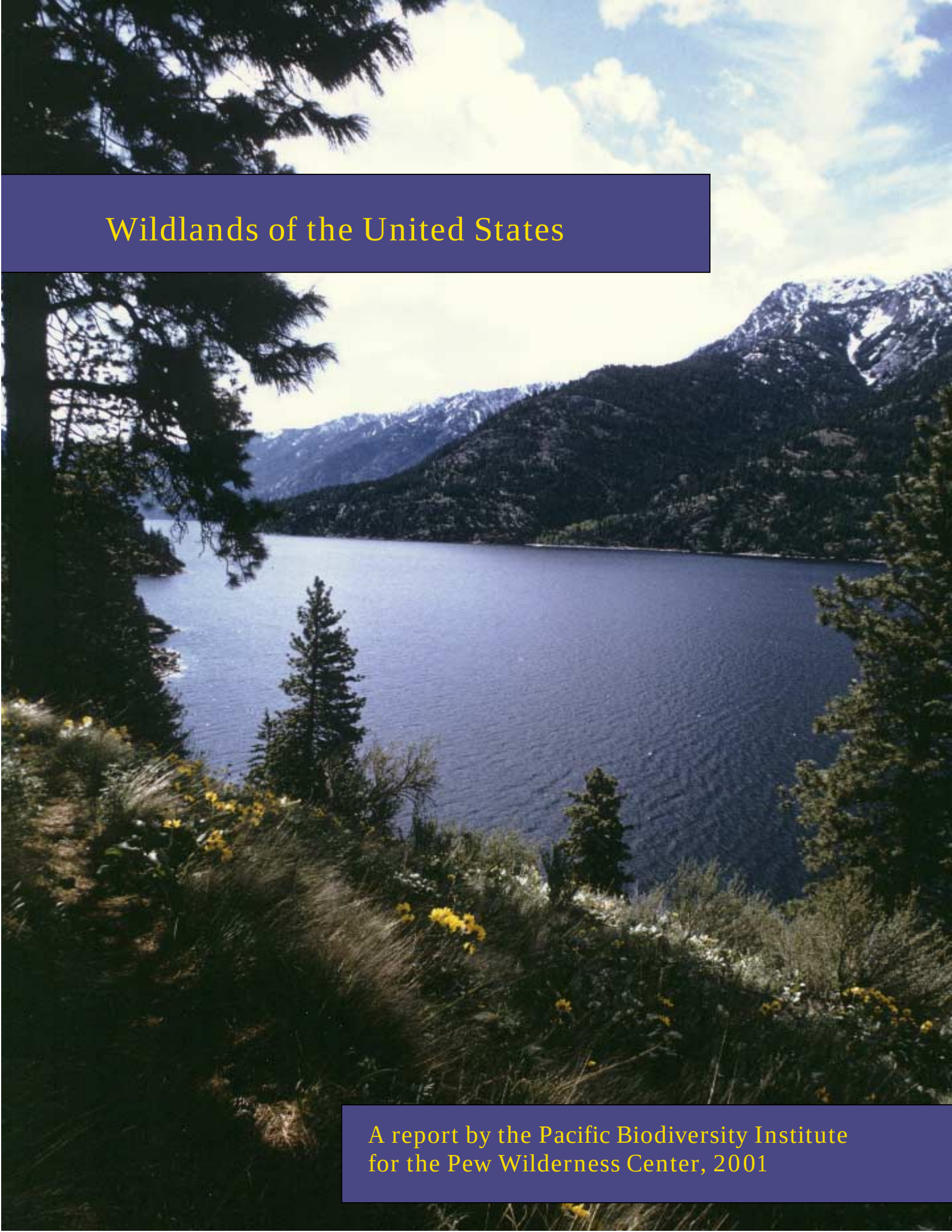

Wildlands of the United States

A report by the Pacific Biodiversity Institute
for the Pew Wilderness Center, 2001

CREDITS

This report details the results of Pacific Biodiversity Institute's inventory of federal and state roadless areas in the United States. This report and the work documented herein were commissioned by the Pew Wilderness Center.

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On the Cover
Roadless area adjacent to the Lake Chelan-Sawtooth Wilderness, Washington. Photo by Peter Morrison.

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EXECUTIVE SUMMARY

Introduction and Objectives

Wilderness and wildlands are a very important part of the American heritage. In many respects our interaction with wilderness has shaped our nation and influenced the character of our citizens. Our remaining wildlands now provide important refuges for animal and plant species that were once common, but have not faired well with the rapid development of our nation. These wildlands also provide immense recreational opportunities and places where people can find refuge and tranquility from this troubled world.

Despite the importance of America's wildlands to the people of our nation, the remaining wildlands have never been mapped across ownerships throughout the United States in a consistent manner. This lack of information has hindered the conservation of some of the richest and most pristine landscapes in the United States. Our project is an attempt to fill this vital knowledge gap.

The Pew Wilderness Center contracted with Pacific Biodiversity Institute in April, 2001 to identify and analyze all roadless areas over 1,000 acres in size on federal and state land in the United States. This project extends an earlier (1994 - 2000) Pacific Biodiversity Institute project that entailed mapping roadless areas in Washington, Oregon, Idaho, Montana, Wyoming, North Dakota, South Dakota, and Nebraska. The objectives of this new project are to:

1. Identify the remaining roadless areas of 1,000 acres or more on federal and state lands in the United States (including Puerto Rico, and the US Virgin Islands).
2. Document the data sources, assumptions and processes Pacific Biodiversity Institute has used to map the roadless areas.
3. Analyze the identified roadless areas in terms of:
    a. Ownership
    b. Existing units of the National Wilderness Preservation System and state equivalents
    c. The most recent Forest Service roadless area inventory (USDA Forest Service 2000)
    d. Similar roadless area surveys conducted on BLM land
    e. Land use/land cover and ecoregions
4. Provide recommendations for continuing roadless area inventories and analysis of roadless area characteristics.

Methods

This project used roadless area inventory and mapping methods developed by Pacific Biodiversity Institute over the last seven years. These methods involve an analysis of the best available information on roads and other permanent human disturbances to determine where undisturbed, roadless areas occur. In this project, we collected, processed, and analyzed extensive data sets to determine the current extent of the wildlands of the United States.

For this study we used the most current road data compiled for the United States at a 1:100,000 scale. We supplemented this information with roads data obtained from US Forest Service National Forests and Grasslands, BLM Regional Offices, and state agencies. We also incorporated information on developed and permanently disturbed areas (agricultural lands, mines, airfields, urban parks, and many other developed areas being erroneously classified as roadless). We relied on the National Land Cover Data (NLCD) recently published by the US Geological Survey for information on these developed lands.

Amount of Roadless Land in the United States

The results of this study represent the most comprehensive, objective inventory to date of the remaining wildlands in the United States. In this study we identified 657 million acres of remaining wild and roadless land on federal and state land in the United States. Areas protected as Wilderness account for 106 million acres – or only 16% of the total. The vast majority of our remaining wildlands exist without formal protection from road building and other development. Together, protected and unprotected wildlands comprise about 29% of the land area of the entire United States. The state of Alaska contains 46.6% of the unprotected roadless area in the United States and 55% of the designated Wilderness.

Most of these wildlands exist as land managed by four principal federal agencies: the Forest Service, Fish and Wildlife Service, Bureau of Land Management, and National Park Service. Over 408 million acres of unprotected wildlands occur on these federal lands.

Distribution of Roadless Areas

Unprotected state-owned wildlands account for 125.6 million acres or 22.2% of all unprotected wildlands in the United States. Alaska state wildlands alone account for 69.1% of all unprotected state wildlands (Table 8). Other states with significant unprotected state wildlands include: Arizona, Michigan, Minnesota, Montana, New York, and Wyoming. In total, 13 states have greater than 1 million acres of unprotected state wildlands. There are over 2 million acres of state owned lands in the United States that have been protected by state legislatures as State Wilderness or some other designation that is equivalent to that of the federal Wilderness Preservation System. New York, California and Alaska contain significant patches of State Wilderness that exceed 100,000 acres in size.

Significant areas of wild and roadless habitat also exist on private lands, tribal and city/county owned lands in the United States. A thorough analysis of this situation was beyond the scope of this project, but these additional wild areas play a significant role in providing habitat for many species that are sensitive to human disturbance. Many conservation efforts are working to protect habitat values on these wildlands that are outside of the federal or state ownerships.

We found 26 states that have over one million acres of unprotected state and federal wildlands (Table 9). Alaska, by far, has the greatest amount of unprotected wildlands. Nevada is the only other state to have over 50 million acres of unprotected wildlands. Three states, Utah, Arizona, and California, have between 25 million and 50 million acres of unprotected wildlands. Six states have between 10 million and 25 million acres of unprotected wildlands, and 18 states have between 1 million and 10 million acres of unprotected wildlands.

Fragmentation of Roadless Areas

Remaining wildlands in the contiguous 48 states, Hawaii, Puerto Rico and the US Virgin Islands are now highly fragmented. Two hundred years ago, one single large block of pristine wilderness over three billion acres in size comprised most of the North American continent. At that time much of the remainder of the continent consisted of smaller wildland blocks with each still exceeded one million acres. Today, most of this wild, pristine habitat has been completely eliminated by the steady progression of human development. What remains is now highly fragmented. Gradually, roads and human developments have bisected and fragmented wild habitat until few large blocks remain. The rate of fragmentation increased dramatically during the last half of the 20th century and now 57.7% of the remaining wildland patches exist as areas of less than 50,000 acres. Only 7.4% of the remaining wildlands are patches of 1,000,000 acres or more.

The remaining unprotected roadless areas of less than 10,000 acres (32.2% of all wildlands) typically are highly dissected and convoluted areas with little intact core area. These small roadless areas often also contain substantial amounts of disturbance from past management activities (e.g., grazing, logging, off-road motorized recreation use).

In contrast with the rest of the country, 85.6% of Alaska's wildlands still remain in very large patches of greater than 1,000,000 acres. Of the Alaskan wildlands that are less than 1,000,000 acres, many are oceanic islands in the Aleutian chain or along coastal Alaska that see little human disturbance. Fragmentation from human disturbances has yet to substantially affect Alaska's wildlands.

Representation of Ecoregions Within Remaining Wildlands

We analyzed the distribution of remaining wildlands in relationship to the ecoregions of the United States to determine how well the various ecological regions were represented in the existing system of protected areas and how much relatively pristine habitat exists in each region. We found that at the ecoregional province level, all 52 provinces in the US contain some wildlands (protected and unprotected wildlands on federal and state land). Twenty-two provinces, including all provinces in Alaska, have greater than 50% of their area still remaining in wildlands. While there are no provinces that do not have any wildlands, nine provinces have less than 5% of their area in wildlands with less than 0.1% of the province protected.

While all 163 ecoregional sections (a finer subdivision below the province level) in the conterminous US contain some wildlands on federal and state land, many sections have very little wild habitat remaining. One third of the sections (64 out of 163) have less than five percent of their area remaining in wildlands. Twenty-eight sections have less than 1%, and seven sections have less than 0.1%. Only twenty-six sections in the conterminous US have greater than 50% of their area still remaining in wildlands. Especially in those provinces and sections that have little or no protected wildlands, it is urgent that protection be given to the remaining relatively pristine remnants.

The US Road Network

Our study identified approximately 7 million miles of roads in the conterminous United States, almost double that mentioned in previous studies. This more accurate estimate of total road length and road impacts, combined with the consideration of agricultural areas and other permanently developed lands (where motorized vehicles have regular access), pushes our estimate of the area impacted by motorized vehicles to over 60% of the land surface of the continental United States.

Comparison with the US Forest Service Roadless Area Inventory

We conducted a comprehensive analysis that compares how our roadless area mapping matched that of the Forest Service. First, there is complete correspondence between the Forest Service Inventory and the PBI inventory on over 53.5 million acres. Over 91.5% of all Forest Service Inventoried Roadless Areas (IRAs) were mapped as roadless by PBI.

This study assesses the accuracy and completeness of the US Forest Service's roadless area inventory presented as part of the recent Roadless Area Conservation Plan. Our analysis of Forest Service data on their Inventoried Roadless Areas revealed that nationwide:

- Forest Service IRAs over 5000 acres in size comprise 55.5 million acres
- Forest Service IRAs between 1000 and 5000 acres in size comprise 2.5 million acres
- Forest Service IRAs less than 1000 acres in size comprise over 600,000 acres

In the eastern US, most of the IRAs are less than 5000 acres in size. Some of the small IRAs are contiguous with existing Wilderness or part of multiple ownership roadless areas. But there are many small, distinct IRA units. In the western United States, most IRAs are over 5000 acres in size and most of the smaller IRA patches are either contiguous with existing Wilderness or part of multiple ownership roadless areas. Even in the west, there are numerous examples of small, distinct IRAs that are less than 5000 acres in size. Our analysis reveals that the US Forest Service did not apply a uniform size criterion to the delineation of IRAs.

We found significant differences between our inventory and the Forest Service Roadless Area inventory. The Forest Service inventory identified 58.6 million acres of unprotected roadless land on Forest Service lands in the United States. Our inventory identified 107.2 million acres of unprotected roadless areas on National Forest land. Closer examination of the numbers reveals that there are many reasons for this large (48.7 million acre) different between the two inventories.

First, our inventory included all roadless areas over 1000 acres in size. Although the Forest Service did map some small roadless areas, most of the roadless areas that they mapped were over 5000 acres, however, some IRAs were less than 1000 acres. Our analysis reveals the inconsistency of definition and methodology used by the Forest Service for mapping Inventoried Roadless Areas (IRAs). The Forest Service mapped very small areas as an IRA in some places, elsewhere large roadless areas (over 10,000 acres) were ignored by the Forest Service.

But these areas of complete agreement between the Forest Service inventory and that conducted by PBI account for only 47.52% of all roadless areas mapped by PBI on National Forest land. We found over 59 million acres of land that qualified for roadless area status that was not mapped by the Forest Service as an IRA. Of this total nearly 20 million acres of roadless land mapped by PBI (but by the Forest Service) are small roadless areas between 1000 and 5000 acres in size. But over 39 million acres of roadless land mapped by PBI (but not by the Forest Service) exists in roadless areas over 5000 acres in size. We found many examples of “uninventoried” roadless areas that meet all roadless area criteria used by both PBI and the Forest Service that were not included in the Forest Service inventory. We also found that the boundaries for most Forest Service Inventoried Roadless Areas did not come close to the edge of all the roads that bounded the area. Often the IRA boundaries went down to some bounding roads but were pulled way back from other bounding roads, excluding considerable wild and roadless land from the IRA.

Possible Enhancements, Future Analysis and Recommendations

The study examines issues regarding jeep trails and unmapped roads within roadless areas. However, more data is necessary to be able to fully assess their impact on roadless lands as mapped by PBI. It is unlikely that inclusion of jeep trails and unmapped roads would drastically affect the results of this inventory. The permanence and ecological impact of these features are reasons to not consider these features when defining roadless area boundaries.

The study also examines the feasibility of using GIS analysis and remote sensing to track changes in roadless areas over time and to determine the wilderness quality of roadless lands. It provides a set of ten recommendations for future work that would improve the roadless-area inventory and provide additional analysis of roadless area characteristics.

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INTRODUCTION

The system of roads in the United States is one of the most pervasive extensions of human development into the natural world. This system of roads causes disturbances to native ecosystems at levels disproportionate to the actual area covered by roads in the United States (Forman 2000). Such disturbances that extend beyond the road cut and into unroaded areas include: introduction of alien species of plants and animals, modification of animal behavior, blockage of animal movement, increases in water runoff and mass-wasting, increased light infiltration into forests, and the introduction of pollutants (Troumbulak and Frissell 2000).

Because of the significant influence of roads on native ecosystems, identifying and preserving the remaining areas not directly impacted (called wildlands or roadless areas) is critical to lasting conservation efforts. Many species are sensitive to human disturbances and find optimal habitats in undisturbed areas. The long-term survival of these and other species is dependent on sufficient habitat across a wide range of ecosystem types. But the current system of protected areas in the United States is not representative of the full range of ecological features (Scott et al. 2001), making identifying and preserving unprotected wildlands even more important.

However, the remaining wildlands have never been mapped across ownerships in a consistent manner. This lack of information has severely hindered the conservation of some of the most pristine environments in the United States. This project is an attempt to fill that vital knowledge gap.

The Pew Wilderness Center (PWC) contracted with Pacific Biodiversity Institute (PBI) in 2001 to identify and analyze all roadless areas over 1,000 acres in size on federal and state land in the United States. This work built on PBI's earlier roadless area mapping work in the northwestern US (Washington, Oregon, Idaho, Montana, Wyoming, North Dakota, South Dakota, and Nebraska) from 1994 to 2000.

OBJECTIVES

The objectives of this project were to:

1. Identify the remaining roadless areas of 1,000 acres or more on federal and state lands in the United States (including Puerto Rico, and the US Virgin Islands).
2. Document the data sources, assumptions and processes Pacific Biodiversity Institute has used to map the roadless areas.
3. Analyze the identified roadless areas in terms of:
    a. Ownership
    b. Existing units of the National Wilderness Preservation System and state equivalents
    c. The most recent Forest Service roadless area inventory (USDA Forest Service 2000)
    d. Similar roadless area surveys conducted on BLM land
    e. Land use/land cover and ecoregions
4. Provide recommendations for continuing roadless area inventories and analysis of roadless area characteristics.

METHODS

This project followed the methods developed during PBI's first inventory of wildlands in Washington State (Morrison et al. 1998). These methods involve an analysis of the best available information on roads and other permanent human disturbances to determine where

undisturbed, wild areas occur. In this project, we collected, processed, and analyzed extensive data sets to determine the current extent of the wildlands of the United States.

Road Data

Accurate mapping of roadless areas for conservation purposes requires the most accurate and up-to-date roads information available. The goal for this project was a roadless areas layer that could be used at a scale of 1:100,000. However, relying solely on available 1:100,000 roads data for delineating roadless areas would have yielded a fundamentally flawed product.

The commonly available US Census Bureau TIGER or USGS Digital Line Graph (DLG) transportation layers are inadequate for mapping roadless areas for several reasons. First, these data layers were created from 1:100,000 scale maps that often are already out of date by the time of their digitizing. The Census Bureau TIGER line file documentation states, "While the Census Bureau has made a reasonable and systematic attempt to gather the most recent information available about the features that this file portrays, the Census Bureau cautions users that the files are no more complete than the source documents used in their compilation, the vintage of those source documents, and the translation of the information on those source documents (US Census Bureau 1999)." Second, the focus of these data layers is on areas with concentrations of people. Updates to the 1990 TIGER line data by the Census Bureau "...came from map annotations made by enumerators as they attempted to locate living quarters by traversing every street feature in their assignment area" (US Census Bureau 1999). Third, road building is continually happening, and the TIGER/DLG data will not capture any road building that has happened since the last survey. For these reasons, the TIGER/DLG data will omit many roads in the areas of highest interest to this project (e.g., in undeveloped areas).

The TIGER/DLG 1:100,000 data is not worthless, however. Because the 1:100,000 roads data sources focus on populated areas, and because the omission of a road in a residential or urban area is not likely to cause erroneous delineation of a roadless area, the TIGER/DLG roads layer is suitable as a "background" or base data layer that needs to be supplemented with higher quality data in the areas where it matters the most. The state and federal agencies that manage the majority of the public land in the US generally maintain higher-quality (but by no means perfect) road data. These agencies are the sources for the data to fill in the holes in the commonly available 1:100,000 data.

To achieve the best roads data layer for mapping roadless areas in the US, PBI started with the Environmental Systems Research Institute (ERSI) Streetmap data, a variant of TIGER/DLG, as our background data layer. ESRI licensed this 1:100,000 data from Geographic Data Technologies (GDT), who derived it from the 1995 U.S. Census TIGER data. This data is superior to the original TIGER data because the editing and corrections that GDT has made to the data.

PBI obtained supplemental roads data by contacting US Forest Service National Forests and Grasslands, BLM Regional Offices, and state agencies (Tables 1, 2, and 3). We then used this data to supplement (add to) or substitute for (replace) the Streetmap data in specific locations in order to improve the accuracy of the Streetmap data in areas most important to roadless area mapping. The decision to use the additional roads data as a supplement to or substitute for the Streetmap data was made on a case-by-case basis by looking at several factors. We first evaluated whether the Streetmap data included roads that an additional data layer did not. For instance, in many urban areas, US Forest Service and BLM data layers tend to miss many city roads and residential developments. These areas could mistakenly be mapped as roadless areas. In some National Forests, the roads data obtained contained only Forest Service roads and not

highways or other federal, state, or county roads that might cross through the forest. If the Streetmap data was found to have valid roads that an additional data layer did not, then we used both data layers together for that area (supplementation). If the additional data layer contained most of the Streetmap roads but had corrections, or additional information, then we excluded the Streetmap data from that area and used only the additional data layer (substitution). The result of this process is a variable scale map of roads across the United States (Figure 1). Details on each of the additional data layers that we used in this project are given in sections below.

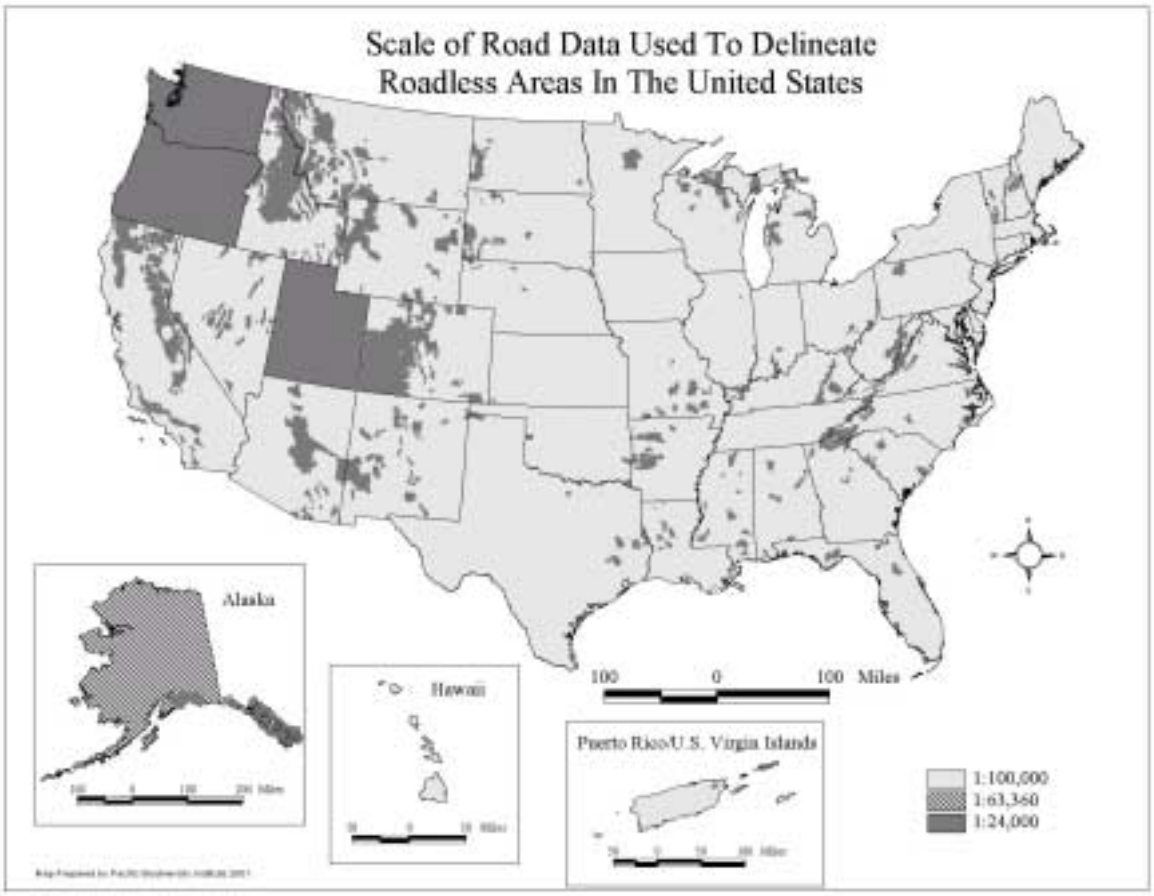

Figure 1. Final scales of the roads layers used to map roadless areas in the United States.

US Forest Service

PBI contacted each of the 141 National Forests and Grasslands administered by the US Forest Service and requested GIS coverages of roads and administrative boundaries at 1:24,000 scale. We received data from 133 National Forests and Grasslands within the time period of the project (Table 1).

Table 1. US Forest Service National Forests and Grasslands roads data received for this project. Those forests and grasslands from which we received data are noted with "Yes." Reasons for not sending us data are given in footnotes.

Region 1 – Northern

Forest/Grassland	Data Received
Beaverhead	Yes
Bitterroot	Yes
Clearwater	Yes
Custer	Yes
Dakota Prairie	Yes
Flathead	Yes
Gallatin	Yes
Helena	Yes
Idaho Panhandle	Yes
Kootenai	Yes
Lewis-Clark	Yes
Lolo	Yes
Nez Perce	Yes

Region 2 – Rocky Mountain

Forest/Grassland	Data Received
Arapaho	Yes
Bighorn	Yes
Black Hills	Yes
Grand Mesa	Yes
Medicine Bow	Yes
Nebraska	Yes
Pawnee	Yes
Pike	Partial[1]
Rio Grande	Yes
San Juan	Yes
Shoshone	Yes
Thunder Basin	Yes
White River	Yes

Region 3 – Southwestern

Forest/Grassland	Data Received
Apache Sitgreave	Yes
Black Kettle	No[2]
Carson	Yes
Cibola	Yes
Coconino	No[3]
Coronado	Yes
Gila	Yes
Kaibab	Yes
Kiowa	No[2]
Lincoln	Yes
McClellan Creek	No[2]
Prescott	No[4]
Rita Blanca	No[2]
Santa Fe	Yes
Tonto	No[5]

Region 4 – Intermountain

Forest/Grassland	Data Received
Ashley	Yes
Biose	Yes
Bridger-Teton	Yes
Caribou	Yes
Curlew	Yes
Dixie	Yes
Fish Lake	Yes
Humboldt	Yes
Manti-LaSal	Yes
Payette	Yes
Salmon-Challis	Yes
Sawtooth	Yes
Targhee	Yes
Uinta	Yes
Wasatch-Cache	Yes

Region 5 – Pacific Southwest

Forest/Grassland	Data Received
Angeles	Yes
Cleveland	Yes
Eldorado	Yes
Inyo	Yes
Klamath	Yes
Lake Tahoe Basin	Yes
Lassen	Yes
Lospadres	Yes
Mendocino	Yes
Modoc	Yes
Pluman	Yes
San Bernardino	Yes
Sequioa	Yes
Shasta Trinity	Yes
Sierra	Yes
Six Rivers	Yes
Stanislaus	Yes
Tahoe	Yes

Region 6 – Pacific Northwest

Forest/Grassland	Data Received
Deschutes	Yes
Fremont	Yes
Gifford-Pinchot	Yes
Malheur	Yes
Mt. Hood	Yes
Mt. Baker-Snoqualmie	Yes
Ochoco	Yes
Okanogan	Yes
Olympic	Yes
Siskiyou	Yes
Siuslaw	Yes
Umatilla	Yes
Umpqua	Yes
Wallowa-Whitman	Yes
Wenatchee	Yes
Willamette	Yes
Winema	Yes

Region 8 – Southern

Forest/Grassland	Data Received
Angeline	Yes
Apalachicola	Yes
Bankhead	Yes
Beinville	Yes
Caddo	Yes
Chattahoochee-Oconee	Yes
Cherokee	Yes
Conecuh	Yes
Croatan	Yes
Daniel Boone	Yes
Davy Crockett	Yes
Delta	Yes
Desoto	Yes
Francis Marion	Yes
George Washington	Yes
Holly Springs	Yes
Homochitto	Yes
Kisatchie	Yes
LBJ	Yes
Nantahala	Yes
Ocala	Yes
Osceola	Yes
Ouachita	Yes
Ozark	Yes
Pisgah	Yes
Sabine	Yes
Sam Houston	Yes
Sumter	Yes
Talladega	Yes
Tombigbee	Yes
Tuskegee	Yes
Uwharrie	Yes

Region 9 – Eastern

Forest/Grassland	Data Received
Allegheny	Yes
Chequamegon	Yes
Chippewa	Yes
Green Mountain	Yes
Hiawatha	Yes
Hoosier	Yes
Huron Manistee	Yes
Mark Twain	Yes
Midewin	Yes
Monongahela	Yes
Ottawa	Yes
Shawnee	Yes
Superior	No[6]
Wayne	Yes
White Mountain	Yes

Region 10 – Alaska

Forest/Grassland	Data Received
Chugach	Yes
Tongass	Yes

1. We received data for only the western portion of the Pike National Forest.
2. No roads data was available for this National Grassland.

3. The Coconino National Forest required that we submit a Freedom of Information Act request to obtain their roads data. We did not receive the data in time to use for this project.
4. The roads data for the Prescott National Forest was still in draft form and would not be released to PBI.
5. The Tonto National Forest did not have a current roads layer that they would release to PBI.
6. The Superior National Forest would not release their roads data to PBI because it is in draft form.

Bureau of Land Management

PBI contacted each BLM region in the United States and requested roads and administrative boundaries layers at 1:24,000 scale. For California and Colorado, we were directed to contact the individual field offices within the region. We received roads data from six states (Table 2). We used the data from only four states, however. The 1:100,000 data from Nevada and Wyoming did not have enough detail to be more useful than the Streetmap data.

Table 2. Bureau of Land Management roads data received for this project

BLM Region	Road Data Availability
Alaska	No roads data available
Arizona	1:100,000 roads data available. Used as supplement to other data sources
California	No roads data available
Colorado	1:24,000 roads data was available for the following 4 Field Offices: - Canyon City - Craig - Glenwood Springs - Montrose
Eastern States	No roads data available
Idaho	No roads data available
Montana	No roads data available
Nevada	1:100,000 roads data available. Originated from USGS Digital Line Graphs. Not used.
New Mexico	No roads data available
Oregon	1:24,000 roads data available for entire state
Utah	1:24,000 roads data available for Grand Staircase-Escalante National Monument
Wyoming	1:100,000 roads data available. Originated from USGS Digital Line Graphs. Not used.

State Data Sources

PBI investigated state-level sources for roads data. Most states had available 1:100,000 roads layers compiled from either TIGER or DLG data. We did not retrieve these data layers as they would not be any better than the Streetmap data (in fact they could be less accurate). We found three states with better than 1:100,000 data (Table 3).

Table 3. State sources of roads data used in this project

Source	Data Layer
Alaska Department of Natural Resources	1:63,600 Infrastructure – This coverage is not complete for the entire state and was used as a supplementary roads layer for Alaska
Utah Automated Geographic Reference Center	1:24,000 Transportation Layer
Wahington Department of Natural Resources	1:24,000 Transportation Layer

Data Processing

As the data was collected, information on projection and attributes used in coding roads was recorded for each data set. Data was imported into ArcInfo coverages and projected into the US-Albers projection (Table 4). If the roads layer contained attributes defining hiking trails,

jeep trails or road status (open, closed, obliterated), then these features were selected out of the data set and a new GIS coverage was created that contained only segments coded as open roads. This process was completed on data sets from all sources. It should be noted that some data sets did not have attributes, and even for data sets with attributes, there are often some road segments that are not coded. Segments without codes were checked against other sources where possible and were handled as deemed appropriate.

Data for Forest Service administrative boundaries was appended together for each Forest Service Region. These coverages were used to erase the Streetmap road data layers for areas administered by the Forest Service. Thus the ESRI Streetmap data was used only for non-Forest Service land unless we had reason to include it. These erased coverages were then appended with the road data for each of the Forests, and with BLM road data if available for that area. The final road coverages for each region had Forest Service data for Forest Service lands, Streetmap data for non-Forest Service lands, and BLM or state data overlapped with the Streetmap data if it was available. The Streetmap data was not erased for BLM areas because of the intricate nature of BLM holdings, as well as the fact that detailed administrative boundaries were not available.

Table 4. Final projection information for US roadless area mapping project

Lower 48 states, Puerto Rico and US Virgin Islands	Alaska	Hawaii
Projection: Albers Units: meters Datum: NAD83 Spheroid: GRS1980 Xshift 0.0000000000 Yshift 0.0000000000 Parameters 1st standard parallel 29 30 0.000 2nd standard parallel 45 30 0.000 central meridian -96 0 0.000 latitude of origin 23 0 0.000 false easting (meters) 0.00000 false northing (meters) 0.00000	Projection: Albers Units: meters Datum: NAD27 Spheroid: Clarke 1866 Xshift 0.0000000000 Yshift 0.0000000000 Parameters 1st standard parallel 55 0 0.000 2nd standard parallel 65 0 0.000 central meridian -154 0 0.000 latitude of origin 50 0 0.000 false easting (meters) 0.00000 false northing (meters) 0.00000	Projection: Universal Transverse Mercator Zone: 4 Datum: NAD27 Spheroid: Clarke 1866

Developed and Permanently Disturbed Areas

Delineating roadless areas using only road locations would result in agricultural lands, urban parks, and many other non-wild areas being erroneously classified as roadless. To prevent this, PBI compiled a GIS layer of developed and permanently disturbed areas for the United States. We relied on the National Land Cover Data (NLCD) recently published by the US Geological Survey (USGS) (http://edcwww.cr.usgs.gov/programs/lccp/natllandcover.html, see also Vogelmann et al. 2001). This land cover data layer divides the lower 48 states into 21 land cover classes by classifying Landsat Thematic Mapper 5 (TM5) satellite imagery from the early to mid-1990's. From the NLCD we created a new layer from the developed and permanently disturbed cover types (Table 5). We then used this layer to exclude developed and permanently disturbed areas from our roadless area assessment.

Table 5. Developed and permanently disturbed land cover codes in the National Land Cover Data layer.

Land Cover Code	Cover Type
21	Low Intensity Residential
22	High Intensity Residential
23	Commercial/Industrial/Transportation
61	Orchards/Vineyards/Other Non-Natural Woody
81	Pasture/Hay
82	Row Crops
83	Small Grains
84	Fallow
85	Urban/Recreational Grasses

Exclusion of Major Water Bodies

In mapping of roadless areas, large bodies of water present a problem. Since there are very few roads over water bodies, they are mapped as roadless unless steps are taken specifically to exclude them or a portion of them. This becomes problematic for several reasons. First, a single body of water may extend through roaded and roadless areas. Second, motorized recreation on waterways can extend into protected areas. Exclusion of water bodies that were influenced by motorized boating, damming or other activities would be a preferable option, but there are no good sources of data nationwide that identify these areas and development of such data was outside the scope of this project. Third, considering major bodies of water as roadless would result in the inclusion of small (much less than 1,000 ac) pieces of land adjacent to the water body also being classified as roadless when they would not otherwise meet roadless area criteria.

For the purposes of this project, we excluded major water bodies from our roadless area analyses using the Major Water Bodies data layer available from ESRI. We corrected the major water bodies layer in several places where it was in obvious error. One implication of this decision was that some roadless areas that extend on either side of a water body might have been eliminated because each part individually would not meet our 1,000-ac limit. Another implication is that there may have been some water bodies that do not have motorized use and are surrounded (either entirely or partially) by roadless land and should be considered part of the roadless area. We do not believe that this possibility measurably affected the results of this study.

Land Ownership and Protection Status

PBI used the Protected Areas Database (PAD) published by Conservation Biology Institute (CBI) as our primary spatial data layer for delineating federal and state lands. During the course of our study, we took a critical look at the PAD and documented all of the problems that we have found to date. The problems documented here are the result of a fairly thorough, but not comprehensive assessment of the PAD. Upon closer analysis, more problems may be discovered. This document does not attempt to address land ownership changes that may have occurred since the publication date of the PAD due to purchases, sales, or swaps.

The errors in the PAD can be divided into several categories: omissions, miscodings, areas not attributed, and incomplete data layer documentation. The specific problems for each category are listed below:

Omissions

Omissions are areas for which there is no polygon present in the PAD. We found the following omissions in the PAD:

- The entire Chippewa National Forest in Minnesota was omitted.
- There were many wilderness areas in the eastern US that were omitted (so many that we stopped counting and found another data layer to use for wilderness areas).
- The Loomis State Forest and several other state-owned areas in Washington were omitted.
- The San Isabel, Rio Grande, Gunnison, and San Juan National Forests all have missing wilderness areas.
- The Green Mountain and Finger Lakes National Forest lands in New York were omitted.
- Over 6.5 Million ac of BLM land in Idaho were omitted.

Miscoding

Miscoded polygons in the PAD corresponded to federal or state owned lands where the wrong owner has been assigned to the polygon. We found the following miscodings in the PAD:

- A portion of the Tahoe National Forest was miscoded as National Grassland.
- The Nevada Test Site was miscoded as US Fish and Wildlife Service (USFWS) land and the Desert National Wildlife Range (adjacent to the Test Site) was coded as Department of Defense (DoD).
- The Theodore Roosevelt Wilderness in North Dakota was coded as US Forest Service (USFS). It is actually National Park Service (NPS).
- The Lake Tahoe Basin Management Unit was coded as NPS when it should have been USFS.
- 1.5 million acres in Montana (the Bankhead-Jones Land Use Lands) were coded as USFWS when they are actually administered by the BLM.
- The White Mountain Wilderness in New Mexico is not attributed to the Lincoln National Forest, of which it is a part.

Areas Not Attributed

For the final PAD, CBI intersected the ownership layer for the United States with the World Wildlife Fund Ecoregions layer. This often results in larger management areas (e.g., National Parks, Wilderness Areas) being split into multiple polygons based on the ecoregions that occur in the management area. We have found the following instances where polygons within a contiguous management area were not given attributes:

- Olympic National Park – a large polygon corresponding to the North Cascades Forests ecoregion had no attributes.
- An inside polygon in the Kaibab National Forest was not attributed.
- Numerous polygons within the Toiyabe National Forest were not attributed, including unattributed wilderness areas.
- Inyo National Forest had an unattributed polygon.
- In the Great Basin National Park, a large portion of the park had no attributes.
- A State of Utah Forest within the Wasatch National Forest was not attributed.

Improper Land Ownership Boundaries

The PAD used as its basis for USFS land, the older Managed Areas Database (MAD, 1997) unless they had more detailed ownership layers from individual states. MAD was assembled at a scale of 1:2,000,000 and the coarseness of USFS ownership boundaries is evident in several National Forests. The MAD data layer also used the administrative (proclamation) boundaries for National Forests in Region 8 and 9 (eastern US). However, unlike the western US, most National Forests in the east do not occupy their entire administrative boundary. There are even fairly large cities within many of the USFS administrative boundaries in the eastern US (e.g.,

Covington, VA, population 7,000, is completely within the George Washington National Forest). The administrative boundaries for the eastern US over-estimated the USFS ownership for a forest by as much as 80 percent.

Incomplete Data Layer Documentation

Due to licensing restrictions, CBI was not permitted to distribute land ownership information for Indiana or New Jersey. This would not have been a problem if we had been aware of its omission from the beginning. However, CBI's documentation of the PAD does not contain any reference to the fact that these states are not included. In fact, CBI's documentation of the PAD actually contains metadata for Indiana and New Jersey land ownership data. The only explanation of the omission of these states that I found was a single sentence on CBI's web site. This is very problematic since users that purchase this data layer may be under the assumption (as we were) that this is a complete data layer for the United States. At the very least, the federal lands in these states could have been included since this data is readily available from other sources.

Action Taken by Pacific Biodiversity Institute

PBI has taken steps to correct all of the problems listed above. In the case of omitted lands, these polygons were appended into the PAD and attributed. For unattributed polygons, we supplied the appropriate coding. We also corrected any miscoded lands that we found. Due to the many problems that we found in the northwestern states, we abandoned use of the PAD for Washington, Oregon, Idaho, Montana, Wyoming, North Dakota, South Dakota, and Nebraska and relied on a data layer that we developed for a previous project.

Our ownership layer for the northwestern states was assembled from 1:24,000 ownership data obtained from each National Forest and Grassland plus ownership data from each individual state and some BLM offices. Adequate statewide ownership data was not available for North and South Dakota. For these states, we supplemented National Forest and Grasslands data with 1:2,000 ownership data developed by ESRI.

To address the problem of omitted and miscoded wilderness areas, we dissolved all wilderness areas back into their respective ownerships and used the National Wilderness Preservation System layer developed by Dave Spildie at the Aldo Leopold Wilderness Research Institute. Although this data layer was done mostly at 1:2,000,000-scale, it is complete for all wilderness areas across all federal ownerships. Spildie is currently working on a 1:100,000-scale version of this data layer.

To address the problem of administrative boundaries vs. actual ownership for USFS land in the eastern US, we contacted each of the national forests in Regions 8 and 9 and obtained from them their surface ownership coverages. We then removed the USFS Region 8 and 9 data from the PAD and substituted the new USFS data.

It is important to note that PBI did not conduct a rigorous accuracy assessment of the PAD. The problems identified came to light during the course of our project and reflect the topics that we were interested in, namely wilderness and special management areas, and other federal lands. We have not looked closely at state lands except in areas that we are very familiar with (e.g., Washington, Idaho).

Other Sources of Ownership Information

The PAD does not cover Hawaii or any of the US protectorates. Also, due to licensing restrictions, ownership information for Alaska was not included. We received ownership information for Alaska from the Alaska Conservation Alliance. Ownership information for Hawaii was obtained from the State of Hawaii Office of Planning. Federal ownership polygons for Puerto Rico and the US Virgin Islands were obtained from their respective agencies and merged into a single federal ownership layer for these areas.

Roadless Area Processing

The process detailed above for assembling roads data resulted in a data layer for the lower 48 states that was too large to process as a single piece or even several larger pieces. Correspondingly, roadless areas were processed using one-degree latitude-longitude tiles (Figure 2). For each tile, the roads layer was clipped to the tile boundary buffered by 10 kilometers so that roadless areas would not be truncated at the boundary. Roadless areas for that tile were then calculated using the procedure detailed below. After the roadless areas were calculated, the tiles were merged together to produce a seamless roadless areas layer. Roadless areas for Alaska, Hawaii, Puerto Rico, and the US Virgin Islands were delineated without this tiling procedure because either their size was much smaller or road density was much lower.

Figure 2. One-degree tiles used in roadless area mapping for the conterminous 48 states.

For this project, our criteria for defining roadless areas was: any area greater than 60 meters from a road that was at least 1,000 acres in size with a minimum width of 200 meters. The calculation of minimum size was made after all excluded areas (e.g., developed and permanently disturbed areas, major water bodies) were removed. This definition was decided upon in cooperation with PWC and is in line with current research on road effects on forested environments (See Frissel et al. 2000).

PBI used previously completed roadless area inventories for Washington, Oregon, Idaho, Montana, Wyoming, Nebraska, North Dakota, and South Dakota. These inventories were conducted between 1999 and 2001 using the same process described below with slight

differences in the resolution of the mapping. For Washington and Oregon, we used a base grid of 20m cells and a 40m setback from the road to determine roadless areas. For the other six states, we used a base grid of 25m cells with a 50m setback.

To achieve precision in the roadless area mapping sufficient to meet the needs of PWC, we used a base grid of 30m cells 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 30m cells was sufficient for the scale of this project. For these reasons, we that any difference between PBI's previously mapped roadless areas and this project would be insignificant. To be included with this project, the existing roadless layers were converted to the base grid of 30m cells and merged with other roadless areas delineated for this project.

To delineate the roadless areas, we first calculated those areas greater than 100 meters from any road using a line-distance function. Any areas falling below the 1,000-acre minimum size were then eliminated. Next, we excluded any permanently developed or disturbed areas as well as major water bodies (see above for detail on creation of these layers). Again, after this procedure, areas falling below 1,000 acres were eliminated.

To detect points of a roadless area below 200 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 eliminated.

Analyses of Roadless Areas

The final roadless area grid was combined with the corrected PAD ownership layer to determine federal and state roadless areas. When private lands are excluded from analyses, areas less than 1,000 acres (of federal or state land) may occur. These were deleted and the remaining areas were coded into two classes - those with between 1,000 and 5,000 acres on federal or state land and those with over 5,000 acres on federal or state land. This is the final roadless area layer used for subsequent analyses and mapping.

The final roadless grid was converted to a polygon layer and intersected with a layer of the US State boundaries, to calculate the number of acres of public roadless areas in each state. It was also intersected with a grid of Bailey's Ecoregions to calculate the acreage in each ecoregion.

RESULTS and DISCUSSION

Management of Federal and State Owned Wildlands in the United States

In this study we identified 551 million acres of remaining unprotected roadless land on federal and state land in the United States. This is approximately 24.4% of the United States. Areas protected as Wilderness account for an additional 105,778,000 ac, or 4.6% of the United States. Alaska alone contains 46.6% of the remaining unprotected roadless area in the United States and 55% of the designated Wilderness.

Wildlands Managed by the Four Principal Federal Agencies

Over 408 million acres of unprotected wildlands occur on land managed by four principal federal land management agencies: the Forest Service, Fish and Wildlife Service, Bureau of Land Management, and National Park Service (Figure 3a and 3b. Of this total, 58.2% occurs in the

contiguous 48 states, Hawaii, Puerto Rico, and the US Virgin Islands (Table 6) and the remaining 41.8% is in Alaska (Table 7). Unprotected wildlands account for 83.6% of total wildlands (Wilderness plus unprotected wildlands) in the contiguous 48 states, Hawaii, Puerto Rico, and the US Virgin Islands. Unprotected wildlands account for 74.6% of total wildlands in Alaska.

Table 6. Roadless and Wilderness acreages for the four principal federal agencies in the contiguous 48 states, Hawaii, Puerto Rico, and the US Virgin Islands.

Owner	Wild Acres (including Wilderness)	Wilderness Acreage	Unprotected Roadless Area Acreage
Bureau of Land Management	134,139,000	5,238,000	128,901,000
National Forests and Grasslands	122,115,000	29,015,000	93,100,000
National Parks and Monuments	21,415,000	10,295,000	11,120,000
US Fish and Wildlife Service	6,749,000	2,009,000	4,739,000
Total - Four Principal Agencies	**284,417,000**	**46,557,000**	**237,860,000**

Table 7. Roadless and wilderness acreages for the four principal federal agencies in Alaska.

Owner	Wild Acres (including Wilderness)	Wilderness Acreage	Unprotected Roadless Area Acreage
Bureau of Land Management	82,958,000		82,958,000
National Forests and Grasslands	19,812,000	5,752,000	14,060,000
National Parks and Monuments	51,645,000	33,753,000	17,892,000
US Fish and Wildlife Service	74,499,000	18,677,000	55,822,000
Total - Four Principal Agencies	**228,914,000**	**58,182,000**	**170,732,000**

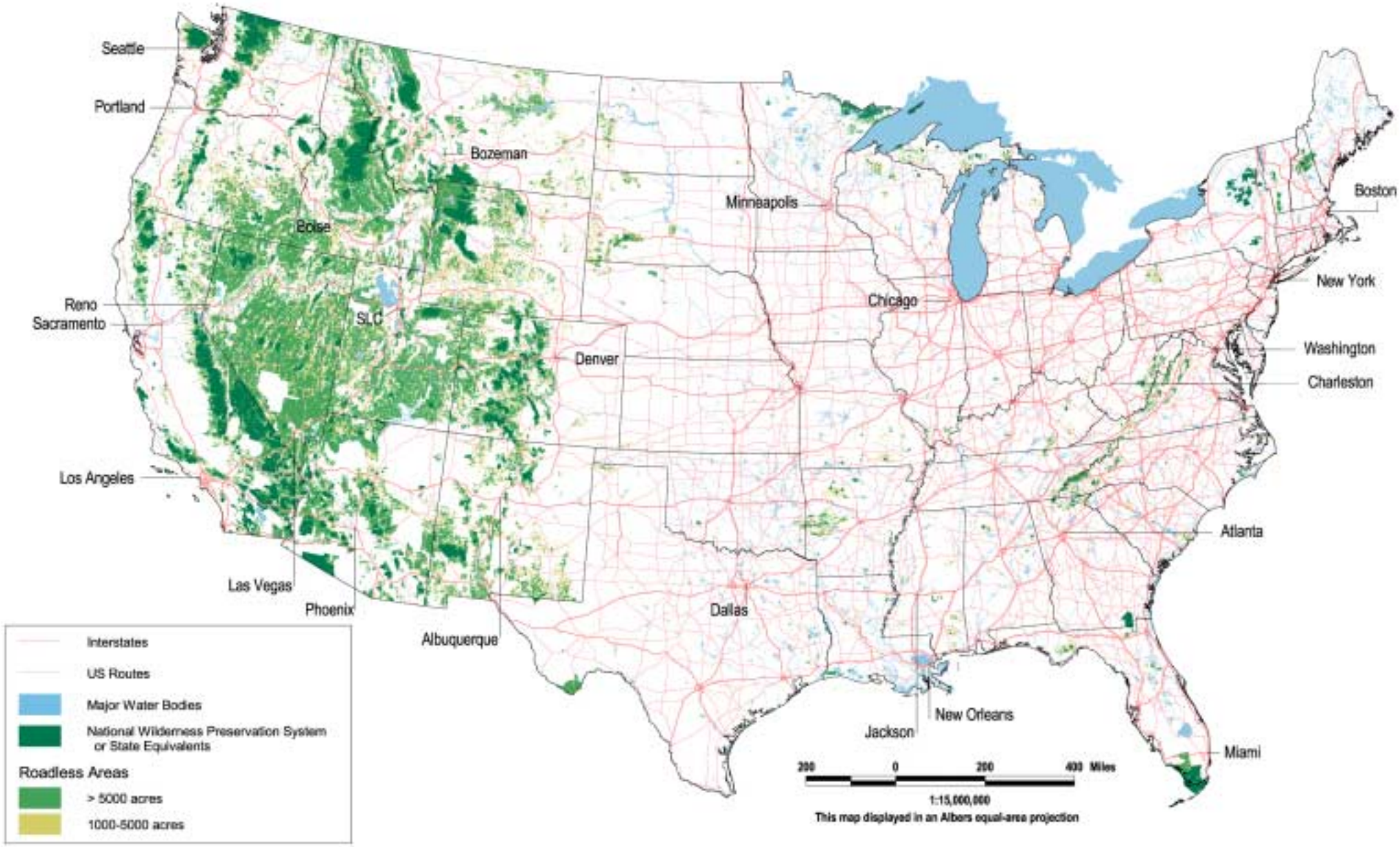

Figure 3a. Wildlands of the contiguous 48 states for the four principal agencies: US Forest Service, US Fish and Wildlife Service, National Park Service, and Bureau of Land Management.

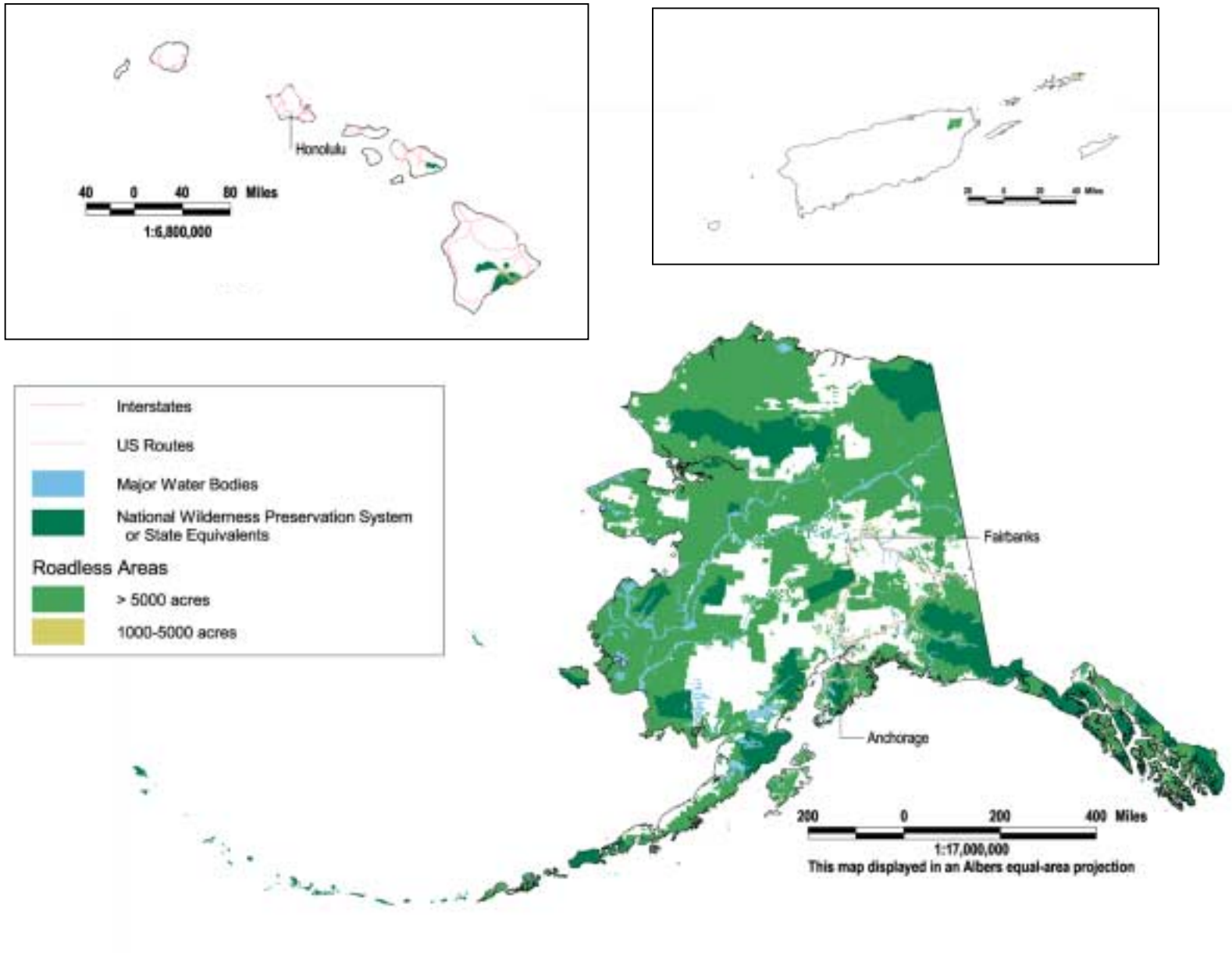

Figure 3b. Wildlands in Alaska, Hawaii, Puerto Rico and the US Virgin Islands for the four principal agencies: US Forest Service, US Fish and Wildlife Service, National Park Service, and Bureau of Land Management.

Wildlands Managed by Other Federal Agencies

We identified 17,759,000 acres of unprotected wildlands on federal agencies other than the four principal agencies. These include lands managed by the Department of Defense, Department of Energy, and Bureau of Reclamation. This accounts for 3.1% of all unprotected wildlands (5.3% of unprotected wildlands in the contiguous 48 states, Hawaii, Puerto Rico, and the US Virgin Islands, and 0.6% of unprotected wildlands in Alaska).

Due to the lack of adequate data on roads and vehicular activities on Department of Defense lands, we have probably over estimated the amount of wildland in this category. While significant roadless areas do exist on Department of Defense lands, they are probably significantly less than we have mapped in this project.

Wildlands on State lands

Unprotected state-owned wildlands account for 125,633,000 acres or 22.2% of all unprotected wildlands in the United States. Alaska state wildlands alone account for 69.1% of all unprotected state wildlands (Table 8). Other states with significant unprotected state wildlands include: Arizona, Michigan, Minnesota, Montana, New York, and Wyoming. In total, 13 states have greater than 1 million acres of unprotected state wildlands.

Table 8. State-owned wildlands and state wilderness equivalents for the United States.

State	Total State Owned Land	State Wildlands	State Wilderness Equivalents	State	Total State Owned Land	State Wildlands	State Wilderness Equivalents
Alaska	89,228,882	87,158,871	322,000	Massachusetts	421,866	199,778	
Arizona	7,640,747	6,317,653		Vermont	240,435	192,122	
Minnesota	29,279,712	4,137,196	97,285	Kentucky	1,667,077	186,354	
Michigan	7,286,463	3,841,648	50,642	Maryland	357,368	178,996	39,412
Montana	5,455,450	3,833,638		Nevada	204,101	159,795	
New York	3,857,220	3,223,203	1,131,768	North Carolina	300,226	156,825	
Wyoming	4,151,595	2,460,801		New Hampshire	196,014	147,933	
Florida	2,946,133	1,837,293		Ohio	438,507	133,777	
Washington	3,447,103	1,748,038		Tennessee	212,078	119,739	
Pennsylvania	2,295,263	1,739,593		Nebraska	252,524	111,912	
Idaho	2,742,769	1,710,902		Virginia	188,466	107,135	
California	1,895,463	1,382,424	436,606	Mississippi	174,551	93,218	
Hawaii	1,374,469	1,199,252		Alabama	128,449	82,381	
Wisconsin	1,434,841	694,215		Connecticut	210,202	71,545	
Maine	643,131	573,515		Texas	98,722	61,728	
North Dakota	320,601	531,444		Illinois	325,131	42,881	
Louisiana	616,342	431,702		South Carolina	124,675	37,807	
Missouri	876,583	385,113		Delaware	68,593	20,493	
Utah	474,936	384,952		Iowa	246,836	16,317	
Georgia	6,209,977	353,611		Rhode Island	26,661	2,718	
West Virginia	528,798	331,475		Kansas	29,114	1,515	
Colorado	440,458	273,394		South Dakota	81,961	911	
Oklahoma	815,468	270,781		Indiana	*	*	
New Mexico	366,747	260,436		New Jersey	*	*	
Arkansas	384,390	256,554		Puerto Rico/Us Virgin Islands	*	*	
Oregon	541,652	247,324					

* State ownership information not available for these states.

There are over 2,077,000 acres of state owned lands in the United States that have been protected by state legislatures as State Wilderness or some other designation that is equivalent to that of the federal Wilderness Preservation System. New York, California and Alaska contain significant patches of State Wilderness that exceed 100,000 acres in size.

Only 1.6% of state owned wildlands in the United States are formally protected as wilderness. The remaining unprotected state owned wildlands offer rich wildlife habitat and usually represent ecoregions that are often unrepresented in the existing protected network of parks and wilderness. A high priority should be given to further study and additional conservation efforts focused on these lands. Some of the greatest conservation gains in this century may come from efforts to better protect these state wildlands.

Wildlands on Other Ownerships

It is worth noting the significant areas of wild and roadless habitat exist on some private lands, tribal lands and city/county owned lands in the United States. A thorough analysis of this situation was beyond the scope of this project, but these wild areas on other ownerships do play a significant role in providing habitat for many species that are sensitive to human disturbance. Many conservation organizations are working on protection efforts involving some of these wildlands that are not in federal or state ownership.

Distribution of State and Federal Wildlands by State

We found 26 states that have over one million acres of unprotected state and federal wildlands (Table 9). Alaska, by far, has the greatest amount of unprotected wildlands. Nevada is the only other state to have over 50 million acres of unprotected wildlands. Three states, Utah, Arizona, and California, have between 25 million and 50 million acres of unprotected wildlands. Six states have between 10 million and 25 million acres of unprotected wildlands, and 18 states have between 1 million and 10 million acres of unprotected wildlands.

Table 9. Unprotected roadless land (on all federal and state ownerships), national Wilderness Areas and state wilderness equivalent sorted by area.

State	Wilderness	State Wilderness Equivalents	Total Unprotected Roadless	State	Wilderness	State Wilderness Equivalents	Total Unprotected Roadless
Alaska	58,182,216	322,000	259,160,469	Louisiana	17,024		1,110,076
Nevada	1,675,123		51,092,614	Georgia	485,484		1,072,484
Utah	801,598		29,033,262	Missouri	71,089		1,023,434
Arizona	4,518,422		27,030,679	Tennessee	66,349		956,275
California	13,975,535	436,606	25,728,887	Mississippi	10,683		927,307
Idaho	4,015,061		24,640,649	Kentucky	16,779		905,952
Montana	3,442,416		22,129,016	New Hampshire	102,932		750,339
Wyoming	3,111,132		21,911,266	Maine	19,392		691,551
New Mexico	1,833,406		19,667,940	Nebraska	12,429		590,140
Colorado	3,171,685		17,190,579	Oklahoma	23,113		582,292
Oregon	2,258,238		17,188,121	South Carolina	60,681		536,304
Washington	4,324,182		7,486,689	Vermont	59,421		488,279
Minnesota	815,154	97,285	5,743,633	Alabama	41,367		438,848
Michigan	247,325	50,642	5,116,531	Ohio	77		225,242
Florida	1,422,325		3,010,677	Illinois	29,688		223,253
South Dakota	73,970		2,283,082	Massachusetts	2,420		211,914
Pennsylvania	9,031		2,097,925	Maryland		39,412	181,977
New York	1,363	1,131,768	2,091,890	Kansas			104,046
Arkansas	153,654		1,928,362	Connecticut			71,887
Virginia	177,212		1,678,044	Puerto Rico/Us Virgin Islands			61,398
Texas	85,333		1,634,020	Iowa			56,571
Wisconsin	42,323		1,552,922	Indiana	12,945		51,939
North Carolina	111,342		1,552,515	Delaware			38,521
North Dakota	39,652		1,334,249	Rhode Island			3,185
Hawaii	142,370		1,265,695	New Jersey	10,341		
West Virginia	80,852		1,122,788				

Only three states have greater than five percent of their area as roadless area (Table 10). An additional eight states have between 2.5 and five percent of total unprotected wildlands. The only western state absent from Table 10 is Washington. While Washington's unprotected wildlands only account for 1.3%, it has the highest proportion of wilderness to unprotected wildlands of any state (0.366). This means that 36.6% of Washington's wildlands are already designated wilderness.

Table 10. States with greater than 2.5% of their area in unprotected wildlands.

State	Percent of State in Unprotected Wildlands
Alaska	45.8
Nevada	9.0
Utah	5.1
Arizona	4.8
California	4.5
Idaho	4.4
Montana	3.9
Wyoming	3.9
New Mexico	3.5
Oregon	3.0
Colorado	3.0

Fragmentation of Wildlands and Size of Wildland Patches

In the contiguous 48 states, Hawaii, Puerto Rico and the US Virgin Islands, 57.7% of wildlands exist in patches of less than 50,000 acres (Figure 4, includes both state and federal wildlands). Wildlands between 1,000 acres and 5,000 acres account for 21.4%. Only 7.4% of wildlands are in patches of 1,000,000 acres or more.

The remaining wildlands in the contiguous 48 states, Hawaii, Puerto Rico and the US Virgin Islands are highly fragmented by roads and relatively permanent human development. Large wildland areas over 500,000 acres account for only 12.1% of all wildlands (Figure 4). The small unprotected roadless areas less than 10,000 acres (32.2% of all wildlands) are often composed of highly dissected and convoluted areas with little intact core area. These small roadless areas often also contain substantial amounts of human disturbance from past management activities (e.g., grazing, logging, off-road motorized recreation use).

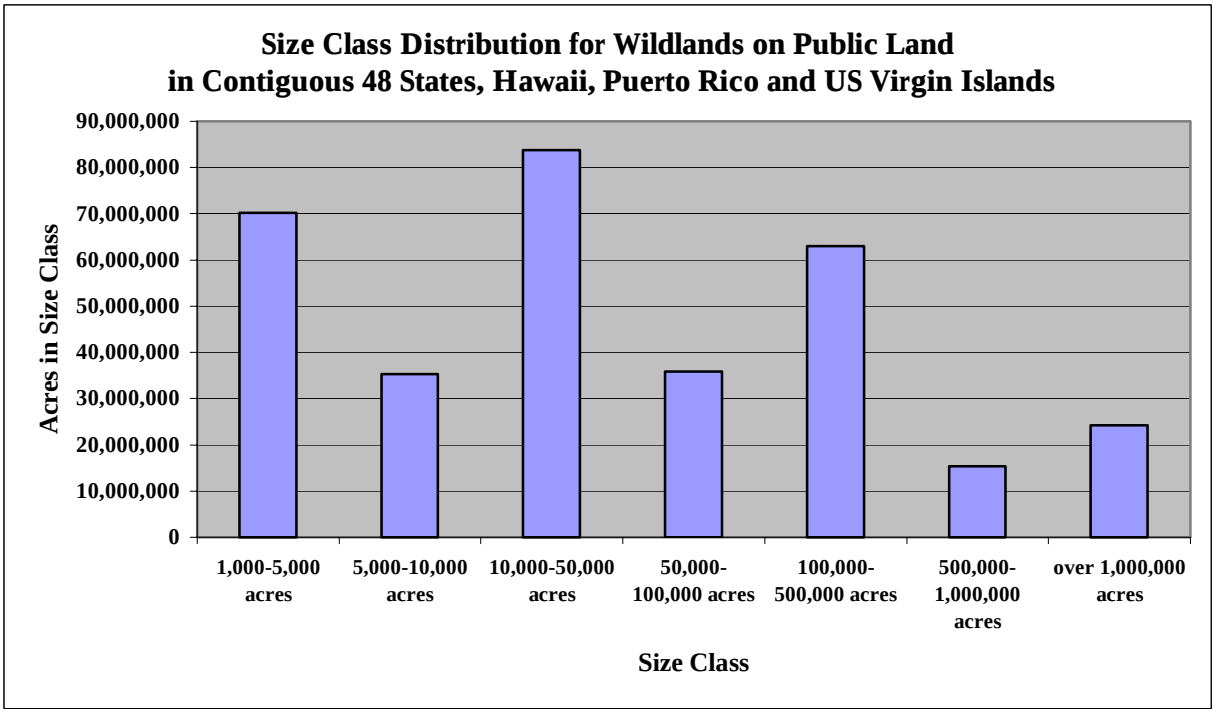

Figure 4. Size-class distribution for wildlands on public lands in the contiguous 48 states, Hawaii, Puerto Rico, and the US Virgin Islands.

In contrast with the rest of the country, 85.6% of Alaska's wildlands remain in very large patches of greater than 1,000,000 ac (Figure 5). Of the Alaskan wildlands that are less than 1,000,000 acres, many of these are oceanic islands in the Aleutian chain or along coastal Alaska that see little human disturbance. Fragmentation from human disturbances has yet to substantially affect Alaska's wildlands.

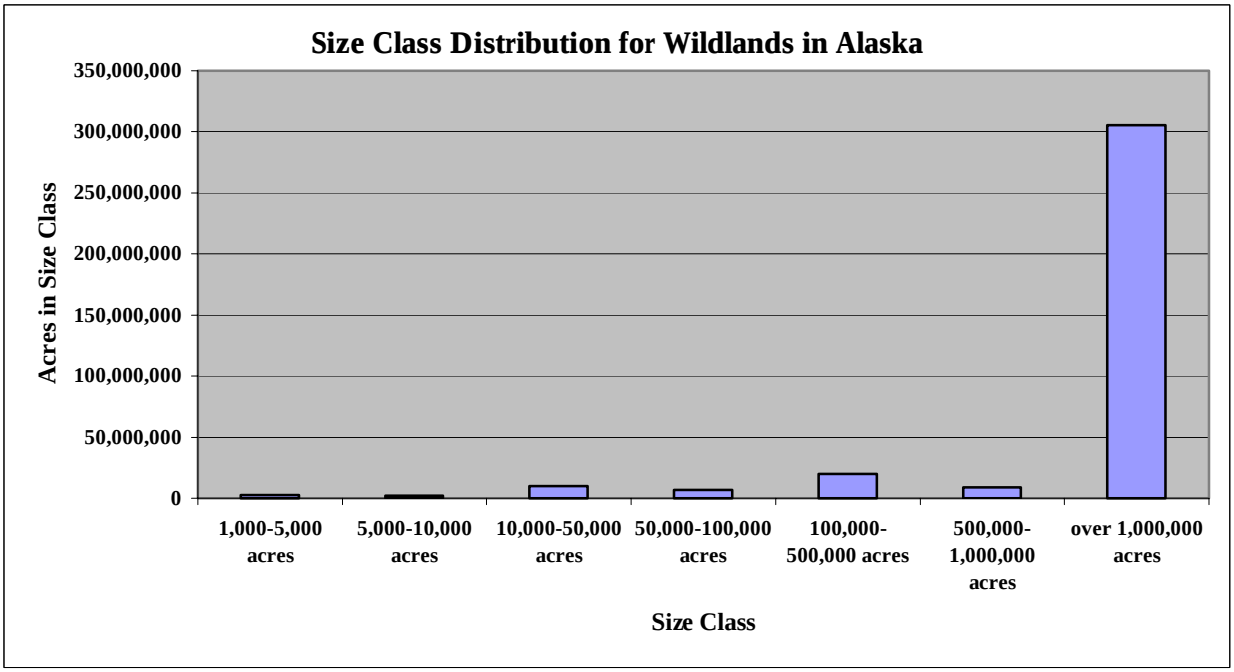

Figure 5. Size-class distribution for wildlands on public lands in Alaska.

Analysis of Wilderness and Roadless Areas by Ecoregion

Ecoregions are a hierarchical method of partitioning the world into units that share broad ecological characteristics (Bailey 1988). At the top of the hierarchy are domains. The United States is divided into four domains (Polar, Dry, Humid Temperate, and Humid Tropical) based on very general climatic (temperature and precipitation) conditions. Domains are broken down into divisions that have more similar climatic conditions. Divisions are subdivided into provinces that not only have more similar climatic characteristics but also have similar geologic make-up. Provinces are divided into sections that, in addition to the similarities of the higher units, also contain similar ecosystem types. Thus, moving down the hierarchy yields smaller areas that have more uniform ecological characteristics.

When considering large regions such as continents or large countries, the concept of ecoregions becomes useful for evaluating how well the current system of protection represents the range of natural conditions. Bailey (1995) identified 52 ecoregional provinces in the United States (34 in the conterminous US, 16 in Alaska, one for Hawaii, and one for Puerto Rico and the US Virgin Islands, Figure 6a) and 193 sections (163 in the conterminous US, 28 in Alaska, one for Hawaii, and one for Puerto Rico and the US Virgin Islands, Figure 6b).

A. Bailey's (1995) Ecoregion Provinces for the conterminous United States

B. Bailey's (1995) Ecoregion Sections for the conterminous United States

Figure 6. Bailey's (1995) ecoregion provinces (a) and sections (b) for the conterminous Unites States.

At the province level, all 52 provinces contain some wildlands (protected and unprotected wildlands on federal and state land, Table 11 and Table 12. Twenty-two provinces, including all provinces in Alaska, have greater than 50% of their area still remaining in wildlands. While there are no provinces that do not have any wildlands, nine provinces have less than 5% of their area in wildlands with less than 0.1% of the province protected.

Table 11. Percent of each Bailey's Ecoregion Province that is roadless in the lower 48 states. This table includes all state and federal wildlands (protected and unprotected) sorted by percent of the ecoregion that is roadless.

Province	Percent of Ecoregion Roadless	Percent of Ecoregion Protected
American Semi-Desert and Desert Province	80.46%	17.46%
Nevada-Utah Mountains-Semi-Desert-Coniferous Forest-Alpine Meadow Province	74.95%	2.22%
Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province	65.18%	11.86%
Middle Rocky Mountain Steppe-Coniferous Forest-Alpine Meadow Province	61.38%	11.23%
Everglades Province	53.44%	16.99%
Sierran Steppe-Mixed Forest-Coniferous Forest-Alpine Meadow Province	53.00%	12.06%
Cascade Mixed Forest-Coniferous Forest-Alpine Meadow Province	52.70%	15.09%
Intermountain Semi-Desert Province	43.96%	0.94%
Northern Rocky Mountain Forest-Steppe-Coniferous Forest-Alpine Meadow Province	41.48%	4.18%
California Coastal Range Open Woodland-Shrub-Coniferous Forest-Meadow Province	37.87%	8.63%
Hawaiian Islands Province	37.44%	3.43%
Arizona-New Mexico Mountains Semi-Desert-Open Woodland-Coniferous Forest-Alpine Meadow Province	35.17%	4.08%
Colorado Plateau Semi-Desert Province	34.15%	2.46%
Chihuahuan Semi-Desert Province	27.88%	0.93%
Intermountain Semi-Desert and Desert Province	25.10%	0.55%
Ouachita Mixed Forest - Meadow Province	18.50%	0.86%
California Coastal Chapparral Forest and Shrub Province	17.29%	3.24%
Adirondack-New England Mixed Forest-Coniferous Forest-Alpine Meadow Province	17.22%	0.59%
Laurentian Mixed Forest Province	17.06%	1.48%
Black Hills Coniferous Forest Province	16.99%	0.42%
Central Appalachian Broadleaf Forest-Coniferous Forest-Meadow Province	14.31%	1.18%
Ozark Broadleaf Forest - Meadow Province	12.67%	1.60%
Great Plains-Palouse Dry Steppe Province	9.36%	0.29%
Pacific Lowland Mixed Forest Province	6.09%	0.58%
Great Plains Steppe Province	5.48%	0.11%
Outer Coastal Plain Mixed Forest Province	5.40%	0.55%
Eastern Broadleaf Forest (Oceanic) Province	2.81%	0.05%
Lower Mississippi Riverine Forest Province	2.67%	0.01%
Puerto Rico Province	2.67%	0.00%
Southeastern Mixed Forest Province	2.01%	0.07%
Eastern Broadleaf Forest (Continental) Province	1.75%	0.09%
Southwest Plateau and Plains Dry Steppe and Shrub Province	1.33%	0.03%
Great Plains Steppe and Shrub Province	0.94%	0.08%
California Dry Steppe Province	0.68%	0.00%
Prairie Parkland (Subtropical) Province	0.50%	0.00%
Prairie Parkland (Temperate) Province	0.21%	0.00%

Table 12. Percent of each Bailey's Ecoregion Province that is roadless in Alaska. This table includes all state and federal wildlands (protected and unprotected) sorted by percent of the ecoregion that is roadless.

Province	Percent Ecoregion Roadless	Percent Ecoregion Protected
Yukon Intermontane Plateaus Tayga-Meadow Province	93.12%	5.10%
Alaska Range Humid Tayga-Tundra-Meadow Province	92.00%	24.89%
Pacific Coastal Mountains Forest-Meadow Province	91.68%	38.46%
Brooks Range Tundra-Polar Desert Province	91.27%	29.86%
Ahklun Mountains Tundra-Meadow Province	91.10%	21.96%
Upper Yukon Tayga-Meadow Province	87.09%	1.38%
Yukon Intermontane Plateaus Tayga Province	86.48%	4.34%
Arctic Tundra Province	83.19%	0.00%
Seward Peninsula Tundra-Meadow Province	79.17%	0.00%
Bering Tundra (Southern) Province	76.39%	9.24%
Bering Tundra (Northern) Province	70.03%	3.16%
Pacific Gulf Coastal Forest-Meadow Province	68.41%	21.72%
Aleutian Oceanic Meadow-Heath Province	66.24%	29.33%
Upper Yukon Tayga Province	64.73%	0.00%
Coastal Trough Humid Tayga Province	63.73%	5.46%

At the section level for the conterminous United States, all 163 sections contain some wildlands (protected and unprotected wildlands on federal and state land, Appendix A). Twenty-six sections have greater than 50% of their area still remaining in wildlands. Over one third of the sections (64 out of 16 3) have less than five percent of their area remaining in wildlands. Forty-nine sections have less than 2.5% in wildlands, 28 sections have less than 1%, and seven sections have less than 0.1%.

This analysis highlights those ecologically distinct areas of the United States that are so impacted by roads and permanent human development that only a minute portion of them remains wild. Especially in those provinces and sections that have little or no protected wildlands, consideration should be given to additional protection of relatively pristine ecosystem remnants.

Impact of Road Network and Permanent Human Development in the United States

A study by the National Research Council (1997) estimated the total system of public roads in the United States at approximately 3.8 million miles (6.2 million km). Using this number as his basis, Forman (2000) estimated that approximately 20% of the conterminous United States is directly influenced by roads. His study does not take into account agricultural or other permanently disturbed lands. Our study identified approximately 7 million miles of roads in the conterminous United States (Figure 7), almost double that of the above mentioned studies. This more accurate estimate of total road length and road impacts, combined with the consideration of agricultural areas and other permanently developed lands (where motorized vehicles have regular access), pushes our estimate of the area impacted by motorized vehicles to over 60% of the land surface of the continental United States.

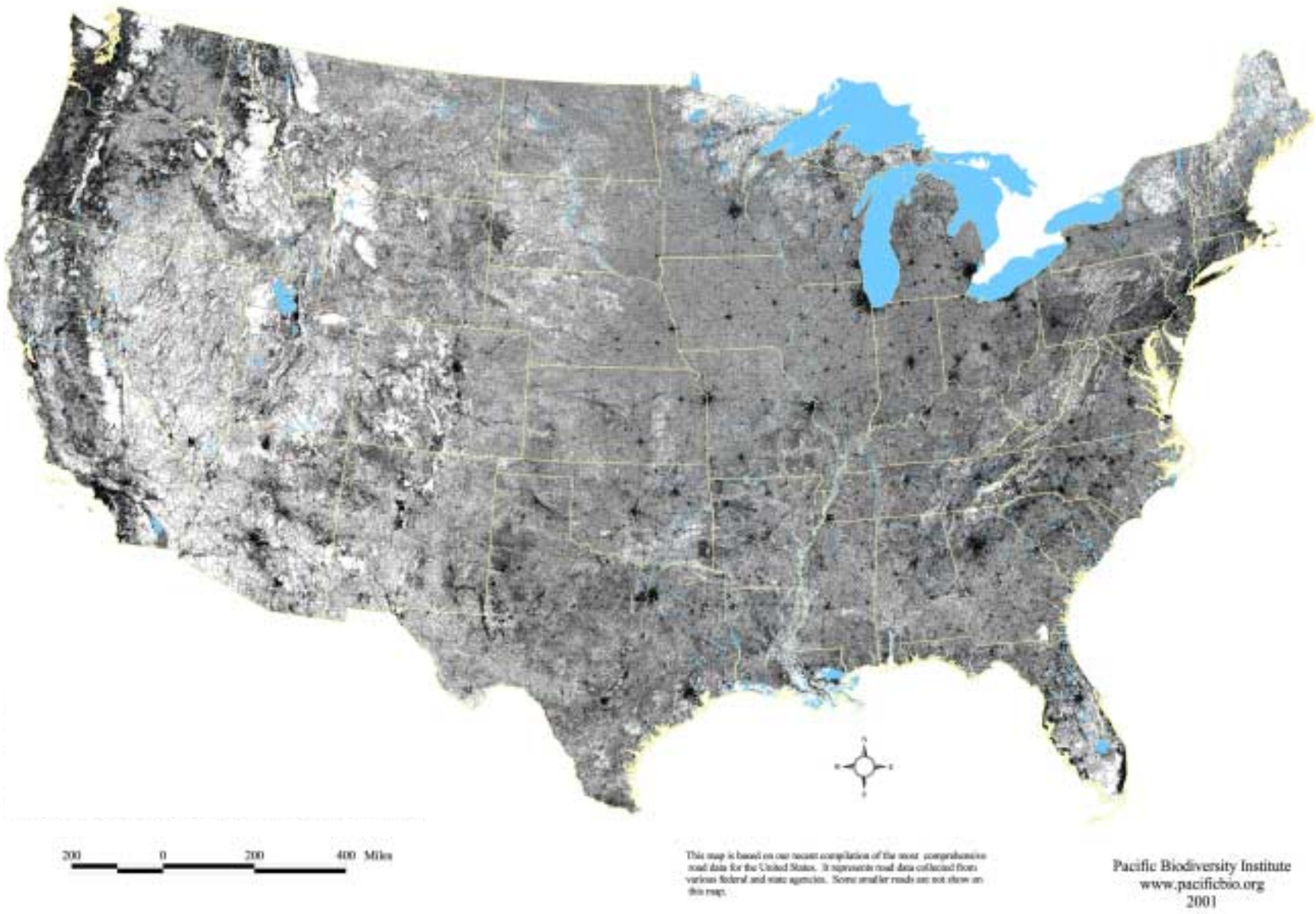

Figure 7. Map depicting all roads in the conterminous United States.

Analysis of the US Forest Service Inventoried Roadless Areas

One of the goals of our study was to assess the accuracy and completeness of the US Forest Service's roadless area inventory presented as part of their recent Roadless Area Conservation Plan (USDA Forest Service 2000). To start with we analyzed the size distribution of the official Forest Service Inventoried Roadless Areas (Table 13). While most Inventoried Roadless Areas (IRAs) are over 5000 acres in size, many are less than 5000 acres in size and a considerable number are less than 1000 acres in size.

Table 13. Size Distribution of Forest Service Inventoried Roadless Areas on National Forests and Grasslands.

Geographic Area	Size Class	Area (acres)
Conterminous US	Greater than 5000 acres	40,937,304
	1000 to 5000 acres	2,302,969
	Less than 1000 acres	493,617
Alaska	Greater than 5000 acres	14,572,735
	1000 to 5000 acres	158,095
	Less than 1000 acres	141,339
Total US	Greater than 5000 acres	55,551,039
	1000 to 5000 acres	2,461,064
	Less than 1000 acres	634,956
	Total	58,647,059

In the eastern US, most of the IRAs are less than 5000 acres in size. Some of the small IRAs are contiguous with existing Wilderness or part of multiple ownership roadless areas. But there are many small, distinct IRA units. In the western United States, most IRAs are over 5000 acres in size and most of the smaller IRA patches are either contiguous with existing Wilderness or part of multiple ownership roadless areas (often in a checkboard landscape). But even in the west, there are numerous examples of small, distinct IRAs that are less than 5000 acres in size. It is apparent that the US Forest Service did not apply a uniform size criterion to the delineation of IRAs.

Comparison with Forest Service Roadless Areas Inventory

We found significant differences between our inventory and the US Forest Service (2000) Roadless Area Inventory. The Forest Service Inventory identified 58.5 million acres of unprotected roadless areas on Forest Service lands in the United States (USDA Forest Service 2000). Our analysis of their GIS data indicated the total area of IRAs was actually over 58.6 million acres (Table 13). Our inventory identified 93.1 million acres of unprotected National Forest roadless land in the contiguous United States and Puerto Rico and 14.1 million acres in Alaska for a total of 107.2 million acres. Closer examination of the numbers reveals that there are many reasons for this large (48.7 million acre) different between the two inventories.

First, our inventory included all roadless areas over 1000 acres in size. Although the Forest Service did map some small roadless areas, most of the roadless areas that they mapped were over 5000 acres in size (Table 13). Some IRAs were even less than 1000 acres in size. The small Inventoried Roadless Areas less than 5000 acres in size were mostly in the eastern United States. Table 13 does illustrate one aspect of the inconsistent definition and methodology used by the Forest Service for mapping Inventoried Roadless Areas (IRAs). The Forest Service mapped very small areas as an IRA in some places while large roadless areas (over 10,000 acres) were ignored by the Forest Service in other places.

We conducted a comprehensive analysis that compares how our roadless area mapping matched that of the Forest Service. First, there is complete correspondence between the Forest Service Inventory and the PBI inventory on over 53.5 million acres (Table 14). Over 91.5% of all IRAs were mapped as roadless by PBI. But these areas of complete agreement between the Forest Service inventory and that conducted by PBI account for only 47.52% of all roadless areas mapped by PBI on National Forest land.

Table 14. Lands mapped by both US Forest Service and PBI as a roadless area within National Forest ownership

PBI Size Class	Acres	Percent of Total IRAs	Percent of all PBI roadless areas on NF land
Lower 48 states: 1,000 to 5,000 acres	1,076,427	2.46%	1.16%
Lower 48 states: Greater than 5,000 ac	39,465,118	90.24%	42.39%
Total Lower 48 States	**40,541,545**	**92.69%**	**43.55%**
Alaska: 1,000 to 5,000 acres	45,217	0.31%	0.23%
Alaska: Greater than 5,000 ac	12,946,178	87.60%	66.22%
Alaska Total	**12,991,395**	**87.91%**	**66.46%**
United States Total	**53,532,941**	**91.51%**	**47.52%**

In our roadless area inventory we found nearly 5 million acres of Inventoried Roadless Area land across the nation that contained roads or other permanent developments that would disqualify it from roadless area status based on the criteria used by PBI (Table 15). A few US Forest Service Inventoried Roadless Areas fell below the 1000 acre minimum size used by PBI.

Table 15. Lands mapped as a US Forest Service Inventoried Roadless Area but not by PBI as a roadless area within National Forest ownership

Region	Acres	Percent of All US Forest Service IRAs
Lower 48 States	**3,177,631**	**7.27%**
Alaska	**1,787,380**	**12.09%**
United States Total	**4,965,011**	**8.49%**

The biggest discrepancy between our inventory of roadless areas in the United States and that conducted by the Forest Service results from the fact that we found significantly more land that qualified for roadless area status than the Forest Service did. We found over 59 million acres of land that qualified for roadless area status that was not mapped as an IRA (Table 16).

Table 16. Lands mapped by PBI as a roadless area within National Forest ownership but not as a US Forest Service Inventoried Roadless Area

Size Class	Acres	Percent of all Roadless Areas Mapped by PBI on National Forest Land
Lower 48 states: 1,000 to 5,000 acres	19,532,130	20.98%
Lower 48 states: Greater than 5,000 ac	33,033,176	35.48%
Total Lower 48 States	**52,565,306**	**56.46%**
Alaska: 1,000 to 5,000 acres	106,492	0.54%
Alaska: Greater than 5,000 ac	6,451,211	33.00%
Alaska Total	**6,557,703**	**33.54%**
United States Total	**59,123,009**	**52.48%**

Nearly 20 million acres of roadless land mapped by PBI but not included in the Forest Service inventory are in small roadless areas between 1000 and 5000 acres in size. But over 39 million acres of roadless land mapped by PBI (but not by the Forest Service) exists in roadless areas over 5000 acres in size. We found many "uninventoried" roadless areas that meet all roadless area criteria used by both PBI and the Forest Service that were not included in the Forest Service inventory. We also found that the boundaries for most Forest Service Inventoried Roadless Areas did not come down to near the edge of all the roads that bounded the area. Often the IRA boundaries went down to some bounding roads but were pulled way back from other bounding roads, excluding considerable wild and roadless land from the IRA.

Some of the differences between our roadless area inventory and the Forest Service inventory may result from incomplete or inaccurate data on roads or other permanent human disturbances and on land ownership. We collected and used the most current information available from each national forest as the basis for our inventory. But it is likely that some roads may have been inaccurately mapped or attributed in their GIS data. This may have caused some of the discrepancies observed above.

Some of the differences between our roadless area inventory and the Forest Service inventory come from the use of different criteria. The Forest Service appears to have left most of the roadless area mapping and delineation criteria up to district and forest level staff. This has caused considerable variation in how the Forest Service has mapped roadless areas. In many cases the Forest Service eliminated logged areas and other human disturbances from IRAs. But in some cases logged areas and other human disturbances are found within IRAs. PBI was consistent in not excluding logged area from a roadless area, but always excluding any permanent human development. This situation is one factor that increased the overall amount of area that we mapped as roadless over what the Forest Service. But many other factors also exist.

Morrison et al. (1998) identified several problems with Forest Service Inventoried Roadless Area mapping on all National Forests in Washington State. They found the most prevalent problem to be inconsistency with which boundaries of the roadless areas were drawn. In some areas, the Inventoried Roadless Area boundary came right to a road; whereas in other areas, the boundary was drawn over a mile away from any bounding road for no obvious reason. Additionally, most USFS roadless area boundaries appeared to be imprecisely drawn, lacking any notable relationship to features of the landscape. Private lands were also inconsistently dealt with. In some roadless areas, private lands were included, but in others they were excluded. Morrison et al. also found many unroaded and unlogged areas in Washington State that were not included in the USFS roadless area inventory. Overall, they found that the Forest Service inventory

significantly underestimated the amount of roadless area that exists in patches over 5000 acres in size and virtually ignored all roadless areas between 1000 and 5000 acres in size. In summary, they found a marked lack of consistency and objectivity with the way the USFS designated roadless areas in Washington State.

Based on these findings, we randomly selected 17 National Forests and conducted qualitative assessments of how well our inventory matched the USFS inventoried roadless areas. Our findings across the United States were consistent with those of Morrison et al. (1998) for Washington State.

We found numerous examples of where roads penetrated into Forest Service Inventoried Roadless Areas (Figure 8). Morrison et al. (1998) also identified this problem. Of the 58.6 million acres of USFS Inventoried Roadless Area, 34.3 million acres have a management status that allows road construction and reconstruction (USDA Forest Service 2000).

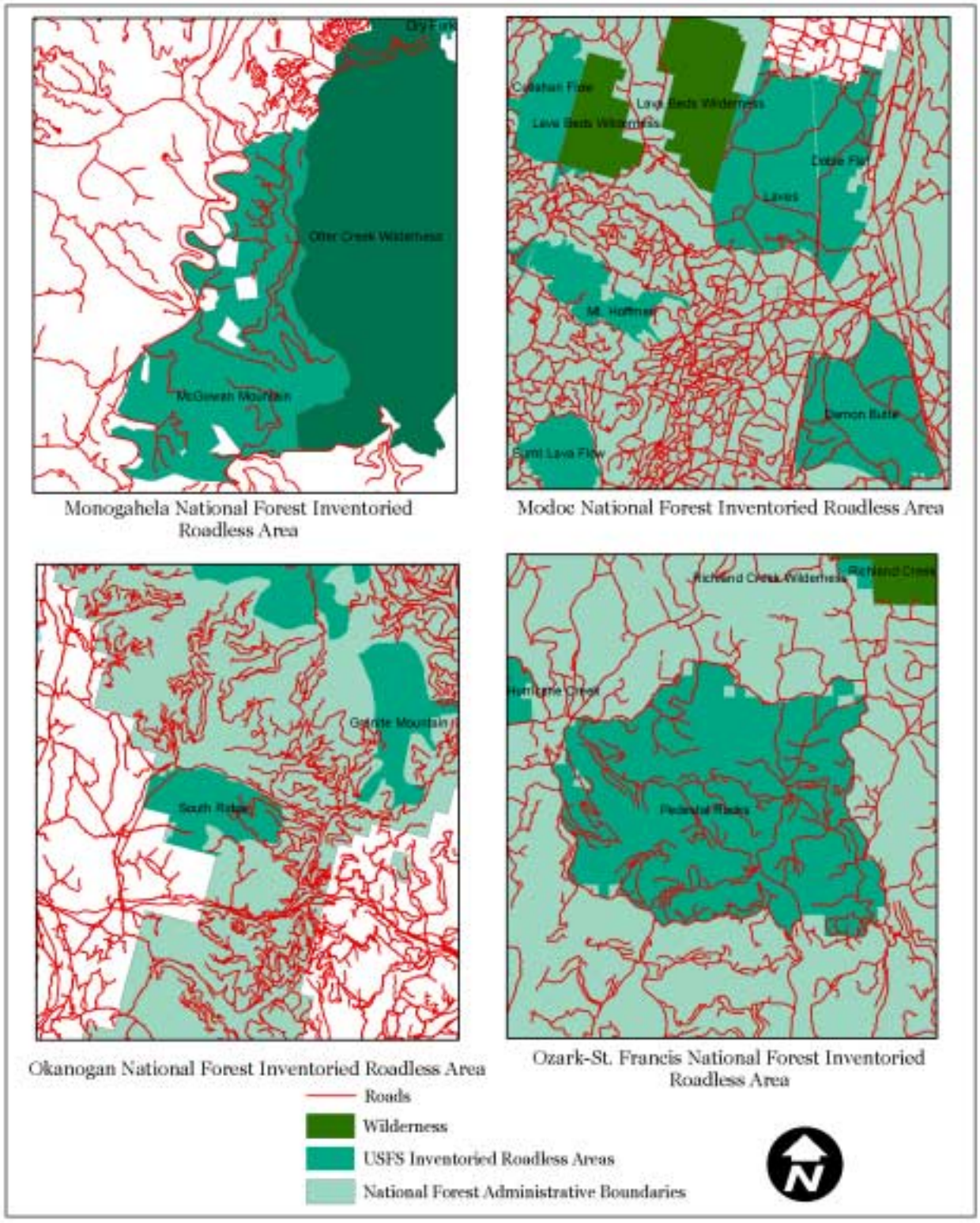

Figure 8. Examples of roads that penetrate into USFS Inventoried Roadless Areas.

We also found numerous examples of where the area we mapped as roadless was much larger than the Forest Service IRA (Figure 9). This could be because some of the areas that we

identified as roadless could have been subject to past management activities such as logging and therefore excluded from the Forest Service inventory (although Morrison et al. [1998] found that logging activity also was inconsistently treated in the definition of Washington Inventoried Roadless Areas). But in most cases that we examined, there was no reasonable explanation why the Forest Service inventory did not agree much more closely with our inventory. We present a case study of the Granite Mountain Roadless Area in Washington (below) as one example of where the two inventories differed.

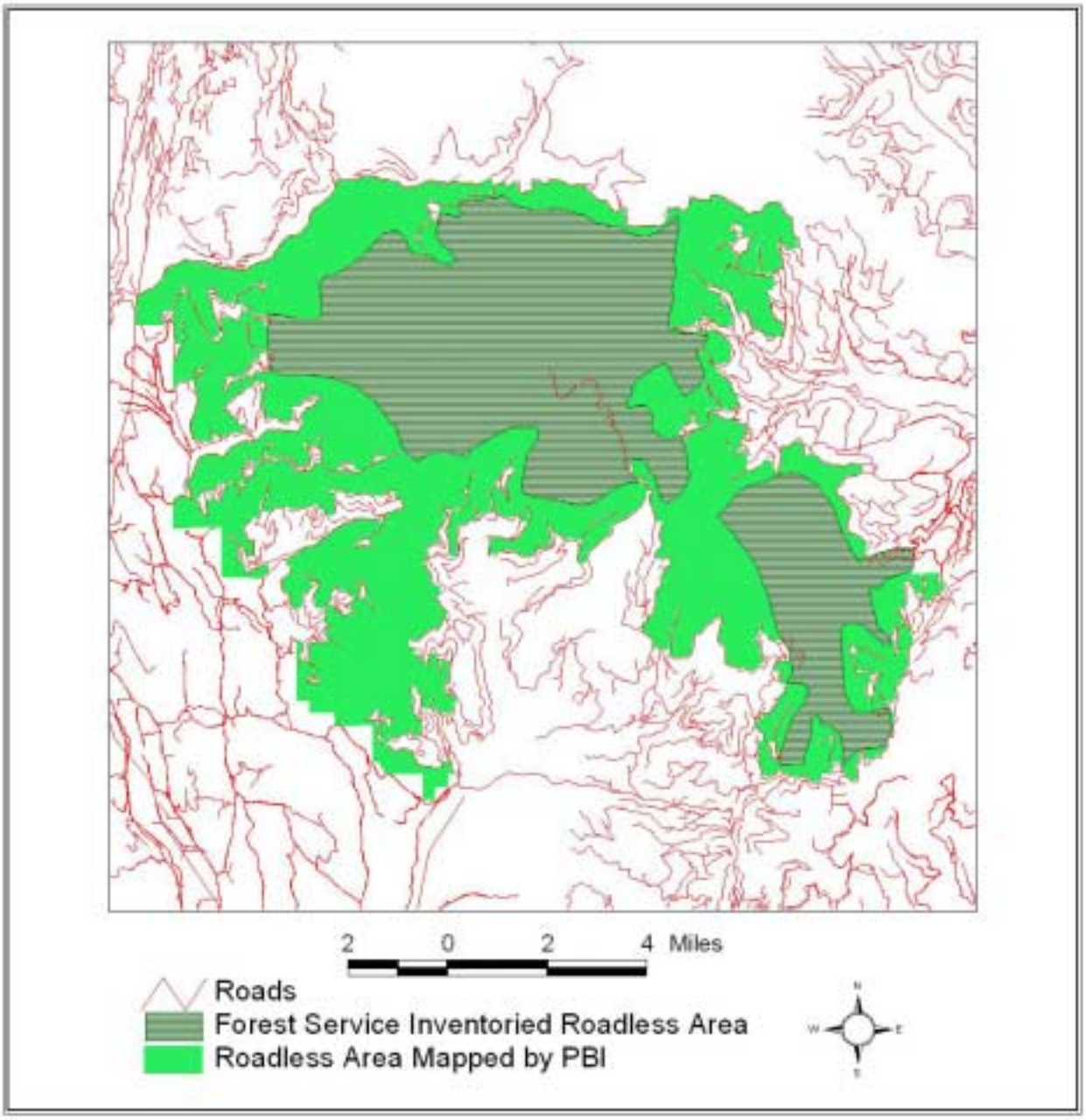

Figure 9. Comparison of Granite Mountain USFS Inventoried Roadless Area to roadless area mapped by Pacific Biodiversity Institute.

From our assessment, we conclude that the USFS inventory of roadless areas is subjective and flawed, and that the inventory that we have conducted, using well-defined criteria, repeatable

methods and the best available data represents the most accurate approximation to the amount of wildlands remaining on USFS land.

Case Study of the Granite Mountain Roadless Area

The Forest Service has progressively revised its estimates of the area of the Granite Mountain Inventoried Roadless Area over the last 30 years (Table 17). First, they have deleted areas from the roadless area because of "logging with roads" – when in fact no such activities occurred. Then they made a series of successive area reductions - for no apparent reasons – resulting in a final area estimate of 27,428 (USDA Forest Service, 2000 GIS layer).

In 1998, PBI completed our first independent evaluation of roadless areas (Morrison et al. 1998) and discovered that the Granite Mountain Roadless Area still contained 54,588 acres of wild land that was over 100 meters from a road and not intensely logged. In PBI's second and more refined roadless area analysis completed in 2000 we used a smaller setback distance from roads (20 meters) and revised our estimate of the Granite Mountain Roadless Area upwards to 64,464 acres. This larger number is the result of additional acreage accumulated around the edge of this large and convoluted roadless area and includes some minor areas where historic logging occurred. Our recent evaluation of this roadless area includes extensive review of the area using a sequence of historical and current satellite images and aerial photographs. Field reviews were also conducted of the area. PBI's independent assessment uses a rigorous methodology and definition and reveals that there are 37,036 acres of roadless land that the Forest Service has chosen to ignore in the Granite Mountain Roadless Area. We determined that the Forest Service had drawn arbitrary boundaries around this roadless area. In some places the USFS boundaries included old fire roads or go right down to the edge of a road. In other places the boundary was arbitrarily drawn over a mile from the closest human disturbance.

Table 17. Changes in Forest Service Area Estimates for the Granite Mountain Inventoried Roadless Area.

Year	Source of Data	Acreage Lost	Acreage Estimate
1964-1972	RARE I		54,100
1979	RARE II	12,320	41,780
1986	ONF* Forest Plan DEIS**	4,364	37,416
1989	ONF Forest Plan FEIS***	8,556	28,860
2000	USFS Roadless Area Conservation Plan GIS Layer	1,432	27,428

* ONF = Okanogan National Forest
** DEIS = Draft Environmental Impact Statement
*** FEIS = Final Environmental Impact Statement

The Forest Service Inventoried Roadless Area boundary for the Granite Mountain Roadless Area is characteristic of the approach that the Forest Service has taken to roadless area mapping around the country. Their work has been compromised by the lack of a rigorous roadless area definition, inventory protocol and mapping criteria. Protocols and methodologies for inventory and mapping of Inventoried Roadless Areas were left to the discretion of district and forest level staff, resulting in little consistency between districts and between forests (Morrison et al. 1998). In most cases, the Forest Service used what we now call "a magic marker" approach to mapping roadless areas – where loosely drawn blobs were inscribed on maps around an area that Forest Service staff considered roadless. As a consequence, the Forest Service roadless area inventory process has been seriously flawed and has yielded highly variable area results.

Comparison to other roadless inventories

We performed a qualitative comparison of our wildlands inventory with the BLM Roadless Area Inventory conducted by Conservation Geography. We found no major discrepancies in any of the 11 states included in their analysis. The minor differences that we found can be attributed to differences in methods of mapping roadless areas, roadless area definition (they mapped only roadless areas greater than 5,000 acres), and our use of finer-scale data in Oregon and Utah. Our inventory resulted in a larger area estimate for roadless lands because we mapped roadless areas down to 1000 acres in size and we used a smaller setback from roads.

Effect of the Inclusion of Jeep Trails

In a qualitative assessment of jeep trails in USFS roadless areas, we concluded that the impact of jeep trails on a roadless area assessment would be relatively minor in most areas, and mostly restricted to smaller roadless areas. The inclusion of jeep trails would further subdivide and fragment roadless areas and this could cause some smaller roadless areas to disappear because they fell below the 1000-acre size limit.

The impact of jeep trails on the landscape and on wildlife habitat is often significantly less than the impact of a road suitable for highway vehicles. Most jeep trails have less traffic than roads that are part of the official road network; therefore wildlife disturbance is often less along these trails than along system roads. Jeep trails, by definition do not involve mechanical road construction, and do not involve cut and fill slopes, which often significantly alter the hydrology of hillslopes. Therefore jeep trails do not have the same potential to increase erosion, as is the case for many dirt and gravel roads that are part of the official road network.

Jeep trails often revegetate easily when use diminishes. Although the soil may be compacted beneath a jeep trail, the soil profile is not disrupted – as in the case of a mechanically constructed roadbed.

We found jeep trails to be inconsistently defined and mapped across the United States. There was wide variation in the amount of jeep trails recorded between national forests. Most of the data sets we received from the national forests recorded different attributes for their roads information. Several of the data sets we received had no attributes describing road type (e.g., highway, jeep trail) or road condition. In other instances, codes for jeep trails were provided in accompanying metadata, but not used in the data layer. Additionally, designation of a segment as a jeep trail, in many cases happened when the original paper maps were produced, so it's current status is questionable because the original maps are so old. There is also a potential for many unmapped jeep trails (see Effects of Unmapped Roads below).

For this project, we have not considered jeep trails as roads. A possible consequence of this decision could be a slight overestimation of the amount of roadless area (if one were to exclude jeep trails from their definition), especially smaller ones. If jeep trails were considered as roads, some smaller areas would be eliminated, and a few of the larger areas would fall into smaller size classes. We do not, however, expect any significant impact on very large roadless areas.

There are several options for incorporating jeep trail information into a roadless area assessment and estimating the impact of jeep trails. Two obvious options are to either include or exclude them as roads. The disadvantage to either of these approaches is that they do not provide much information as to the impact of jeep trails on roadless areas unless they are both performed on subsequent mappings and the results compared. A third option is to not consider jeep trails as roads when defining the roadless areas, but then to use them to attribute each roadless area with the amount of jeep trails it contains. This approach would allow estimation of

the effect of jeep trails by a number of factors (e.g., size class, ownership, land cover type) and would also begin to assess "wilderness quality" of the areas. Reliable information on jeep trails would be necessary for this to be a meaningful analysis.

Effect of Unmapped Roads

Roads that are not mapped will have an obvious effect on the accuracy of any wildlands-mapping project. We took steps to minimize the amount of unmapped roads in our inventory by using the most complete and up-to-date roads information available, but some degree of unmapped roads is inevitable. While calculating an exact number of roadless areas that are impacted by unmapped roads is not possible, it is possible to predict those areas that are most likely to have significant degrees of unmapped roads.

Unmapped roads can be dichotomized into authorized roads that have not yet been mapped and unauthorized roads. Of these two classes, obtaining the most recent updates to roads data is the best method for handling the former. The latter is difficult to assess without extensive field verification or examination of current, high-resolution aerial photography.

The impact of unmapped roads is likely to be greatest in non-forested lands, especially in the southwest. Driving a highway-approved vehicle in a forested environment usually requires removal of trees and some form of surface grading. Such activities are easily recognized and likely to either be stopped (if unauthorized) or the road included on future map revisions. In non-forested environments, especially desert and grasslands, it can be relatively easy to construct light-duty dirt roads and for vehicles to drive off-road. This makes the establishment of unauthorized roads difficult to detect and prevent. A GIS Analyst from BLM in Arizona stated that they didn't bother mapping primitive roads and jeep trails because a road isn't needed to drive most places.

The impact of unmapped roads is also likely to be greatest on BLM lands. The BLM is the largest public landowner in the United States, and most of its land holdings are non-forested (suggesting that unauthorized road creation may be easier on BLM land than on other federal ownerships). Additionally, most BLM regions did not have roads data better than 1:100,000 scale or more recent than the data we used for background data in this project, increasing the likelihood of unmapped roads.

Unmapped roads are likely to impact small roadless areas more than large ones. Most unmapped roads tend to be short extensions of existing roads or connections between existing roads (based on PBI's work digitizing unmapped roads from aerial photography in Washington State). An unmapped road, however, could easily bisect a smaller roadless area, impacting the core of the roadless area and causing each portion of it to fall below the minimum size criteria. Conversely, the same road on a larger roadless area may remove a portion of the roadless area, but has a much smaller impact on the core of the roadless area.

The ecological impact of unmapped roads on wildlife within roadless areas is likely to be small. These roads usually have little traffic and human disturbance along unmapped road corridors is likely to be less than along the official road network. Exceptions to this also exist. Unmapped roads often consist of "use roads" or are constructed to minimal standards. Natural revegetation of these roads often occurs when use diminishes or when these unauthorized roads are closed.

If a policy prohibiting off road vehicle use and vehicle use on unauthorized roads within roadless areas is adopted by federal land management agencies, most unmapped roads will revegetate and become substantially unnoticeable without significant management intervention.

Dealing with unmapped roads is bound to be difficult. Constant road building and the cost of acquiring imagery makes the evaluation of roads data using aerial photography impractical for the entire United States. The best strategy is to continue to incorporate the best roads information available and encourage managing agencies to update their data layers appropriately. When a roadless area of interest for conservation has been identified, more detailed assessments should be conducted to determine the extent, if any, of unmapped roads.

Feasibility of Tracking Changes in Roadless Areas with Time

It would be possible to analyze a chronosequence of historical maps and aerial photos to assess and document how wildlands have changed over time. Similar studies of changing landscape condition have produced dramatic results (Morrison 1990). There has been a continual fragmentation and erosion of roadless areas over the last two centuries. Using historical maps and aerial photographs it would be possible to quickly attribute the current road network GIS layer developed for this project using GIS tools so that roads that existed at several dates in a historical chronosequence were identified. The roadless area analysis we developed could then be rerun on the road network that existed at dates in the chronosequence, resulting in a map of the historical extent of roadless areas.

Tracking ongoing changes in roadless areas may not be fruitful across the entire country over short time intervals (e.g. annual changes). Changes in the quality and completeness of the data available for analysis will probably obscure actual changes in roadless area extent. Available information on roads and the extent of permanent human development continues to improve and annual updates using this information should improve the accuracy of our roadless area delineations. But, the next iteration of the products produced in this project will reflect more the changes in the quality and availability of the data than changes in actual roadless area extent.

In order to track ongoing changes in roadless areas over time, annually updated GIS road data would be needed. This is currently possible for most National Forests in the western US, and should be possible in the future for more National Forests as they update their GIS holdings. Tracking roadless area changes on other ownerships may be more difficult because they don't seem to invest the same amount of energy into maintaining transportation databases as the USFS.

Complicating the matter is that updates to GIS road data will contain not only new roads, but also corrections to existing roads and possibly the addition of previously unmapped roads. Changes to roadless areas defined in future iterations will be due to an increased accuracy of the product as well as changes to the actual roadless areas on the ground. Thus the results of future iterations of roadless-area mapping with respect to changes over time will need to be interpreted with caution. Specific attention may need to be paid to each area that is determined to have changed since the last iteration to determine the cause of the change.

One factor that would confound the ability to assess changes over time is decisions made that change the definition of roadless areas. Such decisions could include: incorporation of jeep trails as roads, changing the setback distance from roads, or changing the minimum size of roadless areas.

Feasibility of Analyzing Wilderness Quality of Roadless Areas as Defined in the Wilderness Act

It is feasible to analyze the wilderness quality of roadless areas, but many aspects of this task include the development of new information beyond what is readily available. Information that would be useful for initially assessing "wilderness quality" could include: past logging activities, utility lines and corridors, mining activities, off-road vehicle activity, presence of jeep trails and legal restrictions. Some of this information is readily available for some areas, while other information would need to be developed through field surveys and analysis of aerial photography and satellite imagery. Additionally, landscape indices such as patch size, core area, edge-to-area ratio, and other measures of fragmentation and landscape connectivity would be useful.

In Washington State, Pacific Biodiversity Institute is finishing a multiyear project in conjunction with other conservation organizations to assess the wilderness quality and ecological values found in all roadless areas. In this project we have mapped all the past logging activity within roadless areas through the use of existing agency data as well as examination of digital aerial photography and satellite imagery. We are also documented known mining activity, utility corridors, jeep trails and other human disturbances that impact the areas. Volunteers have conducted field surveys of many areas. This information is now being compiled into reports on individual areas and a comprehensive, statewide database. This database will contain most of the information needed to assess the wilderness quality of roadless areas. It is feasible to undertake such an effort in other states and the methodology that we have developed and experience we have acquired in Washington State would facilitate such an undertaking elsewhere.

In addition to assessing wilderness quality, it is also possible to prioritize roadless areas so that those with the highest wilderness quality are identified and/or the roadless areas with the highest ecological value are identified. Under such an approach, roadless areas are analyzed against a few basic data layers and only the most pristine are selected for further analyses. Using the new subset of roadless areas, an analysis is performed with additional data layers and the most pristine are selected. This process repeats until all the available information is used. From the final subset, roadless areas may be selected for more detailed, site-level analyses including verification with aerial photography and satellite imagery, and field checking.

RECOMMENDATIONS for FUTURE WORK

The results of this study represent the most comprehensive, objective inventory to date of the remaining wildlands in the United States. While this is the best assessment of its kind currently available, we have identified a number of ways in which this study may be improved during future iterations. These recommendations address the general topics of data quality, project scope (e.g., recommended extensions to the project), and project management. Each recommendation is listed below with a brief discussion.

1. **Update with new roads information** – Road data are constantly being revised not only as new roads are constructed, but also as the quality of the data are improved. We found many agencies that were in the process of organizing and/or updating their road data layers. Additionally, the new TIGER 2000 road data, a product of the 2000 census and an update to the existing TIGER data will soon be released. The most recent and best road data should be obtained each year so that the quality of the wildlands mapping will increase with time.

2. **Update with better ownership data and protected area status** – The most surprising and challenging aspect of this project was the difficulty that we had in obtaining useful and correct ownership data. As a result of our critical assessment of available ownership data, we have entered into a partnership with USGS EROS Data Center, University of Idaho's Landscape Dynamics Lab, and Conservation Biology Institute to develop a more accurate public lands database that will be maintained and updated annually. Accurate GIS layers depicting the boundaries of Wilderness Areas also need to be developed – as these are only approximate in many areas. This GIS information must be updated annually, especially as land exchanges proceed and new protected areas are established.
3. **Incorporate more accurate information on water bodies** – This analysis would greatly benefit from the incorporation of more accurate information on major water bodies (lakes, major rivers and reservoirs). Many water bodies have motorized boat activity, with could disqualify the area from inclusion in a roadless area or proposed Wilderness. It would be desirable to be able to screen out those water bodies that have no motorized activity – as those should be included within roadless areas.
4. **Incorporation of jeep trails as a roadless area attribute** – We recommend that jeep trails be used to attribute the defined roadless areas with the extent of mapped jeep trails. This attribute will allow assessment of the significance of jeep trails to roadless area conservation as well as assessment of wilderness quality.
5. **Extend to other ownerships** – Significant amounts of wildlands exist on lands owned by local governments, tribal entities and private individuals. These areas should be considered in future analyses especially where they adjoin other federal or state lands already being considered.
6. **Inclusion of additional human disturbance factors** – To better understand the quality of the wildlands that we have mapped, additional human disturbance factors, such as powerlines, railroads, ski runs, etc., should be incorporated into our assessment. This will allow us to exclude these areas from our assessment.
7. **Inclusion of citizen wilderness proposals** – Boundaries of areas that advocacy groups are lobbying for protection of would be an informative overlay for the roadless area maps. It would also allow the ecological characteristics of these areas to be analyzed in relation to other unprotected wildlands, potentially providing additional information to the local campaigns.
8. **Evaluation of the ecological characteristics of the roadless areas** – An evaluation of the ecological characteristics would look at the composition and context of unprotected wildlands. Compositional characteristics could include the land cover types occurring within the wildland, percent of ownership types within the wildland, topography, and soil types. Contextual descriptions could include landscape statistics (e.g., edge-to-area ratio, estimated core area) and the relation of the wildland to other unprotected and protected wildlands (e.g., how rare are the land cover types within the wildland compared to those found in protected wildlands). This information would allow a better understanding of the distribution of wildlands in relationship to various ecological characteristics across the nation.
9. **More thorough accuracy assessment of the roadless areas** – The accelerated timeline for this year's wildlands inventory precluded a thorough assessment of the accuracy of the roadless area delineations. While we used the most accurate roads information available and did a fair amount of spot-checking, we recommend that adequate time and money be invested in a more thorough accuracy assessment. This would include time to request aerial photography from a randomly selected set of National Forests to verify results against. Also, people who are knowledgeable of the

roadless areas of a region should be contacted as reviewers of finer-scale maps and their feedback incorporated.

10. **Development of an internet-mapping service featuring the results of this study** – Recent releases of internet-based mapping software have made it possible to produce professional, mapping applications that would allow users to interact with the spatial data produced in this study. Users would be able to zoom in to areas of interest, query for attributes and print custom maps without anything more than a web browser. More advanced applications would even allow selected reviewers to make comments and add new features (e.g., an unmapped road) over the Internet also without any specialized software. Please visit PBI's WildInfoNet for an example of how this technology is being applied to mapping wildlands in Washington State (www.pacificbio.org/wildinfonet/wildinfonet.htm).

CONCLUSIONS

Most of our nation is covered by a dense road network and most ecosystems in the nation have been heavily modified by human activities. The remaining fairly pristine habitat that exists in roadless areas and Wilderness still comprises 24.4% of the United States but only 4.6% of this has permanent protection. Nearly half of the total wildland area that remains is in Alaska. Alaska also contains 55% of the nation's protected Wilderness. Most of the remaining wildlands are highly fragmented and only a few large patches (over 1 million acres) still exist. Alaska is the only state in the nation that still has extensive, relatively unfragmented wildlands on federal, state, tribal and private ownerships. Most ecoregions in the United States have been extensively roaded and otherwise modified by human activities. Remaining pristine areas over 1,000 acres in size are rare in most ecoregions. The protection status of remaining roadless lands in most ecoregions of the country is very low and indicates that the few remaining relatively pristine areas are in jeopardy of alteration by human activities.

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Appendix A. Percent unprotected wildlands by Bailey's Ecoregion Section for the conterminous United States (Federal and State Ownership, sorted by percent).

Section	Percent Ecoregion Roadless	Percent Ecoregion Protected
Southeastern Great Basin Section	86.56%	0.15%
Northern Rockies Section	85.91%	29.99%
Challis Volcanics Section	82.85%	14.97%
Central Great Basin Mountains Section	82.42%	3.52%
Idaho Batholith Section	78.69%	30.92%
Mojave Desert Section	73.89%	22.95%
Yellowstone Highlands Section	73.82%	26.54%
Lahontan Basin Section	70.25%	1.86%
Mono Section	68.40%	6.66%
Northern Canyon Lands Section	66.76%	1.28%
Sierra Nevada Section	64.39%	30.40%
North-Central Highlands Section	63.93%	17.51%
Utah High Plateaus and Mountains Section	63.68%	0.89%
Uinta Mountains Section	61.21%	8.88%
Northeastern Great Basin Section	59.03%	0.43%
Northwestern Basin and Range Section	57.89%	2.59%
Bonneville Basin Section	57.04%	0.78%
South-Central Highlands Section	55.87%	9.65%
Western Cascades Section	55.77%	25.50%
Tavaputs Plateau Section	54.67%	0.00%
Overthrust Mountains Section	53.77%	6.86%
Sonoran Mojave Desert Section	53.68%	13.19%
Beaverhead Mountains Section	53.47%	1.71%
Owyhee Uplands Section	52.90%	0.00%
Grand Canyon Lands Section	52.05%	2.45%
Bighorn Basin Section	51.70%	0.00%
Bitterroot Valley Section	49.08%	14.01%
Greater Green River Basin Section	48.07%	1.15%
Wind River Mountain Section	47.88%	29.51%
Uinta Basin Section	47.69%	0.00%
Snake River Basalts Section	46.20%	1.17%
Tonto Transition Section	45.59%	5.87%
Northern Superior Uplands Section	44.51%	24.25%
Klamath Mountains Section	43.88%	12.06%
Northern Parks and Ranges Section	42.28%	6.40%
Bitterroot Mountains Section	41.36%	1.31%
Modoc Plateau Section	40.53%	1.40%
Northern Minnesota & Ontario Section	40.28%	1.10%
Sonoran Colorado Desert Section	37.86%	5.77%
Southern California Mountains and Valleys Section	37.78%	16.20%
Bear Lake Section	37.56%	0.00%

White Mountain-San Francisco Peaks Section	36.63%	0.96%
Bighorn Mountains Section	36.47%	6.18%
Everglades Section	36.45%	17.15%
Adirondack Highlands Section	36.27%	16.63%
Eastern Cascades Section	35.20%	11.82%
Central Basin and Hills Section	33.44%	0.00%
Flathead Valley Section	32.21%	1.48%
Northern Unglaciated Allegheny Plateau Section	31.86%	0.25%
Basin and Range Section	31.39%	1.09%
Blue Mountains Section	29.66%	9.22%
Southern Cascades Section	28.59%	5.82%
Rocky Mountain Front Section	28.12%	4.53%
Upper Rio Grande Basin Section	27.61%	5.51%
Belt Mountains Section	25.36%	0.38%
Southern Parks and Ranges Section	24.63%	6.77%
Oregon and Washington Coast Ranges Section	23.23%	9.71%
Northern California Interior Coast Ranges Section	22.94%	0.62%
Northern California Coast Ranges Section	22.08%	2.42%
Okanogan Highlands Section	21.04%	0.49%
Northern Rio Grande Intermontane Section	20.77%	3.20%
Central California Coast Ranges Section	20.58%	6.40%
Northern Great Lakes Section	20.11%	0.34%
Northwestern Glaciated Plains Section	19.88%	0.08%
Northern Minnesota Drift & Lake Plains Section	18.59%	0.00%
Sacramento-Monzano Mountain Section	18.26%	0.65%
Ouachita Mountains Section	17.64%	0.86%
Blue Ridge Mountains Section	16.79%	2.02%
Black Hills Section	16.57%	0.42%
Catskill Mountains Section	16.46%	7.29%
Sierra Nevada Foothills Section	15.77%	1.09%
Southern California Coast Section	15.22%	0.97%
Painted Desert Section	15.18%	1.01%
Powder River Basin Section	13.59%	0.00%
High Lava Plains Section	13.17%	0.00%
Northern Ridge & Valley Section	13.10%	0.87%
Central California Coast Section	13.03%	5.54%
Green, Taconic, Berkshire Mountains Section	12.97%	1.25%
Florida Coastal Lowlands (Western) Section	12.54%	0.67%
Palouse Prairie Section	12.06%	4.14%
Southern Superior Uplands Section	12.00%	0.81%
Allegheny Mountains Section	11.15%	1.07%
Boston Mountains Section	11.07%	1.60%
White Mountains Section	10.76%	5.56%
Northwestern Great Plains Section	9.76%	0.21%
Northern California Coast Section	9.50%	0.90%
Northern Cumberland Plateau Section	8.86%	0.23%
Columbia Basin Section	8.75%	0.05%

Western Superior Section	8.71%	0.00%
Lake Agassiz, Aspen Parklands Section	8.37%	0.21%
Navajo Canyonlands Section	8.34%	0.30%
Florida Coastal Lowlands (Eastern) Section	8.29%	1.36%
Arkansas Valley Section	8.19%	0.40%
Central Ridge and Valley Section	7.90%	0.18%
Pecos Valley Section	6.84%	0.26%
Louisiana Coast Prairies and Marshes Section	5.54%	0.08%
Willamette Valley and Puget Trough Section	5.51%	0.58%
Southern Ridge and Valley Section	5.25%	0.40%
Atlantic Coastal Flatlands Section	5.05%	0.56%
New England Piedmont Section	4.77%	0.00%
Coastal Plains and Flatwoods, Western Gulf Section	4.26%	0.29%
Fundy Coastal & Interior Section	4.25%	0.46%
Ozark Highlands Section	4.14%	0.40%
Arkansas Tablelands Section	4.00%	0.00%
Coastal Plains and Flatwoods, Lower Section	3.82%	0.69%
Northern Glaciated Allegheny Plateau Section	3.69%	0.00%
Southern Gulf Prairies and Marshes Section	3.55%	0.00%
Southern Cumberland Mountains Section	3.40%	0.00%
St. Lawrence Valley Section	3.23%	0.16%
Southern Cumberland Plateau Section	2.99%	0.39%
North Central U.S. Driftless and Escarpment Section	2.77%	0.00%
Northern Cumberland Mountains Section	2.69%	0.00%
Middle Atlantic Coastal Plain Section	2.67%	0.00%
Mississippi Alluvial Basin Section	2.66%	0.01%
Interior Low Plateau, Shawnee Hills Section	2.49%	0.24%
Aroostook Hills & Lowlands Section	2.41%	0.00%
Northern Glaciated Plains Section	2.27%	0.04%
Central High Plains Section	2.05%	0.00%
Hudson Valley Section	1.95%	0.16%
Lower New England Section	1.92%	0.02%
Nebraska Sand Hills Section	1.85%	0.00%
Southwestern Great Lakes Morainal Section	1.81%	0.00%
Southern Unglaciated Allegheny Plateau Section	1.77%	0.00%
Central Gulf Prairies and Marshes Section	1.77%	0.00%
Maine & New Brunswick Foothills & Central Lowlands Section	1.61%	0.00%
Eastern Gulf Prairies and Marshes Section	1.58%	0.00%
Mid Coastal Plains, Western Section	1.51%	0.09%
Coastal Plains, Middle Section	1.48%	0.00%
Southern Appalachian Piedmont Section	1.47%	0.01%
Interior Low Plateau, Highland Rim Section	1.45%	0.07%
North-Central Great Plains Section	1.28%	0.06%
Central Maine Coastal & Interior Section	1.28%	0.00%
Southern High Plains Section	1.24%	0.00%
Minnesota & NE Iowa Morainal, Oak Savannah Section	1.11%	0.01%

Upper Gulf Coastal Plain Section	1.09%	0.00%
Texas High Plains Section	0.96%	0.00%
Northeastern Glaciated Plains Section	0.96%	0.03%
Redbed Plains Section	0.86%	0.08%
Edwards Plateau Section	0.79%	0.00%
Great Valley Section	0.68%	0.00%
Red River Valley Section	0.66%	0.00%
Stockton Plateau Section	0.61%	0.00%
Cross Timbers and Prairie Section	0.59%	0.00%
South Central Great Lakes Section	0.59%	0.00%
Erie and Ontario Lake Plain Section	0.51%	0.00%
Western Glaciated Allegheny Plateau Section	0.51%	0.00%
Interior Low Plateau, Bluegrass Section	0.31%	0.00%
Upper Atlantic Coastal Plain Section	0.31%	0.06%
Osage Plains Section	0.31%	0.00%
Western Glaciated Plains Section	0.24%	0.00%
Central Dissected Till Plains Section	0.22%	0.00%
Flint Hills Section	0.20%	0.00%
Northern Appalacian Piedmont Section	0.20%	0.08%
Central High Tablelands Section	0.19%	0.00%
South-Central Great Plains Section	0.15%	0.00%
Central Loess Plains Section	0.11%	0.00%
Oak Woods and Prairies Section	0.09%	0.02%
North-Central Glaciated Plains Section	0.07%	0.00%
Central Till Plains, Oak-Hickory Section	0.07%	0.00%
Rolling Plains Section	0.05%	0.00%
Blackland Prairies Section	0.03%	0.00%
Rio Grande Plain Section	0.01%	0.00%
Central Till Plains, Beech-Maple Section	0.00%	0.00%