Cover photo is by Jamie Juenemann.

PROJECT FUNDING

This project was funded by Defenders of Wildlife, Washington D.C.

EXECUTIVE SUMMARY

Roads have strong ecological impacts, affecting habitat fragmentation, hydrologic functioning, soil erosion, wildlife movements, and many other issues. In order for natural resource managers to adequately understand and address these issues, reliable information on roads is needed.

We evaluated the quality of data related to roads, trails, and roadless areas that is maintained by the Superior National Forest (SNF). We assessed the data in two ways. First, we examined the internal consistency of their data and information derived from that data as reported in Superior National Forest documents. We compared original RARE II roadless areas with roadless data compiled by the SNF in 2000 and provided to the Forest Service at a national level for its Roadless Area Conservation Plan. We also compared roads as mapped in the Forest's GIS Travel Routes and OHV Roads layers.

Second, we compared the Forest Service data to conditions on the ground. We used 2003 color orthophotography for this comparison and also conducted some fieldwork. We created data layers of roads/trails visible in the orthophotos but undocumented by the SNF's data. We also created a data layer of actual roadless areas, using the best available roads information, and compared this to SNF roadless data.

We found numerous problems with the SNF's roads, trails, and roadless area data. Problems include inconsistent and incomplete mapping of roads and roadless areas, poor spatial accuracy and classification accuracy of some roads and trails, and a high proportion of unclassified roads. We document many examples of these problems through maps of Forest Service data overlaid on orthophotos.

We also demonstrate several situations where, by simply reviewing the Forest's GIS data in relation to orthophotography, we were able to provide substantial improvements to their data. Analysis results based on our improvements to the Forest Service data lead to dramatically different conclusions about the miles of road, road density, and acres of roadless areas on the National Forest than those reached without the improvements.

For the area of National Forest (excluding the Boundary Waters Canoe Area) covered by the 2003 orthophotos, the most recent Forest Service data shows 2,071 miles of road with a road density of 1.33 miles per square mile. Using our data improvements we calculated 2,657 miles of roads with a road density of 1.70 miles per square mile – a 28% increase in road miles and density. The Forest Service's RARE II roadless areas and Inventoried Roadless Areas under the Roadless Area Conservation plan each map between 64,000 and 69,000 acres of roadless lands (though in different locations). Using improved roads data and a clear methodology for consistent mapping of roadless areas, we found 298,294 acres of roadless lands within roadless areas of 5,000 acres or greater. In addition, we found many smaller roadless less than 5,000 acres in size.

Our staff has evaluated the quality of both road and roadless area maps and related GIS data in all National Forests of the United States. The road data and the data on roadless

areas in the Superior National Forest stand out as some of the most inaccurate information in the entire National Forest System. The many problems we found with the Superior National Forest's roads, trails, and roadless area data have the potential to greatly compromise the reliability of transportation-related analyses and other assessments that the National Forest may make, based on the data.

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INTRODUCTION

It is widely recognized that roads have strong impacts on forest ecosystems. Roads affect habitat fragmentation, hydrologic functioning, soil erosion, wildlife movements, dispersal of invasive species, mortality of wildlife from vehicle collisions, patterns of insect and disease infestation, and many other issues (Ercelawn 1999). In order for natural resource managers to adequately understand and address these issues, reliable information on roads is needed.

Because of the significance of roads and trails for recreational and commercial activities as well as ecological issues, the Forest Service requires that each National Forest maintain current information on roads and trails. The National Forests have also been directed to evaluate the efficiency of their transportation networks for meeting transportation needs on the Forest while minimizing ecological impacts.

To comply with this directive and inform the Superior National Forest's Land Management Plan revision process, the Superior conducted a Road Analysis Process (SNF 2002). The Forest maintains GIS layers of roads and trails, and recently released a GIS layer and map of roads with their OHV use status (September 2004).

The objective of this project was to evaluate the quality of data related to roads and roadless areas that is maintained by the Superior National Forest. The ability of the Forest Service to make good natural resource management decisions depends greatly on having reliable data and analyses on which to base those decisions.

METHODS

We assessed the quality of the Superior National Forest's (SNF) roads and roadless area data in two ways. First, we examined the internal consistency of their data and information derived from that data as reported in Superior National Forest documents. Second, we compared their data to conditions on the ground. We used 2003 color orthophotography for this comparison and also conducted some fieldwork.

Data Descriptions

We obtained all GIS data on roads, trails, and roadless areas from the Superior National Forest in the spring of 2004, with the exception of an OHV Roads layer, which was obtained upon its release in September 2004. We recognize that all these data are continually updated as road and trail status changes. This report focuses on systemic problems that we found with the SNF's data rather than a few isolated errors that may have easily been updated between the release of this report and the time that we acquired the data.

Descriptions of the roads, trails, and other primary GIS data used in this assessment are provided below. In addition, a few other GIS layers were incorporated into the roadless area evaluation and these are referenced in the roadless area section of this report.

Roads

Travel Routes – This data layer contains classified and unclassified roads. Categories of classified roads that were assigned by the Forest Service and used in this report are: Primary road, Secondary road, Light Duty road, Unimproved road, and Unclassified road. In addition, there are some roads with no assigned category. As defined by 36 CFR 212.1 Unclassified Roads are:

> Roads on National Forest System lands that are not managed as part of the forest transportation system, such as unplanned roads, abandoned travelways, and off-road vehicle tracks that have not been designated and managed as a trail; and those roads that were once under permit or other authorization and were not decommissioned upon the termination of the authorization.

OHV Roads – This layer contains roads, categorized by their OHV status. The Forest Service has 7 categories assigned to roads in this layer (e.g. Non OHV Use Road, OHV All Season Use, State or County Road, etc.), with some roads having no category.

Trails

OHV trails – This layer contains a very small number of trails usable by OHVs that are not contained in the OHV Roads layer. Since almost all areas designated for OHV use are contained in the OHV Roads layer we focused our analysis on that data and did not make use of the OHV trails.

Trails – This layer contains trails, a small portion of which are classified by their primary use. Use types include hiking, biking, hunting/fishing, portage, and other categories. The only motorized use type is snowmobiles.

Roadless Areas

RARE2 – This layer was obtained from the SNF as their official roadless area data. By its name, it presumably contains roadless areas as mapped under the 1976 Roadless Area Review and Evaluation II (RARE II) process.

Inventoried Roadless Areas – These are roadless areas as mapped by the Forest Service in conjunction with their Roadless Area Conservation plan (USDA Forest Service 2000). Data were obtained online at: http://www.roadless.fs.fed.us/.

Imagery

2003 Color Orthophotos – Orthophotos were obtained on-line from the USDA Farm Service Agency for St. Louis, Lake, and Cook counties at: http://www.lmic.state.mn.us/chouse/airphoto_usda.html#fsa

Consistency of Data and Data Reporting

We looked at consistency of the roads and roadless area data from a number of angles. First, we looked at the consistency of mapping and categorizing of features within a given data layer. For example, within the SNF's Travel Routes layer we checked whether the assignment of various road categories (e.g. Unclassified road) was consistent or if a wide variety of road types were inappropriately classified into a single category. Second, we checked for consistency across data layers. For example, we compared the original RARE II roadless data obtained from the Superior National Forest with roadless data compiled by the SNF in 2000 and provided to the Forest Service at a national level for its Roadless Area Conservation Plan. We also compared roads as mapped in the Travel Routes layer with those of the OHV Roads layer. Lastly, we calculated road statistics from the Forest's data and compared these and their current GIS data to statistics and maps of the SNF's 2002 Road Assessment Project and to the 2003 hardcopy Recreation map.

While conducting this review, we found numerous problems with the SNF's roads data. Problems include extremely poor spatial accuracy of some mapped roads and trails and inconsistent categorization and mapping of roads, trails, and roadless areas. As these issues are extremely difficult or time-intensive to assess in a quantitative manner, we documented examples and discuss these issues based on our intensive visual review of the data. Where possible, we conducted quantitative analysis related to these issues for limited areas.

Undocumented Roads and Motorized Trails

We systematically reviewed National Forest lands, mapping roads and motorized trails that are undocumented by the SNF. We measured miles of undocumented roads/trails and analyzed the effects of these on measurements of road density.

We overlaid the SNF's Trails, Travel Routes, and OHV Roads GIS layers on 2003 color orthophotos and on-screen digitized at a 1:10,000 scale roads and motorized trails that were visible on the orthophotos but were not included in any of the SNF GIS layers. In addition, we digitized a few features that were classified by the SNF as trails but were clearly roads. The assessment area included all Forest Service owned lands within the area covered by 2003 orthophotos (Figure 1).

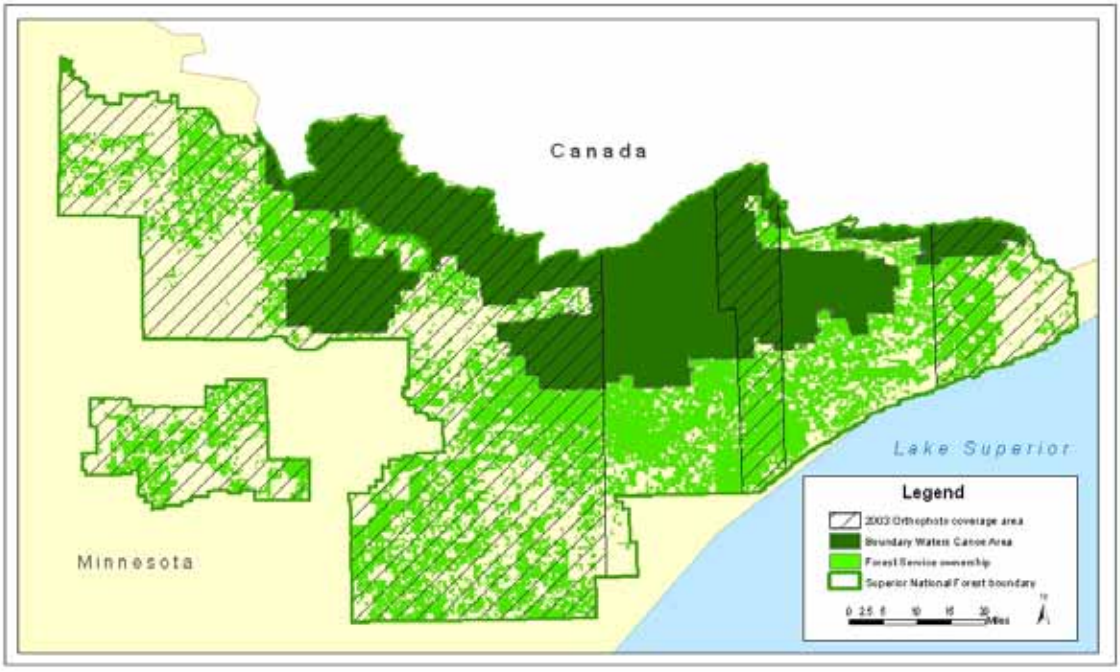

Figure 1. Map of Forest Service ownership and 2003 orthophoto coverage.

We combined the digitized, undocumented roads and motorized trails into a single roads/trails layer. We did this because the Forest Service has a broad definition of trails that includes both motorized and non-motorized trails and it is not possible to reliably differentiate on orthophotos between potential well-maintained motorized "trails" and potential "roads". We did not digitize trails that we thought were not usable by motorized vehicles.

We categorized the digitized features according to the following four categories:

> Level 1 – Roads that appear to be well maintained and in current use. Roads are likely to be passable by cars (unless the entrance is gated or otherwise blocked, which is not detectable on orthophotos)
>
> Level 2 – Roads/trails that are not overgrown but not as well maintained as Level 1 roads. Roads/trails are likely passable by high-clearance vehicles or OHVs.
>
> Level 3 – Roads/trails that are somewhat overgrown but may still provide paths for snowmobiles. Some of these roads/trails may also be passable by some high clearance vehicles or OHVs.
>
> Level 4 - A utility corridor or other swath.

This report focuses on Level 1 and 2 roads/trails, but Level 3 statistics are also reported. Level 1, 2, 3, and 4 features were used in creating a digital layer of roadless lands (see Roadless Areas section below).

To help guide photointerpretation we conducted fieldwork, comparing preliminary photointerpretations with ground truth data for a variety of road/trail types within a sample area. GPS locations were recorded and digital photos were taken at each check point (Figure 2). These were later incorporated into a GIS to provide an on-screen reference for photointerpretation.

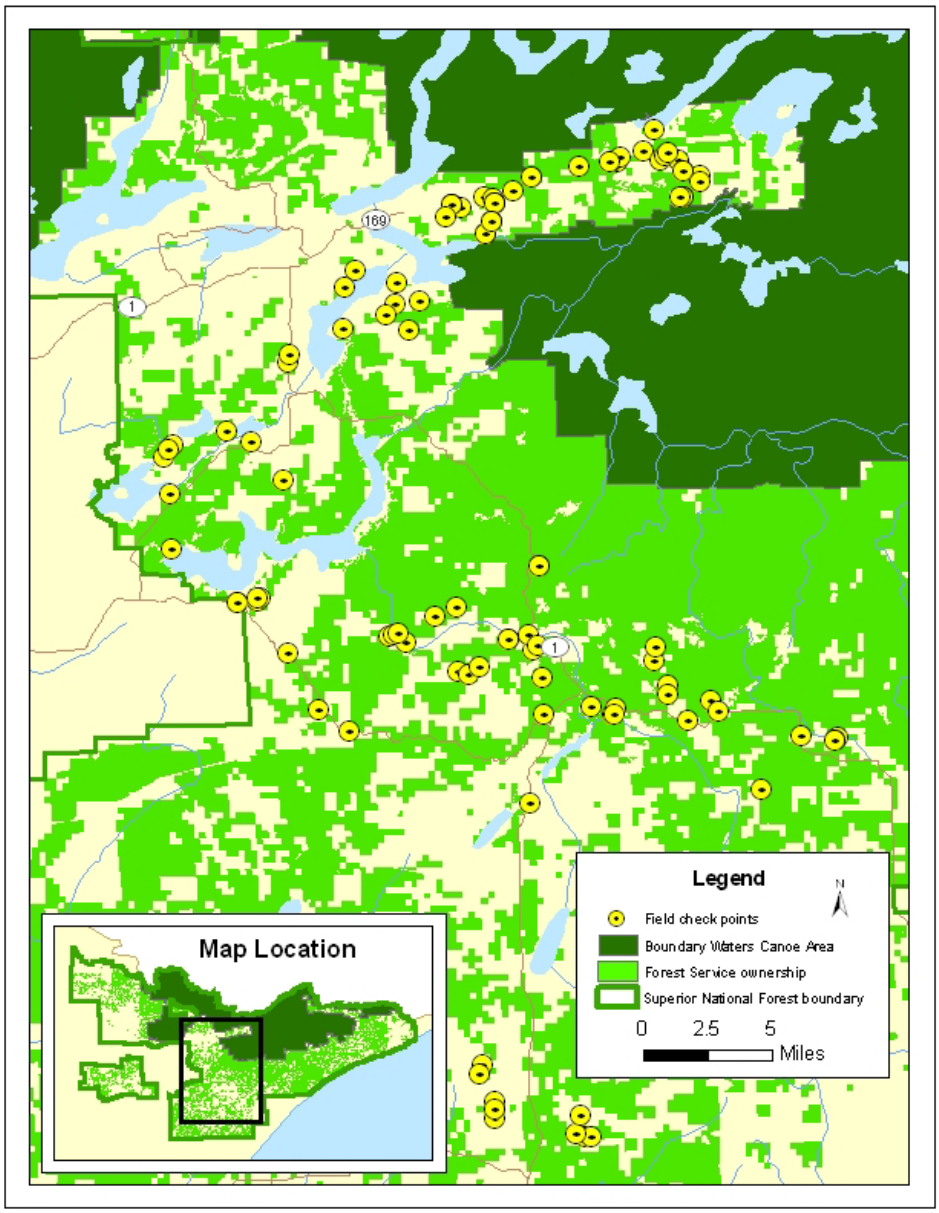

Figure 2. Map of road/trail locations checked in the field.

We used the following guidelines in digitizing and categorizing undocumented roads/trails:

- We attempted to be conservative. For example, if the appropriate level for a feature was questionable, we typically classified it at the lower level. If it was questionable whether a route should be digitized at all, we generally did not digitize it.

- We did not re-digitize roads or trails from the SNF's GIS data that appeared to represent road or trail features visible on the orthophotos, but were simply mis-mapped. Mis-mapped SNF roads and trails were sometimes as far as 250 meters away from their true location.

- We only digitized routes whose path could be traced back to the main road network. In cases where SNF roads and trails were mis-mapped, we connected our digitizing to the true location of the adjacent roads and trails rather than the mis-mapped data.

- We used local context and adjacent SNF mapped roads to aid in photointerpretation. For example, in areas of high canopy closure roads may appear substantially less prominent than in open areas. We used the classification of nearby SNF roads (e.g. Primary road, Light Duty road, etc.) as a guide in photointerpreting and categorizing undocumented features.

Roadless Areas

We used the best available information on roads and other permanent human disturbances to map roadless areas of 1,000 acres or greater on the Superior National Forest. Methods used for mapping roadless areas were similar to those developed during Pacific Biodiversity Institute's first inventory of wildlands in Washington State (Morrison et al. 1998). These methods yield an objective assessment of roadless areas as defined by our input parameters (details provided below).

We compared our roadless area map with Forest Service roadless data. We also compared two sources of Forest Service roadless area data to each other. Forest Service roadless data consists of the 1976 RARE II roadless areas (obtained from the Superior National Forest in 2004) and Inventoried Roadless Areas (IRAs) (USDA Forest Service 2000) as mapped by the Forest Service in conjunction with its Roadless Area Conservation Rule.

Data

The data used to create our roadless area layer are described below.

Roads

We evaluated the Travel Route and OHV Roads data to determine the most complete layer on which to base our roadless area analysis. We chose the OHV Roads since this layer has many roads that are missing from the Travel Route layer and does not have nearly as many roads that, according to the orthophotos, are either completely overgrown or mis-mapped. However, given that the OHV Roads layer is incomplete and does not contain some of the valid roads contained in the Travel Routes data, multiple other sources of information were required to create a reasonably complete and accurate roads layer. We photointerpreted all roads in the Travel Route layer that were not included in the OHV Roads layer and identified those roads that are potentially passable by cars, high clearance vehicles and/or OHVs. We also added in undocumented roads/trails, utility corridors and swaths, and railroads. We compiled the following data into a single roads layer:

1) OHV Roads on National Forest (2,676 miles)
2) Classified and Unclassified roads on National Forest from the Travel Route layer that are not included in the OHV Roads but were determined through photointerpretation to be potentially passable by cars, high clearance vehicles and/or OHVs. (41 miles of Classified roads and 386 miles of Unclassified roads).
3) Roads/trails not documented in the OHV Roads or Travel Routes data that are potentially passable by cars, high clearance vehicles, and/or OHVs and were digitized by PBI (Level 1 - 41 miles, Level 2 – 118 miles, Level 3 - 190 miles. Total 349 miles).
4) Utility corridors and swaths digitized by PBI (Level 4 features) (88 miles)
5) Railroads on National Forest (source: ESRI Streetmap data) (56 miles)

Land Use

We used the Minnesota DNR's 1995 Landsat-based Land Use-Land Cover dataset obtained online at http://deli.dnr.state.mn.us/ to identify all permanently developed land use cover types, including gravel pits/mines, farmsteads and other rural developments, urban and industrial areas, roads, improved trails and rail lines.

Land Ownership and Protection Status

We used ownership and the Boundary Waters Canoe Area obtained from the SNF to identify Forest Service owned lands and protected areas.

Roadless Area Mapping

We defined roadless areas as any area greater than 20 meters from a road that was at least 1,000 acres in size with a minimum width of 400 meters. The calculation of minimum size was made after all developed and permanently disturbed areas (e.g. urban, agriculture, mines, etc.) were removed.

We used a grid cell size of 10 meters for all analyses. Due to the approximation of linear road features by square cells, the actual setback distance from the road will vary somewhat. While a smaller base grid cell size would result in more accurate delineation of roadless areas, the level of accuracy obtained from 10m cells was sufficient for the scale of this project.

We conducted the roadless area analysis on lands owned and managed by the Superior National Forest. Lakes greater than 40 acres, which exist as their own category in the ownership layer, were also included in our analysis area. All other ownerships were excluded.

To delineate the roadless areas, we first calculated those areas greater than 20 meters from any road using a line-distance function. Next, we excluded any permanently developed or disturbed areas as well as major water bodies (Lake Superior). Any areas falling below the 1,000-acre minimum size were then eliminated.

To detect points of a roadless area below 400 meters in width, we used an algorithm to "shrink" and "expand" the roadless areas. This process effectively "pinched off" any narrow necks between larger areas or appendages to a roadless area. After this process, areas falling below 1,000 acres were again eliminated.

The final roadless area grid was converted to a polygon layer. We eliminated the Boundary Waters Canoe Area from the roadless area layer and coded the roadless areas into two size classes - those between 1,000 and 5,000 acres and those over 5,000 acres. This is the final roadless area layer used for mapping and comparison with Forest Service data.

RESULTS

We found significant problems with the Superior National Forest's GIS roads, trails and roadless area data. We also found notable inconsistencies with the GIS roads data and roads data in the Superior National Forest's Road Analysis Process Report (2002) and Recreation Map (2003). The following sections describe and provide examples of problems regarding each of the topics listed below:

1) Inconsistent road maps
2) Unclassified roads and trails
3) Spatial accuracy of road and trail maps
4) Accuracy of road/trail classification
5) Undocumented roads/trails
6) Inconsistencies between GIS roads and the Road Analysis Project Report
7) Inconsistent and incomplete roadless area maps
8) Extensive roading within some mapped "roadless areas"

Inconsistent Road Maps

In this section, we assess the quality and consistency of the SNF's road layers *in relation to each other* and the ability of the Forest Service, based on these data sets, to provide fundamental information on total mileage, location, and density of roads on the National Forest. In later sections we assess in much greater detail the quality and consistency of these data when compared to *actual conditions on the ground*, as interpreted by overlaying the data with 2003 orthophotography.

The Forest Service has 2 primary GIS data layers related to roads: 1) Travel Routes, which contains classified and unclassified roads, and 2) OHV Roads, a new layer (released September 2004) that contains roads categorized by their OHV status (e.g. "Non OHV use road", "OHV all season use", etc.).

We found that both of these layers contain numerous errors and are incomplete when compared to each other and conditions on the ground. More importantly, due to spatial inconsistencies in the data the layers cannot be easily combined to provide a single complete data set from which reliable calculations of total road mileage and road density can be made.

Some of the problems we found with the Travel Routes layer are: 1) the spatial accuracy of some roads is very poor, 2) it does not include many existing, well-maintained roads, 3) it has many Unclassified roads that are so old or so inaccurately mapped that there is no evidence of a corresponding road on recent orthophotography, 4) many Unclassified roads appear to be well-maintained, and at least as prominent as many of the Classified roads, and 5) some of the Classified roads do not correspond to any road visible on recent orthophotography.

The Travel Routes layer covers all ownerships within the Superior NF boundary (Forest Service, private, state, county, etc). As may be expected, the above problems are greatly exacerbated on non-Forest Service lands.

The new OHV Roads layer improves upon the Travel Routes layer by partially addressing some of the problems listed above. However, it does not fully address all of the problems and has some new errors *not* found in the Travel Routes layer. Specifically, the OHV Roads layer improves upon the Travel Routes layer by: 1) improving the spatial accuracy of some roads, 2) including many (but not all) well-maintained roads that were missing from the Travel Routes layer, 3) eliminating some Unclassified and Classified roads in the Travel Routes layer that, when compared to orthophotos, do not appear to exist (Figure 3 – left map shows orthophotography and highlighted areas, right map shows same area overlaid by Travel Routes and OHV Roads data), and 4) further identifying the status of some Unclassified roads, noting roads that exist but should be decommissioned.

Despite these improvements, the OHV Roads layer is still incomplete and contains inconsistencies that make portions of it less accurate than the Travel Routes layer. Many Unclassified roads in the Travel Routes layer that appear in orthophotos to be usable roads or OHV/4WD tracks are not included in the OHV Roads layer. In addition, while the OHV Roads layer *does* contain most of the Classified roads on National Forest lands that also appear as usable roads on the orthophotography, it does not contain all of them (Figure 4). Finally, on non-Forest Service lands within the greater Superior NF boundary, the OHV Roads layer does not include many Classified roads documented in the Travel Routes layer. Which Classified roads are included or not included in the OHV Roads layer appears to be arbitrary and inconsistent (Figure 5).

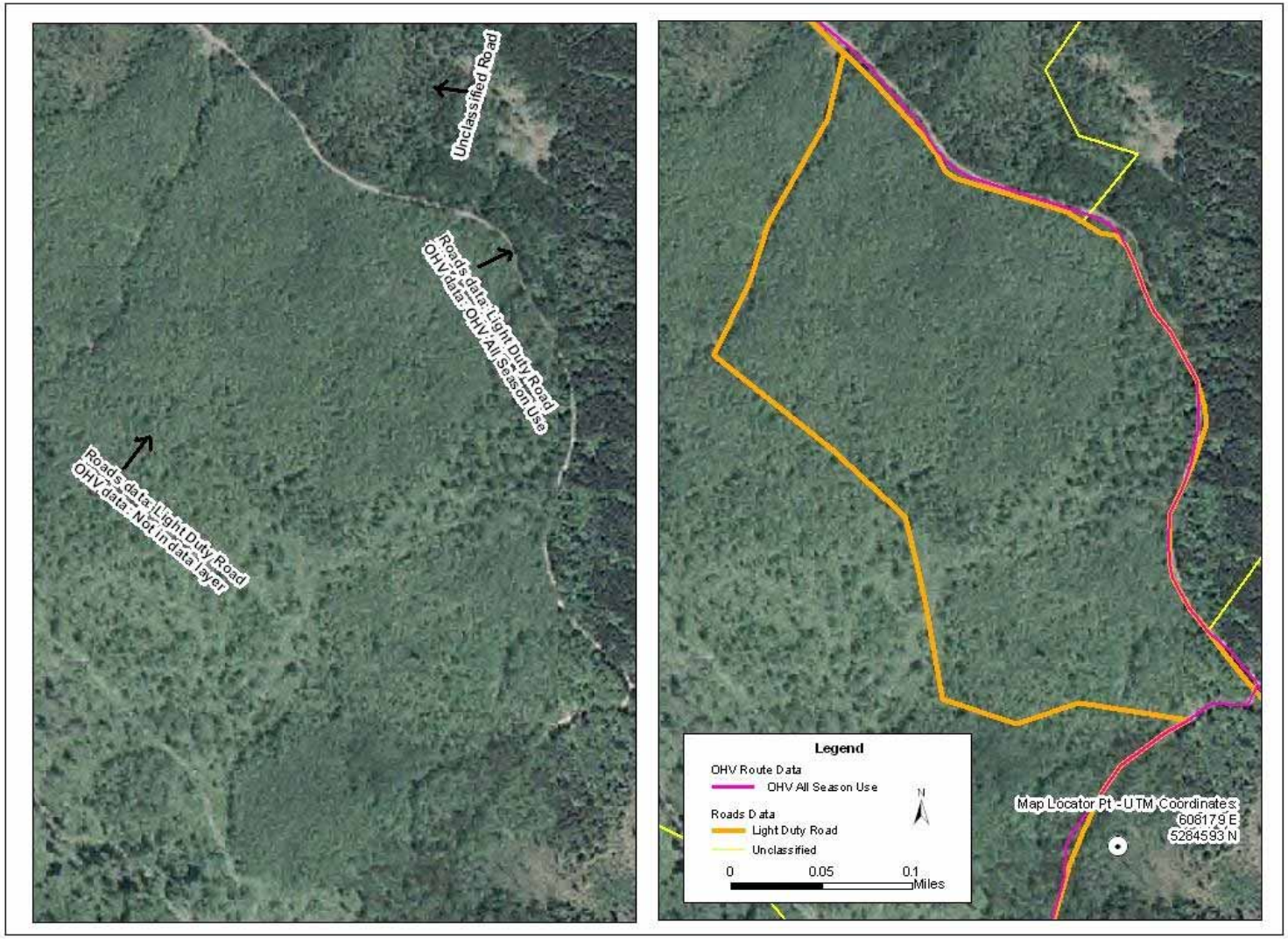

Figure 3. Paired maps showing an area where the OHV Roads layer corrects inappropriate mapping of a Classified road in the Travel Routes layer (Travel Routes data is referred to as Roads data in the figure).

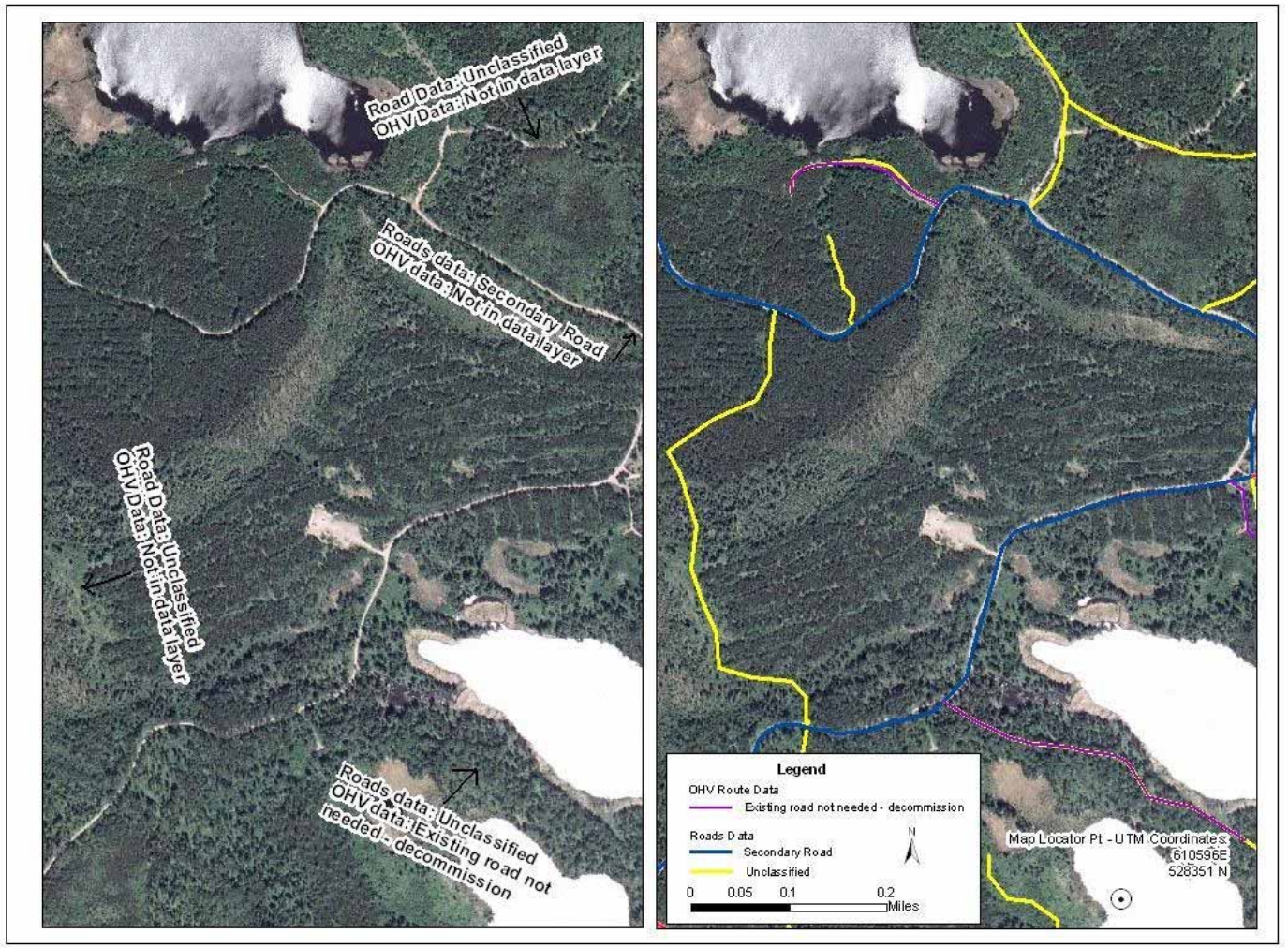

Figure 4. Paired maps showing an existing road on Forest Service owned land that is included in Travel Routes layer but not included in OHV Roads layer. (Travel Routes data is referred to as Roads data in the figure).

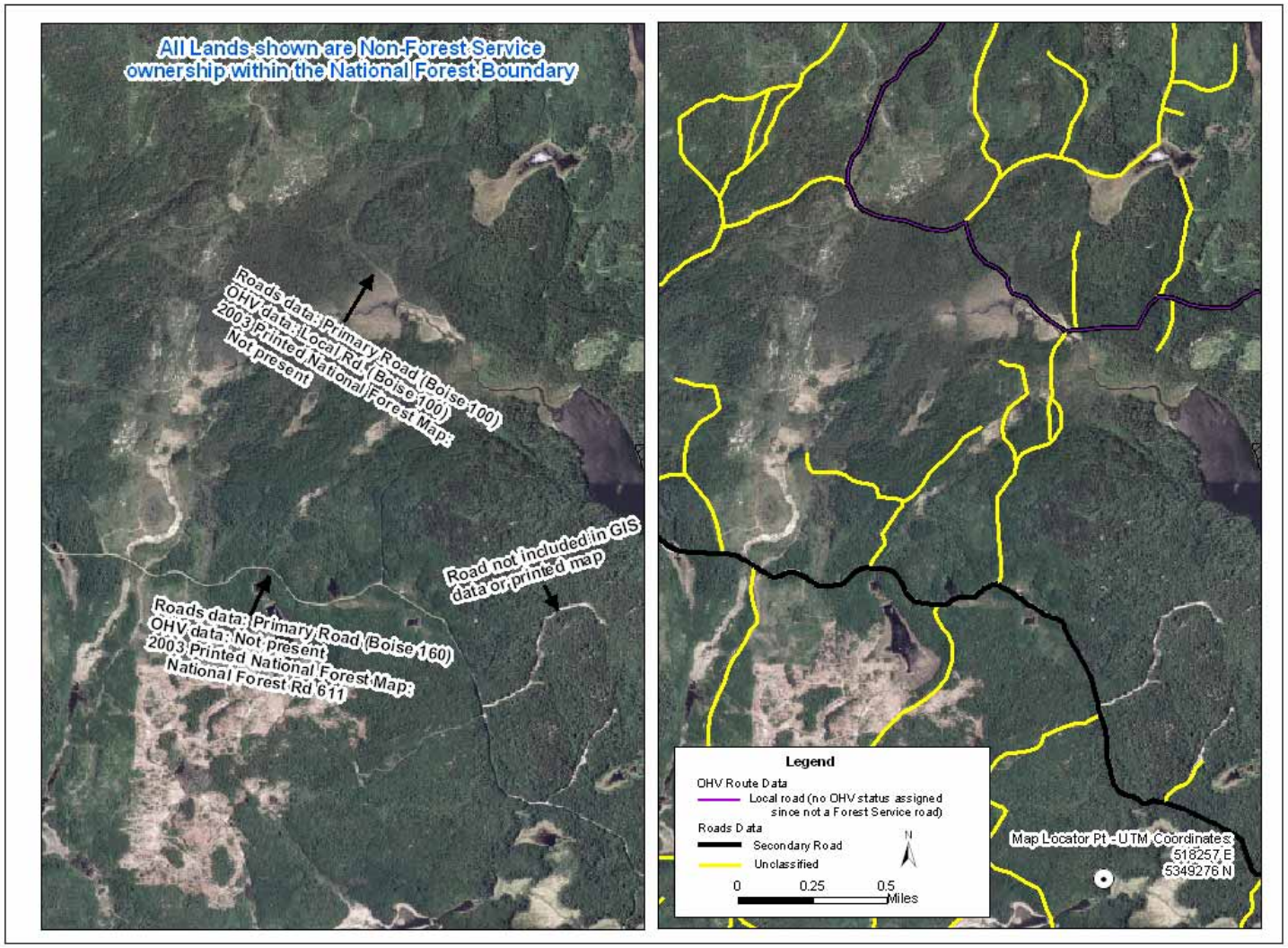

Figure 5. Paired maps illustrating inconsistency of mapping of Classified roads on non-Forest Service ownership within National Forest boundary (Travel Routes data is referred to as Roads data in the figure).

Because of the problems discussed above, the Forest Service has two incomplete, and differently flawed road layers that cannot be easily combined without duplicating or eliminating valid road mileage. Because the mapped location of a road is sometimes different on the OHV Roads layer than the Travel Routes layer it is not possible to automatically identify which roads are missing from one layer or the other by simply overlaying them. In addition, it is not possible to cross-reference these by their road number since many of the roads are not classified. Some automated methods can be used to preliminarily identify missing data from one or the other layer but to do a good, reliable job requires a significant amount of examination and manual categorization of roads. Even if the National Forest did combine these data to create a new layer with the "best" information from both layers, we found significant problems with Unclassified and undocumented roads that would still prevent a combined layer from accurately portraying the road system. These problems are discussed in detail in the following sections.

Unclassified Roads and Trails

Some of the greatest problems with the SNF's data are related to the massive network of Unclassified roads in the Travel Routes layer. Unclassified roads, as defined by 36 CFR 212.1 are:

> Roads on National Forest System lands that are not managed as part of the forest transportation system, such as unplanned roads, abandoned travelways, and off-road vehicle tracks that have not been designated and managed as a trail; and those roads that were once under permit or other authorization and were not decommissioned upon the termination of the authorization.

According to the SNF's GIS data, 52% of the total road mileage on the National Forest is Unclassified (Table 1). Superior NF staff have gone through old records, performed aerial photo interpretation, and used the knowledge of engineering staff to perform mapping work with Unclassified roads (Kendall Cikenak, GIS Analyst for the SNF, pers. comm.).

Table 1. Miles of road by type on the Superior National Forest.

Type	Miles	% of total mileage
Unclassified	3,341	52%
Unimproved Road	782	12%
Light Duty Road	1,014	16%
Secondary Road	214	3%
Primary Road	1,101	17%
TOTAL	6,452	100%

We examined the Unclassified roads in relation to 2003 orthophotography and found categorization of these roads to be highly inconsistent. When viewed as an overlay on the orthophotography, it is clear that Unclassified roads represent a wide variety of road types and conditions, from completely overgrown to current, well-maintained roads. Figure 6 shows two extremes of roads that are both categorized as Unclassified.

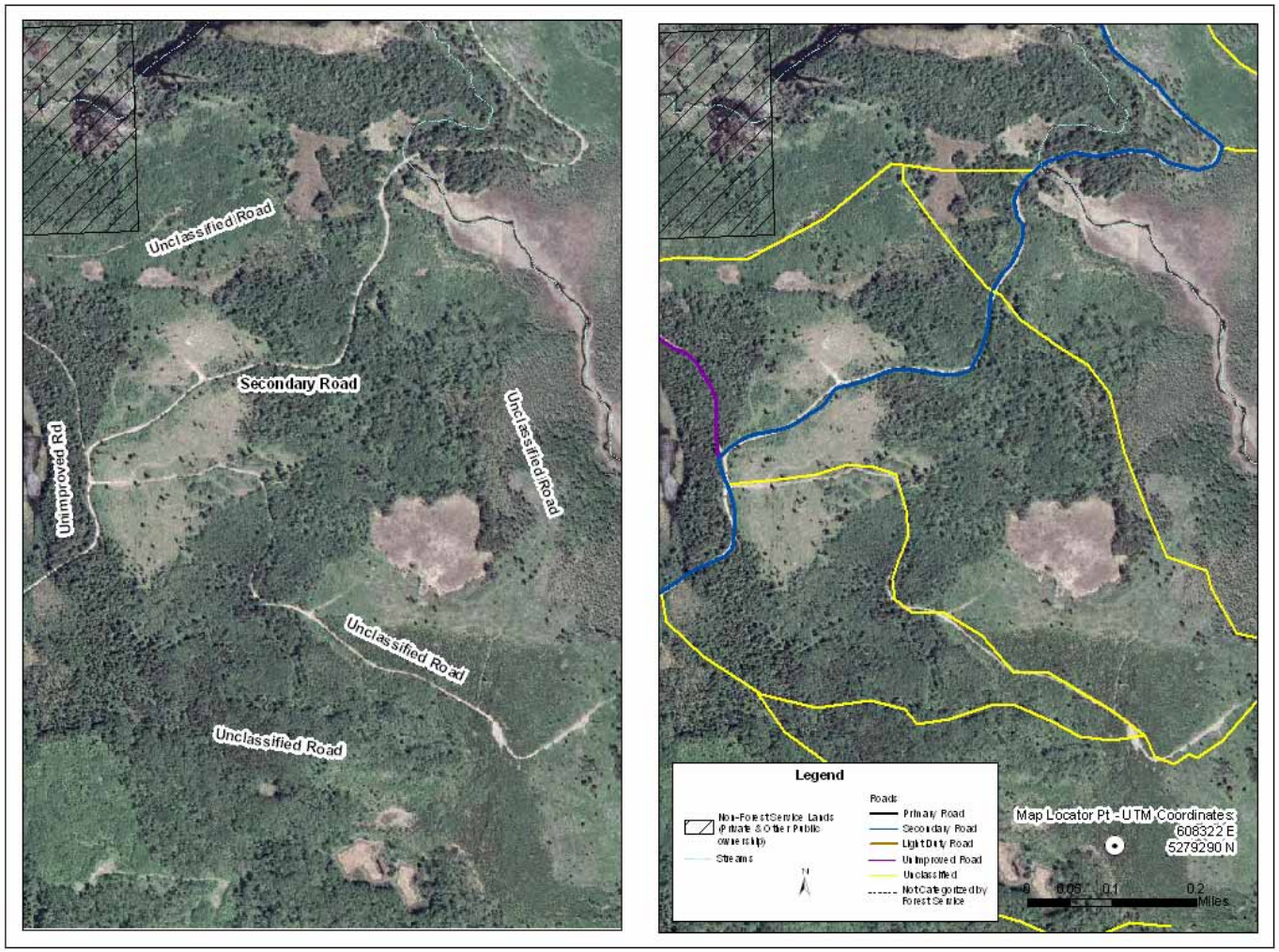

Figure 6. Paired maps showing example of variety of road types categorized as Unclassified in the Travel Routes layer. On the orthophoto, the Secondary road, Unimproved road, and one of the Unclassified roads all look quite similar. Other nearby Unclassified roads are completely overgrown.

In conjunction with refining our roadless area mapping (see roadless area section for details) we viewed and quickly categorized 2,024 miles of Unclassified roads that intersected our preliminary roadless area layer. We categorized the Unclassified roads into one of three classes based on their appearance in the orthophotos: 1) No road or trail, 2) Old road or trail not passable by car, truck, or OHV, and 3) Road or trail passable by car, truck, or OHV. We found that 71% of Unclassified roads had no visible road or trail associated with them. These roads are either extremely overgrown or mis-mapped. 23% of Unclassified roads appeared to be usable by cars, trucks, and/or OHVs, while 6% represented visible roads or trails that are somewhat overgrown and likely not passable by cars, trucks, or OHVs.

Table 2. Categorization of Unclassified Roads from photo interpretation. Most Unclassified roads have no visible trace of a road or trail on the 2003 orthophotos.

PhotoInterpreted Class	Miles	% of Total Miles Evaluated
No road or trail	1,433	71%
Old road or trail not passable by car, truck, or OHV	118	6%
Road or Trail passable by car, truck, or OHV	473	23%
Total Miles	2,024	100%

We did not quantitatively assess the problem of Unclassified roads on lands adjacent to National Forest, but based on visual review the problem of inconsistent categorization is even greater, with many more Unclassified roads actually being current, well-maintained roads. This is particularly noticeable in areas around lakes and other nearby private development.

Spatial Accuracy of Roads/Trails data

We found the spatial accuracy of the roads and trails data to be highly variable and in some places, extremely poor. The original source for the roads and trails data was 1:24,000 USGS Cartographic Feature Files (CFF) and there have been six or seven years of local edits performed on those files (Kendall Cikenak, GIS Analyst for SNF, pers. comm.). Given this history, variation in spatial accuracy is expected. However, one would expect that accuracy should have improved over time with new local edits having a reasonably high degree of accuracy and the most egregious spatial errors from the original CFF data being corrected.

We did not conduct a quantitative assessment of spatial accuracy, which would be a large and complex task. We did however, record locations of particularly inaccurate road and trail locations in our GIS as we were evaluating other aspects of the SNF's road and trail data. We found many examples of poorly mapped roads and trails, some as much as 500+ meters from their true location (Figure 7).

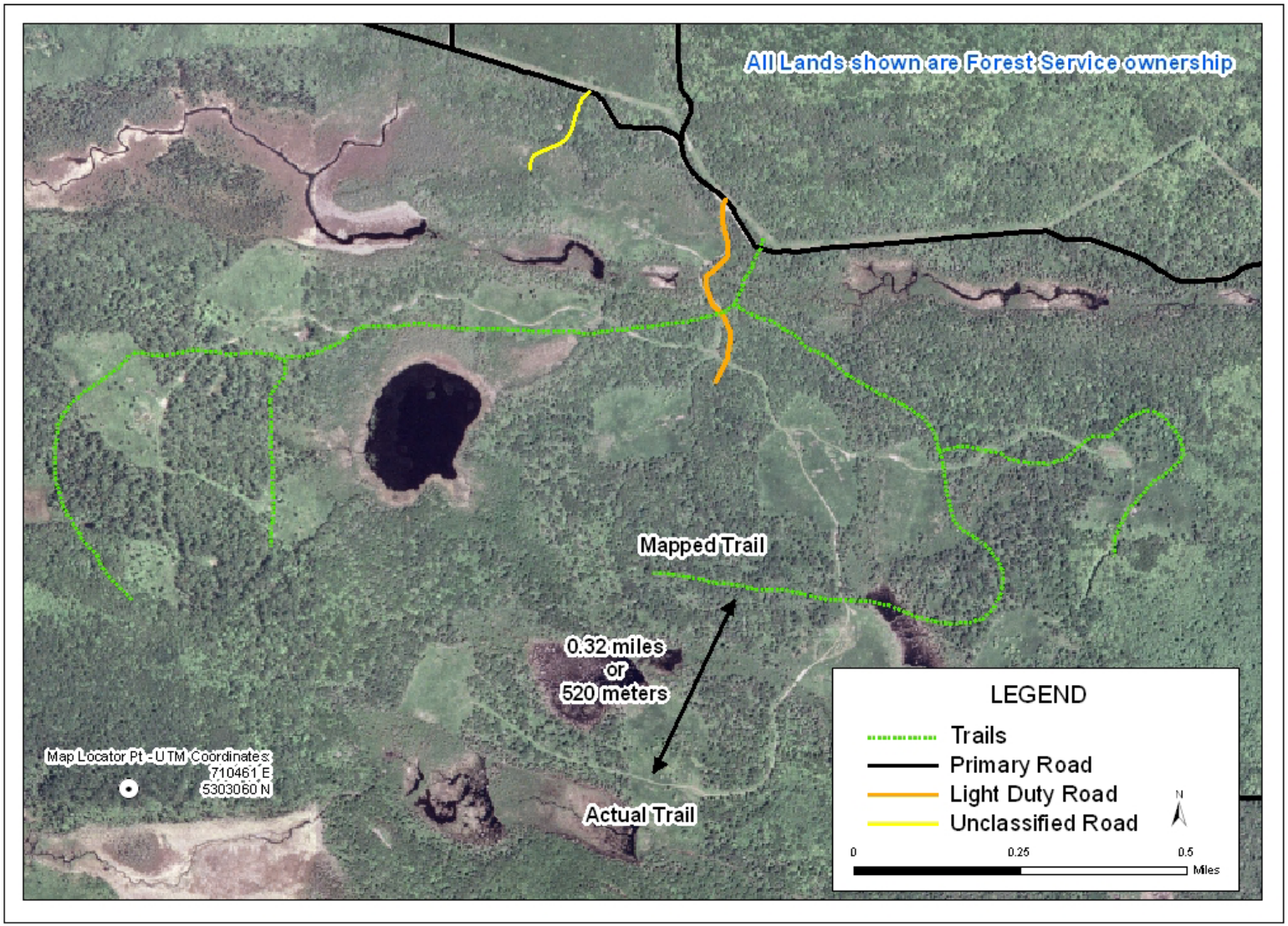

Figure 7. Map showing inaccurately mapped trail.

Accuracy of Road/Trail Classification

By viewing the Travel Routes data over the orthophotos we assessed the level of consistency in the classification of roads. We also compared the consistency of features mapped as roads versus trails. We did not conduct a systematic review. Rather, we simply recorded places of apparent discrepancy that we encountered while viewing the data for other aspects of this project.

While it is not possible to positively differentiate between roads of different classifications and between roads versus trails without a field visit, we found numerous examples of classifications that are highly questionable. Figures 8 and 9 provide examples of just a few of the classification and mapping problems we found that are spread throughout the SNF data.

Figure 8 shows 3 categories of roads in the SNF Travel Routes layer – a Secondary road, Light Duty road, and Unclassified road. The Secondary road correctly appears as the most well maintained road. However, the Light Duty road follows an extremely faint, almost non-visible track while the Unclassified road appears as a maintained road. In addition, a road extension to the Unclassified road that appears as a substantially more prominent feature on the orthophoto than the Light Duty road is not included in any of the SNF's road or trail mapping. PBI digitized this road as part of our Undocumented Roads/Trails analysis (see section below).

Figure 9 shows a potential error in road versus trail mapping, and questionable classification of road types. The map shows a feature identified as a trail (but not included in the OHV Roads or Travel Routes data) that is substantially more prominent on the orthophoto than nearby Unimproved and Light Duty roads. It is possible that the "trail" is a trail *and* road (e.g. a biking trail), but in other places where this is the case, the feature is sometimes correctly mapped as both a road and a trail. In general, Light Duty roads are supposed to be more maintained than Unimproved roads. In this example, the Light Duty road appears less maintained than the Unimproved road, though the difference is somewhat subtle.

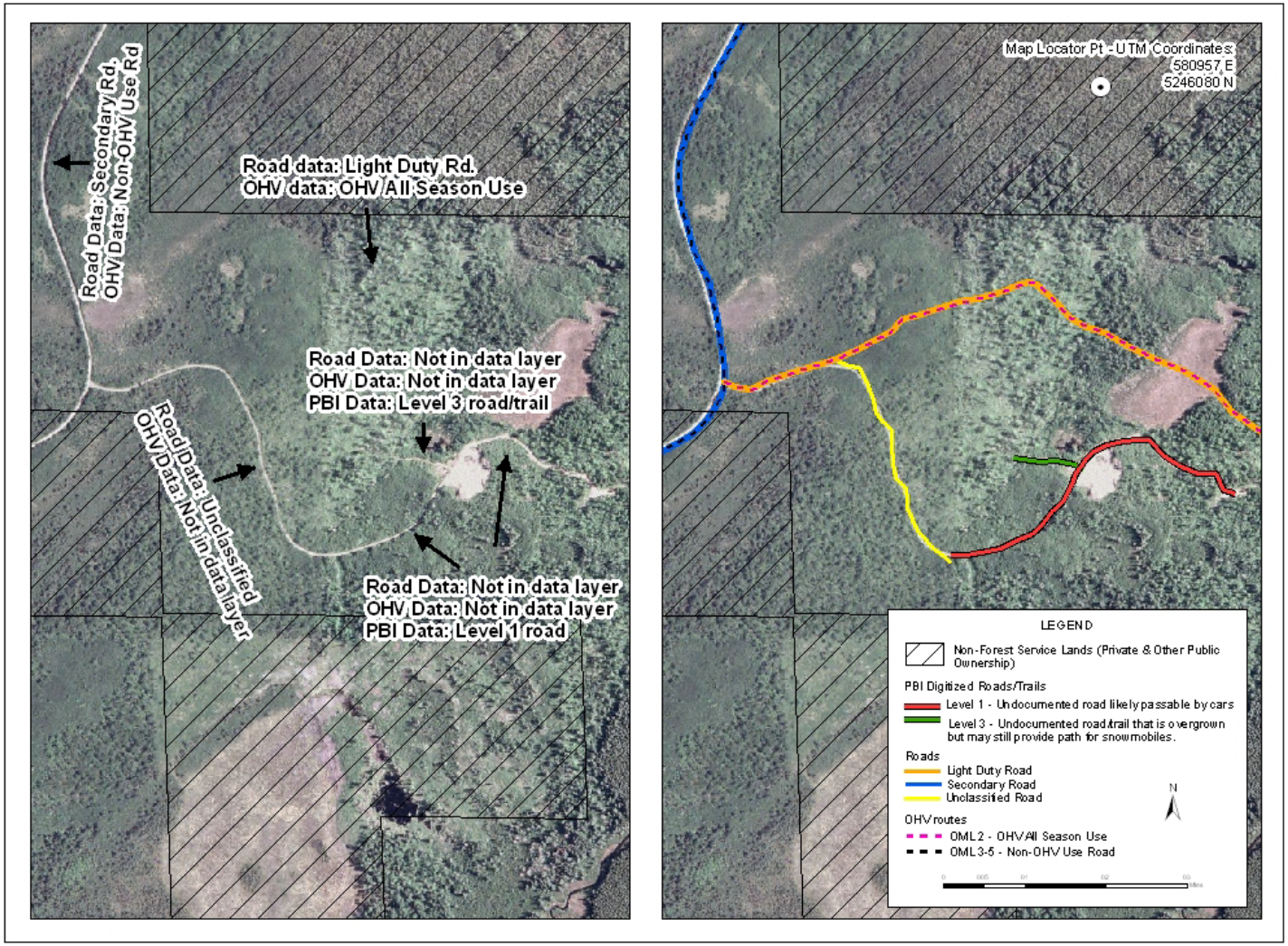

Figure 8. Paired maps showing inaccurate classification and/or mis-mapping of roads. Map compares classification of roads from OHV Roads and Travel Routes data and shows roads not documented in either layer, but digitized by Pacific Biodiversity Institute (PBI). (Travel Routes data is referred to as Roads data in the figure).

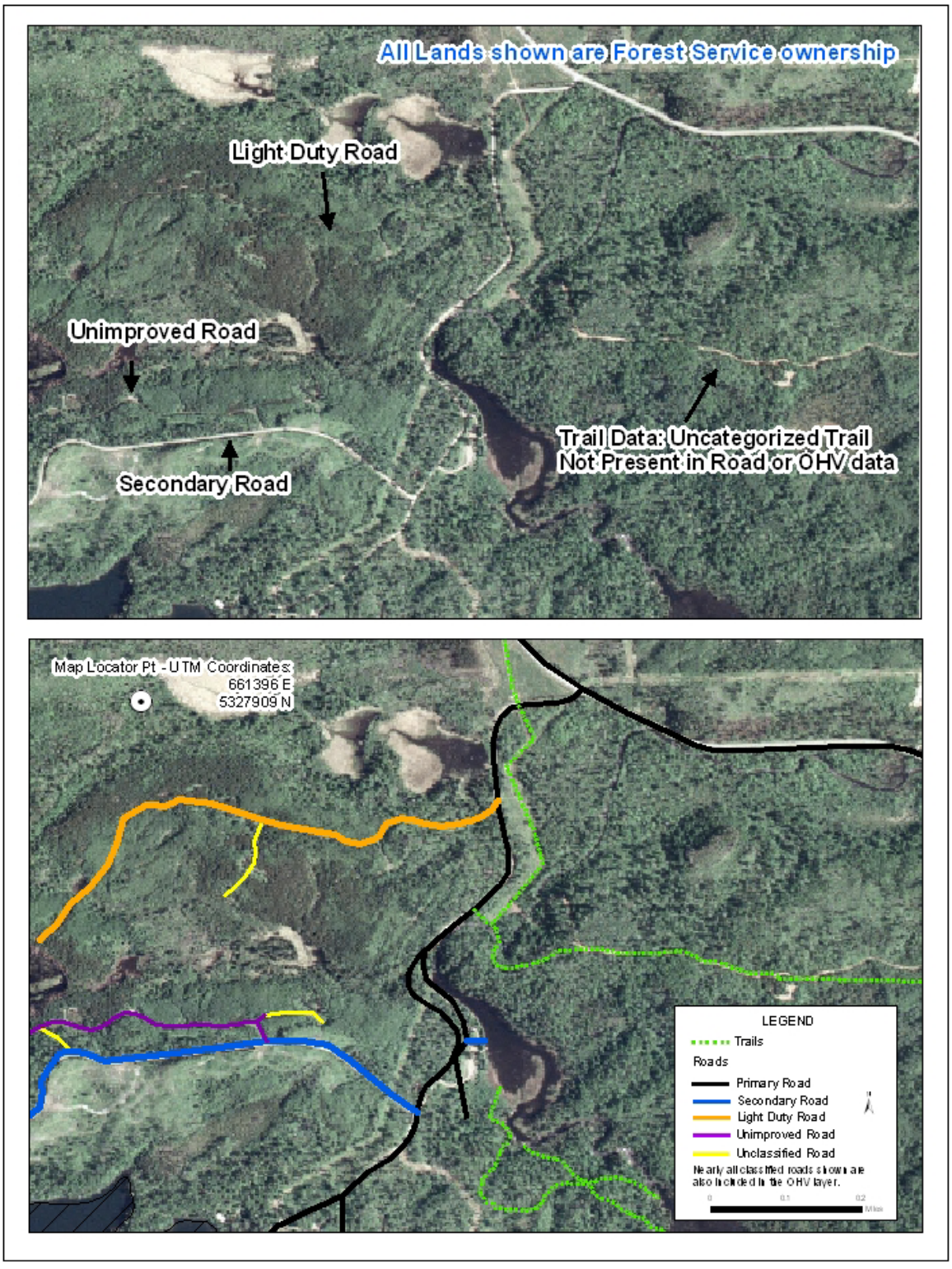

Figure 9. Paired maps showing potential error in classification of trails versus roads in the Trails and Travel Routes GIS layers.

Undocumented Roads/Trails

By examining the 2003 orthophotos we found 159 miles of roads/trails (Level 1 and 2) on National Forest land that are likely usable by passenger vehicles, high clearance vehicles and/or OHVs but are not documented in the Travel Routes or OHV Roads data (Table 3). This is a conservative estimate and does not include an additional 190 miles of undocumented roads/trails (Level 3) which appeared somewhat overgrown but potentially usable as snowmobile routes and some of which may also be usable by high clearance vehicles and/or OHVs. Examples of PBI digitized roads/trails are in Figures 8 and 10. Figure 11 shows a photograph taken during fieldwork of the undocumented road mapped in Figure 10.

We found 427 miles of roads on National Forest that were photointerpreted as usable by passenger vehicles, high clearance vehicles and/or OHVs that were included in the Travel Routes layer but not in the more recent OHV Roads layer (Table 3). It is unclear why these roads were excluded when in many cases less prominent roads were included in the new data layer. There does not appear to be any consistent criteria used in determining which roads from the Travel Routes layer were included or excluded in the OHV Roads layer.

We combined the above types of undocumented roads with the OHV Roads layer to calculate our best estimate of actual road mileage and density on the portion of National Forest covered by the 2003 orthophotos (see Figure 1). We compared this to road mileage and density calculated from the OHV Roads layer alone. We chose to use the OHV Roads layer (versus the Travel Routes layer) as the baseline for our comparison because this is the most recent data available from the National Forest and the OHV Roads layer appears to better represent actual road locations, despite the numerous problems previously discussed.

We found that the total road mileage for National Forest lands with 2003 orthophoto coverage (see Figure 1) increased by 28%, from 2,071 miles to 2,657 miles, when undocumented roads were considered. Road density increased from 1.33 miles per square mile to 1.70 miles per square mile for the same area (Table 4).

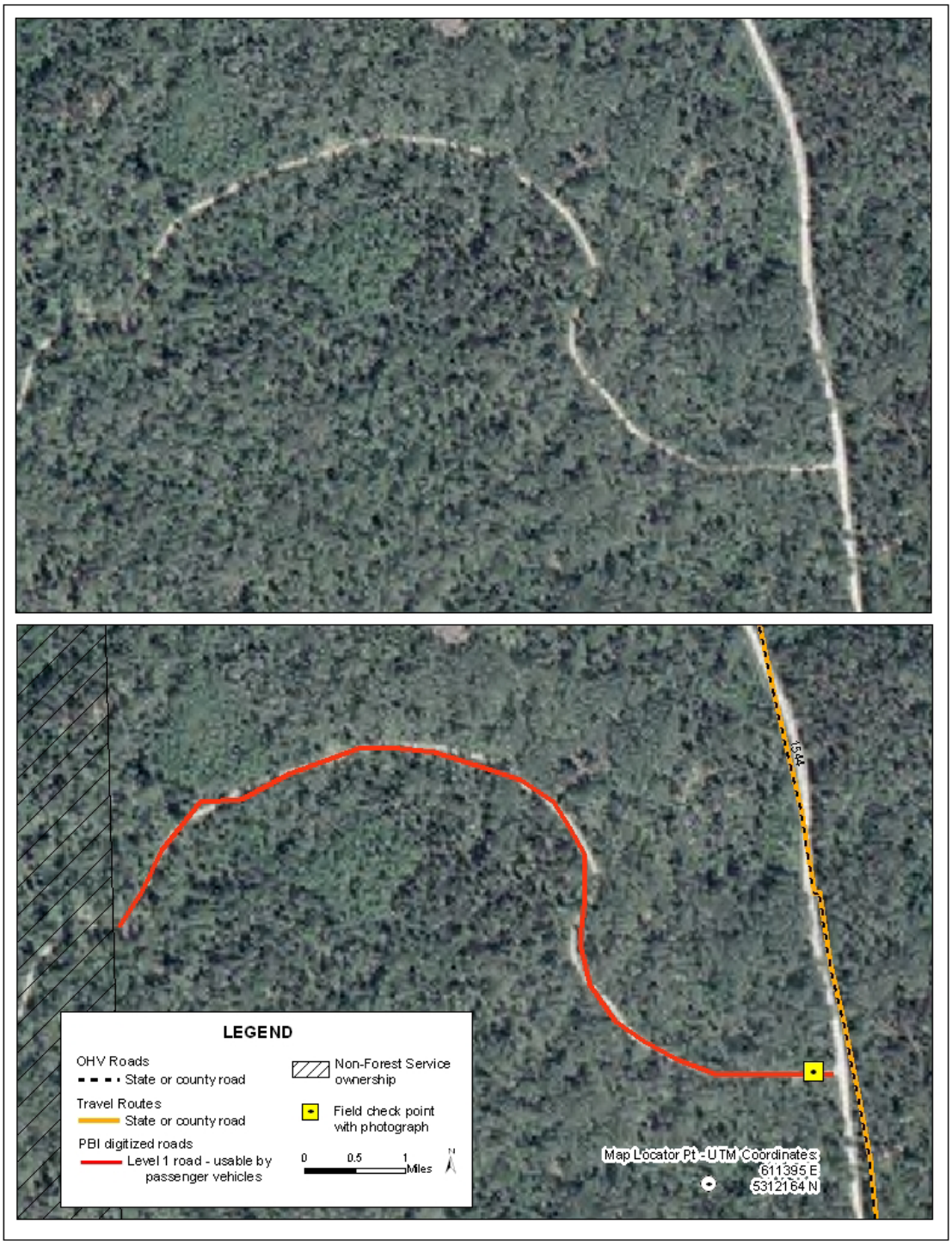

Figure 10. Paired maps showing road undocumented by the Forest Service in both the Travel Routes and OHV Roads data.

Figure 11. Photograph of undocumented road shown in Figure 10.

Table 3. Miles of road on Forest Service ownership that are visible on 2003 orthophotos but not included in the OHV Roads GIS layer.

Road Type	Miles of Road
Roads/Trails undocumented in both OHV Roads & Travel Routes GIS layers that were photointerpreted and digitized by PBI	
Level 1 roads/trails - passable by cars	41
Level 2 roads/trails - passable by high-clearance vehicles and/or OHVs	118
Total Levels 1 & 2	**159**
Roads in the Travel Route layer that are not included in the OHV Roads layer but were determined through photointerpretation to be potentially passable by cars, high clearance vehicles and/or OHVs.	
Classified roads	41
Unclassified roads	386
Total Classified and Unclassified	**427**
All Actual Roads Not Included in OHV Roads Layer	**586**

Table 4. Differences in road mileage and density when calculated for roads documented in the OHV Roads layer versus actual roads (OHV Roads plus undocumented roads). Calculations are for Forest Service owned lands with 2003 orthophoto coverage (Figure 1) and excluding the Boundary Waters Canoe Area.

Road Type	Miles of Road	Road Density (miles/square mile)
OHV Roads	2,071	1.33
All actual roads not included in OHV layer (Level 1 & 2, classified & unclassified roads - mileage from Table 3)	586	0.38
Total Actual Roads	2,657	1.70

Inconsistencies between GIS roads and the Road Analysis Process Report

We examined the roads data associated with the Superior National Forest's Roads Analysis Process (SNF 2002) in relation to the Forest Service's current GIS roads data to check for consistency and accuracy. The Roads Analysis Process (RAP) is an evaluation that all National Forests were instructed to conduct in order to evaluate their current road system in relation to transportation needs on the Forest. Results of the RAP were used to guide the recent revision of the Superior National Forest's Forest Management Plan.

We found many inconsistencies in the mapping and classification of roads in the RAP report when compared with more recent Forest Service data sources. In some cases the RAP data appears to be more correct, in other cases the OHV Roads or Travel Routes layers appear more correct.

The Superior National Forest's RAP focuses on the main forest roads as categorized by Objective Maintenance Level (OML) – those suitable for passenger cars (OML 3) and providing moderate (OML 4) to high (OML 5) degrees of user comfort. The Forest's *Road Inventory* database was the source of road information for the RAP report. The report states that:

> The mileage totals for the OML 3, 4, and 5 roads is stable, since these are the main roads on the Forest, and provide basic access across the Forest to recreation, wilderness and sub-regional areas of the Forest. The mileage totals for the OML 1 & 2 roads tend to vary slightly over time as environmental and roads analyses are completed across the Forest to address land management activities, and roads are either added to the Forest Road system or removed and scheduled for decommissioning.

When we calculated road mileages for the Travel Route and OHV Road layers we found that the total mileage of OML 3-5 roads *was* quite similar to data in the RAP report, with values ranging from 641 miles to 676 miles among the three data sources (Table 5).

However, when we checked *location* of roads categorized as OML 3 to OML 5 we found numerous major discrepancies, as described below.

For the OML 1 and OML 2 roads, we found that mileage totals varied greatly between the RAP, OHV Roads, and Travel Route data. OML 1 total miles varied by 98 miles - from 746 miles to 844 miles. OML 2 miles ranged from 792 to 1128 miles, a difference of 336 miles or 42% of the RAP estimate (Table 5).

Using GIS and visual inspection of hardcopy maps we compared status of OML 3, 4, and 5 roads in the 2004 OHV Roads layer (using its Map Theme attribute), 2004 Travel Routes layer (using the Map Theme and MTC Level attributes), 2003 hardcopy Superior National Forest Recreation map, and 2002 hardcopy OML 3-5 roads map in the RAP report (SNF 2002, Figure 2-10). We expected to see some changes in OML classification from the 2002 to 2004 data as OML status was corrected/changed for some roads and we expected the most recent (2004) data sources to be more similar to each other than to the earlier data. Instead, we found substantial differences among the data sources with the most recent data (OHV roads) appearing less correct in some cases than the earlier data sets.

Figure 12 illustrates numerous inconsistencies for an area in the northwest portion of the Forest. In this 16 by 36 mile area we found 5 major discrepancies in data and numerous other minor ones. Figure 13 provides a close-up view of portions of roads identified in boxes 1 and 2 of Figure 12. For the areas highlighted, the OHV roads classification actually appears less consistent with the roads as they appear in the 2003 orthophoto than the classifications of some earlier data sources.

Table 5. Comparison of road miles as documented by 3 Superior National Forest data sources – the Road Analysis Report (SNF 2002), the Travel Routes and OHV Roads GIS layers.

Objective Maintenance Level	Miles of Road in RAP Report (2002), Table 2-7	Miles of Road according to 2004 Travel Route GIS Data	Miles of Road according to 2004 OHV GIS Data
OML 1- Basic Custodial Care	746	826	844
OML 2 - High Clearance	792	1128	925
OML 3 - Passenger Cars	233	233	Data only available as combined OML 3, 4 & 5 class
OML 4 - Moderate Level of Comfort	328	301	
OML 5 - High Level of Comfort	115	111	
Subtotal OML3, 4 & 5	676	645	641
TOTAL MILES	2,215	2,599	2,410

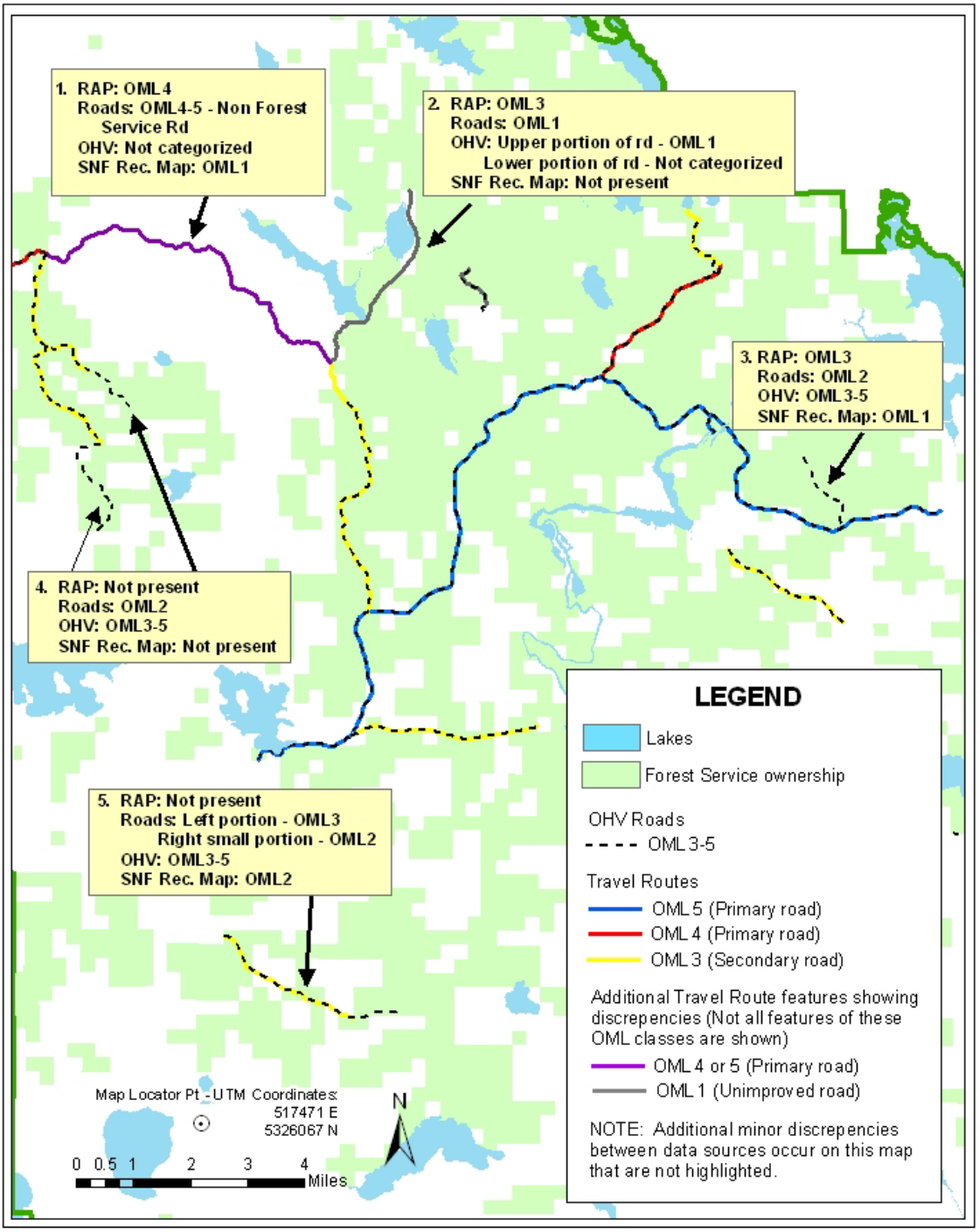

Figure 12. Map showing inconsistencies in classification of roads by Objective Maintenance Level (OML) among 4 Superior National Forest data sources – the Roads Analysis Process Report (2002), the SNF Recreation map (2003), and the 2004 OHV Roads and Travel Routes GIS layers. (Travel Routes data is referred to as Roads data in the figure).

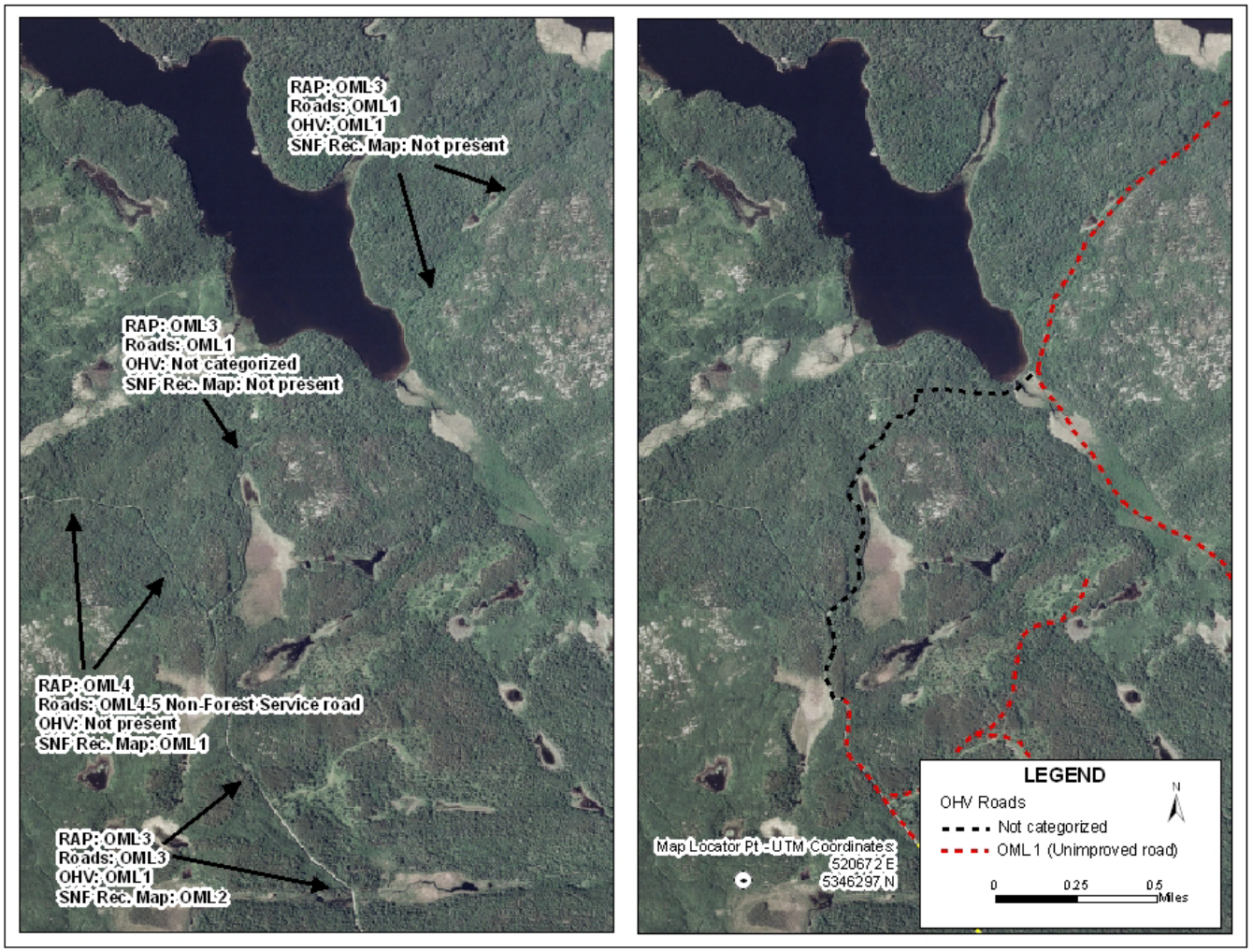

Figure 13. Detailed, paired maps (for highlighted areas 1 & 2 in Figure 12) showing inconsistent classification of roads by Objective Maintenance Level (OML) among 4 Superior National Forest data sources – the Roads Analysis Process Report (2002), the SNF Recreation map (2003), and the 2004 OHV Roads and Travel Routes GIS layers. (Travel Routes data is referred to as Roads data in the figure).

Evaluation of Roadless Area Maps

When we compared the Forest Service's original RARE II roadless areas with the Inventoried Roadless Areas (IRAs) mapped by the Forest Service in 2000 under the Roadless Area Conservation Plan, we found major disagreement over which lands were roadless – but a surprisingly close estimate of total roadless area on the National Forest. The RARE II roadless areas amount to 67,810 acres while the 2000 IRAs amount to 61,990 acres, plus 2,681 acres of inholdings and internal lakes, for a total of 64,671 acres (Table 6).

The level of disagreement between the layers was surprising as IRAs are in part defined as lands inventoried under the RARE II process. Specifically, the Forest Service definition of IRAs (USDA Forest Service 2000) is:

> Undeveloped areas typically exceeding 5,000 acres that met the minimum criteria for wilderness consideration under the Wilderness Act and that were inventoried during the Forest Service's Roadless Area Review and Evaluation (RARE II) process, subsequent assessments, or forest planning.

Although the total area of RARE II roadless areas and the 2000 Inventoried Roadless Areas are within 3,139 acres (or 5,820 acres – excluding inholdings and interior lakes in the IRA 2000 roadless areas), there is little agreement as to the actual location of the roadless areas. The 2000 IRAs only include 16,661 acres of RARE II roadless land (Figure 14). They are largely comprised of 48,010 acres of "newly discovered" roadless terrain that was not mapped in RARE II. Likewise, 51,149 acres of RARE II roadless areas disappeared from the IRA 2000 roadless inventory (Table 6).

In dramatic contrast to the roadless area mapping conducted by the Forest Service, Pacific Biodiversity Institute found 36 roadless areas over 5000 acres in size totaling 298,294 on the Superior National Forest (Figure 15). We also found 112 roadless areas between 1000 and 5000 acres in size totaling 295,456 acres on the Superior National Forest. We found 49 roadless areas (14,998 acres) that are adjacent to the Boundary Waters Canoe Area that could qualify as Wilderness additions. Because some areas of the National Forest do not have recent orthophoto coverage (see Figure 1), we were unable to verify or improve the roads mapping for these areas. As a consequence, the roadless area mapping for these areas is less reliable than for portions of the National Forest with orthophoto coverage. The differences between our roadless inventory and those conducted in the past by the Forest Service are listed in Table 6 and illustrated in Figures 16 and 17.

Table 6. Comparison of Forest Service roadless area inventories with that of Pacific Biodiversity Institute.

Roadless Description	Area (acres)
Forest Service RARE II and IRA 2000 agree, both roadless	16,661
Forest Service RARE II roadless but not roadless in IRA 2000	51,149
Forest Service IRA 2000 roadless but not roadless in RARE II	45,329
Inholdings and lakes in IRA 2000 roadless but not RARE II roadless	2,681
Actual roadless areas over 5000 acres in size or potential roadless additions adjacent to Boundary Waters Canoe Area as mapped by PBI	298,294
Actual roadless areas 1000 to 5000 acres in size as mapped by PBI	295,456
Actual roadless areas adjacent to Boundary Waters Canoe Area but less than 1000 acres or potential roadless additions as mapped by PBI	14,998

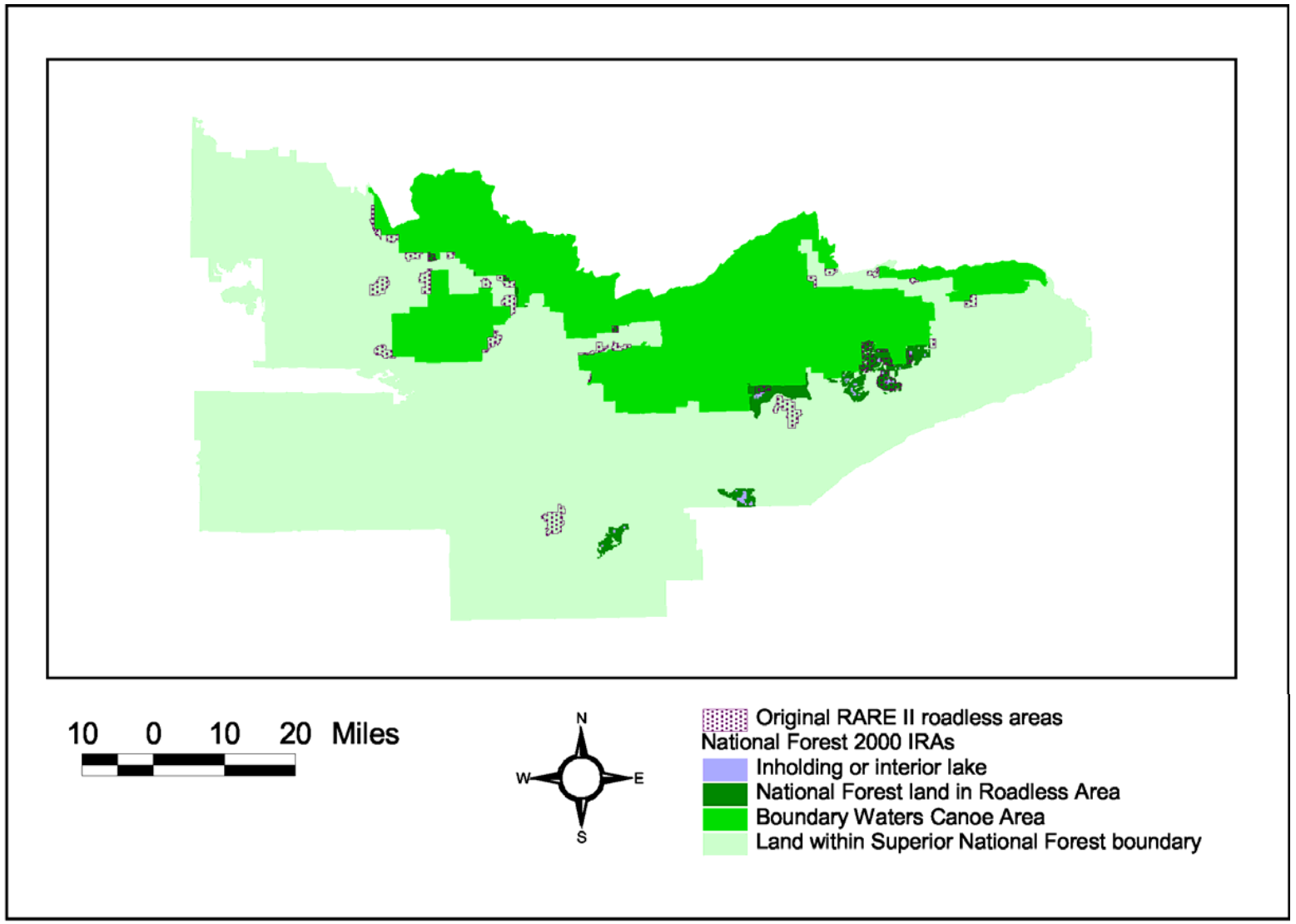

Figure 14. Comparison showing limited overlap of RARE II roadless areas with Inventoried Roadless Areas delineated in the 2000 Roadless Area Conservation Plan.

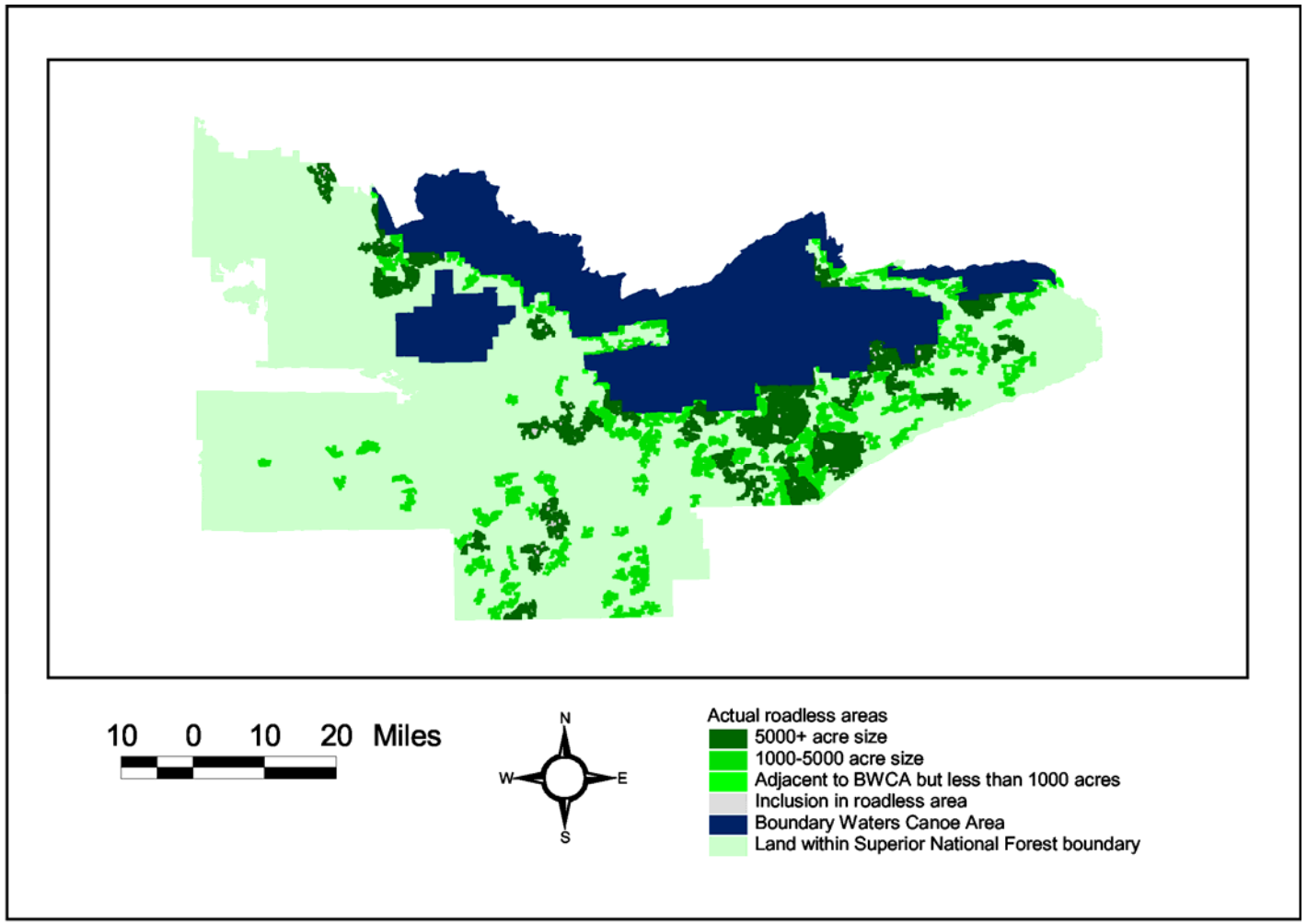

Figure 15. Actual roadless areas delineated by Pacific Biodiversity Institute using the most current information on roads and development.

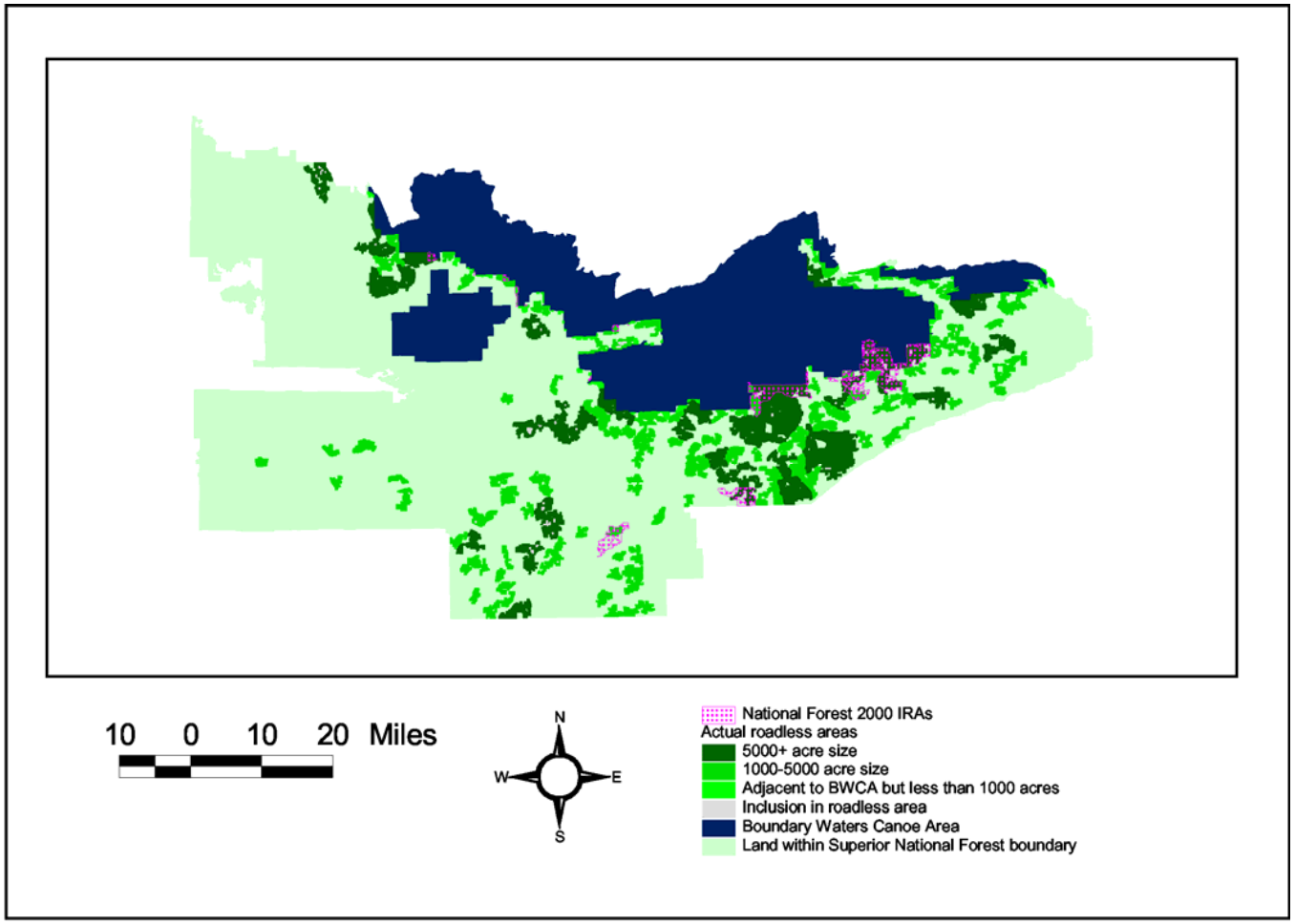

Figure 16. Map comparing the actual roadless areas delineated by Pacific Biodiversity Institute with Inventoried Roadless Areas delineated in the 2000 Roadless Area Conservation Plan. Very few of the areas that are actually roadless were included in the Forest Service 2000 inventory. Yet, some areas included in the Forest Service inventory contain significant roading and would not have qualified as a roadless area under Pacific Biodiversity Institute's criteria.

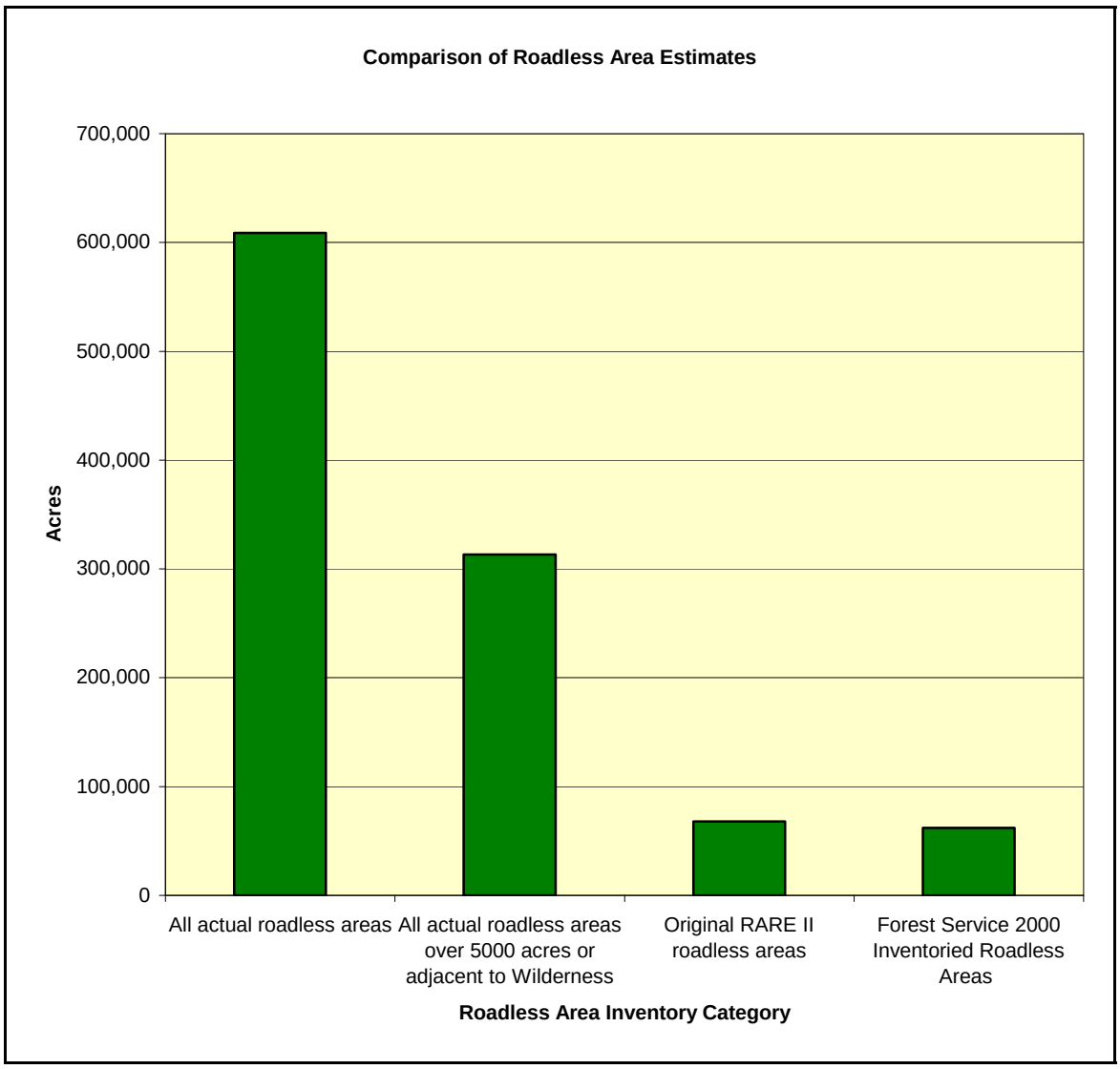

Figure 17. Comparison of actual roadless areas mapped by PBI on the Superior National Forest in 2 size classes with the original Forest Service RARE II roadless areas and the Inventoried Roadless Areas delineated in the Forest Service 2000 Roadless Area Conservation Plan. Although the two Forest Service estimates are quite similar, the actual on-the-ground locations that they represent are drastically different.

Example 1 – The Hogs Lake Roadless Area

The Hogs Lake roadless area (Figure 18) is a good example of the confusing history of roadless area mapping on the Superior National Forest. This roadless area was mapped in the original RARE II effort and its area was reported to be 7,209 acres (Superior

National Forest RARE II GIS theme). But this roadless area was completely ignored in the Forest Service's 2000 roadless inventory. Using all the most current information on locations of roads and developments, we have determined that the actual size of the roadless area is currently over 24,000 acres. Examination of aerial photography reveals the absence of roads and a natural landscape of forests, rivers lakes and wetlands – both within the original RARE II roadless area and in the uninventoried part of the roadless area (Figure 19). There appears to be no difference between the landscape condition of the original RARE II roadless area and the rest of the roadless area mapped by Pacific Biodiversity Institute.

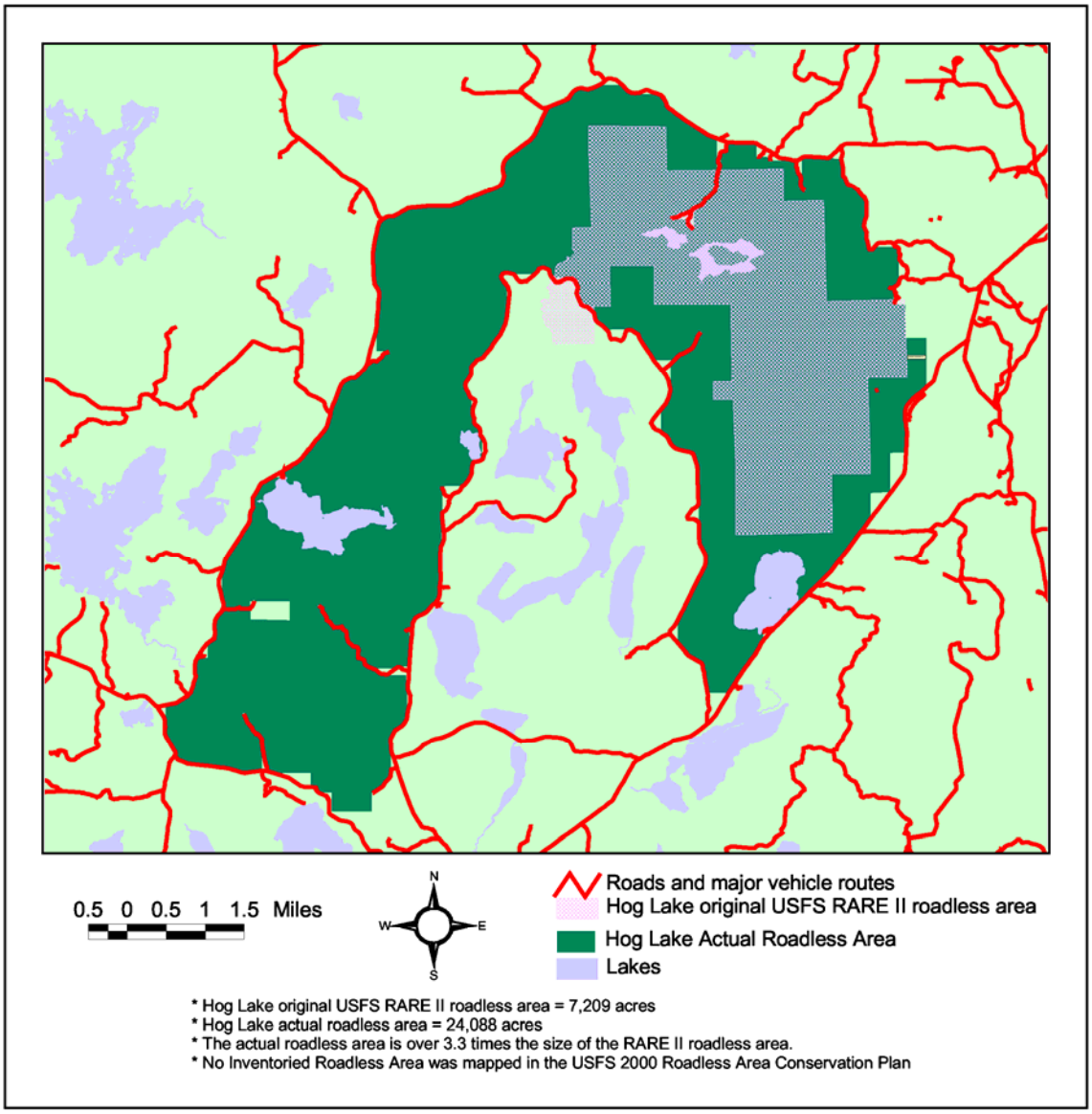

Figure 18. Comparison of the actual Hogs Lake roadless area as mapped by Pacific Biodiversity Institute with the Forest Service's original RARE II roadless area. This significant area of apparent roadless terrain is not included in the Forest Service's 2000 inventory of roadless areas.

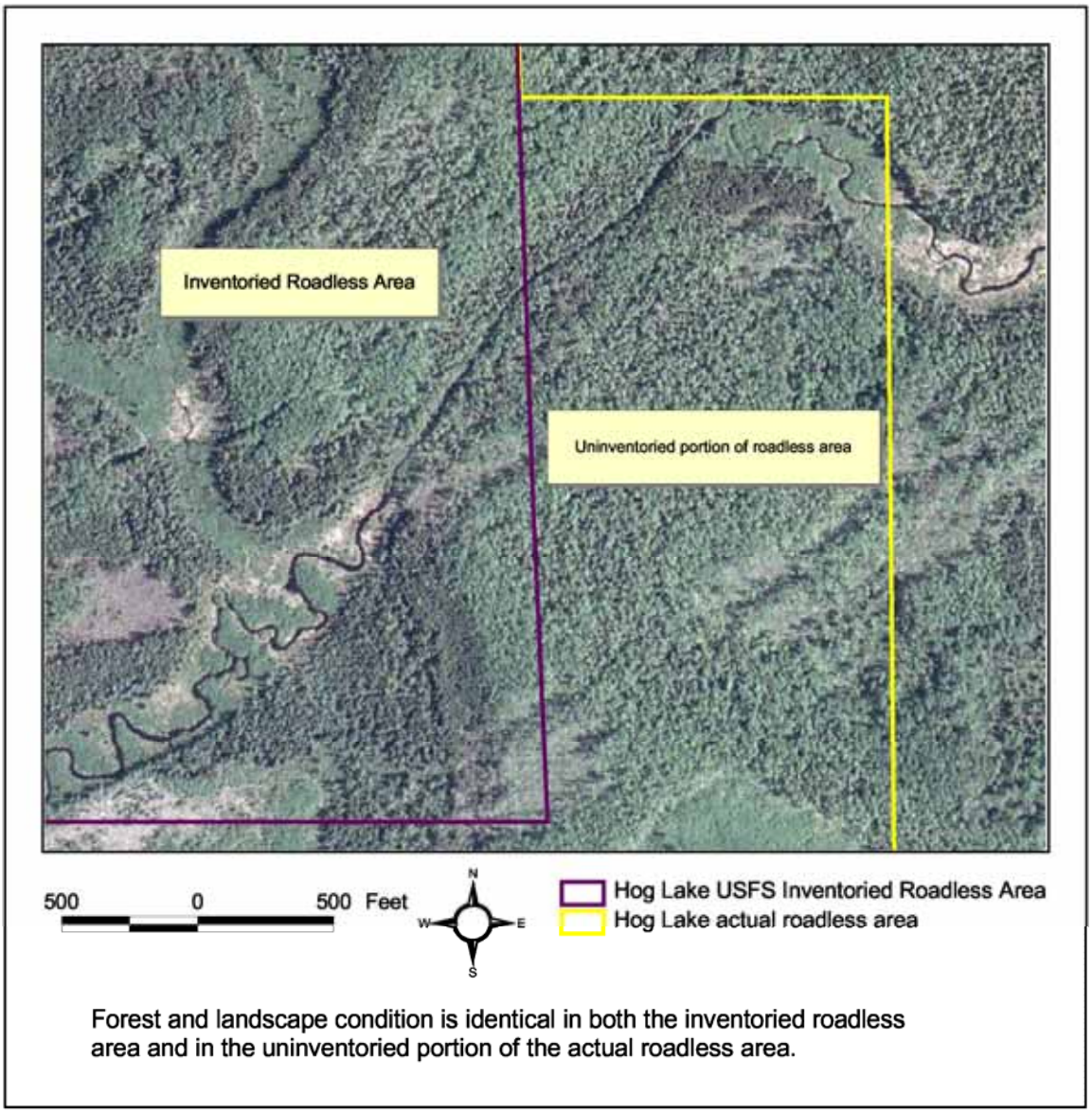

Figure 19. A detailed comparison of part of the actual Hogs Lake roadless area as mapped by PBI with the Forest Service's original RARE II roadless area. There are no apparent visual distinctions between the natural landscape qualities of the Forest Service's inventory area and the surrounding roadless area delineated by PBI.

Example 2 – The Phantom Lake Roadless Area

The Phantom Lake Inventoried Roadless Area (Figure 20) was delineated by the Forest Service in 2000 despite the fact that no RARE II roadless areas were mapped in this location. This disparity represents another example of the apparently inconsistent methodology used by the Forest Service to delineate roadless areas on the Superior National Forest. The Inventoried Roadless Area contains 6,409 acres according to the Forest Service. But much of this area is covered by many roads and recent logging (Figures 20, 21 and 22). Pacific Biodiversity Institute only mapped a small roadless area of 1,853 acres in this general location. It appears that the rest of the area would not qualify as roadless because of all the existing roads. The rather extensive logging in much of the Forest Service IRA is also apparent in the aerial photography. This example is opposite from the one presented in Example 1 and illustrates the inconsistency of the Forest Service roadless area mapping.

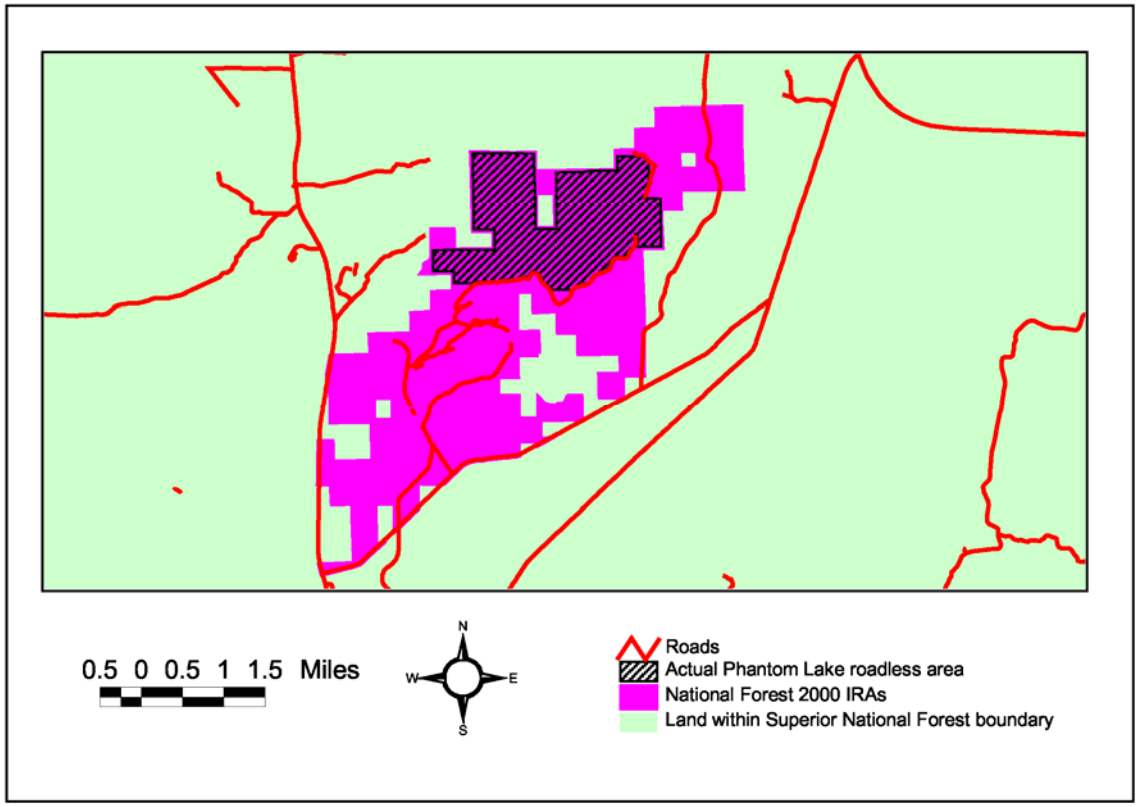

Figure 20. Comparison of the actual Phantom Lake roadless area as mapped by Pacific Biodiversity Institute with the Forest Service's 2000 Inventoried Roadless Area. Note that roads crisscross and bisect much of the IRA.

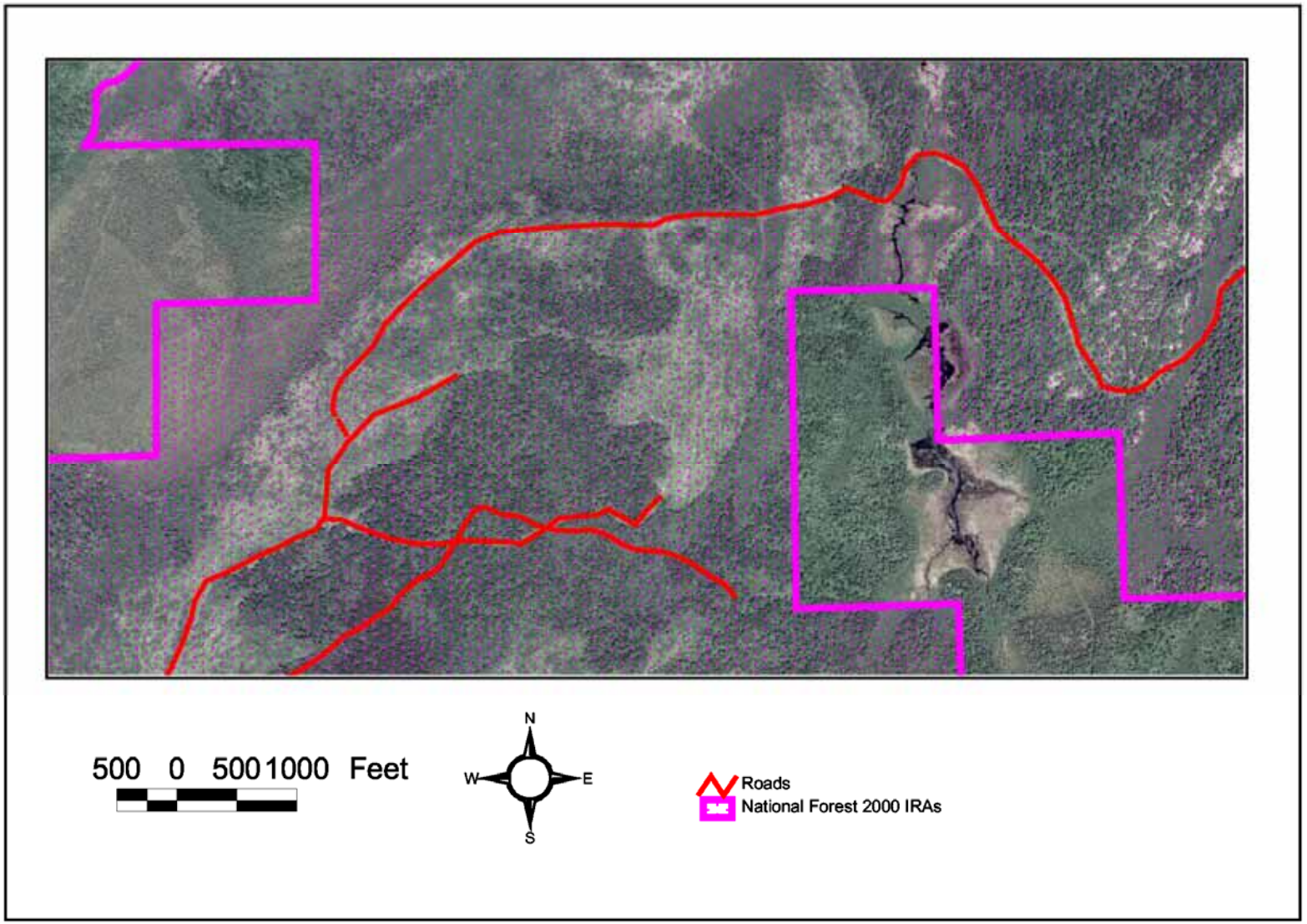

Figure 21. Detailed view of a portion of the Phantom Lake Inventoried Roadless Area as mapped by the Forest Service in 2000. Note that roads crisscross and bisect much of the IRA. Logged areas are also readily visible.

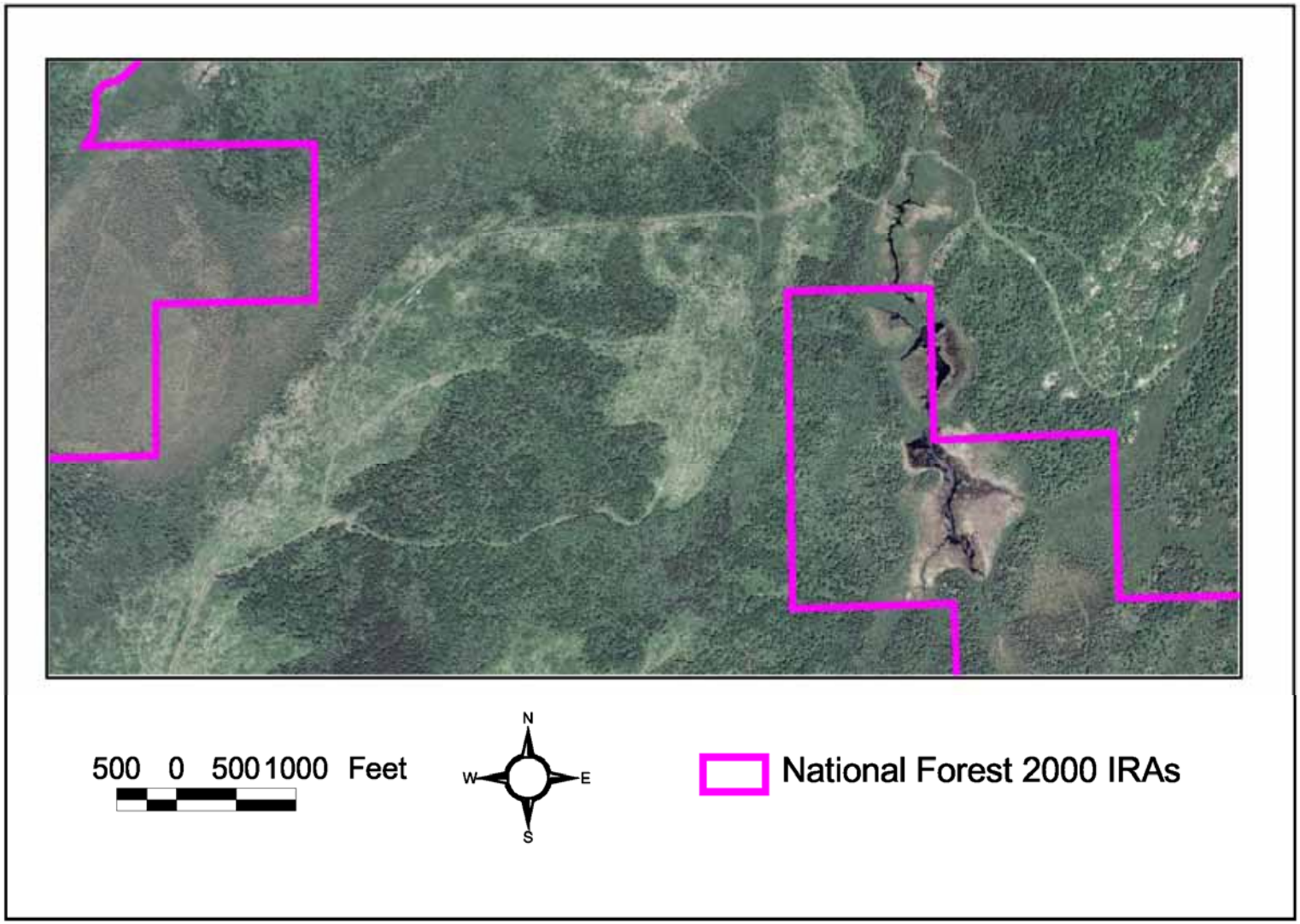

Figure 22. Aerial photography revealing roads and logging in a portion of the Phantom Lake Inventoried Roadless Area as mapped by the Forest Service in 2000. This map covers the same area as Figure 21.

DISCUSSION

Our staff has evaluated the quality of both road and roadless area maps and related GIS data in all National Forests of the United States. The road data and the data on roadless areas in the Superior National Forest stand out as some of the most inaccurate information in the entire National Forest System. In contrast, many National Forests across the country have developed highly accurate data on the location and classification of their transportation network.

The Forest Service has acknowledged some shortcomings of its data. For example, the Forest's Trail Management Plan (SNF 2003) notes the presence of hundreds of miles of unauthorized ATV trails which, presumably, are not mapped. The Road Analysis Process Report (SNF 2002) notes a number of roads that are misclassified and discusses the importance of continued assessment of roads at finer scales.

A major concern identified in this report is that recent efforts by the Forest Service to quantify and assess its roads and roadless areas are flawed in some ways that its previous data was not. Through revision of its GIS Travel Routes layer to create the 2004 OHV Roads layer, and through revision of the 1976 RARE II roadless area map to create the 2000 Inventoried Roadless Area map, the Forest Service had excellent opportunities to correct and update their baseline data. Instead, while some corrections *were* made, new errors were generated. The result is that the Forest Service is left with different data layers intended to represent the same features, with each being inaccurate and incomplete in different ways.

One of the greatest challenges we found in working with the Forest Service's roads and roadless data is the high level of inconsistency within and between its GIS data layers. Despite intensive and extensive review of the data in relation to current landscape conditions (as visible in 2003 orthophotos and field examinations), we were unable to find patterns or understand the logic as to why some roads and roadless areas were included or excluded from their data layers. For example, many areas that are actually roadless were not included in their roadless area layers while other roaded and recently logged areas (according to orthophotos and the Forest Service's own road data) were mapped as roadless.

Typically, roads and trails are some of the easiest landscape features to map. Roads and trails tend to be prominent features on aerial photography and their location can easily be checked using digital orthophotos and other image data. Roads can also be easily mapped on the ground using GPS technology. The Superior National Forest is fortunate to have high quality, recent orthophotography that covers much of its area. While it cannot be used to classify or map roads at the level of detail needed by the Forest Service for management purposes, particularly in areas of high canopy cover, it can be used to easily improve spatial accuracy of roads and trails and identify some existing roads and trails that are missing from current data sets.

In this report, we demonstrated several situations where, by simply reviewing the Forest's GIS data in relation to orthophotography, we were able to provide substantial improvements to their data. Analysis results based on our improvements to the Forest Service data lead to dramatically different conclusions about the miles of road, road density, and acres of roadless areas on the National Forest than those reached without the improvements.

For the area of National Forest (excluding the Boundary Waters Canoe Area) covered by the 2003 orthophotos (see Figure 1), the most recent Forest Service data shows 2,071 miles of road with a road density of 1.33 miles per square mile. Using our data improvements we calculated 2,657 miles of roads with a road density of 1.70 miles per square mile – a 28% increase in road miles and density. Increases in road mileage are significant because they can have substantial and disproportionate influence on many measures of landscape fragmentation, such as patch size and core areas (Hawbaker and Radeloff 2004). Road density and fragmentation measurements are important for the management of some sensitive species on the Forest, including lynx and wolves (Mladenoff et al. 1995, Mech et al. 1988).

The Forest Service's RARE II roadless areas and Inventoried Roadless Areas under the Roadless Area Conservation plan each map between 64,000 and 69,000 acres of roadless lands (though in different locations). Using improved roads data and a clear methodology for consistent mapping of roadless areas, we found 298,294 acres of roadless lands within roadless areas of 5,000 acres or greater. In addition, we found many smaller roadless less than 5,000 acres in size.

Although we were unable to verify roadless area mapping for the portions of the Forest not covered by 2003 orthophotos (see Figure 1), it is clear that despite heavy roading in some areas, significant unprotected roadless lands remain. Many roadless areas are quite small in size and are often partially penetrated by roads. The wildlands that once existed in the Superior National Forest are now highly fragmented, but some relatively large, and many small wild patches remain throughout much of the forest. Given its inaccurate data on roadless areas, the Forest Service is unable to portray and consider the ecological value of these true roadless areas in its management decisions.

The many problems we found with the Superior National Forest's roads, trails, and roadless area data have the potential to greatly compromise the reliability of transportation-related analyses and other assessments that the National Forest may make, based on the data. Special consideration should be given to the fact that, according to the Superior National Forest, these data and analyses derived from them were used to inform the recent process of revising the Forest's Land Management Plan, which will guide Forest management for many years to come.

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