

Technical Memorandum 8260-06-02

Grand Teton National Park 2002-2005 Vegetation Mapping Project Final Report

NPS-USGS Vegetation Mapping Program



U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Environmental Services Division
Remote Sensing and GIS Group
Denver, Colorado

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This report was prepared for the U.S. National Park Service and the U.S. Geological Survey's Center for Biological Informatics by the Remote Sensing and Geographic Information Group of the Bureau of Reclamation's Technical Service Center, Denver, Colorado in cooperation with Grand Teton National Park and NatureServe.

Technical Memorandum No. 8260-06-02

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USGS-NPS VEGETATION MAPPING PROGRAM

Grand Teton National Park and John D. Rockefeller, Jr. Memorial Parkway

Final Project Report

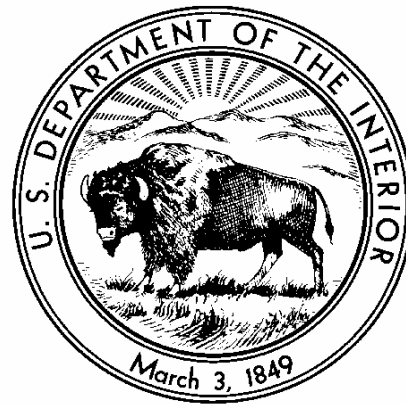
2002-2005 Vegetation Mapping Project
Bureau of Reclamation Technical Memorandum 8260-06-02

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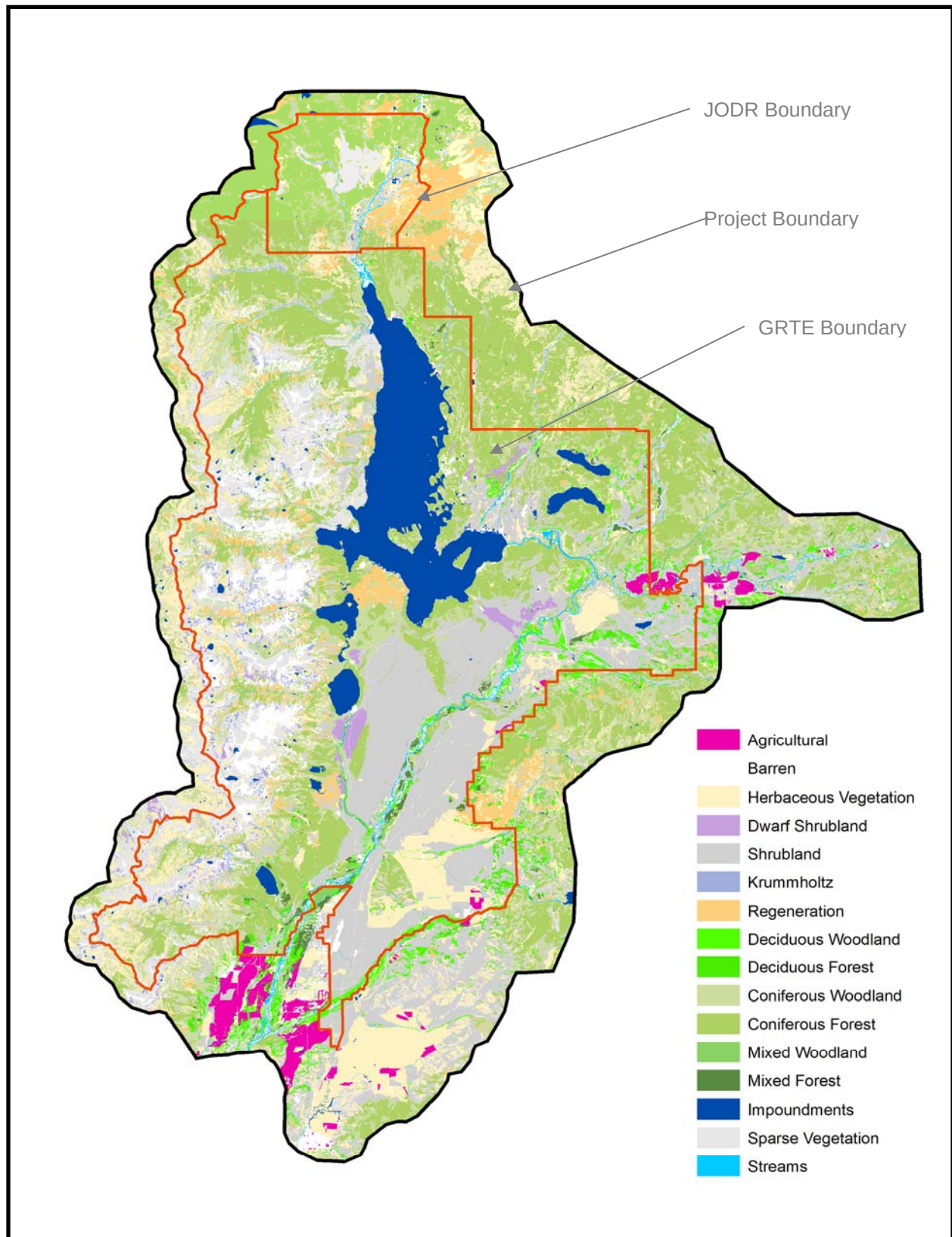


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FINAL MAP OVERVIEW



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Grand Teton National Park**



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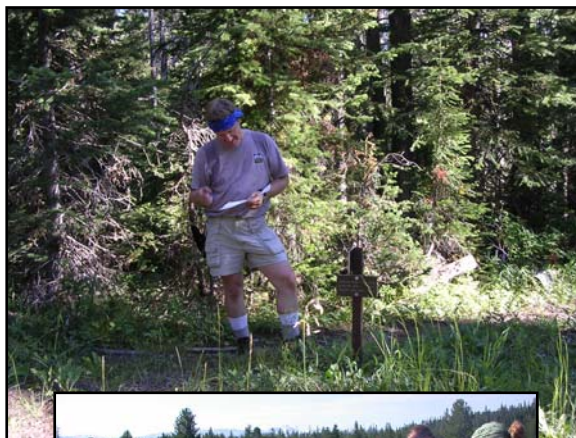
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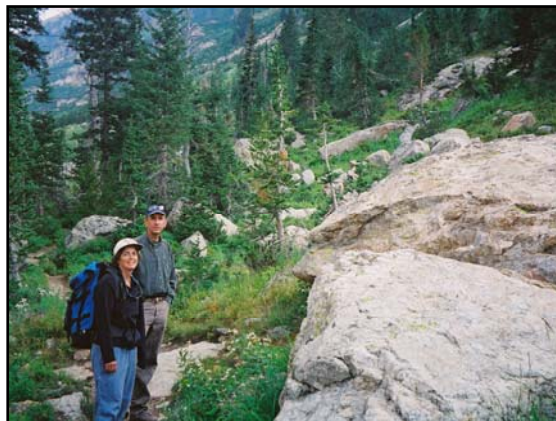
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Kelly McCloskey was the linchpin that held this project together. Completing a full circle, Kelly started on this project with the park; she then transitioned over to a contractor and is now again working for GRTE. Kelly did a little bit of everything-- setting up the contracts, coordinating the work, helping with the field work, interpreting photos, and reviewing numerous drafts of the classification, maps, and report. Through this whole thing she somehow managed to find time to finish her doctoral dissertation ...thanks Kelly!

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Finally, let me conclude by apologizing to anyone I may have inadvertently left off this list. Please know that I had a great experience working and meeting with everyone associated with this endeavor and I really appreciate all the effort that went into this project. - Dan.

LIST OF ABBREVIATIONS AND ACRONYMS

AA	Accuracy Assessment
AML	Arc Macro Language
BOR	Bureau of Reclamation (also USBR)
BPU	Biophysical Unit
BRD	Biological Resource Division (of the USGS)
CBI	Center for Biological Informatics (of the USGS/BRD)
CIR	Color Infrared Photography
DEM	Digital Elevation Model
DLG	Digital Line Graph
DRG	Digital Raster Graphic
DOQQ	Digital Orthophoto Quarter Quadrangle
FGDC	Federal Geographic Data Committee
GIS	Geographic Information System(s)
GPS	Global Positioning System
GRTE	Grand Teton National Park
JODR	John D. Rockefeller, Jr. Memorial Parkway
MMU	Minimum Mapping Unit
NAD	North American Datum
NBII	National Biological Information Infrastructure
NER	The National Elk Refuge
NPS	U.S. National Park Service
NRCS	Natural Resources Conservation Service
NVC	National Vegetation Classification
NVCS	National Vegetation Classification System
RSGIS	Remote Sensing and Geographic Information Group
TNC	The Nature Conservancy
USBR	United States Bureau of Reclamation (also BOR)
USDA-SCS	U.S. Dept. Of Agriculture – Soil Conservation Service
USFS	United States Forest Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WYNDD	Wyoming Natural Diversity Database

LINKS

http://biology.usgs.gov/npsveg/index.html	USGS-NPS Vegetation Mapping Program
http://usgs.gov	United States Geologic Survey
http://biology.usgs.gov/cbi	USGS Center for Biological Informatics
http://biology.usgs.gov/cbi/nbii	National Biological Information Infrastructure
http://www.nps.gov/grte	Grand Teton National Park
http://www.nps.gov/jodr	John D. Rockefeller, Jr. Memorial Parkway
http://www.fws.gov/nationalelrefuge	The National Elk Refuge
http://www.usbr.gov	United States Bureau of Reclamation
http://www.natureserve.org	NatureServe
http://www.natureserve.org/explorer	NatureServe Explorer® online database server
http://plants.usda.gov	NRCS PLANTS Database

EXECUTIVE SUMMARY

Grand Teton National Park (GRTE) and the John D. Rockefeller Memorial Parkway (JODR) encompass approximately 522 square miles in Northwest Wyoming directly south of Yellowstone National Park and just east of the Idaho border. This rugged terrain supports over 1000 species of vascular plants growing in communities representing forests, sagebrush flats, riparian corridors, wetlands and alpine tundra. In 2002 this project was started to map the vegetation and to develop a classification for the plant communities in the study area. This report documents those efforts.

To complete the task of mapping the diverse vegetation at GRTE, a multi-year program was initiated. This consisted of two major tasks. Phase one, directed by Grand Teton National Park in conjunction with NatureServe and the Wyoming Natural Diversity Database program developed a vegetation classification using the National Vegetation Classification System (NVCS). Phase two, directed by the U.S. Bureau of Reclamation's (BOR) Remote Sensing and GIS group based in Denver, Colorado produced a digital vegetation map. To classify the vegetation, 635 representative plots located throughout the approximately 550,087 acre (222,613 ha) project area (parks + environs) were sampled during the summers of 2002 and 2003. Analysis of the plot data using ordination and clustering techniques produced 167 distinct plant associations, 10 of which were newly described at Grand Teton National Park. In addition, 40 unique plant associations known only from the park (i.e. Park Specials) were also described. A total of 207 plant association descriptions and a field key are included in this report.

To produce the digital map, a combination of 1:12,000-scale true color aerial photography, 1:12,000-scale true color ortho-rectified imagery, and 3 years of ground-truthing were used to interpret the complex patterns of vegetation and land-use. In the end, 52 map units were developed and directly cross-walked or matched to corresponding plant associations and land-use classes. All of the interpreted and remotely sensed data were converted to Geographic Information System (GIS) databases using ArcGIS® software. Draft maps were printed, field tested, reviewed and revised. 1,122 accuracy assessment data points were collected and used to determine the map's accuracy. After final revisions, the accuracy assessment revealed an overall thematic accuracy of 82%.

Products developed for Grand Teton National Park are described and presented in this report, and are stored on the accompanying CD-ROM. These include:

- *A Final Report* that includes a vegetation key, accuracy assessment information, and a photo interpretation key;
- *A Spatial GIS Database* containing vegetation, plots, accuracy assessment, & flight line index layers;
- *Digital Photos* from each sample plot along with representative ground photos for each map class and miscellaneous park views;
- *Printable Graphics* of all spatial database layers;
- *Metadata* for spatial database layers which is Federal Geographic Data Committee (FGDC)-compliant
- *Vegetation Descriptions* of the vegetation communities.

In addition, GRTE and the NPS Inventory and Monitoring Program both received copies of:

- 9x9-inch Prints of the 1:12,000-scale Aerial Photography;
- Uncompressed Digital Orthophotos;
- Digital data files and hard copy data sheets of the observation points, vegetation field plots, and accuracy assessment points;
- Hardcopy vegetation maps.

The DVD attached to this report contains text and metadata files, keys, lists, field data, spatial data, the vegetation map, graphics, and ground photos. Please check the following USGS website for posting of this information: <http://biology.usgs.gov/npsveg/index.html>

For more information on the NVCS and NVC associations in the United States please go to NatureServe's website: <http://www.natureserve.org>.

PROJECT STATISTICS

Field Work 2002-2004:

Plot Sampling = 635 Plots:

- o 167 Plots Sampled in 2002 by staff from the Wyoming Natural Diversity Database and Grand Teton National Park
- o 248 Plots Sampled in 2003 by Grand Teton National Park staff
- o 220 Existing Vegetation Sample Plots
 - 78 Plots incorporated from the Caribou-Targhee National Forest
 - 115 Plots incorporated from the Bridger-Teton National Forest
 - 27 Plots incorporated from recent projects in Grand Teton National Park
- Accuracy Assessment Points = 1,122
 - o 1,112 Points collected in 2004 by Grand Teton National Park
 - o 10 Points collected in 2004 by other staff
- 994 Documented Plant Species

Classification:

- 207 Plant Associations sampled and described

GIS Database 2002-2005:

- Project Size = 550,087 acres
 - o Grand Teton National Park = 309,500 acres
 - o John D. Rockefeller Jr. Memorial Parkway = 23,679 acres
 - o Total Environs = 216,767 acres
 - o Elk Refuge = 25,000 acres
 - o Remaining Environs = 191,908 acres
- Photography and Imagery acquired by Horizons Inc., Rapid City, South Dakota
 - o Aerial Photography for Photo-Interpretation = 1:12,000 true color
 - o Basemap Imagery = 1:12,000-scale true color, 3-band, 1 meter pixel, created from 1:40,000-scale aerial photography
 - o Date of Photography and Ortho-photography = 7/10/02
- 52 Map Classes
 - o 42 Vegetated
 - o 10 Non-vegetated
- Minimum Mapping Unit = ½ hectare
- Total Size = 47,602 Polygons
- Average Polygon Size = 17 acres
- Overall Thematic Accuracy = 82%

Project Completion Date: 12/31/05



1. INTRODUCTION

1.1 Background

USGS-NPS Park Vegetation Mapping Program

In 1994, the U.S. Geological Survey (USGS) and National Park Service (NPS) formed the USGS-NPS Vegetation Mapping Program to cooperatively inventory and map the vegetation in United States National Parks. The goals of this program are to provide baseline ecological data for park resource managers, obtain data that can be examined in a regional and national context, and provide opportunities for future inventory, monitoring, and research activities (FGDC 1997, Grossman et al. 1998).

Use of the National Vegetation Classification (NVC) as the standard vegetation classification system is central to fulfilling the goals of this national program. This system:

- is vegetation based;
- uses a systematic approach to classify a continuum;
- emphasizes natural and existing vegetation;
- uses a combined physiognomic-floristic hierarchy;
- identifies vegetation units based on both qualitative and quantitative data;
- is appropriate for mapping at multiple scales.

The use of the NVCS and the USGS-NPS vegetation mapping protocols facilitate effective resource stewardship by ensuring compatibility and widespread use of the information throughout the NPS as well as by other federal and state agencies. These vegetation maps and associated information support a wide variety of resource assessment, park management, and planning needs. In addition they can be used to provide a structure for framing and answering critical scientific questions about vegetation communities and their relationship to environmental conditions and ecological processes across the landscape.

The NVC has primarily been developed and implemented by The Nature Conservancy (TNC) and the network of State Natural Heritage Programs over the past twenty years (Grossman et al. 1998). Currently it is maintained and updated by NatureServe. Additional support has come from federal agencies, the Federal Geographic Data Committee (FGDC), and the Ecological Society of America. Refinements to the classification occur in the process of application, leading to ongoing proposed revisions that are reviewed both locally and nationally. TNC and NatureServe have made available a 2-volume publication presenting the standardized classification, providing a thorough introduction to the classification, its structure, and the list of vegetation types found across the United States as of April 1997 (Grossman et al. 1998). *Volume I: The National Vegetation Classification Standard* can be found on the Internet at:

<http://www.natureserve.org/publications/library.jsp>.

NatureServe has since superseded Volume II of the publication (the classification listing), providing regular updates to ecological communities in the United States and Canada. This online database server, NatureServe Explorer®, can also be found on the Internet at:

<http://www.natureserve.org/explorer>.

GRTE Vegetation Mapping Project

The specific decision to map the vegetation at Grand Teton National Park was made in response to guidelines set forth in both the NPS Natural Resources Inventory and Monitoring Program and the NPS National Fire Plan. Under these guidelines, GRTE was viewed as a top-priority park based on its need for the program's vegetation map products. Driving this need was the park's inability to spatially analyze the vegetation at a fine enough scale to accurately predict vegetation response to management activities. Central to their concerns were the need for modeling the spread and intensity of fire, especially in and around wildland-urban interface zones. Additionally, the vegetation map will provide data to support inventory and monitoring activities and to

identify and quantify habitat for plant and animal species of interest.

In 2001 a scoping meeting was held to define the range of the project and determine data needs. Biologists, ecologists, researchers and managers from neighboring government and private agencies participated. In 2002 GRTE staff, with support from the NPS Vegetation Mapping Coordinator, entered into agreements with the U.S. Bureau of Reclamation's Remote Sensing and Geographic Information Group (RSGIS) to undertake the mapping portion of this project, the Wyoming Natural Diversity Database (WYNDD) Program for field data collection and NatureServe to complete the plant association classification work. WYNDD was replaced in the second and third field seasons by NPS staff.

NatureServe, BOR, WYNDD and GRTE ultimately formed a team, each responsible for a specific portion of the project as outlined in the program standards and flowchart provided by the Center for Biological Informatics (USGS/BRD) (**Appendix A**). WYNDD initially, and subsequently GRTE, took the lead in collecting the standardized field samples and entering this data into a digital database. NatureServe's Western Regional Office was tasked with classifying this data and providing a list and global descriptions for the GRTE plant associations. The BOR was responsible for aerial photo interpretation and creating a digital vegetation map and spatial database. GRTE staff reviewed and evaluated the draft classification, wrote local vegetation descriptions for all associations, cross-walked associations to map classes, and wrote and field-tested the key to the vegetation classification. GRTE staff also provided logistical and technical support, and helped coordinate activities.

As a team, our objectives were to produce final products consistent with the national program's mandates. These included:

- A Vegetation Classification based on the National Vegetation Classification System.

- A Map Unit Classification based on GRTE-specific requirements;
- A spatial database of GRTE's vegetation, using remote sensing and Geographic Information System (GIS) techniques;
- Digital and hard copy vegetation maps with a minimum 80% accuracy

1.2 Scope of Work

Vegetation mapping for GRTE occurred within a 550,087 acre project boundary, encompassing the executive boundary of Grand Teton National Park (GRTE), the executive boundary of the John D. Rockefeller, Jr. Memorial Parkway (JODR), the executive boundary of the National Elk Refuge (NER), a general 1-mile environment radius, and some special extended wildland-urban interface areas around the town of Jackson and along Highway 26, east of the park. The 1-mile buffer is intended to provide overlap for eventual integration of NPS, USFS and NER map products. The final project area determination was based on management needs, financial constraints, and time limitations (**Figure 1**).

1.3 Grand Teton National Park

Located in the northwest corner of Wyoming just south of Yellowstone National Park, Grand Teton National Park and the John D. Rockefeller, Jr. Memorial Parkway encompass over 333,772 acres, ranging in elevation from 6,350 feet (1,935 m) on the valley floor to 13,770 feet (4,197m) at the summit of the Grand Teton. GRTE and JODR lie in Teton County Wyoming with primary access restricted to entrances at the north, south, and east of the park. Besides Yellowstone National Park to the north, other major public lands surrounding GRTE include the Bridger-Teton National Forest to the south and east, the Caribou Targhee National Forest to the west, and the National Wildlife Elk Refuge to the southeast.

The park headquarters is in Moose, WY with other major facilities at Jenny Lake, Signal Mountain, Jackson Lake, Colter Bay, and Flagg Ranch (**Figure 2**).

[*NOTE: GRTE staff operate the JODR and for the purposes of this report GRTE refers to both park units unless otherwise specified.]

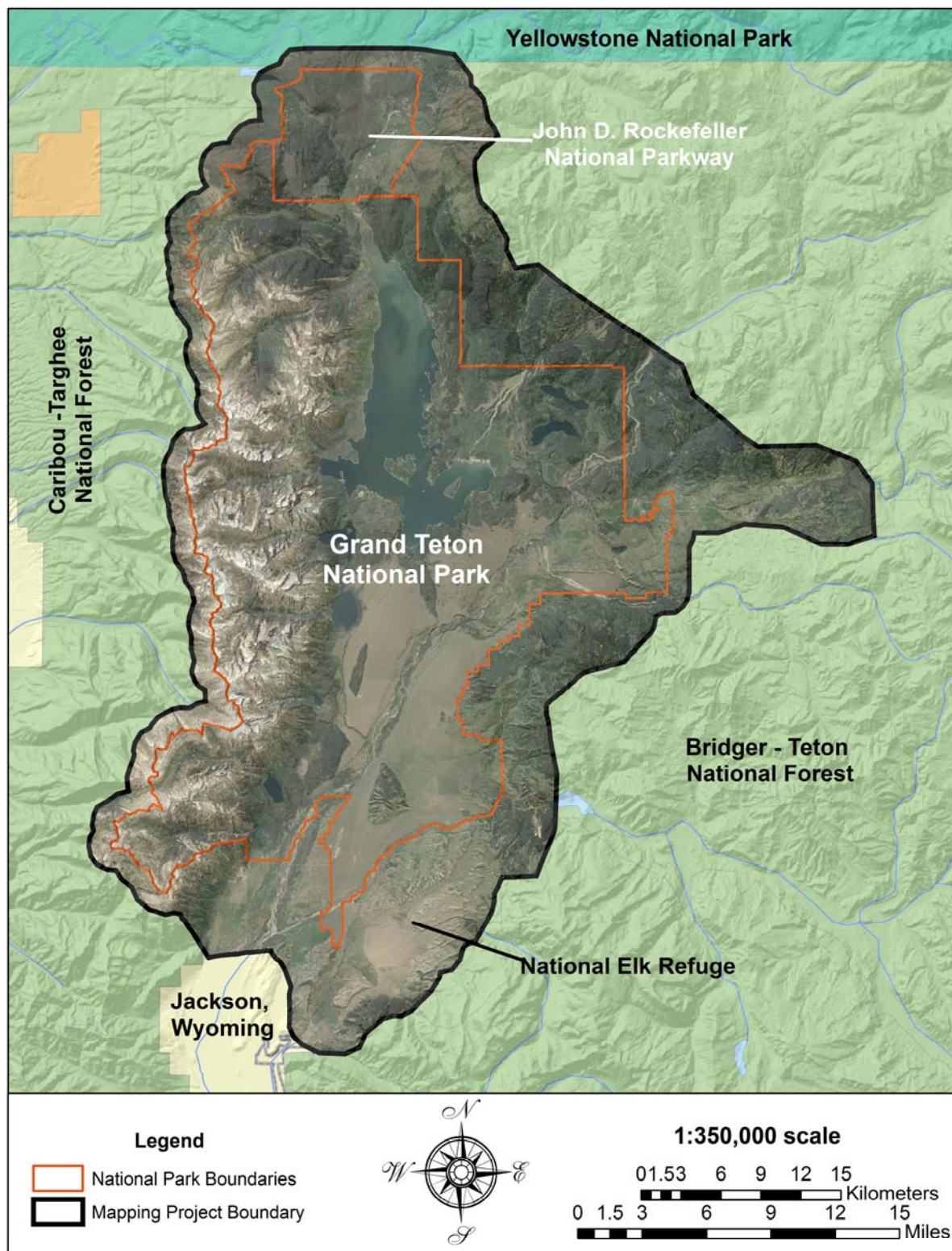


Figure 1. Vegetation Mapping Project and Park Boundaries.
(Color background image is a mosaic of the new Grand Teton Orthophoto created for this project.)

USGS-NPS Vegetation Mapping Program
Grand Teton National Park

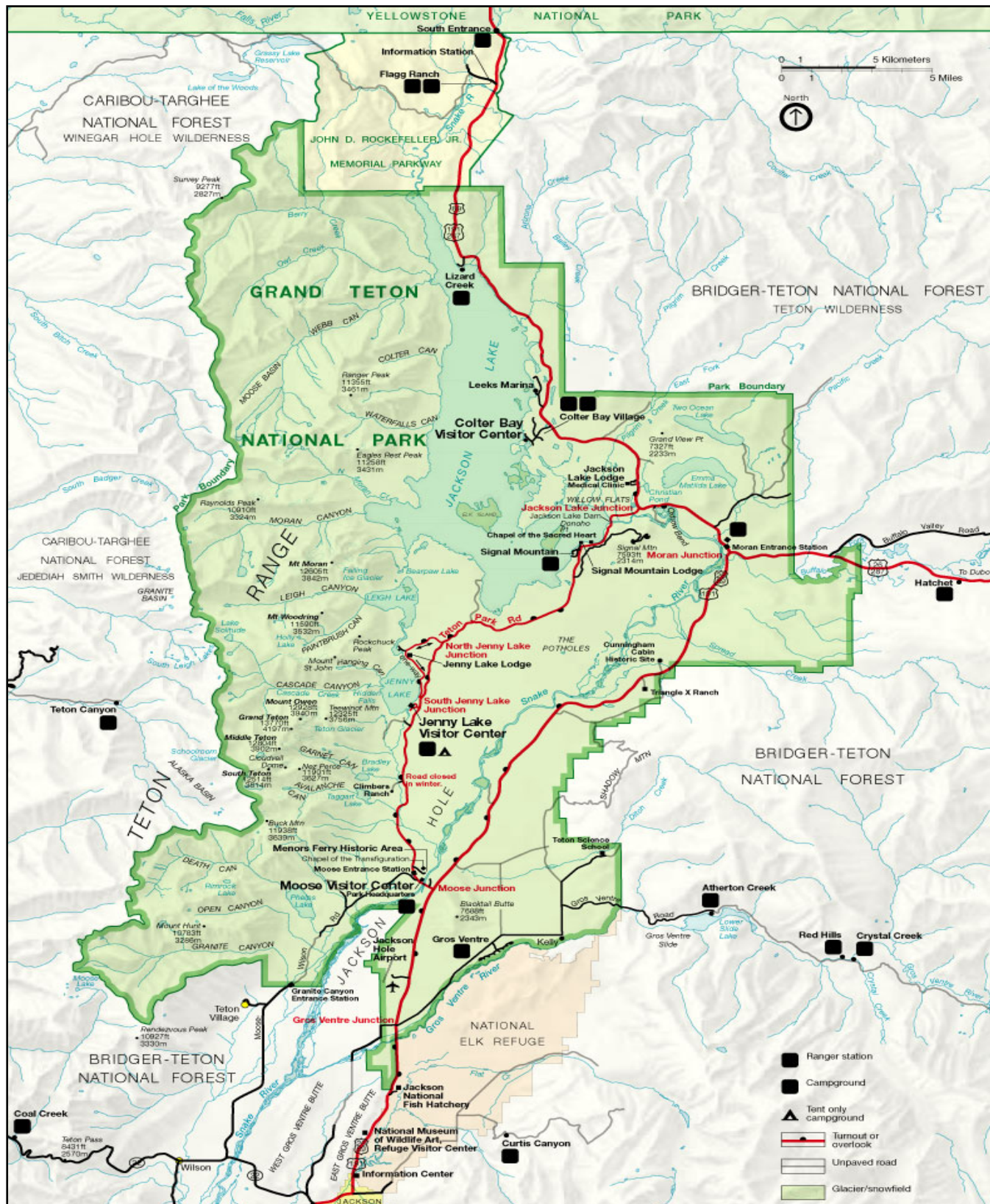


Figure 2. Grand Teton National Park Map.
 (obtained and modified from Grand Teton National Park Website (www.nps.gov/grte))

Grand Teton National Park is world renown for its stunning scenery radiating from the crystal blue lakes, bare granite, and dark conifers set against the snow-capped peaks of the Teton Mountain Range. The Tetons are the youngest range in the Rocky Mountains and their relatively recent geologic age has left them craggy and rough. Their ruggedness, sheer elevation relief of over 7,000 feet from valley to summit, plus their easy viewing from the valley floor all add to the impressiveness of these spectacular mountains.

Highlights of any trip to GRTE include enjoying the view from Jackson Lake Lodge of Mt. Moran, viewing Grand Teton and surrounding peaks, hiking into the backcountry wilderness along one of the many scenic canyons, and wildlife watching. For these reasons and many others GRTE and JODR draw around 2.5 million and 1.1 million annual visitors, respectively. GRTE and JODR are relatively large national park units based on their 2-dimensional land area; however they are truly immense if you consider surface area or 3-dimensional size.

Geology

(Adapted from: Geology of Grand Teton National Park: <http://www2.nature.nps.gov/geology/parks/grte> and Digital Geology of Idaho: <http://geology.isu.edu/nsf-isugeol/>)

Of all the forces in nature the creation of mountains has to be one of the most remarkable. Nowhere is this more evident than at GRTE. Created 6 to 9 million years ago, the Teton Range can best be imagined as the splitting of two large blocks along a common north-south fault (Teton Fault). The resulting east, or downthrown block, sinks some 16,000 feet, forming the base of Jackson Hole Valley. At the same time, the west or up-thrown block, juts upwards almost 7,000 feet creating the Teton Mountains; overall a total dramatic displacement of more than 23,000 feet (**Figure 3**).

Over time the valley block was filled in by thousands of feet of sediment, rock, and volcanic ash. Later, large glaciers scraped this valley, creating huge depressions or

“holes” such as the one that underlies Jackson Lake. At the same time the mountain block was also being eroded by water and glaciers. These forces effectively stripped away most of the soft sedimentary rock leaving behind the harder bands of gneiss. Into these bands water further carved out steep, rugged valleys that have been gradually smoothed and polished by ensuing glaciers. Combined, the glacial events in both the valley and in the mountains helped move massive amounts of material creating the many lakes and moraines characteristic of GRTE today.

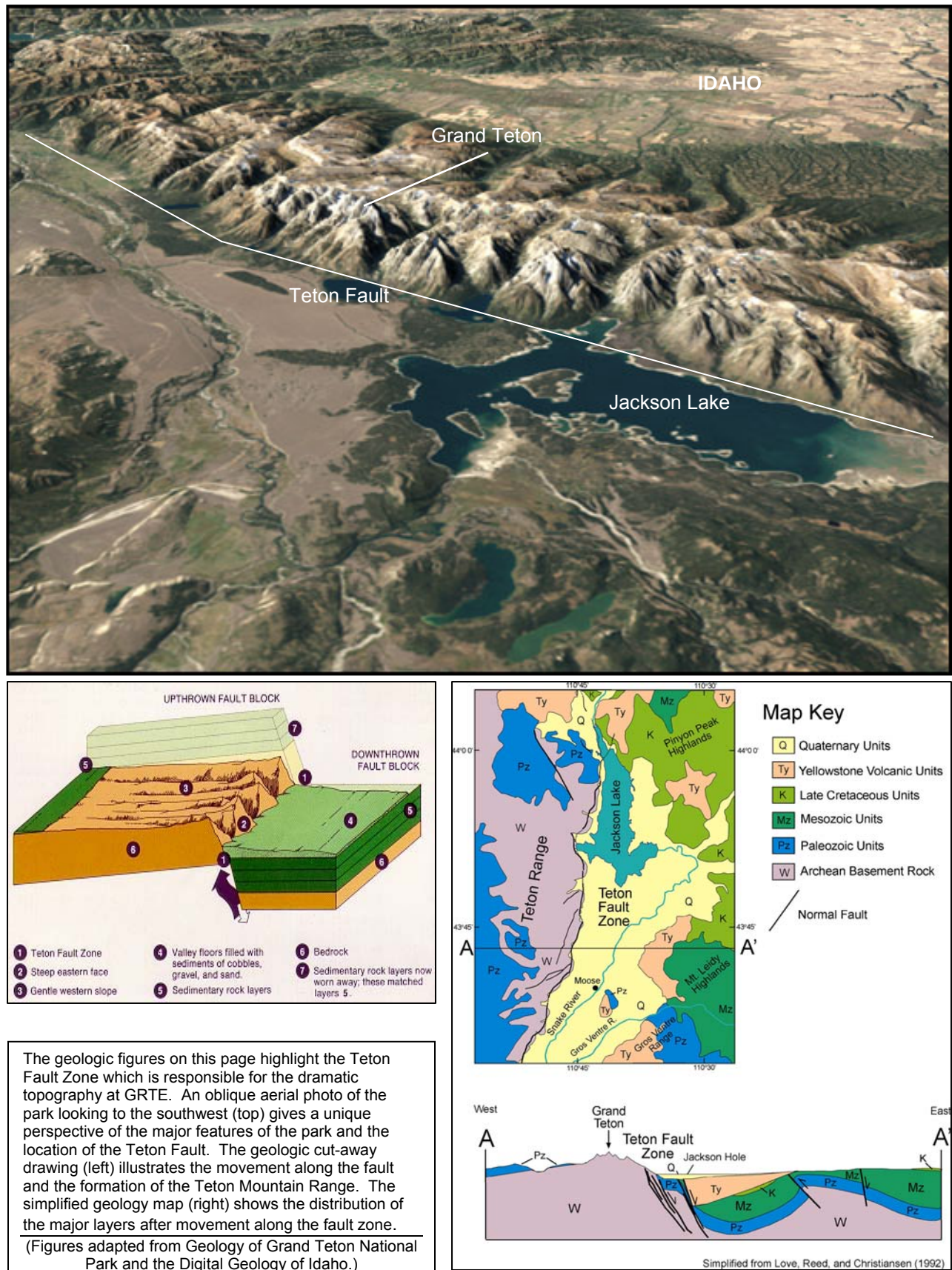
Topography

The Teton Mountain range is the focal point of GRTE and is close to the border of the Caribou-Targhee National Forest and Grand Teton National Park. The range is steeper on the east side with numerous canyons running nearly perpendicular to the north-south range (**Figure 3**).

From south to north, the peaks of the Teton Crest include: Prospectors Mountain (11,241 ft), Static Peak (11,303 ft), Mount Wister (11,490 ft), South Teton (12,514 ft), Middle Teton (12,804 ft), Grand Teton (13,770ft), Mount Owen (12,928 ft), Teewinot Mountain (12,325 ft), Rockchuck Peak (11,144 ft), Mount Woodring (11,590 ft), Mount Moran (12,605 ft), Traverse Peak (11,051 ft), Eagles Pest (11,258 ft), Ranger Peak (11,355 ft), Owl Peak (10,612 ft), Forellen Peak (9,776 ft), and (Survey Peak 9,277 ft). From south to north the major canyons include: Granite, Death, Avalanche, Garnet, Cascade, Paintbrush, Leigh, Moran, and Webb Canyons.

The park boundary runs just west of the crest of the Teton Range. Trails from the west side ascend gently sloping canyons and valleys eventually accessing the park over passes including: Fox Creek, Mount Meek, Hurricane, Nord, and Jackass Passes.

Figure 3. Grand Teton National Park Geology Overview



The eastern portion of the park is comprised of the Jackson Hole valley and the foothills of the Gros Ventre Mountains. Contained in this region are large areas that have been scraped and pot-holed by glacial activity. Glaciers left resistant rock which form hills, buttes, and outcrops. Prominent features include the East and West Gros Ventre Buttes, Blacktail Butte, Timbered Island (a moraine), Burned Ridge (a moraine), Antelope Flats, and Baseline Flats. The valley gradually gives way to undulating hills and low mountains to the East and North. The Snake River and its terraces is another prominent feature of the valley's geomorphology.

Climate

As anyone who has ever visited GRTE knows, the weather can be warm and sunny one day and cold and snowy the next. In fact GRTE experiences dramatic shifts in temperature and precipitation both throughout the year and with changes in elevation. In Jackson Hole, a typical winter will deposit 15 feet of snow on the valley floor with the mountains receiving much, much more. Temperatures also change significantly with elevation- decreasing an average of four degrees Fahrenheit for every 1,000 feet (<http://www.nps.gov/grte>). This shift in climate across the park results in a variable growing season averaging 4-5 months in the low elevations versus 2-3 months in the high alpine.

The first snowfall on the valley floor will likely occur by November 1 but the snowfall in the mountains can literally occur at any time of year. The average winter temperatures at Moose range from a daily maximum of 29°F to a minimum of 6°F. The spring months between March and May are usually cool and wet with average temperatures ranging from 22°F to 49°F. Summer usually begins around June and continues through August. During this time the average daily temperature is 76°F and nighttime temperatures can reach the lower 40s. Fall days are spectacular with only the occasional rain and snow shower. The average daily maximum for this time is 54°F and the minimum average is a cool 25°F.

Hydrology

Most of the yearly moisture in GRTE is received either during summer thunderstorms or in the form of snow. The Teton Mountain Range averages nearly 500 inches of snow during the winter. Some areas of snow remain throughout the year and many small glaciers still exist in the park. Some of the most visible include the Middle Teton, Teton, Peterson, Schoolroom, Falling Ice, Skillet, and Triple Glaciers.

Eventually all of the melting snow and ice flows down one of the feeder streams into either a cirque lake (i.e. Lake Solitude, Marion Lake) or directly into the canyons creating dramatic water falls and cascades. The canyons at GRTE contain many perennial creeks that swell in the spring and gradually drop throughout the summer and fall. Important watercourses in the Teton canyons include Granite Creek, Taggart Creek, Cascade Creek, Leigh Creek, Moran Creek, Moose Creek, Owl Creek, and Berry Creek.

Most of these mountain streams feed into one of the many glacial lakes. These range in size from Bradley (about 84 acres) and Taggart (111 acres) Lakes to Jackson Lake that is over 26,100 acres. Some of the other more prominent lakes include Phelps, Jenny, String, and Leigh Lakes. On the east side of the park large wetlands, natural ponds, and pocket lakes occur. These are fed through a combination of streams, springs, and seeps. These waters include Ditch, Lost, Spread, Lava, Pacific, Pilgrim, Arizona, Lizard, Nickel and Dime Creeks, and Emma Matilda and Two Ocean Lakes.

All of the lakes, creeks, and streams in GRTE eventually flow into the Snake River which flows from the north through the park. The Gros Ventre River is a major tributary which flows into the Snake River just north of the National Elk Refuge. The Snake is a braided river system with numerous channels and oxbows. Its relatively large floodplain supports large area of wetlands especially in the JODR north of Jackson Lake.

Jackson Lake is the largest lake in the park. The lake is on the Snake River and is located on the site of a large natural glacial basin. The storage capacity of this lake was augmented in 1910 with the addition of the Jackson Lake Dam located on its east side. The storage capacity of Jackson Lake is approximately 624,000 acre-ft of water at a mean elevation of 6760 feet (BOR website: <http://www.usbr.gov/dataweb>). Water releases are controlled by the BOR and provide irrigation water for downstream users. Minimum flows are maintained throughout the year for the benefit of park resources.

Vegetation

GRTE's extreme elevation relief coupled with its geologic complexity creates a myriad of growing conditions supporting a large number of plants and plant communities. During the course of this study we found that species could be broadly separated into life zones based on topographic position (primarily slope, aspect and elevation). The resulting pattern reflects an altitudinal gradient starting with low elevation sagebrush, grassland, wetland and riparian communities to montane conifer and aspen woodlands to higher subalpine forests and alpine tundra (**Figure 4**). Tucked in the many mesic canyons are also large stands of deciduous shrublands, avalanche-disturbed regeneration vegetation, and lush forb and graminoid meadows.

It should be noted that one constant found in this study with regards to the vegetation at GRTE was that there are no constants. In fact we were surprised when the species occurring in the representative life zones, ecosystems, and plant associations were predictable. This seems to follow other studies of Rocky Mountain vegetation (Weber 1976; Peet 1988) where the authors have advised that the vegetation within life zones can blend together and leapfrog around the landscape. This patterning coupled with the difficult topography and regular disturbance events (i.e. fire, flooding and avalanche) seemed to result in a patchwork mosaic of vegetation types that can only be generally divided into the seven distinct vegetation zones (modified from Stohlgren 1998) described below:

1. In the lowest elevation from about 6350 feet to 6900 feet **Sagebrush Flats** cover large plains. Excellent examples can be seen along Highway 26 and Teton Park Road. Dominant species include low sagebrush (*Artemisia arbuscula*), mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) and bitterbrush (*Purshia tridentata*).

The extensive sagebrush shrublands at GRTE may at first appear uniform but on closer inspection they vary dramatically. On slightly drier sites low sagebrush dominates, while mountain big sage and bitterbrush are on the moderate sites. Moisture areas may support shrubby cinquefoil (*Dasiphora floribunda*) and silver sage (*Artemisia cana*), or rabbitbrush (*Ericameria nauseosa*). Drier well drained hillsides often lack shrubs, and instead various bunchgrasses dominate. These include bluebunch wheatgrass (*Pseudoroegneria spicata*) and various needlegrasses (*Stipa* spp.).

In some areas of GRTE, the sagebrush and grassland types may extend unto the lower toeslopes of the surrounding mountains. Here the grasslands give way to more forb-dominated meadows. Composition and density of the communities in this area of the park varies with changes in soil moisture and parent material. Conspicuous mesic forbs occurring on these sites include arrowleaf balsamroot (*Balsamorhiza sagittata*), one-flowered helianthella (*Helianthella uniflora*) and mulesears (*Wyethia amplexicaulis*).

2. **Riparian Forests** comprised of broad-leaved deciduous cottonwoods (*Populus angustifolia* & *P. balsamifera*) alders (*Alnus incana*), and willows (*Salix* spp.) line the Snake River corridor and its many tributaries. Also common, especially at the south end of Jackson Hole, are large stands of blue spruce (*Picea pungens*) and aspen (*Populus tremuloides*). These may also intermingle with the willow and cottonwood forming complex mosaics. The understory and herbaceous layers in riparian communities are often lush, containing Kentucky bluegrass (*Poa pratensis*), a naturalized but non-native

species, various groundsels (*Senecio* spp.) and asters (*Aster* spp., *Erigeron* spp.). These areas tend to be much more diverse than upslope areas and adjacent coniferous forests ([Peet 1978](#); [Baker 1990](#)).

3. The **Montane Seral Forests** at GRTE are dominated by lodgepole pine and aspen forests. These forests are commonly found between 6500 to 7500 feet on all exposures. Lodgepole pine forests are characterized by their dense tree structure and a sparse or absent understory dominated by pinegrass, elk sedge (*Carex geyeri*), grouse whortleberry (*Vaccinium scoparium*), and/or highbush huckleberry (*Vaccinium membranaceum*). Aspen stands are characterized by a well-developed understory with an array of shrubs, forbs and graminoid species represented in each stand. In the absence of disturbance most lodgepole and aspen stands will eventually be replaced by Douglas-fir or spruce-fir climax communities, though stable lodgepole forests do occur in the northern reaches of the study area, and stable aspen stands are found on the eastern edge. Lodgepole and aspen ecosystems are fire-resilient and can be rejuvenated by constant fire or avalanche disturbance, resulting in rapid growth of even-aged stands. Historic fire intervals for lodgepole pine forests can range from 100 to 300 years ([Romme and Knight 1981](#)).
4. At GRTE **Douglas-Fir Woodlands** grow in montane life zones between the sagebrush flats and the spruce-fir forest, spanning an elevation range from roughly 6500 to 8000 feet. Douglas-fir (*Pseudotsuga menziesii*) stands tend to grow on south-facing slopes and along mesic drainages. Here they form mixed stands with other common conifers including limber pine (*Pinus flexilis*), lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). The understory tends to be fairly open, and is often dominated by pinegrass (*Calamagrostis rubescens*) or spirea (*Spiraea betulifolia*). Douglas-fir trees tend to be bushy in appearance as a result of their open canopy and mature trees are

tolerant of frequent, low-intensity surface fires. It is estimated that fire intervals in Douglas-fir forests in Wyoming average 50-100 years ([Loope and Gruell 1973](#)).

5. The subalpine zone of GRTE is characterized by **Spruce - Fir Forests** consisting primarily of Englemann spruce and subalpine fir. These species occur together between 6700 and about 9500 feet; interfingering with the montane life zone and occurring as stunted krummholz islands and mats in the alpine. Disturbance in this zone is related to fire and insect outbreaks. Stand-replacing fires typically occur at 200- to 400-year intervals, and infestations of spruce budworm and spruce beetle may occur more frequently ([Veblen et al. 1991](#)).
6. On dry slopes at high elevations throughout GRTE, **Subalpine Whitebark Pine Forests** replace and intermingle with spruce-fir forests. Whitebark pine (*Pinus albicaulis*) is the dominant species, able to withstand the severe environmental conditions on these exposed areas. Common understory species include grouse whortleberry, Ross sedge (*Carex rossii*), and smooth woodrush (*Luzula piperi*). The whitebark pine forests at GRTE provide unique wildlife habitat and forage. They are of special concern to GRTE with increasing rates of mortality due to white pine blister rust and susceptibility to mountain pine beetle infestations contributing to possible decline of this high-elevation forest type. It is estimated that 7% of the whitebark pines in GRTE are dead and that 5-15% of the live trees are infected with rust. Fire intervals for whitebark pine vary from 50 to as much as 300 years ([Kendall 1995](#)).
7. Stunted vegetation, shrubby mats, and windswept trees are common traits found in GRTE's **treeline vegetation**. Treeline in GRTE occurs at about 10,000 feet. Above this elevation, the environmental conditions, including soil temperature and wind velocity, become too harsh to allow normal tree growth. The result is krummholz trees characterized by flagging or layering of branches on their lee sides, gnarled trunks and diminished size. Most trees at treeline never grow above 3-4 feet

but occasionally some stands will have a few emergents over 5 feet. Dominant treeline species include Engelmann spruce, subalpine fir, and whitebark pine. Gooseberry currant (*Ribes montigenum*) is a common understory shrub.

8. The complex, diverse vegetation directly above treeline at GRTE is identified as **alpine tundra**. This includes an assortment of meadows, fell fields, and talus slopes supporting a wide range of grasses, sedges, and small forbs. Dwarf shrubs, including willows, are also present, particularly in wet areas. Vegetation in this zone is similar to that in the arctic with species common to both. The growing season in these areas is extremely short. A wide variety of species occurs here.

Exotic Plants

Numerous problematic non-native and invasive plant species are found within the park and are being actively controlled. These include spotted knapweed (*Centaurea maculosa*), houndstongue (*Cynoglossum officinale*), St. John's wort (*Hypericum perforatum*), Dyer's woad (*Isatis tinctoria*), and bull thistle (*Cirsium vulgare*), to name just a few. Also, many non-native grasses and forbs such as Kentucky bluegrass, smooth brome (*Bromus inermis*),

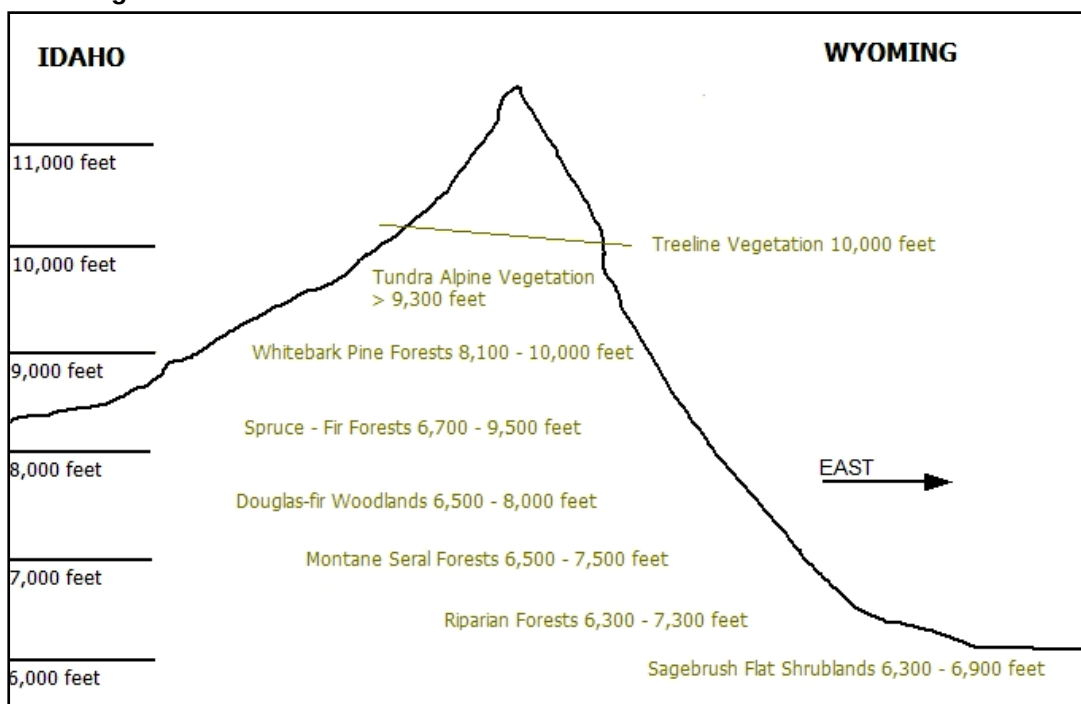
and white clover (*Trifolium repens*) which were originally established within the former farming and ranch sites scattered throughout GRTE have expanded into neighboring native plant communities.

Wildlife

The diverse vegetation at GRTE creates many habitats supporting a wide range of fauna --everything from moose to mosquitoes. In the high country animals such as pica and yellow bellied marmots are able to withstand the severe conditions and on the valley floor herds of bison can be found grazing alongside elk, deer, and pronghorn antelope.

In a larger context, GRTE lies within the 11 million acre Greater Yellowstone Area which is considered one of the most intact temperate ecosystems remaining on earth. The animals in this region migrate across vast areas in search of food and favorable conditions. Large animals using this ecosystem include wolves, moose, elk, mule deer, pronghorn antelope, black and grizzly bears, lynx, mountain lions, wolverines, and bighorn sheep (<http://www.nps.gov/grte>).

Figure 4. Theoretical cross-section of the life zone in the Teton Mountains.



2. METHODS

Based on the overall project scope and the assignment of responsibilities, the project was divided into six major steps following the USGS flowchart (**Appendix A**):

1. Plan, gather data, and coordinate tasks;
2. Survey GRTE to understand and sample the vegetation;
3. Classify vegetation using field data to NVCS standards and crosswalk to recognizable map units;
4. Acquire aerial photography and interpret using the classification scheme and crosswalk;
5. Transfer the interpreted data to a digital form;
6. Ground-truth and assess the accuracy of the final map product.

All protocols for this project as outlined in the following sections can be found in documents produced by The Nature Conservancy (1994a, 1994b, and 1994c) for the USGS-NPS Vegetation Mapping Program and found at this website:
<http://biology.usgs.gov/npsveg>.

2.1 Planning, Data Gathering and Coordination

A scoping meeting was held in May of 2001 and attended by representative USGS, NPS, NatureServe, BOR, and WYNDD staff. The goals of this meeting were to (1) inform the park staff and interested neighbors about the program, (2) learn about the park's management issues and concerns, (3) review existing data, (4) develop a schedule and assign tasks, (5) get a commitment from the park, (6) define possible cooperation with others, and (7) define a project boundary.

This meeting in addition to follow-up meetings, conference calls and e-mails helped determine three important project decisions:

1. The project was defined with a boundary encompassing 526,700 acres. This included GRTE, JODR, the National Elk Refuge, a 1-mile general environs, and

extensions into special adjacent urban areas.

2. New 1:12,000-scale true-color aerial photography would be acquired. Also, new 1:12,000 true-color orthophoto base maps would be acquired for the park to help with the digital transfer.
3. Assignment of work responsibilities to the participants were as follows:

GRTE-NPS Responsibilities

- Provide oversight and project funding in conjunction with USGS-CBI;
- Supply digital boundary files, ancillary data files, and secure relevant data from neighboring lands;
- Supply safety and GPS equipment and provide training;
- Assist with fieldwork and logistical considerations (2002);
- Staff and coordinate the field crews, supply housing, provide logistical support, database maintenance, data entry and review (2003-2004);
- Design the sampling strategy (2003-2004);
- Collect representative plot data (2003);
- Collect accuracy assessment data (2004);
- Work with NatureServe to develop the vegetation classification
- Compile, review, and update drafts of the vegetation map, classification and report;
- Write Park Specific (local) vegetation descriptions
- Write a field key to the vegetation types
- Accept the final products and close the project.

WYNDD Responsibilities (2002)

- Design the sampling strategy;
- Coordinate the field crews, supply housing and logistical support;
- Collect representative plot data;
- Write 2002 progress report;

NatureServe Responsibilities

- Work with NPS to develop a vegetation classification for the study area based on the NVC using quantitative analysis

and ecological interpretation of the field data;

- Provide guidance regarding the crosswalk of vegetation types to Map units
- Provide global vegetation descriptions

BOR Responsibilities

- Help with overall project facilitation and coordination;
- Provide the specifications and help GRTE acquire new 1:12,000 scale true-color aerial photography and orthorectified imagery;
- Verify vegetation and land use/land cover signatures on the aerial photographs;
- Develop map units linked to the NVC;
- Provide field maps and GIS support to the field crews;
- Interpret and delineate vegetation and land-use types using aerial photographs;
- Transfer and automate interpreted data to a digital spatial database;
- Produce spatial layers of plot and accuracy assessment site locations;
- Assist with the accuracy assessment by picking the stratified random target points, creating field maps and providing GIS support;
- Provide a final report describing all aspects of the project;
- Provide a visual guide to the photo signatures of each map unit;
- Document FGDC-compliant metadata for all vegetation data.
- Create a CD-ROM with reports, metadata, guides, vegetation classification, plot data, spatial data, the vegetation database (map), graphics, and ground photos.

We began work by gathering copies of maps, soil surveys, reports, and other documents describing the park and its environmental setting. GRTE provided species lists, previous vegetation maps and study points, geology maps, and other relevant information. NatureServe provided a list of potential plant associations.

At this time, we also evaluated existing plot data from previous studies at GRTE and

from the neighboring National Forests to assess their suitability for use in the vegetation classification and mapping. Select plot data from the Bridger-Teton and Caribou-Targhee National Forests, as well as recent plots from GRTE which met program standards were incorporated into the dataset. These data were used in classification as well as photo interpretation.

2.2 Field Survey

Overall, the field methods used for developing the classification and conducting the accuracy assessment at GRTE followed the methodology outlined by the USGS-BRD/NPS Vegetation Mapping Program (Grossman *et al.* 1994). Some additions and deviations were made, including the use of Modified Whittaker plots instead of macro or Relevé plots by WYNDD in 2002 and collection of additional fire fuels-related information. A summary of the methodology, as it was applied at GRTE, is presented below:

Provisional classification of plant associations

As the 2002 field season approached, preparations were made by GRTE, WYNDD, and NatureServe for collecting sample plot data. This involved creating a preliminary list of vegetation associations and alliances from the NVC based on previous studies and local knowledge. The resulting list was initially used to set targets for data collection. Each association was targeted for 3-5 plots. Associations that were relatively well known and described from other areas were assigned fewer plots, and those that were thought to be new to GRTE or known from elsewhere, but not well characterized, were assigned more. The preliminary list of vegetation types was a working document that was refined as new information became available from the vegetation sampling.

Sampling Design: Stratified Random Gradsect

Our ultimate goal was to obtain a thorough description for the entire range of plant communities, both the common and the rare (Austin and Heyligers 1991). However, we

felt that a complete census of all the vegetation would not be achievable or practical for such a large and remote park. As a result, we felt it necessary to select sampling locations using "Gradsect Sampling" (GRADient-directed tranSECTs) (Gillison and Brewer 1985). Gradsect is a survey technique that addresses 1) the need for representative sampling across the gradient of variation, 2) the need for efficient sampling, considering practical logistical problems, and costs, and 3) the value of replicated and stratified random sampling. The modified Gradsect methodology would allow field crews to visit the full spectrum of physical environments and thus most of the vegetation types.

We decided that a spatial-historical model coupled to a 30-meter digital elevation model (DEM) of the park would be more predictive of vegetative diversity and more efficient than a linear transect approach. A working group of WYNDD, NPS, and NatureServe ecologists and botanists familiar with the region selected the model's driving variables; they chose those thought to influence vegetation composition and structure. During this process, practical constraints were also considered including limited time and money to develop new digital data layers.

For the modified Gradsect, we created unique Biophysical Units (BPUs) that divide the landscape by physical parameters into units we thought would ensure the sampling that would capture the range of unique habitats within the study area. We divided the study area into two major sections, the mountains or high country, and the valley floor. Different parameters were used for the two sections. The mountain BPUs were split by elevation, geology and solar budget, while the valley floor was divided based on geology, agricultural (land use) history, and solar budget (**Table 1**). A digital map of each layer was created using ArcView GIS. These GIS layers were then added together to generate map coverage of all combinations occurring in GRTE, with each unique combination representing a Biophysical Unit (BPU).

The resulting BPU types within the park were then sub-divided using a cost-surface

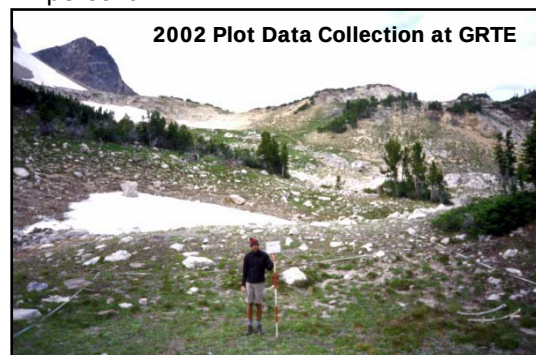
analysis, which favored polygons that were more accessible, of adequate size, and spatially dispersed. This cost-surface process for selecting sampling locations was especially important for GRTE due to access difficulties caused by the park's steep, variable terrain.

2002 Field Sampling Methods

Armed with both the preliminary list of associations and the Gradsect BPUs, WYNDD kicked off the 2002 field season at a field crew training meeting. During this meeting it was decided by WYNDD to use three different sampling methods: 1) Modified-Whittaker (Stohlgren et al. 1995) plots, 2) Detailed Descriptions, and 3) Observation Points. The Mod-Whit Plots and Detailed Descriptions were used to define vegetation types. Observation Points, as well as the plots and detailed descriptions, were important to the photointerpreters for ground-truthing.

The majority of vegetation samples in 2002 were Modified-Whittaker plots. The Modified-Whittaker sampling method was advocated by WYNDD, because they believed it to be a more accurate, quantitative, and repeatable method of vegetation cover estimation than estimates of cover across a macroplot.

Modified Whittaker plots at GRTE were comprised of a series of 10 nested microplots within a larger macro plot. The cover value of each plant species was estimated within the microplots then averaged for the entire plot. This was followed by documenting the presence of any new species in successively larger plots. Cover values of plant species present in the macroplot, but not present in any of the 10 microplots, were recorded as less than 1 percent.



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Within each plot, the crews visually divided the vegetation into strata, and the height and canopy cover of vegetation was estimated for each stratum. Physiognomic class, leaf phenology, and type of dominant stratum were recorded. The species of each stratum were then listed and percent canopy cover estimated using a twelve-point cover scale (<1%, 1-5%, >5-15% ...) (Daubenmire 1959). Additional species within the vegetation unit that occurred outside of sampled plots were listed separately. Non-vascular species cover was summed as either lichen or moss depending on life-form. No attempt was made to identify individual species of non-vascular plants.

Environmental information was also collected including: elevation, slope, aspect, landform, topographic position, soil texture and drainage, hydrologic (flooding) regime and evidence of disturbance or wildlife use. The unvegetated surface was recorded as percent cover of each of the following: bedrock, litter and duff, wood, bare soil, large rocks (>10 cm), small rocks (0.2-10 cm), and sand (0.1-2 mm).

The Detailed Description plot method was used when Modified-Whittaker plots could not be applied for certain vegetation, such as concentric wetlands comprised of a large, central zone ringed by 2-3 narrower or more linear zones or bands. In these cases, vegetation zones were described and illustrated on the data sheets, and cover values of individual species were estimated within each zone. Only cover values of plant

species within the large, central zone were reported. Sample locations were recorded from plot centers using Trimble GeoExplorer GPS units provided by the park. Universal Transverse Mercator (UTM) X-Y coordinates and elevation were recorded both manually on the plot forms and stored as waypoints in the GPS unit. All readings, including the accuracy estimates, were downloaded from the units, differentially corrected, and transferred to an Access database. Average error ranged between ± 5 -10 meters in open areas, with more error associated in canyons and under dense vegetation.

Photos were taken at each plot. A photo was taken of the first corner, where a permanent stake was buried for future monitoring purposes. This photo was taken from along the first line of the plot. Another was taken to document the view of the plot. This one was taken from the edge of the plot looking into the center of it. Four other photos were taken along the four Brown's fuels transects (see below). All of the photos were named with a labeled white board mounted on a survey pole.

WYNDD conducted the vegetation sampling, along with 2 NPS personnel. The additional personnel were originally hired by the park to sample fuels at the same locations where vegetation was sampled for the vegetation mapping project. However, all crew members were trained to collect both vegetation cover data and fuels data to allow for maximum efficiency in the field.

Table 1. Environmental variables and classes used in the Gradsect analysis for GRTE.

The combination of variable classes is called a Biophysical Unit or BPU.

East Side (Valley Flats)	228 BPUs possible (actual # lower as not all combinations exist)	West Side (Mountains)	192 BPUs possible (actual # lower as not all combinations exist)
Geology	19 classes Volcanic, Sedimentary, Gneiss, Glacial outwash, Quaternary alluvium, etc.	Geology	12 classes Volcanic, Sedimentary, Gneiss, limestone, Alluvial/Colluvial, etc.*
Land Use	3 classes Active Grazing Historic Grazing No Grazing	Elevation	4 classes meters (rounded feet) 1901 – 2375 (6201-7800 ft) 2376 – 2750 (7801-9050 ft) 2751 – 2900 (9051-9515 ft) > 2901 (>9515 ft)
Solar Insulation	4 classes Full Sun, Partial Sun, Full Shade, Partial Shade	Solar Insulation	4 classes Full Sun, Partial Sun, Full Shade, Partial Shade

2003 Field Sampling Methods

In 2003, GRTE staff assumed the responsibility for data collection. They collected data in much the same way as in 2002 with some exceptions including using Relevé macroplots instead of Modified Whittaker plots and not focusing as much on the BPU's but rather using local knowledge and previously sampled data to find representative sample stands in communities that didn't have enough plots in them yet. In addition, as in 2002, field crews were instructed to avoid areas where vegetation was transitional between types, such as ecotones.

All plot information was recorded on a modified plot form (**Appendix B**). Environmental information included: elevation, slope, aspect, landform, topographic position, soil texture and drainage, hydrologic (flooding) regime and evidence of disturbance or wildlife use. Pick lists of environmental variables were provided to help standardize naming (**Appendix B**). The unvegetated surface was recorded as percent cover of each of the following: bedrock, litter and duff, wood, bare soil, large rocks (>10 cm), small rocks (0.2-10 cm), sand (0.1-2 mm), lichens, mosses, and fungi. Vegetation structure and species composition were sampled using plots that varied in size depending on the dominant physiognomy of the vegetation. Forest, woodland and shrubland plots were 400 m², while dwarf-shrubland and herbaceous vegetation plots were 100 m². Plot dimensions were recorded on the forms and the plot shape usually was square, but was modified to best represent the vegetation (e.g. narrow, linear rectangles for riparian vegetation).

Within each plot, the crews visually divided the vegetation into strata, and the height and canopy cover of vegetation was estimated for each stratum. Physiognomic class, leaf phenology, and type of dominant stratum were recorded. The species of each stratum were then listed and percent canopy cover estimated using a twelve-point cover scale (<1%, 1-5%, >5-15% ...) (Daubenmire 1959). Additional species within the vegetation unit that occurred outside of sampled plots were listed separately. No attempt was made to identify individual non-vascular plant species. Species that were not identifiable in the field were collected for later identification. Species were recorded by scientific epithet familiar to researchers and

synonymized with the nomenclature of Kartesz (1999).

For plots with trees, the diameter at breast height (DBH) was measured and recorded for trees with DBH greater than 10 cm. Trees with stems 5-10 cm DBH were tallied. Multi-stemmed trees were also measured and recorded as such. Finally, a provisional vegetation type was assigned to the plot. Please see **Appendix B** for more information on the plot data collection.

Photos were taken at each plot. A photo was taken of the first corner, where a permanent stake was buried for future monitoring purposes. This photo was taken from along the first line of the plot. Another was taken to document the view of the plot. This one was taken from the edge of the plot looking into the center of it. Four other photos were taken along the four Brown's fuels transects (see below). All of the photos were named with a labeled white board mounted on a survey pole.



Fire Specific Data

At GRTE, additional vegetation data related to fire fuel loading and fire modeling was also collected in tandem at many of the vegetation plots. In 2002, additional GRTE fire program personnel accompanied the vegetation field crew to collect fire-modeling data and in 2003 all members of the field crew were trained to collect the fire data. Data such as height to live crown, fuel types and fuel amount were collected in each plot.

See appendices for more information regarding fire data.

Data Collection: Plot Summary

Our field sampling goals were to have 3-5 plots per plant association with less well-understood and more diverse associations receiving more sampling. All plots were to be spread across GRTE to capture diversity. Plot sampling was conducted during the summers of 2002 and 2003 by WYNDD and GRTE staff, respectively. This combined effort resulted in 167 plots sampled in 2002 and 248 plots sampled in 2003. An additional 220 plots were added to the total by incorporating 78 plots provided by the Caribou-Targhee National Forest, 115 plots from the Bridger-Teton National Forest, and 27 pre-existing GRTE plots. All plots provided similar high-quality data, with the National Forest plots located predominantly in the environs portion of the project area (**Figure 5**).

2.3 Plot Data Management and Classification Analysis

Upon completion of the plot data collection in 2002 and again in 2003, data were entered into the NPS PLOTS database (TNC 1997), a MS Access-derived program. PLOTS database was developed expressly for the NPS vegetation and mapping program so that the electronic data entry fields mirror the standard field forms (**Appendix D**).

This was facilitated by assigning each plant species a unique, standardized code and name based on the PLANTS database developed by National Resources Conservation Service in cooperation with the Biota of North America Program (<http://plants.usda.gov>). After data entry, we checked for any errors such as duplicate entries or erroneously selected plant names (from database pick-lists). Problems regarding unknown species, especially those with high cover, were resolved, as were other taxonomic issues such as grouping some subspecies and varieties judged to be ecologically similar.

Prior to quantitative analysis the database was prepared for use in the analytical programs. Data preparation included:

- correcting species duplicative names and concatenating estimated cover if necessary;
- correcting strata (vegetative layers tree, shrub, herbaceous) codes for consistency;

- From corrected strata data we used tree “pseudospecies”. Each tree species has three possible values in the data: cover as a mature tree, cover as a sapling-sized tree, and cover as a seedling;
- removing plots with incomplete or missing data;

After formatting, the data were analyzed in a series of runs in PC-ORD Multivariate Analysis software package (McCune and Mefford 1999). The process involved partitioning the larger data set into smaller sets until sufficient resolution was achieved to classify stands into an existing NVC association or to develop a new type.

This was accomplished by using Indicator Species Analysis (Dufrêne and Legendre 1997, as cited in McCune and Grace 2002). Indicator Species Analysis calculates the abundance (percent cover) and constancy (frequency) of species, producing indicator values for each species in a group. Indicator Values are tested for significance using randomized (Monte Carlo) technique. A species that is a perfect indicator of a particular group should always be present in that group and never occur in other groups.

Further analysis using Agglomerative Clustering with Sørensen distance and Flexible beta linkage functions (McCune and Grace 2002) was used to explore each of the indicator groups, and define plant associations. Preliminary plant associations were then compared with the NVC (NatureServe 2005). Throughout, care was taken not to over-emphasize local variations found at GRTE compared to more extensive information compiled at the regional level. Nevertheless, several types in the NVC were revised based on these analyses and new associations were identified from GRTE’s data.

Park ecologists and botanists worked with NatureServe to refine and finalize the classification for the park. Plant association descriptions and literature references contained within the NVC were compared to GRTE results. Quantitative tables of cover and constancy by GRTE associations were generated by the PLOTS database, and compared to published tables. Based on qualitative comparisons, some associations

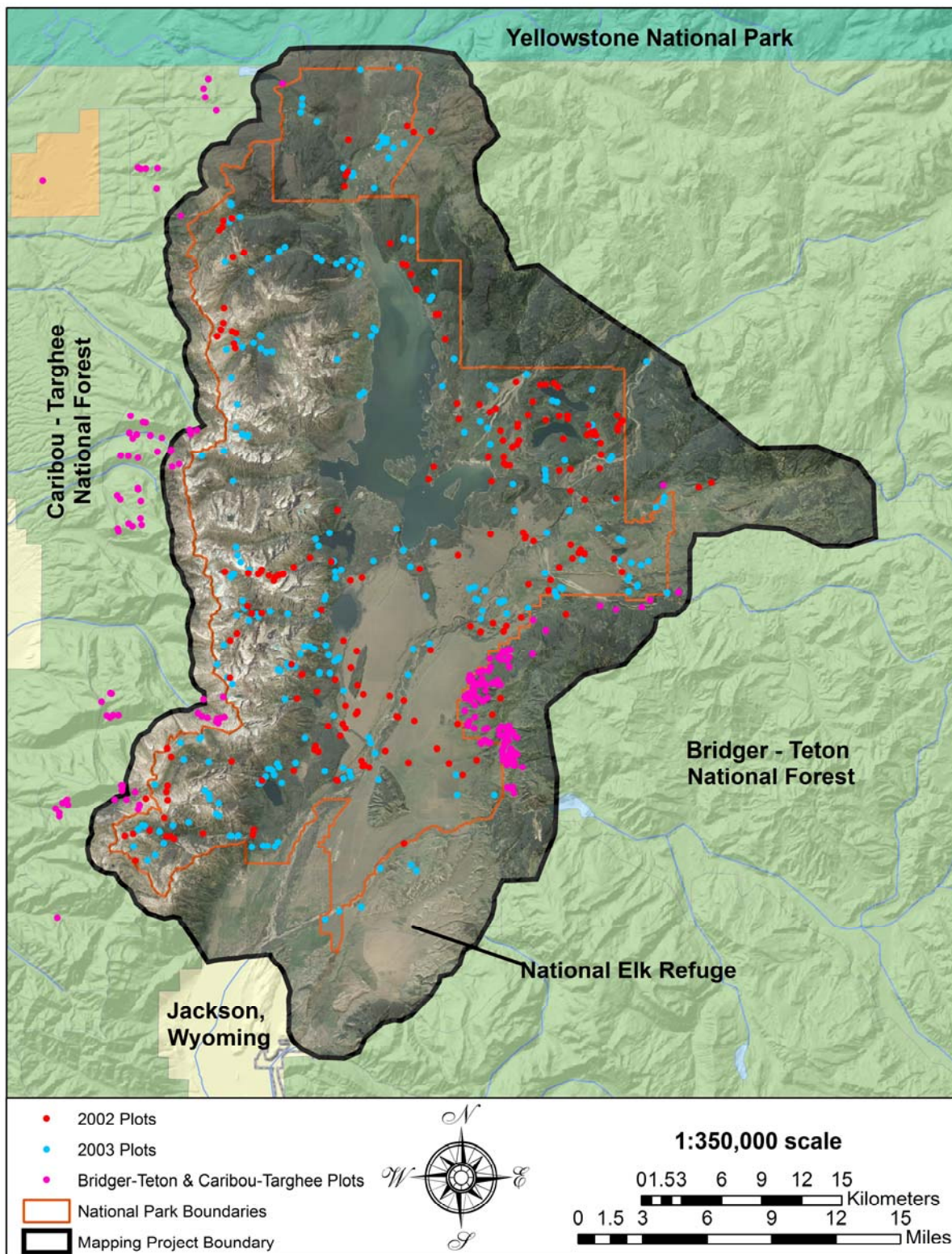


Figure 5. Location of all vegetation plots collected at Grand Teton National Park

were changed, and some plots were moved from one association to another and in some cases new associations were created.

GRTE plot data was then used to update and improve world-wide descriptions (Global) NVC plant associations. GRTE specific (Local) descriptions were written based on GRTE plot and AA data. The final GRTE classification contains 207 plant associations (**Table 7**). The full NVC hierarchical classification, global and local descriptions are available in **Appendix D**.

Once the associations were finalized, a dichotomous key was developed for use during the Accuracy Assessment (**Appendix C**). In addition, we linked the final associations to map classes (see **Section 3.3**) for use in the photo-interpretation and mapping portions of the project.

2.4 Aerial Photography and Orthophotos

Mapping Challenges

Experience told us that GRTE's rugged mountains, steep canyons, and thick forests would create shadow and scale distortion on the aerial photography. Specifically, we expected the sheer mountain slopes to block light from reaching canyon bottoms resulting in large shadows obscuring vegetation and hindering photo-interpretation. This would be compounded by the extreme change in topographic relief. To help overcome these obstacles we specified to our photography contractor to acquire and produce both aerial photography and new orthophotos using true color photography.

Aerial Photography

Horizons, Inc. (Rapid City, SD) flew true-color aerial photography for GRTE at scales of 1:12,000 and 1:40,000 on July 10-11, 2002. The 1:12,000 scale photos were acquired in stereo with 60 percent forward overlap and 40 percent side overlap. We chose true-color film because of its ability to penetrate shadows allowing shapes of vegetation to be discerned. At the larger scale of 1:12,000, it took over 1,752 frames along 70 flightlines to cover the same area. This included multiple flightlines over the same areas to account for change in elevation and maintain consistent ground height. At the 1:40,000-scale, Horizons exposed

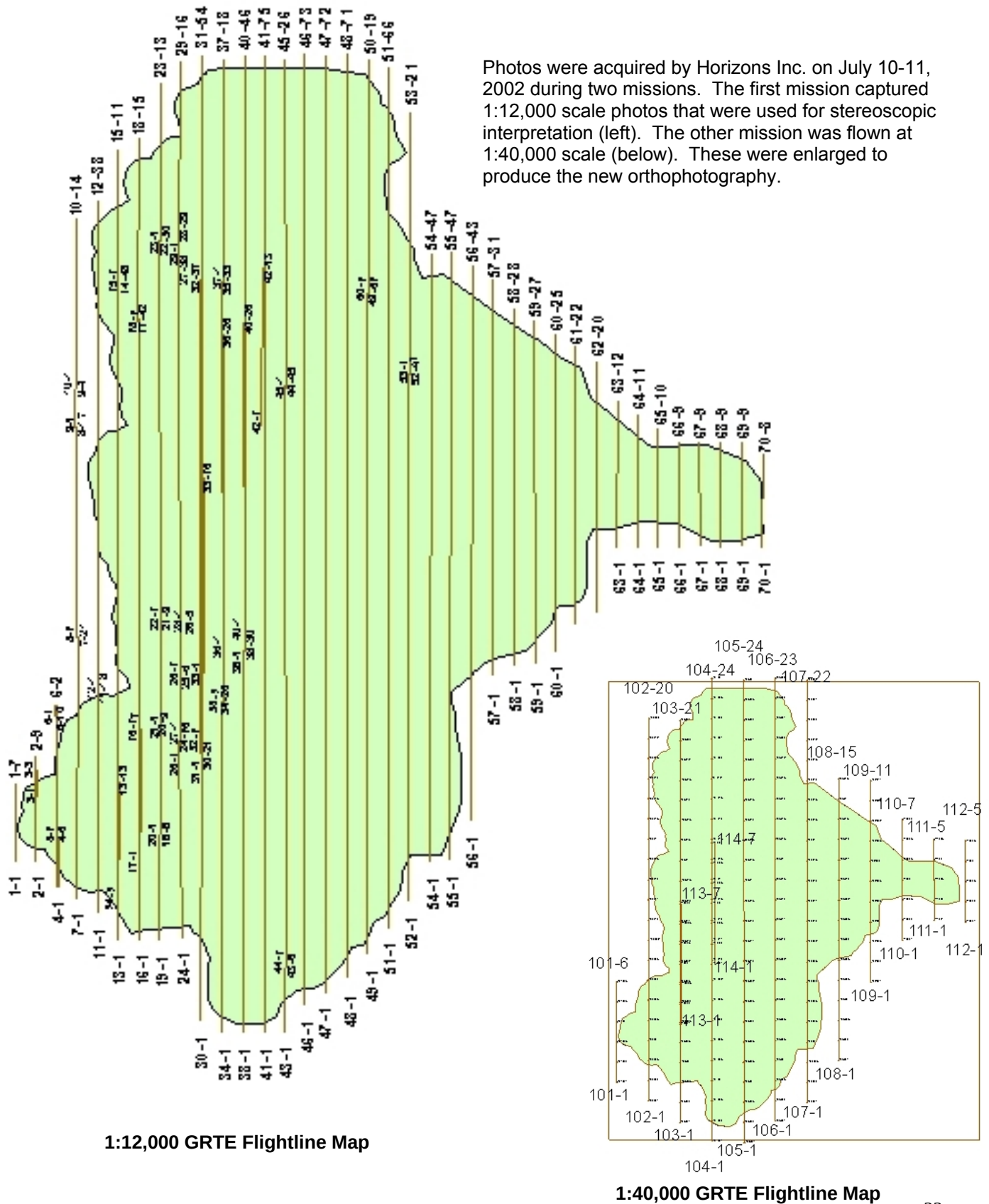
approximately 207 frames along 14 flightlines to cover the project area. Frame overlap on both sets of photography was between 50% and 60% along the flight lines and 20% to 30% between the flight lines (**Figure 6**).

1:12,000 True Color Orthophotos

In addition to 9x9 inch prints of the 1:12,000-scale aerial photography, we also had Horizons Inc develop new orthophotography from the 1:40,000 scale aerial photos at a uniform scale of 1:12,000 with 1-meter pixel resolution. This was delivered to us as both digital files and hardcopy photos. Acquiring new orthophotos was based on a cost analysis comparing the price of the processing versus the amount of time saved in the digital transfer stage. Basically, we determined that the orthophotos would save the project money in the long run by dramatically reducing digitizing labor costs. Further, since the mosaic was created by cropping only the best portions of the aerial photos, most of the shadows were removed (**Figure 7**). Unlike aerial photos, the orthophotos made it possible to measure directly on them allowing UTM XY coordinates and other measurements to be accurately located.

Horizons Inc created the orthophotos by removing the distortion caused by the tilting of the camera and scale variation in the terrain. This was achieved by digitally scanning the film at 21 microns for a 1 meter pixel resolution and creating a mosaic. The resulting imagery was then rectified or corrected through a mathematical process that warps and stretches the image between known control points. For GRTE, control points were collected using airborne GPS referencing the base station at the Driggs, Idaho Airport. Final adjustment and bridging of the photography was solved using Erio Technologies ALBANY software and digital elevation models obtained from the USGS National Elevation Dataset (NED). The orthophotography from Horizons Inc was compressed into a mosaic using MrSid software by the BOR using a compression ratio of 20x.

Figure 6. Aerial Photo Flightline Maps for GRTE.



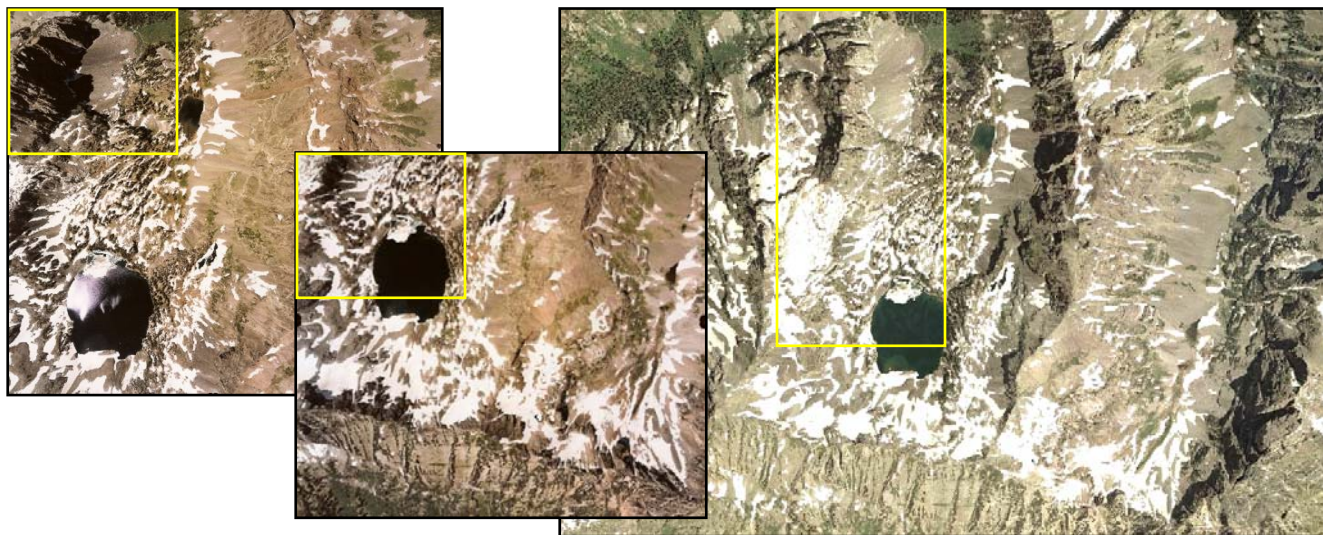


Figure 7. Comparison of the 1:12,000-scale aerial photographs and orthophotography.
Examples are a stereo-pair of Lake Solitude (left and center) and the same area on the orthophoto (right).
Notice the shadows and distortion in outlined areas and its change between photos.

2.5 Photo-interpretation and Map Units

Photo-interpretation

Based on our success with other NPS vegetation mapping projects we interpreted the vegetation at GRTE directly onto the photographic hardcopy printouts of the orthophotos. This deviated from other vegetation mapping efforts where the actual 9x9 inch aerial photos were interpreted. However, at GRTE we felt that photo interpretation of the vegetation could be conducted far more efficiently and as accurately using the aerial photographs only in an ancillary role. This was accomplished by interpreting in two stages. The preliminary interpretation identified patches of readily identifiable homogenous vegetation (areas with similar tone, texture, color, and landscape position) on the orthophotos. We then used the 9x9 inch aerial photos in stereo-magnification in a second interpretation to map the final NVC-derived map units. For both levels of interpretation, we split the orthophoto into 70, 1:12,000 scale sheets and printed them on photographic paper with a 1,000 meter UTM grid. These were then covered with translucent (semi-frosted) Mylar, fastened together, and backlit on a light table. All UTM grid points were marked on the overlays and the initial polygons were delineated by hand.



Once all the obvious vegetation and land-use classes were delineated we proceeded into the second stage. In this round of interpretation we used a stereoscope to help recognize complex photo signatures and three-dimensional features on the 9X9 aerial photos. We then manually transferred these to the orthophotos (**Figure 8**). Finally, in order to insure completeness and accuracy, digital transfer specialists reviewed all of the interpreted orthophotos for consistency and recommended changes where necessary.

Map Units

The map units delineated on the orthophotos were derived from the NVC classification as constrained by the limitations of the photography. We combined the preliminary NVC classification with the aerial photo signatures to determine how many plant associations could be recognized on the photos. In some instances, one NVC association corresponded to one map unit. However, due to the nature of the vegetation at GRTE we found that most associations could not be recognized consistently on the photos. This problem was addressed by combining associations into meaningful groups such as complexes and mosaics, or scaling up the NVC to the alliance level. Also, some of the associations at GRTE occurred in different phases that could be recognized on the photography. This included the regeneration in post-burn and avalanche areas. All of the resulting map units were correlated or “crosswalked” by noting when plant associations were lumped into a single map unit or when associations were split into multiple map units.

To round-out the mapping scheme, we created map units for land-use types based on the system developed by Anderson (1976). This includes unvegetated lands not included in the NVC, such as roads, facilities, and agricultural fields. A separate class of map modifiers or “Park Specials” was defined especially for GRTE to cover types that were easily mapped, wanted by the park, but not included in either the NVC or Anderson. This included things like noting when we could see individual whitebark pine and aspen trees. A final list of the map units appears in **Table 8**.

2.6 Digital Transfer

The transfer process for GRTE involved taking the interpreted line work and rendering it into a comprehensive digital network of attributed polygons. To accomplish this, we created an ArcInfo® GIS database using in-house protocols. The protocols consist of a shell (master file) of Arc Macro Language (AML) scripts and menus (nearly 100 files) that automate the transfer process, thus insuring that all spatial and attribute data are consistently linked and stored properly. The actual transfer of information from the interpreted orthophotos to a digital, geo-referenced format involved scanning, rasterizing,

vectorizing, cleaning, building topology, and labeling each polygon.

The scanning technique involved a multi-step process whereby the Mylar overlay sheets produced during the photo interpretation stage were scanned into a digital form. The digital image file (tagged image format .tif) created from the scanned sheet was then converted from a raster image to a vector file using RSGIS-developed AMLs in ArcInfo®. The vector file was then geo-referenced to the matching digital version of the orthophoto. The essential principle of geo-referencing was to match control points (the UTM grid) as marked on the orthophotos to the same ones in the digital images. In this manner the transfer was 1-to-1.



Once scanned and registered, we removed all erroneous information such as dangling lines. After cleaning we joined the lines into polygons by building topology in the GIS program. The resulting polygons were then edge matched with those from adjacent orthophotos. Finally, we created labels for each polygon and use these to add the attribute information. Using this process we created one final coverage or spatial database for the entire project.

Attribution for all the polygons at GRTE included information pertaining to map units, NVC associations, Anderson land-use classes, fire-specific designations and other relevant data. Attribute modifiers requested by GRTE included height, cover, presence of whitebark pine, and presence of aspen. All of the attribute items are listed in **Table 2** and are referenced in the GRTE vegetation look-up table included on the accompanying CD-ROM.

USGS-NPS Vegetation Mapping Program Grand Teton National Park

Transferring interpreted information from the aerial photo to the hardcopy orthophoto overlay



Registered digital cover scanned and vectorized on orthophoto

Interpreted vegetation (Mylar overlay) ready to be scanned



Digital GRTE new orthophoto basemap

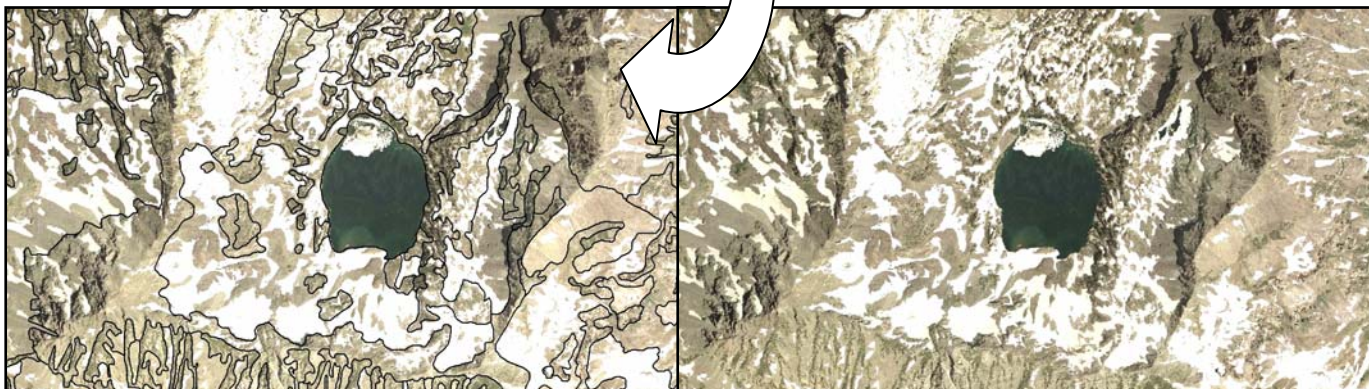


Figure 8. Example of the photo interpretation and transfer process used at GRTE.

2.7 Map Verification and Accuracy Assessment

Map Verification

As we completed the photo interpretation and digital transfer process for individual quadrangles, draft 1:12,000-scale hard copy vegetation maps were printed for review. In all cases we checked these draft maps against the interpreted photographs to ensure that the polygons were labeled properly and to locate any extra or missing lines. We also compared the map labels to the plot data if they fell in the same location. Copies of the revised draft map were then sent to the park for review. They were also taken into the field by the photo interpreters for ground-truthing. During the ground-truthing process, we collected more general observation

points using a portion of the plot form (**Appendix B**) and verified aerial photograph signatures using landmarks and GPS waypoints. The map and map units were then modified to correct any mistakes.

Accuracy Assessment

Once the draft vegetation layer was completed and digitized we were ready to conduct the accuracy assessment (AA). Typically in mapping exercises we consider both thematic or attribute map accuracy as well as the positional or polygon line accuracy. However when mapping vegetation we usually omit the positional accuracy since rarely does vegetation split on discrete edges that can be positively located in the field. The subjectivity involved in this effort plus the high resolution and accuracy

Table 2. Polygon attribute items and descriptions used in the GRTE GIS coverage.

<u>ATTRIBUTE</u>	<u>DESCRIPTION</u>
AREA*	Surface area of the polygon in meters squared
PERIMETER*	Perimeter of the polygon in meters
GRTEVEG#*	Unique code for each polygon minus the universal polygon (2 - 47,603)
GRTEVEG-ID*	Unique identification code for each polygon (1 - 47,602)
MAP_CODE	Final Map Unit Codes - PI derived, project specific
VEG_NAME	Map Unit Scientific Description Name - PI derived, project specific
VEG_CNAME	Map Unit Common Description Name - PI derived, project specific
PHYSIO	Physiognomic Groups – vegetation types sharing physiognomic features
ECOLOGY	Ecological Groups - vegetation types sharing ecological processes
LUC_II	Use and Land Cover Classification System (Anderson et al. 1976)
LOCATION	Location of the majority of the polygon (Park or Environs)
ACRES	Surface area of the polygon in acres
HECTARES	Surface area of the polygon in hectares
ELEV_M	Elevation of the polygon centroid in meters
ELEV_FT	Elevation of the polygon centroid in feet
SLOPE	Average slope of the polygon at the centroid in degrees (0 flat - 90°)
ASPECT	Average aspect of the polygon at the centroid in degrees (0 flat - 360°)
DENS_MOD	Modifier - Percent cover of the upper stratum layer in the polygon Percent cover classes: Sparse < 25%, Open 25 - 50%, Discontinuous 50 - 75%, Closed 75 - 100%
PTRN_MOD	Modifier - Vegetation pattern within the polygon Vegetation pattern classes: Homogeneous – Evenly Dispersed, Alternating, Clumped / Bunched, Gradational / Transitional
HT_MOD	Modifier - Height range of the dominant vegetation layer Height classes: <1, 1-5, 5-15, 15-30, >30 meters
DOM_MOD	Modifier – Dominant species present, only for mixed classes
ASPEN	Presence of aspen in the polygon (Yes/No)
WHITEBARK	Presence of whitebark pine in the polygon (Yes/No)
BURN	Evidence of recent burning (Yes/No)
CULTIVATED	Evidence of recent agricultural-related cultivation (Yes/No)
DECADENT	Evidence of dead or dying, over-mature trees (Yes/No)
ASN_Cegl	Project Association Name Code - NVC Association(s)
ASN_Cegl2	Project Association Name Code - NVC Association(s) (continued)
COMMENT1	General Description about the map unit and its distribution
COMMENT2	General Comment of how the map unit relates to other map units
COMMENT3	Specific Comment about individual polygons
(*ArcInfo® default items)	



Map
Verification at
GRTE



of our basemaps led us to assume that we were well within National Map Accuracy Standards for 1:12,000-scale maps (± 30 feet) and that any additional effort to assess positional accuracy would be unproductive. The AA process at GRTE included four steps: AA Sample Design, AA Sample Site Selection, AA Data Collection and AA Data Analysis. Each step is discussed in detail below.

AA Sample Design

The selection of AA sample points at GRTE followed the standard protocols and methods described in the NBS/NPS Vegetation Mapping Program, Accuracy Assessment Procedures manual (TNC 1994a). Using this manual as a guide we streamlined and modified the process using automated and custom GIS programs. The overall goal of our methods was to balance both the scientific principles that govern sampling and statistical analysis with the practical and logistical constraints of getting around a rugged landscape. To accomplish this, we considered both the statistical and the cost constraints as they related to each class's frequency and abundance. This was based on the five possible scenarios provided to us in the field manual (**Table 3**). In the end, we selected stratified random sites throughout the park for each map unit, included the relative cost to travel to each site based on a cost-surface analysis and provided additional back-up points in case the primary points were inaccessible.

AA Site Selection

Once we decided on the number of AA target sites for each map class we loaded these parameters into our in-house GIS programs. These allowed us to repeat the sample selection process multiple times yielding a primary set of points and three back-up sets of points.

During the GIS routines we were able to also set a variety of options that forced the program to select random points 10 meters away from any polygon lines, 50 meters away from any other point, and eliminate any point that was considered to have extremely arduous access or was in a dangerous location. Being able to choose minimum distance to polygon boundaries helped us to minimize ecotonal boundaries and account for the horizontal error typically encountered in common GPS units (± 5 m). The resulting target locations were restricted to only

within the boundaries of GRTE and JODR due to time and financial constraints.

AA Data Collection

The field crews were provided with draft field maps, overview maps, map unit definitions, the key to the associations (**Appendix C**), digital spreadsheets containing the location of the target AA sites, and training in protocols (**Appendix B**). All maps contained the color-coded primary set of AA sites as well as the locations for the three back-up sets. If a target from the primary set was inaccessible for any reason, the crews could substitute from any of the back-up sets of points.

GRTE hired, trained, and supervised a team of seven biological technicians and botanists to collect AA data during the 2004 field season. Fire management and vegetation management provided additional personnel to the data collection effort. The field crews traveled to the AA sample sites and determined the vegetation association using the key to plant associations. At each target they recorded the primary, secondary, and sometime tertiary associations that occurred within a roughly 50-meter radius. They also recorded basic vegetation strata and environmental data, and percent canopy cover of the major species in each stratum (see AA point form in **Appendix B**). Also, they recorded other nearby vegetation types outside the 50-meter radius and any recent disturbance that may have altered the vegetation.

At GRTE we modified the AA form and association key to include the map codes and map classes. Specifically we attached the cross-walked map codes to each of the associations in the key so that when an association was keyed the user could see which map classes corresponded to it. Further, next to the blanks on the form for associations we included blanks to record the map codes. This allowed the field crews to make an assessment of not only the association on the ground but also the map class. By recording the map class as well as the association we were able to greatly reduce the amount of time usually spent cross-walking the completed field forms to the map classes and vastly speed up the data analysis stage.

Table 3. Target number of AA samples per map class based on number of polygons and area.

Scenario	Description	Polygons in class	Area occupied by class	Recommended number of samples in class
Scenario A:	The class is abundant. It covers more than 50 hectares of the total area and consists of at least 30 polygons. In this case, the recommended sample size is 30.	> 30	> 50 ha	20
Scenario B:	The class is relatively abundant. It covers more than 50 hectares of the total area but consists of fewer than 30 polygons. In this case, the recommended sample size is 20. The rationale for reducing the sample size for this type of class is that sample sites are more difficult to find because of the lower frequency of the class.	< 30	> 50 ha	20
Scenario C:	The class is relatively rare. It covers less than 50 hectares of the total area but consists of more than 30 polygons. In this case, the recommended sample size is 20. The rationale for reducing the sample size is that the class occupies a small area. At the same time, however, the class consists of a considerable number of distinct polygons that are possibly widely distributed. The number of samples therefore remains relatively high because of the high frequency of the class.	> 30	< 50 ha	20
Scenario D:	The class is rare. It has more than 5 but fewer than 30 polygons and covers less than 50 hectares of the area. In this case, the recommended number of samples is 5. The rationale for reducing the sample size is that the class consists of small polygons and the frequency of the polygons is low. Specifying more than 5 sample sites will therefore probably result in multiple sample sites within the same (small) polygon. Collecting 5 sample sites will allow an accuracy estimate to be computed, although it will not be very precise.	5, 30	<50 ha	5
Scenario E:	The class is very rare. It has fewer than 5 polygons and occupies less than 50 hectares of the total area. In this case, it is recommended that the existence of the class be confirmed by a visit to each sample site. The rationale for the recommendation is that with fewer than 5 sample sites (assuming 1 site per polygon) no estimate of level of confidence can be established for the sample (the existence of the class can only be confirmed through field checking).	< 5	< 50 ha	Visit all and confirm

During 2004 a total of 1,122 points were sampled. Points were fairly well distributed although access and logistical difficulty removed some areas west of Jackson Lake from the sample pool (**Figure 9**). Types occurring in this location were found in other areas of the park that were more accessible and conducive to sampling.

AA Data Analysis

Upon completion of the fieldwork, NPS staff entered all AA data into the PLOTS database and reviewed it for data entry errors. Incomplete data on the field sheets, were corrected if possible. The results were imported from the database into a GIS layer where we visually compared them to the vegetation map coverage. At the same time we also digitally compared the AA Points to the original target locations to check the quality of the data. This process revealed nine points that either had poor GPS accuracy or were located in the wrong target polygon. Subsequently, AA points 04R143, 04K103, 04J032, 04X322, 04X623, 04X311, 04X313, 04K114, and 04X406 were removed from analysis.

Even though the actual assessment of the vegetation map can be boiled down to comparing the field data to the map, it is a complicated process. In the case of GRTE, we benefited from previous studies at Rocky Mountain, Zion, and Wupatki National Parks (Salas et al 2005, Hansen et al. 2004) where they streamlined the process and also applied multi-level assessments and the use of fuzzy logic (**Table 4**). Specifically we incorporated many of the in-house GIS programs developed for Zion and Rocky Mountain to compare the AA data and generate confidence intervals, kappa statistics, and error matrices (contingency tables). We also used the fuzzy AA methods described both at Rocky Mountain and Wupatki to evaluate the data multiple levels, starting with a **Binary** assessment (right/wrong) and moving through **Acceptable** and **Reasonable** levels.

Binary Accuracy Assessment

As a place to start, we objectively took all of the AA points and created a reference layer. We then restricted this layer to only the primary map code recorded by the field crews in the field. Through an automated process, this layer was then compared to the digital vegetation polygon data (predictive layer). All of the statistics and

calculations used on these data are described at length in the program manuals (TNC 1994a) and are summarized in **Table 4**.

Acceptable Accuracy Assessment

To evaluate the acceptable level of accuracy we recalculated the reference layer (AA Field Data) to be equal to the predicted layer (digital polygon map) if the second or third choices on the field form were correct. In other words, the polygon was calculated as correct if either the primary, secondary or tertiary choice on the field form matched the polygon label. The changes were made to the AA point GIS file and all of the calculations and statistics described for the Binary AA were re-run.

Reasonable Accuracy Assessment

Finally to calculate the reasonable error, we first looked at all of the possible choices reported on the field form. This included the primary, secondary and tertiary associations along with any recorded within a 50 meter radius. If any of these matched their corresponding polygon label we recalculated them to the correct AA code. Second we evaluated by hand all of the AA points that didn't match in the previous levels. This involved reviewing the data sheets for the following general issues:

- **GPS errors:** The point was located incorrectly (wrong polygon) due to projection issues, GPS limitations (+/- error), or the target was placed too close to a polygon boundary.
- **Ecotone errors:** A point occurred in a zone of transition between two types.
- **Intuitive errors:** A point was classified differently than the polygon label but was overruled by NPS or BOR staff. These errors were usually due to discrepancies between the actual cover values and what the stand was called by the field crews. Also sometimes the stand that was assessed was too small of an area (*i.e.* inclusion).

In some cases points were re-labeled to better reflect the actual data collected. All of the changes were made to the AA point GIS file and the calculations and statistics described for the Binary AA were re-run.

Final assessments for each point were recorded in an error matrix (*i.e.*, contingency table). Contingency tables and statistics were generated for all three levels (**Tables 11-13**).

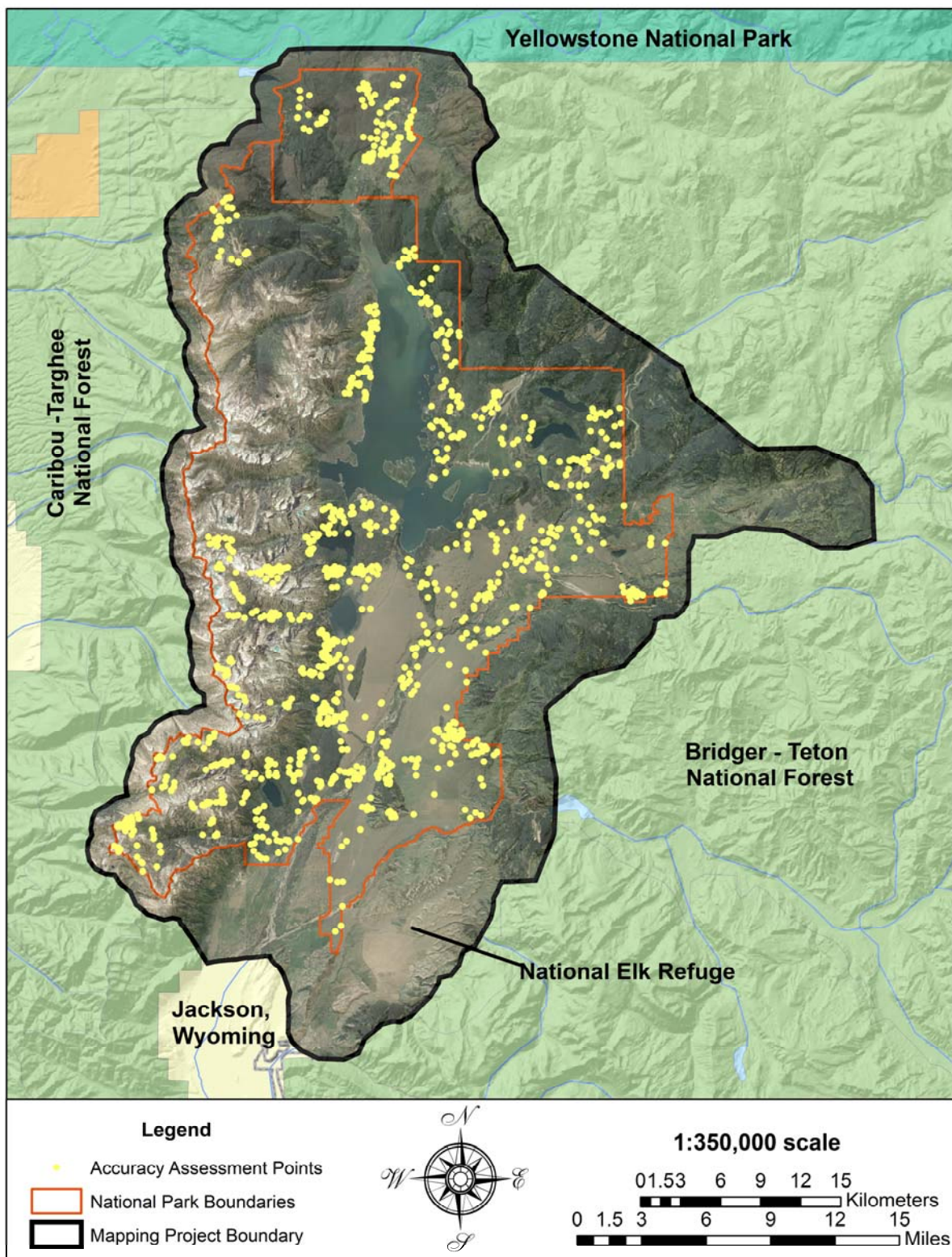


Figure 9. Locations of Accuracy Assessment Points collected at GRTE.

Table 4. AA Level based on Fuzzy Logic.

AA Levels	Name	Fuzzy Logic Descriptions
1	ABSOLUTE	Absolutely Wrong: This answer is absolutely unacceptable. Very Wrong
2	UNDERSTANDABLE	Understandable but Wrong: Not a good answer. There is something about the site that makes the answer understandable but there is clearly a better answer. This answer would pose a problem for the users of the map
3	REASONABLE	Reasonable Answer: Maybe not the best possible answer but it is acceptable; this answer does not pose a problem to the user if it is seen on the map. Correct
4	ACCEPTABLE	Good Answer: Would be happy to find this answer given on the map. Very Right
5	BINARY	Absolutely Right: No doubt about the match. Perfect

Table 5. Summary of AA statistics used at GRTE.

Statistic	Formula	Description
User's - accuracy:	$\frac{n_{ii}}{n_{i+}}$	Where i is the land cover type, n_{ii} is the number of matches between map and reference data and n_{i+} is the total number of samples of i in the map. This formula is the number of "correct" observations divided by the sum of the column
Producer's accuracy	$\frac{n_{ii}}{n_{+i}}$	Where n_{+i} = total number of sample of i in the reference data. This formula is the number of "correct" observations divided by the sum of the row
Confidence Interval	$\hat{p} \pm \left\{ z_{\alpha} \sqrt{\frac{\hat{p}(1-\hat{p})}{n} + \frac{1}{(2n)}} \right\}$	Where $z_{\alpha} = 1.645$ (this comes from a table of the z-distribution at the significance level for a two-sided limit with a 90% confidence interval). The term $1/(2n)$ is the correction for continuity. The correction should be applied to account for the fact the binomial distribution describes discrete populations $\hat{p}$ = the sample accuracy (0 -1.0), n = the number of sites sampled.
Kappa Index	$k = \frac{N \sum_{i=1}^r x_{ii} - \sum_{i=1}^r (x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^r (x_{i+} \times x_{+i})}$	Where N is the total number of sites in the matrix, r is the number of rows in the matrix, x_{ij} is the number in row i and column j , x_{+i} is the total for row i , and x_{+j} is the total for column j (Jensen1996).

3. RESULTS

3.1 NVC at GRTE

NVC Associations

The NVC associations at GRTE were determined through analytical methods using indicator species analysis. **Figures 10a** and **10b** show the optimal number of groups used at GRTE. **Figure 10a** shows that nine groups have the lowest sum total of all significant values indicating high compositional similarity within these groups. Conversely, in **Figure 10b**, nine groups have the greatest number of indicator species that are unique to those groups. **Table 6** shows the nine groups and their significant indicator species.

The final classification for GRTE resulted in 207 associations. Of that total, 167 are existing NVC associations and 40 are new local associations that were defined by this project. The classification results reflect both the high diversity of vegetation in the park and the degree of comprehensive vegetation classification work in this region. **Table 7** has a complete list of GRTE plant associations that were described by this study, and **Appendix D** provides complete descriptions for each of them

General characteristics of the vegetation

During the course of the field work and data analyses several observations about the vegetation at GRTE were made by NatureServe and NPS ecologists. These include the following:

1. The vegetation at GRTE is very diverse following the variable topography ranging from the undulating valley floor to foothills, canyons, and alpine peaks. Although there have been previous local classifications and vegetation research completed in and near the park none were done in as a comprehensive and detailed fashion, and most were based on classifying potential or climax vegetation. Since this project was quite extensive and classified and mapped existing vegetation several new NVC alliances and several new associations were

described, and ranges of several existing types were expanded.

2. Coniferous forests and sagebrush shrublands have been intensively studied in and around Grand Teton National Park from the Habitat Type perspective (i.e. Steele et al 1987, Pfister et al 1977, and Hironaka et al 1983). These studies classify potential or climax communities with many seral communities mentioned as occurring in a habitat type, but not fully described. Mapping and classifying current (existing) vegetation necessitated giving these seral communities more recognition. They were classified, described, and mapped, which resulted in the identification of a higher number of plant associations than described in previous publications
3. A wide variety of sagebrush shrublands are conspicuous on the valley floor as well as in the mountains of Grand Teton National Park. *Artemisia tridentata* ssp. *vaseyana* (mountain big sagebrush) is the most abundant; there are 15 associations in which it is present. It forms large, continuous stands on the valley floor, on foothills and mid-elevation mountain slopes. It can occur as the dominant shrub or may co-occur with other shrubs such as *Symphoricarpos oreophilus* (snowberry) or *Purshia tridentata* (bitterbrush). In addition to mountain big sagebrush, *Artemisia tridentata* spp. *spiciformis* (spike big sagebrush) stands also occur in the park on south to east facing slopes. *Artemisia arbuscula* ssp. *arbuscula* (low sagebrush) occurs on the valley floor on more gravelly soils, and in areas with perched water tables. Finally, *Artemisia cana* (silver sagebrush) occurs in wetter areas or along riparian courses on the valley floor.
4. GRTE has a wide variety of Rocky Mountain coniferous forests in many stages of maturity. The upper elevations and older stands are dominated by *Abies lasiocarpa* (subalpine fir) and *Picea engelmannii* (Engelmann spruce). We describe some 16 upland spruce-fir plant

associations, 4 of which are new to the NVC. Recently burned areas and those with nutrient-limited soils are often dominated by stands of *Pinus contorta* (lodgepole pine). There are 10 plant associations describing these lodgepole pine forests; 2 are new to the NVC.

5. Additional forest types include those dominated by *Pseudotsuga menziesii* (Douglas-fir), which occurs on warm southerly slopes of the mountains and in the foothills. There are 9 plant associations, one of which is newly described here. The highest elevation forests in GRTE are the domain of the oldest and often largest trees in the park, *Pinus albicaulis* (Whitebark pine). Three plant associations describe these communities
6. *Populus tremuloides* (quaking aspen) stands, though occupying a small portion of the total landscape are numerous and diverse; becoming even more conspicuous in the fall. The largest stands are along the foothills and on the slopes on the east side of the valley; however pockets of aspen occur up to 8,000 feet in the mountains and canyons. Previous classification work in the surrounding region by Mueggler (1988) describes many existing aspen community types. The 20 aspen associations for GRTE concur with his descriptions, 5 of these types describe communities in which aspen is co-dominant with coniferous trees.
7. There are northern Rocky Mountain species and maritime-influenced species that are less common in GRTE than might be expected. For example *Xerophyllum tenax* (beargrass) is abundant in Glacier National Park, but appears in only the northern part of this study area. *Menziesia ferruginea* (Fool's Huckleberry), also very abundant in Glacier National Park and the forests of western Montana, is uncommon in GRTE, occurring in moist woods in the canyons. It is present in only one of the plant associations described for this project.
8. The GRTE landscape, which is dominated by forest and sagebrush communities, is

also rich with smaller patches of grasslands, mesic meadows and deciduous shrublands. These are described in over 40 plant associations. In addition there are 64 riparian and wetland plant associations also documented through this project. Many of these types are previously undescribed because they are considered seral or successional communities. Some of these include those dominated by *Ceanothus velutinus* (snowbush ceanothus), *Pteridium aquilinum* (bracken fern), or *Calamagrostis canadensis* (Canada reedgrass).

9. Among the additional communities described are mixed conifer communities of varying compositions and a variety of shrublands. New shrubland types include those that are often overshadowed by surrounding forests; numerous poorly described riparian willow and alder types; and avalanche chutes that contain short-stature trees as well as a diverse array of shrubs.

3.2 Photo-interpretation and Map Units

We recognized and delineated 52 map units on the true color aerial photographs for GRTE. This included 10 barren, unvegetated, or land-use types and 42 vegetation map classes (**Table 8**). All map units were developed from a combination of an initial NVC vegetation classification provided by NatureServe with input from park biologists and BOR ecologists, fieldwork, and preliminary photo-interpretation.

Please reference **Appendix E** for detailed descriptions and representative photos for all vegetation map units.



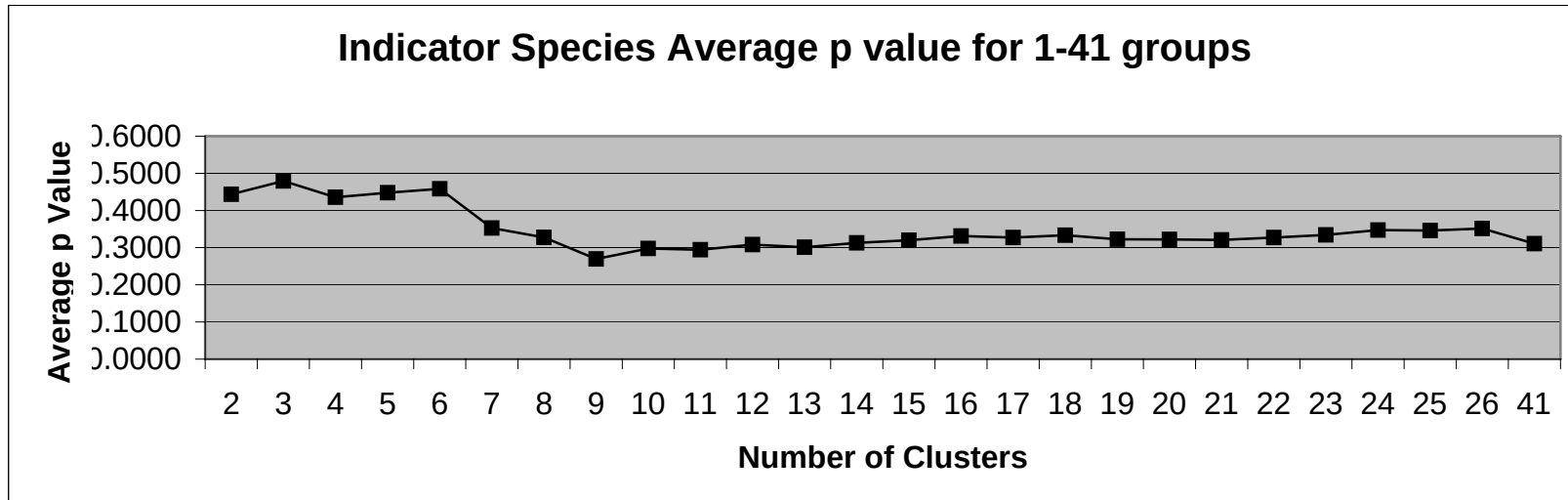


Figure 10a. Indicator Species Analysis for 41 groups.

Rather than dividing the GRTE data into *a priori* arbitrary groups, the ISA shows 9 groups have the highest species fidelity to those groups.

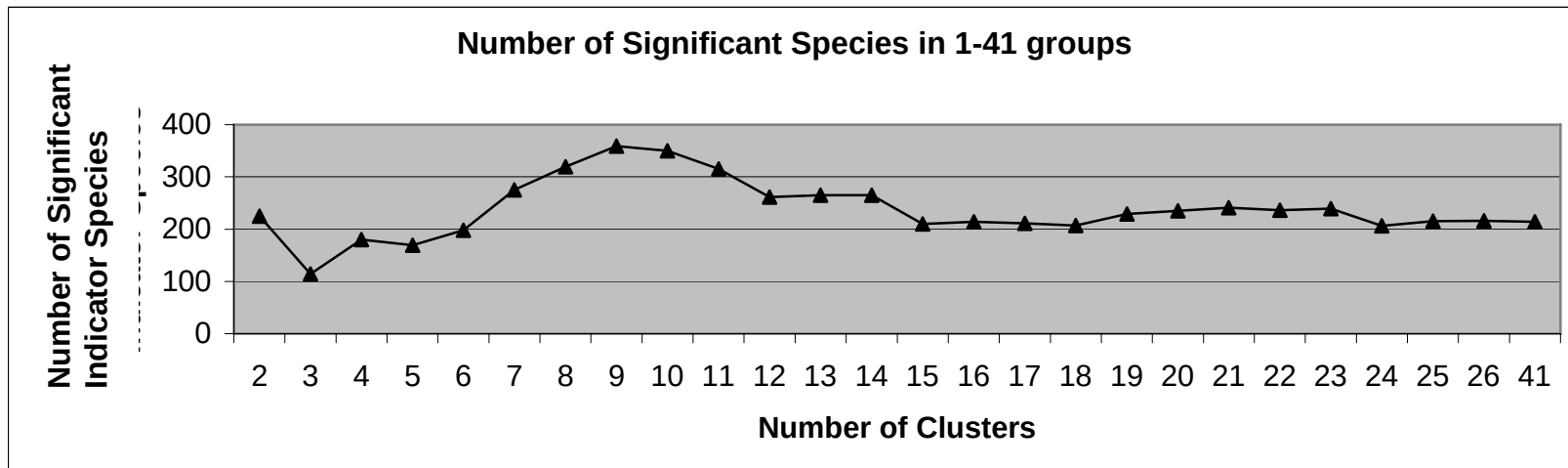


Figure 10b. Indicator Species Analysis for GRTE 637 plots.

By dividing the data into 9 groups, we get the most number of significant indicator species. Nine groups were then further refined into plant associations through Cluster Analysis.

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Table 6. Examples of Significant Species in the 9 groups from Indicator Species Analysis.

Grp	Group Name	# Plots	Example Indicator Species (sci name)	IS Value	P Value	Total # sig. spp in group (p<.001)
1	Dry Meadows	108	<i>Balsamorhiza sagittata</i>	20.6	0.001	3
			<i>Agastache urticifolia</i>	18.3	0.001	
			<i>Helianthella uniflora</i>	16.3	0.001	
2	Aspen Forests	39	<i>Populus tremuloides</i>	96.5	0.001	13
			<i>Chamerion angustifolium</i>	44.5	0.001	
			<i>Calamagrostis rubescens</i>	35.7	0.001	
3	Cold Forests (Lodgepole Pine, Whitebark Pine)	108	<i>Vaccinium scoparium</i>	42.4	0.001	8
			<i>Pinus contorta</i>	31.3	0.001	
			<i>Carex geyeri</i>	28.8	0.001	
			<i>Pinus contorta</i> --Seedling	19.3	0.001	
			<i>Pinus albicaulis</i>	13.6	0.001	
4	Douglas-Fir Forests	40	<i>Pseudotsuga menziesii</i>	88.4	0.001	5
			<i>Paxistima myrsinites</i>	36.6	0.001	
			<i>Spiraea betulifolia</i>	21.5	0.001	
5	Sagebrush Shrublands	55	<i>Artemisia tridentata</i> ssp. <i>vaseyana</i>	72.5	0.001	45
			<i>Eriogonum umbellatum</i>	63.3	0.001	
			<i>Lupinus sericeus</i>	40.7	0.001	
			<i>Festuca idahoensis</i>	30.7	0.001	
			<i>Artemisia arbuscula</i>	25.3	0.001	
			<i>Koeleria macrantha</i>	24	0.001	
6	Wetland Shrublands and Wet Meadows	74	<i>Deschampsia caespitosa</i>	37.9	0.001	27
			<i>Geum macrophyllum</i>	36.9	0.001	
			<i>Salix wolfii</i>	32.3	0.001	
			<i>Fragaria virginiana</i>	24.6	0.001	
			<i>Salix boothii</i>	22.8	0.001	
			<i>Carex utriculata</i>	22.8	0.001	
7	Spruce-Fir (moist) Forests	70	<i>Abies lasiocarpa</i>	56.6	0.001	26
			<i>Picea engelmannii</i>	49.5	0.001	
			<i>Arnica latifolia</i>	35.1	0.001	
			<i>Vaccinium membranaceum</i>	23.1	0.001	
			<i>Abies lasiocarpa</i> --Seedling	23	0.001	
			<i>Arnica cordifolia</i>	22.9	0.001	
8	Alpine Vegetation	86	<i>Polygonum bistortoides</i>	25.3	0.001	33
			<i>Sibbaldia procumbens</i>	20.4	0.001	
			<i>Senecio crassulus</i>	20	0.001	
			<i>Trisetum spicatum</i>	17.2	0.001	
			<i>Carex paysonis</i>	16.9	0.001	
			<i>Claytonia lanceolata</i>	13	0.001	
9	Riparian Forests and Weedy Places	55	<i>Phleum pratense</i>	50.2	0.001	20
			<i>Poa pratensis</i>	47.3	0.001	
			<i>Populus angustifolia</i>	36.2	0.001	
			<i>Picea pungens</i>	26.7	0.001	
			<i>Dasiphora floribunda</i>	24.1	0.001	
			<i>Juncus balticus</i>	15.5	0.001	
			<i>Potentilla gracilis</i>	15.3	0.001	
			<i>Populus angustifolia</i>	12.2	0.001	
			<i>Bromus inermis</i>	11.3	0.001	
			<i>Artemisia cana</i>	10.5	0.001	
			<i>Populus balsamifera</i>	10.3	0.001	

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Table 7. List of NVC Plant Associations found at Grand Teton National Park.

Scientific Name	Common Name	Elcode*
Forest and Woodlands		
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Acer glabrum</i> Forest	Subalpine Fir - Engelmann Spruce / Rocky Mountain Maple Forest	CEGL000294
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Actaea rubra</i> Forest	Subalpine Fir - Engelmann Spruce / Red Baneberry Forest	CEGL000295
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Arnica cordifolia</i> Forest	Subalpine Fir - Engelmann Spruce / Heartleaf Leopardbane Forest	CEGL000298
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Arnica latifolia</i> Forest	Subalpine Fir - Engelmann Spruce / Daffodil Leopardbane Forest	CEGL000299
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Calamagrostis canadensis</i> Forest	Subalpine Fir - Engelmann Spruce / Bluejoint Forest	CEGL000300
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Calamagrostis rubescens</i> Forest	Subalpine Fir - Engelmann Spruce / Pinegrass Forest	CEGL000301
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Carex geyeri</i> Forest	Subalpine Fir - Engelmann Spruce / Geyer's Sedge Forest	CEGL000304
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Luzula glabrata</i> var. <i>hitchcockii</i> Forest	Subalpine Fir - Engelmann Spruce / Hitchcock's Smooth Woodrush Woodland	CEGL000317
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Menziesia ferruginea</i> Forest	Subalpine Fir - Engelmann Spruce / Fool's-huckleberry Forest	CEGL000319
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Ribes</i> (<i>montigenum</i> , <i>lacustre</i> , <i>inerme</i>) Forest	Subalpine Fir - Engelmann Spruce / (Western Prickly Gooseberry, Bristly Black Currant, White-stem Gooseberry) Forest	CEGL000331
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Ribes lacustre</i> Forest	Subalpine Fir - Engelmann Spruce / Bristly Black Currant Forest	NEW-GRTE-067
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Shepherdia canadensis</i> Forest	Subalpine Fir - Engelmann Spruce / Russet Buffaloberry Forest	NEW-GRTE-060
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Streptopus amplexifolius</i> Forest	Subalpine Fir - Engelmann Spruce / Clasping Twisted-stalk Forest	CEGL000336
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Symphoricarpos albus</i> Forest	Subalpine Fir - Engelmann Spruce / Common Snowberry Forest	CEGL000337
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Thalictrum occidentale</i> Forest	Subalpine Fir - Engelmann Spruce / Western Meadowrue Forest	CEGL000338
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Vaccinium membranaceum</i> / <i>Xerophyllum tenax</i> Forest	Subalpine Fir - Engelmann Spruce / Square-twig Blueberry / Bear-grass Forest	CEGL005917
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Vaccinium membranaceum</i> Rocky Mountain Forest	Subalpine Fir - Engelmann Spruce / Square-twig Blueberry Rocky Mountain Forest	CEGL000341
<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> / <i>Vaccinium scoparium</i> Forest	Subalpine Fir - Engelmann Spruce / Grouseberry Forest	CEGL000344
<i>Abies lasiocarpa</i> - <i>Pinus albicaulis</i> / <i>Vaccinium scoparium</i> Woodland	Subalpine Fir - Whitebark Pine / Grouseberry Woodland	CEGL000752

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<i>Abies lasiocarpa</i> - <i>Pseudotsuga menziesii</i> - <i>Pinus contorta</i> Forest	Subalpine Fir - Engelmann Spruce - Lodgepole Pine Forest	NEW-GRTE-059
<i>Abies lasiocarpa</i> Krummholz Shrubland	Subalpine Fir - Engelmann Spruce Krummholz Shrubland	CEGL000985
<i>Picea engelmannii</i> / <i>Equisetum arvense</i> Forest	Engelmann Spruce / Field Horsetail Forest	CEGL005927
<i>Picea engelmannii</i> / <i>Galium triflorum</i> Forest	Engelmann Spruce / Sweet-scent Bedstraw Forest	CEGL002174
<i>Picea pungens</i> / <i>Actaea rubra</i> Forest	Blue Spruce / Red Baneberry Forest	NEW-GRTE-064
<i>Picea pungens</i> / <i>Alnus incana</i> Woodland	Blue Spruce / Speckled Alder Woodland	CEGL000894
<i>Picea pungens</i> / <i>Equisetum arvense</i> Woodland	Blue Spruce / Field Horsetail Woodland	CEGL000389
<i>Picea pungens</i> / <i>Juniperus communis</i> Forest	Blue Spruce / Common Juniper Forest	CEGL000392
<i>Picea pungens</i> / <i>Shepherdia canadensis</i> Forest	Blue Spruce / Russet Buffaloberry Forest	NEW-GRTE-076
<i>Pinus albicaulis</i> - <i>Abies lasiocarpa</i> Woodland [Provisional]	Whitebark Pine - Subalpine Fir Woodland	CEGL000128
<i>Pinus albicaulis</i> / <i>Vaccinium scoparium</i> Forest	Whitebark Pine / Grouseberry Forest	CEGL000131
<i>Pinus contorta</i> / <i>Calamagrostis canadensis</i> Forest	Lodgepole Pine / Bluejoint Forest	CEGL000138
<i>Pinus contorta</i> / <i>Calamagrostis rubescens</i> Forest	Lodgepole Pine / Pinegrass Forest	CEGL000139
<i>Pinus contorta</i> / <i>Carex geyeri</i> Forest	Lodgepole Pine / Geyer's Sedge Forest	CEGL000141
<i>Pinus contorta</i> / <i>Carex rossii</i> Forest	Lodgepole Pine / Ross' Sedge Forest	CEGL000144
<i>Pinus contorta</i> / <i>Ceanothus velutinus</i> Forest	Lodgepole Pine / Tobacco-brush Forest	CEGL000145
<i>Pinus contorta</i> / <i>Dasiphora floribunda</i> Forest	Lodgepole Pine / Shrubby-cinquefoil Forest	NEW-GRTE-062
<i>Pinus contorta</i> / <i>Hierochloe hirta</i> Forest	Lodgepole Pine / Northern Sweet Grass Forest	NEW-GRTE-061
<i>Pinus contorta</i> / <i>Shepherdia canadensis</i> Forest	Lodgepole Pine / Russet Buffaloberry Forest	CEGL000163
<i>Pinus contorta</i> / <i>Spiraea betulifolia</i> Forest	Lodgepole Pine / Shinyleaf Meadowsweet Forest	CEGL000164
<i>Pinus contorta</i> / <i>Vaccinium membranaceum</i> Rocky Mountain Forest	Lodgepole Pine / Square-twig Blueberry Rocky Mountain Forest	CEGL000169
<i>Pinus contorta</i> / <i>Vaccinium scoparium</i> Forest	Lodgepole Pine / Grouseberry Forest	CEGL000172
<i>Pinus flexilis</i> / <i>Pseudoroegneria spicata</i> Woodland	Limber Pine / Bluebunch Wheatgrass Woodland	CEGL000813

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<i>Populus angustifolia</i> - <i>Picea pungens</i> / <i>Poa pratensis</i> Forest	Narrowleaf Cottonwood - Blue Spruce / Kentucky Bluegrass Forest	NEW-GRTE-080
<i>Populus angustifolia</i> - <i>Picea pungens</i> / <i>Shepherdia canadensis</i> Forest	Narrowleaf Cottonwood - Blue Spruce / Russet Buffaloberry Forest	NEW-GRTE-055
<i>Populus angustifolia</i> / <i>Artemisia tridentata</i> ssp. <i>vaseyana</i> / <i>Eriogonum umbellatum</i> Outwash Woodland	Narrowleaf Cottonwood / Mountain Big Sagebrush / Sulphurflower Wild Buckwheat Dry Outwash Woodland	CEGL002537
<i>Populus angustifolia</i> / <i>Poa pratensis</i> Woodland	Narrowleaf Cottonwood / Kentucky Bluegrass Woodland	CEGL005963
<i>Populus angustifolia</i> / <i>Shepherdia canadensis</i> Forest	Narrowleaf Cottonwood / Russet Buffaloberry Forest	NEW-GRTE-056
<i>Populus angustifolia</i> / <i>Symphoricarpos</i> (<i>albus</i> , <i>occidentalis</i> , <i>oreophilus</i>) Forest	Narrowleaf Cottonwood / (Common Snowberry, Western Snowberry, Mountain Snowberry) Woodland	CEGL002648
<i>Populus balsamifera</i> (ssp. <i>trichocarpa</i> , ssp. <i>balsamifera</i>) / <i>Symphoricarpos</i> (<i>albus</i> , <i>occidentalis</i> , <i>oreophilus</i>) Forest	(Black Cottonwood, Balsam Poplar) / (Common Snowberry, Western Snowberry, Mountain Snowberry) Forest	CEGL000677
<i>Populus balsamifera</i> (ssp. <i>trichocarpa</i> , ssp. <i>balsamifera</i>) / Mixed Herbs Forest	Black Cottonwood / Mixed Herbs Forest	CEGL000675
<i>Populus balsamifera</i> (ssp. <i>trichocarpa</i> , ssp. <i>balsamifera</i>) / <i>Prunus virginiana</i> Forest	Black Cottonwood / Choke Cherry Forest	NEW-GRTE-086
<i>Populus balsamifera</i> (ssp. <i>trichocarpa</i> , ssp. <i>balsamifera</i>) / <i>Cornus sericea</i> Forest	Black Cottonwood / Red-osier Dogwood Forest	CEGL000672
<i>Populus tremuloides</i> - <i>Abies lasiocarpa</i> / <i>Carex geyeri</i> - <i>Calamagrostis rubescens</i> Forest	Quaking Aspen - Subalpine Fir / Geyer's Sedge - Pinegrass Forest	CEGL000525
<i>Populus tremuloides</i> - <i>Abies lasiocarpa</i> / Tall Forbs Forest	Quaking Aspen - Subalpine Fir / Tall Forbs Forest	CEGL000533
<i>Populus tremuloides</i> - <i>Pinus contorta</i> / <i>Carex geyeri</i> - <i>Calamagrostis rubescens</i> Forest	Quaking Aspen - Lodgepole Pine / Geyer's Sedge - Pinegrass Forest	CEGL000536
<i>Populus tremuloides</i> - <i>Pinus contorta</i> / <i>Symphoricarpos oreophilus</i> Forest	Quaking Aspen - Lodgepole Pine / Mountain Snowberry Forest	CEGL000538
<i>Populus tremuloides</i> - <i>Pseudotsuga menziesii</i> / <i>Amelanchier alnifolia</i> Forest	Quaking Aspen - Douglas-fir / Saskatoon Serviceberry Forest	CEGL000543
<i>Populus tremuloides</i> / <i>Amelanchier alnifolia</i> - <i>Symphoricarpos oreophilus</i> / <i>Bromus carinatus</i> Forest	Quaking Aspen / Saskatoon Serviceberry - Mountain Snowberry / California Brome Forest	CEGL000566
<i>Populus tremuloides</i> / <i>Amelanchier alnifolia</i> - <i>Symphoricarpos oreophilus</i> / <i>Calamagrostis rubescens</i> Forest	Quaking Aspen / Saskatoon Serviceberry - Mountain Snowberry / Pinegrass Forest	CEGL000567
<i>Populus tremuloides</i> / <i>Amelanchier alnifolia</i> - <i>Symphoricarpos oreophilus</i> / <i>Thalictrum fendleri</i> Forest	Quaking Aspen / Saskatoon Serviceberry - Mountain Snowberry / Fendler's Meadowrue Forest	CEGL000569
<i>Populus tremuloides</i> / <i>Amelanchier alnifolia</i> / <i>Carex geyeri</i> Forest	Quaking Aspen / Saskatoon Serviceberry / Geyer's Sedge Forest	NEW-GRTE-087
<i>Populus tremuloides</i> / <i>Amelanchier alnifolia</i> / <i>Pteridium aquilinum</i> Forest	Quaking Aspen / Saskatoon Serviceberry / Northern Bracken Forest	CEGL000565
<i>Populus tremuloides</i> / <i>Amelanchier alnifolia</i> Avalanche Chute Shrubland	Quaking Aspen / Saskatoon Serviceberry Avalanche Chute Shrubland	CEGL005886

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<i>Populus tremuloides</i> / <i>Calamagrostis rubescens</i> Forest	Quaking Aspen / Pinegrass Forest	CEGL000575
<i>Populus tremuloides</i> / <i>Ceanothus velutinus</i> Forest	Quaking Aspen / Tobacco-brush Forest	CEGL000581
<i>Populus tremuloides</i> / <i>Salix scouleriana</i> Forest	Quaking Aspen / Scouler's Willow Forest	CEGL000604
<i>Populus tremuloides</i> / <i>Shepherdia canadensis</i> Forest	Quaking Aspen / Russet Buffaloberry Forest	CEGL000606
<i>Populus tremuloides</i> / <i>Symphoricarpos albus</i> Forest	Quaking Aspen / Common Snowberry Forest	CEGL000609
<i>Populus tremuloides</i> / <i>Symphoricarpos oreophilus</i> / <i>Calamagrostis rubescens</i> Forest	Quaking Aspen / Mountain Snowberry / Pinegrass Forest	CEGL000612
<i>Populus tremuloides</i> / <i>Symphoricarpos oreophilus</i> / Tall Forbs Forest	Quaking Aspen / Mountain Snowberry / Tall Forbs Forest	CEGL000615
<i>Populus tremuloides</i> / <i>Symphoricarpos oreophilus</i> / <i>Thalictrum fendleri</i> Forest	Quaking Aspen / Mountain Snowberry / Fendler's Meadowrue Forest	CEGL000616
<i>Populus tremuloides</i> / Tall Forbs Forest	Quaking Aspen / Tall Forbs Forest	CEGL000618
<i>Populus tremuloides</i> / <i>Phleum pratense</i> Semi-Natural Forest	Quaking Aspen / Timothy Semi-Natural Forest	CEGL005829
<i>Populus tremuloides</i> / <i>Poa pratensis</i> Forest	Quaking Aspen / Kentucky Bluegrass Forest	CEGL003148
<i>Populus tremuloides</i> / <i>Thalictrum fendleri</i> Forest	Quaking Aspen / Fendler's Meadowrue Forest	CEGL000619
<i>Pseudotsuga menziesii</i> / <i>Thalictrum occidentale</i> Forest	Douglas-fir / Western Meadowrue Forest	NEW-GRTE-006
<i>Pseudotsuga menziesii</i> / <i>Acer glabrum</i> Forest	Douglas-fir / Rocky Mountain Maple Forest	CEGL000418
<i>Pseudotsuga menziesii</i> / <i>Amelanchier alnifolia</i> Forest	Douglas-fir / Saskatoon Serviceberry Forest	CEGL000420
<i>Pseudotsuga menziesii</i> / <i>Calamagrostis rubescens</i> Forest	Douglas-fir / Pinegrass Woodland	CEGL000429
<i>Pseudotsuga menziesii</i> / <i>Carex geyeri</i> Forest	Douglas-fir / Geyer's Sedge Forest	CEGL000430
<i>Pseudotsuga menziesii</i> / <i>Osmorhiza berteroi</i> Forest	Douglas-fir / Mountain Sweet-cicely Forest	CEGL000445
<i>Pseudotsuga menziesii</i> / <i>Spiraea betulifolia</i> Forest	Douglas-fir / Shinyleaf Meadowsweet Forest	CEGL000457
<i>Pseudotsuga menziesii</i> / <i>Symphoricarpos albus</i> Forest	Douglas-fir / Common Snowberry Forest	CEGL000459
<i>Pseudotsuga menziesii</i> / <i>Symphoricarpos oreophilus</i> Forest	Douglas-fir / Mountain Snowberry Forest	CEGL000462
<i>Pseudotsuga menziesii</i> / <i>Vaccinium membranaceum</i> Forest	Douglas-fir / Square-twig Blueberry Forest	CEGL000466

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Shrublands and Shrub Steppe		
<i>Acer glabrum</i> Avalanche Chute Shrubland	Rocky Mountain Maple Avalanche Chute Shrubland	CEGL001061
<i>Alnus incana</i> / <i>Equisetum arvense</i> Shrubland	Speckled Alder / Field Horsetail Shrubland	CEGL001146
<i>Alnus incana</i> / <i>Glyceria striata</i> Shrubland	Speckled Alder / Fowl Mannagrass Shrubland	CEGL000228
<i>Alnus incana</i> / Mesic Forbs Shrubland	Speckled Alder / Mesic Forbs Shrubland	CEGL001147
<i>Alnus incana</i> / Mesic Graminoids Shrubland	Speckled Alder / Mesic Graminoids Shrubland	CEGL001148
<i>Artemisia arbuscula</i> ssp. <i>arbuscula</i> / <i>Festuca idahoensis</i> Shrub Herbaceous Vegetation	Dwarf Sagebrush / Idaho Fescue Shrub Herbaceous Vegetation	CEGL001409
<i>Artemisia arbuscula</i> ssp. <i>arbuscula</i> / <i>Pseudoroegneria spicata</i> Shrub Herbaceous Vegetation	Dwarf Sagebrush / Bluebunch Wheatgrass Shrub Herbaceous Vegetation	CEGL001412
<i>Artemisia cana</i> (ssp. <i>bolanderi</i> , ssp. <i>viscidula</i>) / <i>Poa pratensis</i> Semi-natural Shrubland	(Bolander Silver Sagebrush, Mountain Silver Sagebrush) / Kentucky Bluegrass Semi-natural Shrubland	CEGL002988
<i>Artemisia tridentata</i> ssp. <i>spiciformis</i> Shrub Herbaceous Vegetation [Provisional]	Spiked Big Sagebrush Shrub Herbaceous Vegetation	CEGL002993
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> / <i>Bromus carinatus</i> Shrubland	Mountain Big Sagebrush / California Brome Shrubland	CEGL001021
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> / <i>Bromus inermis</i> Shrubland	Mountain Big Sagebrush / Smooth Brome Shrubland	NEW-GRTE-075
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> / <i>Carex geyeri</i> Shrub Herbaceous Vegetation	Mountain Big Sagebrush / Geyer's Sedge Shrub Herbaceous Vegetation	CEGL001532
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> / <i>Festuca idahoensis</i> Shrub Herbaceous Vegetation	Mountain Big Sagebrush / Idaho Fescue Shrub Herbaceous Vegetation	CEGL001533
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> / <i>Hesperostipa comata</i> Shrubland	Mountain Big Sagebrush / Needle-and-Thread Shrubland	CEGL002931
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> / <i>Poa pratensis</i> Shrubland	Mountain Big Sagebrush / Kentucky Bluegrass Sagebrush Shrubland	CEGL002528
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> / <i>Pseudoroegneria spicata</i> Shrubland	Mountain Big Sagebrush / Bluebunch Wheatgrass Shrubland	CEGL001030
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> - <i>Purshia tridentata</i> / <i>Festuca idahoensis</i> Shrubland	Mountain Big Sagebrush - Bitterbrush / Idaho Fescue Shrubland	NEW-GRTE-048
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> - <i>Purshia tridentata</i> / <i>Balsamorhiza sagittata</i> Shrubland	Mountain Big Sagebrush - Bitterbrush / Arrow-Leaf Balsamroot Shrubland	NEW-GRTE-047
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> - <i>Purshia tridentata</i> / <i>Bromus inermis</i> - <i>Poa pratensis</i> Shrubland	Mountain Big Sagebrush - Bitterbrush / Smooth Brome - Kentucky Bluegrass Shrubland	NEW-GRTE-081
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> - <i>Symphoricarpos oreophilus</i> / <i>Carex geyeri</i> Shrubland	Mountain Big Sagebrush - Mountain Snowberry / Geyer's Sedge	NEW-GRTE-088

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<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> - <i>Symphoricarpos oreophilus</i> / <i>Bromus carinatus</i> Shrubland	Mountain Big Sagebrush - Mountain Snowberry / California Brome Shrubland	CEGL001035
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> - <i>Symphoricarpos oreophilus</i> / <i>Festuca idahoensis</i> Shrubland	Mountain Big Sagebrush - Mountain Snowberry / Idaho Fescue Shrubland	CEGL001036
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> - <i>Symphoricarpos oreophilus</i> / <i>Hesperostipa comata</i> Shrubland	Mountain Big Sagebrush - Mountain Snowberry / Needle-and-Thread Shrubland	CEGL001039
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> - <i>Symphoricarpos oreophilus</i> / <i>Pseudoroegneria spicata</i> Shrubland	Mountain Big Sagebrush - Mountain Snowberry / Bluebunch Wheatgrass Shrubland	CEGL001038
<i>Artemisia tripartita</i> ssp. <i>tripartita</i> / <i>Hesperostipa comata</i> Shrub Herbaceous Vegetation	Threetip Sagebrush / Needle-and-Thread Shrub Herbaceous Vegetation	CEGL001539
<i>Betula nana</i> / Mesic Forbs - Mesic Graminoids Shrubland	Swamp Birch / Mesic Forbs - Mesic Graminoids Shrubland	CEGL002653
<i>Ceanothus velutinus</i> Shrubland	Tobacco-brush Shrubland	CEGL002167
<i>Chrysothamnus viscidiflorus</i> Shrubland	Green Rabbitbrush Shrub Herbaceous Vegetation	CEGL002530
<i>Cornus sericea</i> Shrubland	Red-osier Dogwood Shrubland	CEGL001165
<i>Dasiphora floribunda</i> / <i>Carex</i> spp. Shrubland	Shrubby-cinquefoil / Sedge species Shrubland	CEGL001106
<i>Dasiphora floribunda</i> / <i>Deschampsia caespitosa</i> Shrubland	Shrubby-cinquefoil / Tufted Hairgrass Shrubland	CEGL001107
<i>Dryas octopetala</i> - <i>Carex</i> spp. Dwarf-shrub Herbaceous Vegetation	Eight-petal Mountain-avens - Sedge species Dwarf-shrub Herbaceous Vegetation	CEGL001893
<i>Prunus virginiana</i> -(<i>Prunus americana</i>) Shrubland	Choke Cherry - (American Plum) Shrubland	CEGL001108
<i>Prunus virginiana</i> / <i>Carex geyeri</i> Shrubland	Choke Cherry / Geyer's Sedge Shrubland	NEW-GRTE-045
<i>Rhamnus alnifolia</i> Shrubland	Alderleaf Buckthorn Shrubland	CEGL001132
<i>Salix arctica</i> – <i>S. petrophila</i> / <i>Caltha leptosepala</i> Dwarf-shrubland	Arctic Willow - Alpine Willow / White Marsh-marigold Dwarf-shrubland	CEGL001429
<i>Salix arctica</i> – (<i>S. petrophila</i> , <i>S. nivalis</i>) / <i>Polygonum bistortoides</i> Dwarf-shrubland	Arctic Willow - (Alpine Willow, Snow Willow) / American Bistort Dwarf-shrubland	CEGL001431
<i>Salix boothii</i> / <i>Carex utriculata</i> Shrubland	Booth's Willow / Beaked Sedge Shrubland	CEGL001178
<i>Salix boothii</i> / Mesic Forbs Shrubland	Booth's Willow / Mesic Forbs Shrubland	CEGL001180
<i>Salix boothii</i> / Mesic Graminoids Shrubland	Booth's Willow / Mesic Graminoids Shrubland	CEGL001181
<i>Salix drummondiana</i> / <i>Carex utriculata</i> Shrubland	Drummond's Willow / Beaked Sedge Shrubland	CEGL002631

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<i>Salix drummondiana</i> / Mesic Forbs Shrubland	Drummond's Willow / Mesic Forbs Shrubland	CEGL001192
<i>Salix drummondiana</i> / Mesic Graminoid Shrubland	Drummond's Willow / Mesic Graminoid Shrubland	NEW-GRTE-077
<i>Salix eastwoodiae</i> Shrubland [Provisional]	Sierran Willow Shrubland	CEGL001194
<i>Salix geyeriana</i> - <i>Salix wolfii</i> / Mesic Graminoid Shrubland	Geyer's Willow - Wolf Willow / Mesic Graminoids Shrubland	NEW-GRTE-033
<i>Salix geyeriana</i> / <i>Calamagrostis canadensis</i> Shrubland	Geyer's Willow / Bluejoint Shrubland	CEGL001205
<i>Salix geyeriana</i> / <i>Carex praticola</i> Shrubland	Geyer's Willow / Northern Meadow Sedge Shrubland	NEW-GRTE-034
<i>Salix geyeriana</i> / <i>Carex utriculata</i> Shrubland	Geyer's Willow / Beaked Sedge Shrubland	CEGL001207
<i>Salix geyeriana</i> / Mesic Graminoids Shrubland	Geyer's Willow / Mesic Graminoids Shrubland	CEGL001210
<i>Salix glauca</i> / <i>Deschampsia caespitosa</i> Shrub Herbaceous Vegetation	Grayleaf Willow / Tufted Hairgrass Shrubland	CEGL001137
<i>Salix glauca</i> Shrubland	Grayleaf Willow Shrubland	CEGL001136
<i>Salix lemmonii</i> / <i>Carex pellita</i> Shrubland	Lemmon's Willow / Woolly Sedge Shrubland	NEW-GRTE-035
<i>Salix lemmonii</i> / Mesic Tall Forbs Shrubland	Lemmon's Willow / Mesic-Tall Forbs Shrubland	CEGL002771
<i>Salix lemmonii</i> / Mesic Graminoids Shrubland	Lemmon's Willow / Mesic Graminoids Shrubland	CEGL002069
<i>Salix lutea</i> / Mesic Graminoids Shrubland	Yellow Willow / Mesic Graminoids Shrubland	CEGL002073
<i>Salix planifolia</i> / <i>Carex utriculata</i> Shrubland	Planeleaf Willow / Beaked Sedge Shrubland	CEGL005937
<i>Salix planifolia</i> / Mesic Forbs Shrubland [Provisional]	Planeleaf Willow / Mesic Forbs Shrubland	CEGL002893
<i>Salix wolfii</i> / <i>Calamagrostis canadensis</i> Shrubland	Wolf Willow / Bluejoint Shrubland	CEGL002064
<i>Salix wolfii</i> / <i>Carex aquatilis</i> Shrubland	Wolf Willow / Aquatic Sedge Shrubland	CEGL001234
<i>Salix wolfii</i> / <i>Carex pellita</i> Shrubland	Wolf Willow / Woolly Sedge Shrubland	NEW-GRTE-040
<i>Salix wolfii</i> / <i>Carex praegracilis</i> Shrubland	Wolf Willow / Clustered Field Sedge Shrubland	NEW-GRTE-041
<i>Salix wolfii</i> / <i>Carex utriculata</i> Shrubland	Wolf Willow / Beaked Sedge Shrubland	CEGL001237
<i>Salix wolfii</i> / <i>Deschampsia caespitosa</i> Shrubland	Wolf Willow / Tufted Hairgrass Shrubland	CEGL001238
<i>Salix wolfii</i> / Mesic Forbs Shrubland	Wolf Willow / Mesic Forbs Shrubland	CEGL001240

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<i>Spiraea betulifolia</i> Shrubland	Shinyleaf Meadowsweet Shrubland	CEGL005835
<i>Spiraea splendens</i> Shrubland	Rose Meadowsweet Shrubland	NEW-GRTE-046
<i>Symphoricarpos oreophilus</i> Shrubland	Mountain Snowberry Shrubland	CEGL002951
<i>Vaccinium (caespitosum, scoparium)</i> Dwarf-shrubland	(Dwarf Blueberry, Grouseberry) Dwarf-shrubland	CEGL001140
<i>Vaccinium membranaceum</i> Shrubland	Square-twigg Blueberry Shrubland	NEW-GRTE-078
Herbaceous Grass and Grass-Like Dominated Vegetation		
<i>(Balsamorhiza serrata) - Poa secunda</i> Herbaceous Vegetation	(Serrate Balsamroot) - Curly Bluegrass Herbaceous Vegetation	CEGL001782
<i>Calamagrostis canadensis</i> Western Herbaceous Vegetation	Bluejoint Western Herbaceous Vegetation	CEGL001559
<i>Calamagrostis rubescens</i> Herbaceous Vegetation	Pinegrass Herbaceous Vegetation	CEGL005862
<i>Carex aquatilis</i> Herbaceous Vegetation	Aquatic Sedge Herbaceous Vegetation	CEGL001802
<i>Carex buxbaumii</i> Herbaceous Vegetation	Brown Bog Sedge Herbaceous Vegetation	CEGL001806
<i>Carex geyeri</i> Herbaceous Vegetation	Geyer's Sedge Herbaceous Vegetation	CEGL005864
<i>Carex hoodii</i> Herbaceous Vegetation	Hood's Sedge Herbaceous Vegetation	NEW-GRTE-021
<i>Carex illota</i> Herbaceous Vegetation	Small-head Sedge Herbaceous Vegetation	CEGL001876
<i>Carex microptera</i> Herbaceous Vegetation	Small-wing Sedge Herbaceous Vegetation	CEGL001792
<i>Carex nardina</i> Scree Herbaceous Vegetation	Nard Sedge Scree Herbaceous Vegetation	CEGL001812
<i>Carex nebrascensis</i> Herbaceous Vegetation	Nebraska Sedge Herbaceous Vegetation	CEGL001813
<i>Carex paysonis - Sibbaldia procumbens</i> Herbaceous Vegetation	Payson's Sedge - Creeping Glow-wort Herbaceous Vegetation	CEGL005865
<i>Carex pellita</i> Herbaceous Vegetation	Woolly Sedge Herbaceous Vegetation	CEGL001809
<i>Carex rossii</i> Herbaceous Vegetation	Ross' Sedge Herbaceous Vegetation	NEW-GRTE-027
<i>Carex utriculata</i> Herbaceous Vegetation	Beaked Sedge Herbaceous Vegetation	CEGL001562
<i>Carex vesicaria</i> Herbaceous Vegetation	Inflated Sedge Herbaceous Vegetation	CEGL002661
<i>Danthonia spicata</i> Herbaceous Vegetation	Poverty Wild Oat Grass Herbaceous Vegetation	NEW-GRTE-025

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<i>Deschampsia caespitosa</i> - <i>Carex microptera</i> Herbaceous Vegetation	Tufted Hairgrass - Small-wing Sedge Herbaceous Vegetation	CEGL001883
<i>Deschampsia caespitosa</i> Herbaceous Vegetation	Tufted Hairgrass Herbaceous Vegetation	CEGL001599
<i>Eleocharis acicularis</i> Herbaceous Vegetation	Needle Spikerush Herbaceous Vegetation	CEGL001832
<i>Eleocharis palustris</i> Herbaceous Vegetation	Marsh Spikerush Herbaceous Vegetation	CEGL001833
<i>Festuca idahoensis</i> - <i>Danthonia intermedia</i> Herbaceous Vegetation	Idaho Fescue - Timber Oatgrass Herbaceous Vegetation	CEGL001612
<i>Festuca idahoensis</i> - <i>Geranium viscosissimum</i> Herbaceous Vegetation	Idaho Fescue - Sticky Geranium Herbaceous Vegetation	CEGL001618
<i>Festuca idahoensis</i> - <i>Helianthella uniflora</i> Herbaceous Vegetation	Idaho Fescue - Rocky Mountain Dwarf Sunflower Herbaceous Vegetation	NEW-GRTE-001
<i>Hesperostipa comata</i> Herbaceous Vegetation	Needle and Thread Grass Herbaceous Vegetation	NEW-GRTE-008
<i>Juncus balticus</i> Herbaceous Vegetation	Baltic Rush Herbaceous Vegetation	CEGL001838
<i>Juncus drummondii</i> – <i>Antennaria lanata</i> Herbaceous Vegetation	Drummond's Rush - Woolly Pussytoes Herbaceous Vegetation	CEGL001904
<i>Juncus parryi</i> – <i>Sibbaldia procumbens</i> Herbaceous Vegetation	Parry's Rush / Creeping Glow-wort Herbaceous Vegetation	CEGL005871
<i>Leucopoa kingii</i> / <i>Phlox pulvinata</i> Herbaceous Vegetation	Spike Fescue - Cushion Phlox Herbaceous Vegetation	CEGL001913
<i>Phleum pratense</i> - <i>Poa pratensis</i> - <i>Bromus inermis</i> Herbaceous Vegetation	Timothy - Kentucky Bluegrass - Smooth Brome Semi-natural Herbaceous Vegetation	CEGL005874
<i>Poa palustris</i> Herbaceous Vegetation	Fowl Bluegrass Herbaceous Vegetation	CEGL001659
<i>Pseudoroegneria spicata</i> - <i>Balsamorhiza sagittata</i> - <i>Poa secunda</i> Herbaceous Vegetation	Bluebunch Wheatgrass - Arrowleaf Balsamroot - Curly Bluegrass Herbaceous Vegetation	CEGL001662
<i>Pseudoroegneria spicata</i> - <i>Poa secunda</i> Herbaceous Vegetation	Bluebunch Wheatgrass - Curly Bluegrass Herbaceous Vegetation	CEGL001677
<i>Pseudoroegneria spicata</i> Herbaceous Vegetation	Bluebunch Wheatgrass Herbaceous Vegetation	CEGL001660
Herbaceous Broadleaf Dominated Meadows		
<i>Apocynum androsaemifolium</i> Herbaceous Vegetation	Spreading Dogbane Herbaceous Vegetation	NEW-GRTE-039
<i>Arnica longifolia</i> Herbaceous Vegetation	Spear-Leaf Leopardbane Herbaceous Vegetation	NEW-GRTE-005
<i>Caltha leptosepala</i> Herbaceous Vegetation	White Marsh-marigold Herbaceous Vegetation	CEGL001954
<i>Erigeron peregrinus</i> Herbaceous Vegetation	Subalpine Fleabane Herbaceous Vegetation	NEW-GRTE-017
<i>Eucephalus engelmannii</i> Herbaceous Vegetation	Engelmann's Wayside-Aster Herbaceous Vegetation	NEW-GRTE-079

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<i>Geranium viscosissimum</i> Herbaceous Vegetation	Sticky Geranium Herbaceous Vegetation	CEGL002536
<i>Helianthella uniflora</i> Herbaceous Vegetation	Rocky Mountain Dwarf Sunflower Herbaceous Vegetation	NEW-GRTE-003
<i>Heracleum maximum</i> - <i>Rudbeckia occidentalis</i> Herbaceous Vegetation	Cow-parsnip - Western Coneflower Herbaceous Vegetation	CEGL001940
<i>Ivesia gordonii</i> - <i>Eriogonum caespitosum</i> Herbaceous Vegetation	Alpine Mousetail - Matted Wild Buckwheat Herbaceous Vegetation	CEGL001903
<i>Ligusticum filicinum</i> - <i>Delphinium X occidentale</i> Herbaceous Vegetation	Fernleaf Wild Lovage - Duncecap Larkspur Herbaceous Vegetation	CEGL001941
<i>Menyanthes trifoliata</i> Herbaceous Vegetation	Buckbean Herbaceous Vegetation	CEGL003410
<i>Mertensia ciliata</i> Herbaceous Vegetation	Mountain Bluebells Herbaceous Vegetation	CEGL001944
<i>Nuphar lutea</i> Floating Aquatic Vegetation	Yellow Pond-lily Herbaceous Vegetation	CEGL002001
<i>Phlox multiflora</i> Alpine Cushion Herbaceous Vegetation	Rocky Mountain Phlox Alpine Cushion Herbaceous Vegetation	NEW-GRTE-030
<i>Pteridium aquilinum</i> Herbaceous Vegetation	Northern Bracken Herbaceous Vegetation	CEGL002544
<i>Pteryxia hendersonii</i> Alpine Herbaceous Vegetation	Henderson's Pteryxia Alpine Cushion Herbaceous Vegetation	NEW-GRTE-029
<i>Senecio triangularis</i> - <i>Mimulus guttatus</i> Herbaceous Vegetation	Arrowleaf Ragwort - Seep Monkeyflower Herbaceous Vegetation	CEGL001988
<i>Symphyotrichum ascendens</i> Herbaceous Vegetation	Western American-Aster Herbaceous Vegetation	NEW-GRTE-004

***ELCODE** represents NatureServe's internal database tracking code for each recognized plant association.
- NVC associations without pre-existing definitions are labeled as NEW-GRTE-### in the ELCODE column



Examples of *Ceanothus velutinus* Shrubland (left) and *Artemisia tridentata* ssp. *vaseyana* - *Pursha tridentata* / *Balsamorhiza sagittata* Shrubland (right) Associations.



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Table 8. Map units identified in Grand Teton National Park.

The units are organized into ecological groups. "Level" refers to whether the map unit represents a NVC plant association or alliance (NVC unless otherwise noted), a phase of an association/alliance, a complex or mosaic of multiple associations/alliances, a local plant community/plant population, or a land use class. Anderson Land Use Classes are identified by Roman numerals.

Map Code	Map Unit Name	Map Unit Common Name	Level
FORESTS AND WOODLANDS			
FSF	<i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> Forest	Subalpine Fir - Engelmann Spruce Forest	Complex
FWB	<i>Pinus albicaulis</i> Forest	Whitebark Pine Forest	Complex
FLM	<i>Pinus flexilis</i> Forest	Limber Pine Forest	Alliance
FLP	<i>Pinus contorta</i> Forest	Lodgepole Pine Forest	Complex
FDF	<i>Pseudotsuga menziesii</i> Forest	Douglas-fir Forest	Complex
FBS	<i>Picea pungens</i> Riparian Forest	Blue Spruce Riparian Forest	Complex
FAP	<i>Populus tremuloides</i> Forest	Aspen Forest	Alliance
FMC	Mixed Conifer Forest	Mixed Conifer Forest	Mixed Alliances
FJ	<i>Juniperus scopulorum</i> Woodland	Rocky Mountain Juniper Woodland	Local Plant Community
FEP	Mixed Evergreen - <i>Populus</i> spp. Forest	Mixed Evergreen - Poplar Forest	Complex
FCW	<i>Populus angustifolia</i> - <i>P. balsamifera</i> Riparian Forest	Cottonwood Riparian Forest	Complex
FRM	Mixed Conifer - <i>Populus</i> spp. Riparian Forest	Mixed Conifer - Cottonwood Riparian Forest	Alliance
KRM	Krummholz Woodland	Krummholz Woodland	Association
REGENERATION			
RAM	Mixed <i>Abies lasiocarpa</i> - <i>Picea engelmannii</i> Woodland - Deciduous Shrubland Regeneration	Mixed Subalpine Fir - Engelmann Spruce Woodland - Deciduous Shrubland Regeneration	Alliance Phase
RLP	<i>Pinus contorta</i> Woodland Regeneration	Lodgepole Pine Woodland Regeneration	Alliance Phase
RLC	<i>Pinus contorta</i> - <i>Ceanothus velutinus</i> Woodland Regeneration	Lodgepole Pine - Ceanothus Woodland Regeneration	Association Phase
RAP	<i>Populus tremuloides</i> Woodland Regeneration	Aspen Woodland Regeneration	Alliance Phase
RMC	Mixed Conifer Woodland Regeneration	Mixed Conifer Woodland Regeneration	Mixed Alliance Phases

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SHRUBLAND			
SAI	<i>Alnus incana</i> Shrubland	Alder Shrubland	Complex
SDS	Mixed Deciduous Shrubland	Mixed Deciduous Shrubland	Complex
SMR	Mixed Tall Deciduous Shrubland	Mixed Tall Deciduous Shrubland	Complex
SCV	<i>Ceanothus velutinus</i> Shrubland	Ceanothus Shrubland	Association
SSD	<i>Artemisia</i> spp. Dry Shrubland	Sagebrush Dry Shrubland	Complex
SSW	<i>Artemisia</i> spp. / <i>Dasiphora floribunda</i> Mesic Shrubland	Sagebrush / Shrubby Cinquefoil Mesic Shrubland	Association
SES	<i>Artemisia</i> spp. - <i>Purshia tridentata</i> Mixed Shrubland	Sagebrush - Antelope bitterbrush Mixed Shrubland	Complex
SWL	<i>Salix</i> spp. Shrubland	Willow Shrubland	Complex
DWARF-SHRUBLAND			
DSA	<i>Salix arctica</i> Dwarf Shrubland	Arctic Willow Dwarf Shrubland	Association
DSE	<i>Artemisia arbuscula</i> Dwarf Shrubland	Low Sagebrush Dwarf Shrubland	Alliance
HERBACEOUS			
HDA	Alpine Herbaceous Vegetation	Alpine Herbaceous Vegetation	Complex
HWM	Alpine Mesic Meadows	Alpine Mesic Meadows	Mosaic
HSA	Subalpine Mixed Herbaceous Vegetation	Subalpine Mixed Herbaceous Vegetation	Complex
HFX	Montane Xeric Forb Herbaceous Vegetation	Montane Xeric Forb Herbaceous Vegetation	Complex
HFD	Montane Mesic Forb Herbaceous Vegetation	Montane Mesic Forb Herbaceous Vegetation	Complex
HBR	<i>Pteridium aquilinum</i> Herbaceous Vegetation	Bracken Fern Herbaceous Vegetation	Association
HGL	Mixed Grassland Herbaceous Vegetation	Mixed Grassland Herbaceous Vegetation	Complex
HGS	Flooded Wet Meadow Herbaceous Vegetation	Flooded Wet Meadow Herbaceous Vegetation	Mosaic
HA	Herbaceous Aquatics	Herbaceous Aquatics	Mosaic
SPARSE VEGETATION			
VCT	Cliff and Talus Sparse Vegetation	Cliff and Talus Sparse Vegetation	Complex
VLP	Limestone Pavement Sparse Vegetation	Limestone Pavement Sparse Vegetation	Complex
VEH	Exposed Hillside Sparse Vegetation	Exposed Hillside Sparse Vegetation	Complex
VRB	Recently Burned Sparse Vegetation	Recently Burned Sparse Vegetation	Complex
VSL	Exposed Lake Shoreline – Stream Deposit Sparse Vegetation	Exposed Lake Shoreline – Stream Deposit Sparse Vegetation	Complex

USGS-NPS Vegetation Mapping Program
Grand Teton National Park

NON-VEGETATED			
NIP	Cropland and Pasture	Irrigated Fields	Level II
NID	Canals	Irrigation Ditches	Level II
NSM	Strip Mines, Quarries, and Gravel Pits	Strip Mines, Quarries, and Gravel Pits	Level II
NST	Streams	Streams	Level II
NVS	Sandy Areas other than Beaches	Non-vegetated Sand Bars	Level II
NGS	Perennial Snow or Ice	Glacier / Snow	Level I
NRK	Bare Exposed Rock	Rock Outcrop / Cliff	Level II
NLP	Natural and Artificial Lakes and Ponds	Lakes and Reservoirs	Level II
NRF	Mixed Urban or Built-up Land	Residential and Facilities	Level II
NRD	Transportation, Communications, and Utilities	Roads and Trails / Trailheads	Level II

¹Complex: a group of plant associations that cannot be mapped individually on the aerial photographs but occur together predictably on the landscape. Complexes typically are composed of associations with similar physiognomies, thus are more difficult to tell apart on the photos.

²Mosaic: individual associations are recognizable on the aerial photography but are too intermixed to map as separate polygons.

³Local Plant Community: represents discrete stands of vegetation that are too small and/or occur too infrequently to classify.



Examples of the FMC Mixed Conifer Forest Map Class containing a mix of even-aged lodgepole pine and spruce-fir (left) older lodgepole pine with successional spruce-fir in the understory (right).



3.3 Relationship between Map Units and Plant Associations

The GRTE map units represent a compromise between the detail of the NVC, the needs of the park and the limitations of the photography. As a result, the mapping scheme does not exactly match the NVC. Rather, the vegetation map units are linked (i.e. "crosswalked") to the NVC plant associations.

Here are the possible map scheme scenarios that we encountered: 1) when a plant association or alliance had a unique photo signature and could be readily delineated on the photos, the map unit adopted the plant association/alliance name. This was considered a one-to-one relationship. 2) When plant associations occurred in stands too small to map or when related plant associations shared the same signature and could not be distinguished

on the photos, several plant associations were collapsed into a single map unit referred to as a complex of NVC associations, a many-to-one relationship. 3) Similarly, when associations were recognizable on the aerial photography but were too intermixed to map as separate polygons a mosaic designation was used; another many-to-one relationship. 4) Next, when more than one phase of a single plant association was recognized on the photos, a plant association was split into several map classes (i.e. mature forest stands of a single association vs. immature stands of the same association). This is considered a one-to-many situation. 5) Finally, non-vegetated areas and vegetation types not recognized by the NVC received special map unit designations.

Below is a comprehensive breakdown of the crosswalking of the NVC associations to the map units for GRTE:

-Map Units Representing Single NVC Units (either existing or new)

(One ALLIANCE/Association-to-One Map Class)

The following map units were created from the NVC and represent established or provisional plant alliances that could be discerned and delineated on the aerial photography.

Map Code	Map Unit NVC Plant ALLIANCE/ Association(s)
FLM	LIMBER PINE FOREST
	LIMBER PINE WOODLAND ALLIANCE
	Limber Pine / Bluebunch Wheatgrass Woodland
FAP	ASPEN FOREST
	QUAKING ASPEN FOREST ALLIANCE
	Quaking Aspen / Saskatoon Serviceberry - Mountain Snowberry / California Brome Forest
	Quaking Aspen / Saskatoon Serviceberry - Mountain Snowberry / Pinegrass Forest
	Quaking Aspen / Saskatoon Serviceberry - Mountain Snowberry / Fendler's Meadowrue Forest
	Quaking Aspen / Saskatoon Serviceberry / Geyer's Sedge Forest
	Quaking Aspen / Saskatoon Serviceberry / Northern Bracken Forest
	Quaking Aspen / Pinegrass Forest
	Quaking Aspen / Tobacco-brush Forest
	Quaking Aspen / Scouler's Willow Forest
	Quaking Aspen / Russet Buffaloberry Forest
	Quaking Aspen / Common Snowberry Forest
	Quaking Aspen / Mountain Snowberry / Pinegrass Forest
	Quaking Aspen / Mountain Snowberry / Tall Forbs Forest
	Quaking Aspen / Mountain Snowberry / Fendler's Meadowrue Forest
	Quaking Aspen / Tall Forbs Forest
	Quaking Aspen / Fendler's Meadowrue Forest
	Quaking Aspen / Timothy Semi-Natural Forest
	Quaking Aspen / Kentucky Bluegrass Forest

- FRM RIPARIAN MIXED CONIFER - POPLAR FOREST**
NARROWLEAF COTTONWOOD TEMPORARILY FLOODED WOODLAND ALLIANCE
Narrowleaf Cottonwood - Blue Spruce / Kentucky Bluegrass Forest
Narrowleaf Cottonwood - Blue Spruce / Russet Buffaloberry Forest
- FMC MIXED CONIFER FOREST**
SUBALPINE FIR – ENGELMANN SPRUCE FOREST ALLIANCE
Subalpine Fir - Engelmann Spruce - Lodgepole Pine Forest
(note: Map Unit may also contain other conifer dominated associations)
- KRM KRUMMHOLZ WOODLAND**
SUBALPINE FIR – ENGELMANN SPRUCE - LIMBER PINE KRUMMHOLZ
SHRUBLAND ALLIANCE
Subalpine Fir - Engelmann Spruce Krummholz Shrubland
- SCV CEANOTHUS SHRUBLAND**
CEANOTHUS SHRUBLAND ALLIANCE
Tobacco-brush Shrubland
- SES SAGEBRUSH – ANTELOPE BITTERBRUSH MIXED SHRUBLAND**
MOUNTAIN BIG SAGEBRUSH SHRUBLAND ALLIANCE
Mountain Big Sagebrush - Bitterbrush / Idaho Fescue Shrubland
Mountain Big Sagebrush - Bitterbrush / Arrow-Leaf Balsamroot Shrubland
Mountain Big Sagebrush - Bitterbrush / Smooth Brome - Kentucky Bluegrass
Shrubland
- SSW SAGEBRUSH / SHRUBBY CINQUEFOIL MESIC SHRUBLAND**
SHRUBBY – CINQUEFOIL TEMPORARILY FLOODED SHRUBLAND ALLIANCE
Shrubby-cinquefoil / Sedge species Shrubland
Shrubby-cinquefoil / Tufted Hairgrass Shrubland
- DSE LOW SAGEBRUSH DWARF SHRUBLAND**
DWARF SAGEBRUSH SHRUB HERBACEOUS ALLIANCE
Dwarf Sagebrush / Idaho Fescue Shrub Herbaceous Vegetation
Dwarf Sagebrush / Bluebunch Wheatgrass Shrub Herbaceous Vegetation
- DSA ARCTIC WILLOW DWARF SHRUBLAND**
ARCTIC WILLOW DWARF SHRUBLAND ALLIANCE
Arctic Willow - (Alpine Willow, Snow Willow) / American Bistort Dwarf-shrubland
ARCTIC WILLOW SATURATED DWARF-SHRUBLAND ALLIANCE
Arctic Willow - Alpine Willow / White Marsh-marigold Dwarf-shrubland
GRAYLEAF WILLOW TEMPORARILY FLOODED SHRUBLAND ALLIANCE
Grayleaf Willow / Tufted Hairgrass Shrubland
Grayleaf Willow Shrubland
- HBR BRACKEN FERN HERABCEOUS VEGETATION**
NO ALLIANCE
Northern Bracken Herbaceous Vegetation
- HFX MONTANE XERIC FORB HERBACEOUS VEGETATION**
NO ALLIANCE
Spreading Dogbane Herbaceous Vegetation

-Map Units Representing Aggregations of Plant Associations (Mosaic)

(Many ALLIANCES/Associations-to-One Map Class)

Associations are recognizable on the aerial photography but are too intermixed to map as separate polygons.

Map Code	Map Unit
	<i>NVC Plant ALLIANCE/ Association(s)</i>

HWM ALPINE MESIC MEADOWS

- DRUMMOND'S RUSH HERBACEOUS ALLIANCE
 - Drummond's Rush - Woolly Pussytoes Herbaceous Vegetation
- TUFTED HAIRGRASS SEASONALLY FLOODED HERBACEOUS ALLIANCE
 - Tufted Hairgrass Herbaceous Vegetation
 - Tufted Hairgrass - Small-wing Sedge Herbaceous Vegetation
- NARD SEDGE HERBACEOUS ALLIANCE
 - Nard Sedge Scree Herbaceous Vegetation

HGS FLOODED WET MEADOW HERBACEOUS VEGETATION

- SEDGE (SMALL-HEAD) SEASONALLY FLOODED HERBACEOUS ALLIANCE
 - Small-head Sedge Herbaceous Vegetation
- SEDGE (BEAKED) SEASONALLY FLOODED HERBACEOUS ALLIANCE
 - Beaked Sedge Herbaceous Vegetation
- AQUATIC SEDGE SEASONALLY FLOODED HERBACEOUS ALLIANCE
 - Aquatic Sedge Herbaceous Vegetation
- SMALL-WING SEDGE SEASONALLY FLOODED HERBACEOUS ALLIANCE
 - Small-wing Sedge Herbaceous Vegetation
- WOOLLY SEDGE SEASONALLY FLOODED HERBACEOUS ALLIANCE
 - Woolly Sedge Herbaceous Vegetation
- NEEDLE SPIKERUSH SEASONALLY FLOODED HERBACEOUS ALLIANCE
 - Needle Spikerush Herbaceous Vegetation
- MARSH SPIKERUSH SEASONALLY FLOODED HERBACEOUS ALLIANCE
 - Marsh Spikerush Herbaceous Vegetation
- BALTIC RUSH SEASONALLY FLOODED HERBACEOUS ALLIANCE
 - Baltic Rush Herbaceous Vegetation
- FOWL BLUEGRASS HERBACEOUS VEGETATION
 - Fowl Bluegrass Herbaceous Vegetation
- ARROWLEAF RAGWORT SEMIPERMANENTLY FLOODED HERBACEOUS ALLIANCE
 - Arrowleaf Ragwort - Seep Monkeyflower Herbaceous Vegetation
- BLUEJOINT SEASONALLY FLOODED HERBACEOUS ALLIANCE
 - Bluejoint Western Herbaceous Vegetation
- BROWN BOG SEDGE SEASONALLY FLOODED HERBACEOUS ALLIANCE
 - Brown Bog Sedge Herbaceous Vegetation
- NEBRASKA SEDGE SEASONALLY FLOODED HERBACEOUS ALLIANCE
 - Nebraska Sedge Herbaceous Vegetation
- INFLATED SEDGE SEASONALLY FLOODED HERBACEOUS ALLIANCE
 - Inflated Sedge Herbaceous Vegetation

HA HERBACEOUS AQUATICS

- WHITE MARSH-MARIGOLD SATURATED HERBACEOUS VEGETATION
 - White Marsh-marigold Herbaceous Vegetation
- NO ALLIANCE
 - Buckbean Herbaceous Vegetation
 - Yellow Pond-lily Herbaceous Vegetation
 - (Cattail Herbaceous Vegetation)

-Map Units Representing Aggregations of Plant Associations (Complex)

(Many ALLIANCES/Associations-to-One Map Class)

In cases where closely related plant associations could not be distinguished on the photos, they were combined into a single map unit. Often these occurred from the inability to recognize the understory species or to distinguish between very similar species.

Map Code	Map Unit
	<i>NVC Plant ALLIANCE/ Association(s)</i>
FSF	SUBALPINE FIR-ENGELMANN SPRUCE FOREST
	SUBALPINE FIR – ENGELMANN SPRUCE FOREST ALLIANCE
	Subalpine Fir - Engelmann Spruce / Rocky Mountain Maple Forest
	Subalpine Fir - Engelmann Spruce / Red Baneberry Forest
	Subalpine Fir - Engelmann Spruce / Heartleaf Leopardbane Forest
	Subalpine Fir - Engelmann Spruce / Daffodil Leopardbane Forest
	Subalpine Fir - Engelmann Spruce / Pinegrass Forest
	Subalpine Fir - Engelmann Spruce / Geyer's Sedge Forest
	Subalpine Fir - Engelmann Spruce / Fool's-huckleberry Forest
	Subalpine Fir - Engelmann Spruce / (Western Prickly Gooseberry, Bristly Black Currant, White-stem Gooseberry) Forest
	Subalpine Fir - Engelmann Spruce / Bristly Black Currant Forest
	Subalpine Fir - Engelmann Spruce / Russet Buffaloberry Forest
	Subalpine Fir - Engelmann Spruce / Common Snowberry Forest
	Subalpine Fir - Engelmann Spruce / Western Meadowrue Forest
	Subalpine Fir - Engelmann Spruce / Square-twig Blueberry / Bear-grass Forest
	Subalpine Fir - Engelmann Spruce / Square-twig Blueberry Rocky Mountain Forest
	Subalpine Fir - Engelmann Spruce / Grouseberry Forest
	Engelmann Spruce / Sweet-scent Bedstraw Forest
	SUBALPINE FIR TEMPORARILY FLOODED FOREST ALLIANCE
	Subalpine Fir - Engelmann Spruce / Claspig Twisted-stalk Forest
	SUBALPINE FIR SEASONALLY FLOODED FOREST ALLIANCE
	Subalpine Fir - Engelmann Spruce / Bluejoint Forest
	ENGELMANN SPRUCE SEASONALLY FLOODED FOREST ALLIANCE
	Engelmann Spruce / Field Horsetail Forest
	SUBALPINE FIR WOODLAND ALLIANCE
	Subalpine Fir - Engelmann Spruce / Hitchcock's Smooth Woodrush Woodland
FWB	WHITEBARK PINE FOREST
	WHITEBARK PINE FOREST ALLIANCE
	Whitebark Pine / Grouseberry Forest
	WHITEBARK PINE WOODLAND ALLIANCE
	Whitebark Pine - Subalpine Fir Woodland
	WHITEBARK PINE – SUBALPINE FIR WOODLAND ALLIANCE
	Subalpine Fir - Whitebark Pine / Grouseberry Woodland
FLP	LODGEPOLE PINE FOREST
	LODGEPOLE PINE FOREST ALLIANCE
	Lodgepole Pine / Pinegrass Forest
	Lodgepole Pine / Geyer's Sedge Forest
	Lodgepole Pine / Ross' Sedge Forest
	Lodgepole Pine / Tobacco-brush Forest
	Lodgepole Pine / Shrubby-cinquefoil Forest
	Lodgepole Pine / Northern Sweet Grass Forest
	Lodgepole Pine / Russet Buffaloberry Forest
	Lodgepole Pine / Shinyleaf Meadowsweet Forest
	Lodgepole Pine / Square-twig Blueberry Rocky Mountain Forest

Lodgepole Pine / Grouseberry Forest
LODGEPOLE PINE SEASONALLY FLOODED FOREST ALLIANCE
Lodgepole Pine / Bluejoint Forest

FDF DOUGLAS-FIR FOREST

DOUGLAS-FIR FOREST ALLIANCE
Douglas-fir / Western Meadowrue Forest
Douglas-fir / Rocky Mountain Maple Forest
Douglas-fir / Saskatoon Serviceberry Forest
Douglas-fir / Geyer's Sedge Forest
Douglas-fir / Mountain Sweet-cicely Forest
Douglas-fir / Shinyleaf Meadowsweet Forest
Douglas-fir / Common Snowberry Forest
Douglas-fir / Mountain Snowberry Forest
Douglas-fir / Square-twig Blueberry Forest
DOUGLAS-FIR WOODLAND ALLIANCE
Douglas-fir / Pinegrass Woodland

FBS BLUE SPRUCE RIPARIAN FOREST

BLUE SPRUCE FOREST ALLIANCE
Blue Spruce / Common Juniper Forest
Blue Spruce / Russet Buffaloberry Forest
BLUE SPRUCE TEMPORARILY FLOODED WOODLAND ALLIANCE
Blue Spruce / Speckled Alder Woodland
Blue Spruce / Field Horsetail Woodland
Blue Spruce / Red Baneberry Forest

FEP MIXED EVERGREEN - POPLAR FOREST

SUBALPINE FIR – QUAKING ASPEN FOREST ALLIANCE
Quaking Aspen - Subalpine Fir / Geyer's Sedge - Pinegrass Forest
Quaking Aspen - Subalpine Fir / Tall Forbs Forest
LODGEPOLE PINE – QUAKING ASPEN FOREST ALLIANCE
Quaking Aspen - Lodgepole Pine / Geyer's Sedge - Pinegrass Forest
Quaking Aspen - Lodgepole Pine / Mountain Snowberry Forest
QUAKING ASPEN – DOUGLAS-FIR FOREST ALLIANCE
Quaking Aspen - Douglas-fir / Saskatoon Serviceberry Forest

FCW COTTONWOOD RIPARIAN FOREST

BLACK COTTONWOOD TEMPORARILY FLOODED FOREST ALLIANCE
Black Cottonwood, Balsam Poplar) / (Common Snowberry, Western Snowberry, Mountain Snowberry) Forest
Black Cottonwood / Mixed Herbs Forest
Black Cottonwood / Choke Cherry Forest
Black Cottonwood / Red-osier Dogwood Forest
NARROWLEAF COTTONWOOD TEMPORARILY FLOODED WOODLAND ALLIANCE
Narrowleaf Cottonwood / Mountain Big Sagebrush / Sulphurflower Wild
Buckwheat Dry Outwash Woodland
Narrowleaf Cottonwood / Kentucky Bluegrass Woodland
Narrowleaf Cottonwood / Russet Buffaloberry Forest
Narrowleaf Cottonwood / (Common Snowberry, Western Snowberry, Mountain Snowberry) Woodland

SSD SAGEBRUSH DRY SHRUBLAND

MOUNTAIN BIG SAGEBRUSH SHRUBLAND ALLIANCE
Mountain Big Sagebrush / California Brome Shrubland
Mountain Big Sagebrush / Smooth Brome Shrubland
Mountain Big Sagebrush / Geyer's Sedge Shrubland
Mountain Big Sagebrush / Needle-and-Thread Shrubland

Mountain Big Sagebrush / Kentucky Bluegrass Sagebrush Shrubland
Mountain Big Sagebrush / Bluebunch Wheatgrass Shrubland
Mountain Big Sagebrush - Mountain Snowberry / California Brome Shrubland
Mountain Big Sagebrush - Mountain Snowberry / Idaho Fescue Shrubland
Mountain Big Sagebrush - Mountain Snowberry / Needle-and-Thread Shrubland
Mountain Big Sagebrush - Mountain Snowberry / Bluebunch Wheatgrass Shrubland
Mountain Big Sagebrush - Mountain Snowberry / Geyer's sedge Shrubland
MOUNTAIN BIG SAGEBRUSH SHRUB HERBACEOUS ALLIANCE
Mountain Big Sagebrush / Idaho Fescue Shrub Herbaceous Vegetation
BOLANDER SILVER SAGEBRUSH MOUNTAIN SILVER SAGEBRUSH SHRUBLAND ALLIANCE
Bolander Silver Sagebrush, Mountain Silver Sagebrush / Kentucky Bluegrass Semi-natural Shrubland
THREETIP SAGEBRUSH SHRUB HERBACEOUS ALLIANCE
Threetip Sagebrush / Needle-and-Thread Shrub Herbaceous Vegetation
SPIKED BIG SAGEBRUSH SHRUB HERBACEOUS ALLIANCE
Spiked Big Sagebrush Shrub Herbaceous Vegetation

SWL WILLOW DECIDUOUS SHRUBLAND

BOOTH'S WILLOW TEMPORARILY FLOODED SHRUBLAND ALLIANCE
Booth's Willow / Beaked Sedge Shrubland
Booth's Willow / Mesic Forbs Shrubland
Booth's Willow / Mesic Graminoids Shrubland
DRUMMOND'S WILLOW TEMPORARILY FLOODED SHRUBLAND ALLIANCE
Drummond's Willow / Mesic Forbs Shrubland
Drummond's Willow / Mesic Graminoid Shrubland
DRUMMOND'S WILLOW SEASONALLY FLOODED SHRUBLAND ALLIANCE
Drummond's Willow / Beaked Sedge Shrubland
SIERRAN WILLOW
Sierran Willow Shrubland
GEYER'S WILLOW TEMPORARILY FLOODED SHRUBLAND ALLIANCE
Geyer's Willow - Wolf Willow / Mesic Graminoids Shrubland
Geyer's Willow / Mesic Graminoids Shrubland
GEYER'S WILLOW SEASONALLY FLOODED SHRUBLAND ALLIANCE
Geyer's Willow / Bluejoint Shrubland
Geyer's Willow / Northern Meadow Sedge Shrubland
Geyer's Willow / Beaked Sedge Shrubland
LEMMON'S WILLOW SEASONALLY FLOODED SHRUBLAND ALLIANCE
Lemmon's Willow / Woolly Sedge Shrubland
Lemmon's Willow / Mesic-Tall Forbs Shrubland
Lemmon's Willow / Mesic Graminoids Shrubland
YELLOW WILLOW TEMPORARILY FLOODED SHRUBLAND ALLIANCE
Yellow Willow / Mesic Graminoids Shrubland
PLANELEAF WILLOW SEASONALLY FLOODED SHRUBLAND ALLIANCE
Planeleaf Willow / Beaked Sedge Shrubland
Planeleaf Willow / Mesic Forbs Shrubland
WOLF WILLOW TEMPORARILY FLOODED SHRUBLAND ALLIANCE
Wolf Willow / Tufted Hairgrass Shrubland
Wolf Willow / Mesic Forbs Shrubland
WOLF WILLOW SEASONALLY FLOODED SHRUBLAND ALLIANCE
Wolf Willow / Bluejoint Shrubland
Wolf Willow / Aquatic Sedge Shrubland
Wolf Willow / Woolly Sedge Shrubland
Wolf Willow / Clustered Field Sedge Shrubland
Wolf Willow / Beaked Sedge Shrubland

SAI ALDER SHRUBLAND

SPECKLED ALDER TEMPORARILY FLOODED SHRUBLAND ALLIANCE
 Speckled Alder / Mesic Forbs Shrubland
 Speckled Alder / Mesic Graminoids Shrubland
SPECKLED ALDER SEASONALLY FLOODED SHRUBLAND ALLIANCE
 Speckled Alder / Field Horsetail Shrubland
 Speckled Alder / Fowl Mannagrass Shrubland
ALDERLEAF BUCKTHORN TEMPORARILY FLOODED SHRUBLAND ALLIANCE
 Alderleaf Buckthorn Shrubland

SMR MIXED TALL DECIDUOUS SHRUBLAND

CHOKE CHERRY SHRUBLAND ALLIANCE
 Choke Cherry - (American Plum) Shrubland
 Choke Cherry / Geyer's Sedge Shrubland
RED-OSIER DOGWOOD TEMPORARILY FLOODED SHRUBLAND ALLIANCE
 Red-osier Dogwood Shrubland

SDS MIXED DECIDUOUS SHRUBLAND

MOUNTAIN SNOWBERRY SHRUBLAND ALLIANCE
 Mountain Snowberry Shrubland
SWAMP BIRCH SEASONALLY FLOODED SHRUBLAND ALLIANCE
 Swamp Birch / Mesic Forbs - Mesic Graminoids Shrubland
GREEN RABBITBRUSH SHRUB HERBACEOUS ALLIANCE
 Green Rabbitbrush Shrub Herbaceous Vegetation
DWARF BLUEBERRY, GROUSEBERRY DWARF-SHRUBLAND ALLIANCE
 Dwarf Blueberry, Grouseberry Dwarf-shrubland
SHINYLEAF MEADOWSWEET SHRUBLAND ALLIANCE
 Shinyleaf Meadowsweet Shrubland
NO ALLIANCE
 Rose Meadowsweet Shrubland
 Square-twig Blueberry Shrubland

HGL MIXED GRASSLAND HERBACEOUS VEGETATION

PINEGRASS HERBACEOUS ALLIANCE
 Pinegrass Herbaceous Vegetation
IDAHO FESCUE HERBACEOUS ALLIANCE
 Idaho Fescue - Timber Oatgrass Herbaceous Vegetation
 Idaho Fescue - Sticky Geranium Herbaceous Vegetation
 Idaho Fescue - Rocky Mountain Dwarf Sunflower Herbaceous Vegetation
KENTUCKY BLUEGRASS HERBACEOUS ALLIANCE
 Timothy - Kentucky Bluegrass - Smooth Brome Semi-natural Herbaceous Vegetation
BLUEBUNCH WHEATGRASS HERBACEOUS ALLIANCE
 Bluebunch Wheatgrass - Arrowleaf Balsamroot - Curly Bluegrass Herbaceous Vegetation
 Bluebunch Wheatgrass - Curly Bluegrass Herbaceous Vegetation
 Bluebunch Wheatgrass Herbaceous Vegetation
NO ALLIANCE
 Needle and Thread Grass Herbaceous Vegetation
 Hood's Sedge Herbaceous Vegetation
 Ross' Sedge Herbaceous Vegetation
 Poverty Wild Oat Grass Herbaceous Vegetation
GEYER'S SEDGE HERBACEOUS ALLIANCE
 Geyer's Sedge Herbaceous Vegetation
CURLY BLUEGRASS HERBACEOUS ALLIANCE
 (Serrate Balsamroot) - Curly Bluegrass Herbaceous Vegetation

HFD MONTANE MESIC FORB HERBACEOUS VEGETATION

FERNLEAF WILD LOVAGE HERBACEOUS ALLIANCE

Fernleaf Wild Lovage - Duncecap Larkspur Herbaceous Vegetation

MOUNTAIN BLUEBELLS HERBACEOUS VEGETATION

Mountain Bluebells Herbaceous Vegetation

STICKY GERANIUM HERBACEOUS VEGETATION

Sticky Geranium Herbaceous Vegetation

COW-PARSNIP TEMPORARILY FLOODED HERBACEOUS ALLIANCE

Cow-parsnip - Western Coneflower Herbaceous Vegetation

HSA SUBALPINE MIXED HERBACEOUS VEGETATION

NO ALLIANCE

Subalpine Fleabane Herbaceous Vegetation

Engelmann's Wayside-Aster Herbaceous Vegetation

Spear-Leaf Leopardbane Herbaceous Vegetation

Spreading Dogbane Herbaceous Vegetation

Rocky Mountain Dwarf Sunflower Herbaceous Vegetation

Western American-Aster Herbaceous Vegetation

HDA TUNDRA

PARRY'S RUSH HERBACEOUS ALLIANCE

Parry's Rush / Creeping Glow-wort Herbaceous Vegetation

SPIKE FESCUE HERBACEOUS ALLIANCE

Spike Fescue - Cushion Phlox Herbaceous Vegetation

EIGHT-PETAL MOUNTAIN-AVENS DWARF-SHRUB HERBACEOUS ALLIANCE

Eight-petal Mountain-avens - Sedge species Dwarf-shrub Herbaceous Vegetation

ALPINE MOUSETAIL HERBACEOUS ALLIANCE

Alpine Mousetail - Matted Wild Buckwheat Herbaceous Vegetation

PAYSON'S SEDGE HERBACEOUS ALLIANCE

Payson's Sedge - Creeping Glow-wort Herbaceous Vegetation

NO ALLIANCE

Rocky Mountain Phlox Alpine Cushion Herbaceous Vegetation

Henderson's Pteryxia Alpine Cushion Herbaceous Vegetation



**Examples of the HSA Subalpine
Mixed Herbaceous Vegetation
Map Unit**



-Map Units Representing Multiple Age Classes of a Plant Association

(Many ALLIANCES/Associations-to-One Map Class)

The following map units represent plant associations that are divided into multiple map units because of structural differences easily discerned on the aerial photographs. Map units used to delineate these types can be considered local variations of the plant communities or plant populations.

Map Code	Map Unit
	<i>NVC Plant ALLIANCE/ Association(s)</i>

RAM MIXED SUBALPINE FIR – ENGELMANN SPRUCE WOODLAND – DECIDUOUS SHRUBLAND REGENERATION

SUBALPINE FIR – ENGELMANN SPRUCE FOREST ALLIANCE
 Subalpine Fir - Engelmann Spruce / Rocky Mountain Maple Forest
 Subalpine Fir - Engelmann Spruce / Red Baneberry Forest
 Subalpine Fir - Engelmann Spruce / Heartleaf Leopardbane Forest
 Subalpine Fir - Engelmann Spruce / Daffodil Leopardbane Forest
 Subalpine Fir - Engelmann Spruce / Pinegrass Forest
 Subalpine Fir - Engelmann Spruce / Geyer's Sedge Forest
 Subalpine Fir - Engelmann Spruce / Fool's-huckleberry Forest
 Subalpine Fir - Engelmann Spruce / (Western Prickly Gooseberry, Bristly Black Currant, White-stem Gooseberry) Forest
 Subalpine Fir - Engelmann Spruce / Bristly Black Currant Forest
 Subalpine Fir - Engelmann Spruce / Russet Buffaloberry Forest
 Subalpine Fir - Engelmann Spruce / Common Snowberry Forest
 Subalpine Fir - Engelmann Spruce / Western Meadowrue Forest
 Subalpine Fir - Engelmann Spruce / Square-twig Blueberry / Bear-grass Forest
 Subalpine Fir - Engelmann Spruce / Square-twig Blueberry Rocky Mountain Forest
 Subalpine Fir - Engelmann Spruce / Grouseberry Forest
 Subalpine Fir - Engelmann Spruce - Lodgepole Pine Forest
 Engelmann Spruce / Sweet-scent Bedstraw Forest
 SUBALPINE FIR TEMPORARILY FLOODED FOREST ALLIANCE
 Subalpine Fir - Engelmann Spruce / Clasping Twisted-stalk Forest
 SUBALPINE FIR SEASONALLY FLOODED FOREST ALLIANCE
 Subalpine Fir - Engelmann Spruce / Bluejoint Forest
 ENGELMANN SPRUCE SEASONALLY FLOODED FOREST ALLIANCE
 Engelmann Spruce / Field Horsetail Forest
 SUBALPINE FIR WOODLAND ALLIANCE
 Subalpine Fir - Engelmann Spruce / Hitchcock's Smooth Woodrush Woodland

RLP LODGEPOLE PINE WOODLAND REGENERATION

LODGEPOLE PINE FOREST ALLIANCE
 Lodgepole Pine / Pinegrass Forest
 Lodgepole Pine / Geyer's Sedge Forest
 Lodgepole Pine / Ross' Sedge Forest
 Lodgepole Pine / Shrubby-cinquefoil Forest
 Lodgepole Pine / Northern Sweet Grass Forest
 Lodgepole Pine / Russet Buffaloberry Forest
 Lodgepole Pine / Shinyleaf Meadowsweet Forest
 Lodgepole Pine / Square-twig Blueberry Rocky Mountain Forest
 Lodgepole Pine / Grouseberry Forest
 LODGEPOLE PINE SEASONALLY FLOODED FOREST ALLIANCE
 Lodgepole Pine / Bluejoint Forest

RLC LODGEPOLE PINE – CEANOTHUS WOODLAND REGENERATION

LODGEPOLE PINE FOREST ALLIANCE

Lodgepole Pine / Tobacco-brush Forest

RAP ASPEN WOODLAND REGENERATION

QUAKING ASPEN FOREST ALLIANCE

Quaking Aspen / Saskatoon Serviceberry - Mountain Snowberry / California Brome Forest

Quaking Aspen / Saskatoon Serviceberry - Mountain Snowberry / Pinegrass Forest

Quaking Aspen / Saskatoon Serviceberry - Mountain Snowberry / Fendler's Meadowrue Forest

Quaking Aspen / Saskatoon Serviceberry / Geyer's Sedge Forest

Quaking Aspen / Saskatoon Serviceberry / Northern Bracken Forest

Quaking Aspen / Pinegrass Forest

Quaking Aspen / Tobacco-brush Forest

Quaking Aspen / Scouler's Willow Forest

Quaking Aspen / Russet Buffaloberry Forest

Quaking Aspen / Mountain-Ash

Quaking Aspen / Common Snowberry Forest

Quaking Aspen / Mountain Snowberry / Pinegrass Forest

Quaking Aspen / Mountain Snowberry / Tall Forbs Forest

Quaking Aspen / Mountain Snowberry / Fendler's Meadowrue Forest

Quaking Aspen / Tall Forbs Forest

Quaking Aspen / Fendler's Meadowrue Forest

AMELANCHIER ALNIFOLIA SHRUBLAND ALLIANCE

Quaking Aspen / Saskatoon Serviceberry Avalanche Chute Shrubland

ROCKY MOUNTAIN MAPLE SHRUBLAND ALLIANCE

Rocky Mountain Maple Avalanche Chute Shrubland

RMC MIXED CONIFER WOODLAND REGENERATION

SUBALPINE FIR – ENGELMANN SPRUCE FOREST ALLIANCE

Subalpine Fir - Engelmann Spruce - Lodgepole Pine Forest

-Map Units Representing No Association

These map units were created for GRTE to describe vegetation that had no corresponding NVC association for the following reasons, respectively:

- Local Stands - Represents infrequent or rare types that can not be classified to an association since no plots or points were collected;

Map Code	Map Unit
----------	----------

**FJ ROCKY MOUNTAIN JUNIPER WOODLAND STANDS
(Local Stands)**



Examples of
the FJ - Rocky
Mt. Juniper
Woodland (left)
and RAP –
Aspen
Woodland
Regeneration
(Right) Map
Units



3.4 Vegetation Map

A total of 550,087 acres comprising 333,320 acres in GRTE and an additional 216,767 acres in the environs was mapped using 52 map classes. This included 10 land cover classes and 42 vegetation classes. Of all the map units, the most frequent was Subalpine Fir - Engelmann Spruce Forest with 6,579 polygons. The most abundant map unit in terms of area was also Subalpine Fir - Engelmann Spruce Forest covering 81,813 acres or about 15% of the project area. Almost 30% of the project area was covered by two map classes, Subalpine Fir - Engelmann Spruce Forest and Lodgepole Pine Forest. All of the frequencies for each map units (i.e., number of polygons) along with acreage per map unit are listed in **Table 10**.

The minimum mapping unit was defined as 0.5 hectares for this project, however this definition was used as a loose guideline and the actual minimum threshold defined by the resolution of the aerial photography was 0.25 acres. This ability to recognize small patches of vegetation is reflected in the high number of polygons created (47,602) and the average size of the polygons for this project, 17 acres **Table 9**.

Other useful statistics were included in the GIS layer by combining the vegetation polygons with a Digital Elevation Model (DEM) obtained from the USGS National Elevation Data coverage (10 meter resolution) and supplied by GRTE. Through a linking procedure between the centroid of the polygons and the DEM the average slope, aspect, and height of the polygon centers were calculated.

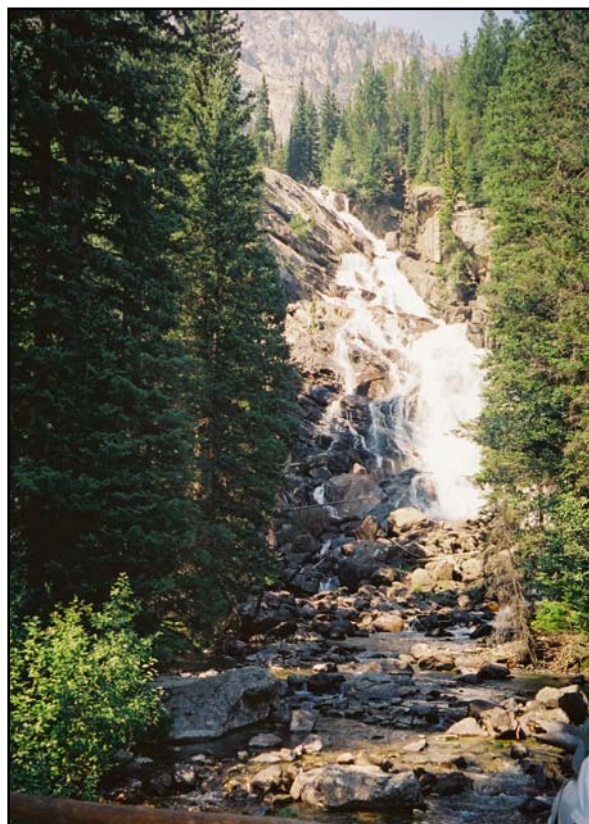


Schoolroom Glacier

Table 9. Summary statistics for Grand Teton National Park vegetation map.

Park Polygons	27,095
Project Polygons	47,602
Park Avg. Acres	16
Project Avg. Acres	17
Park Total Acres	333,320
Project Total Acres	550,087
Park Avg. Hectares	7
Project Avg. Hectares	7
Park Total Hectares	134,890
Project Total Hectares	222,613

Hidden Falls



3.5 Accuracy Assessment

The 2004 accuracy assessment effort yielded 1,122 points that were distributed throughout the park, though some areas were eliminated due to difficult or dangerous terrain. Many points were used to update the classification and local description as well as for the AA analysis. This strengthened the classification resulting in a more complete final product.

Accuracy Assessment Analysis

Actual analysis of the AA points involved a point by point review in two stages. During stage one, an initial assessment of the AA field call versus the vegetation polygon was conducted by GRTE staff. At this time, the actual field form data were evaluated for consistency between the assigned map unit name and the actual recorded foliar cover values of the dominant species. Also some of the field names assigned to the plant associations in the field were subsequently changed and these were updated to the most recent NVC name. As a result some of the AA points were changed to reflect the species cover values. Finally the crosswalk of the plant association to the map class was reviewed on the field form and some were changed to more recent versions of the map classes.

During the second stage, we compared each point to the vegetation map by creating a GIS layer of the AA points and spatially joining this to the vegetation layer. In a stepwise fashion, AA points that clearly matched a polygon were scored as correct in the binary assessment, points that matched using the field crews second or third calls were scored correct in the acceptable assessment and points that justifiably matched any of the polygons in a 20-m buffer were scored correct in the reasonable assessment.

Binary Accuracy Assessment

The initial binary assessment revealed an overall accuracy of 66%. Concentrations of error were in the herbaceous and shrub types. Obvious confusion occurred between similar types with common species. For example the Montane Mesic Forb Herbaceous Vegetation (HFD) and the Montane Xeric Forb Herbaceous Vegetation (HFX) types likely contain similar

species and were hard to distinguish on the aerial photography. This appears to be reflected in the 48% commission error for each class. Also these types illustrate the difficulty in resolving the difference in scale and perspective between viewing the vegetation on the aerial photography and assessing it on the ground. The high omission error for these types (53% and 34%) is likely a response in part to not mapping small pockets of these types that may have been on the cusp of the minimum mapping unit or were in reality actual inclusions within larger forest types.

Acceptable Accuracy Assessment

When we included the second and third field choices into the analysis the overall accuracy improved to 73%. This is likely a result of similar classes with common species being identified. Accuracies for individual classes improved with some low values for isolated forest, shrub and herbaceous types.

Reasonable Accuracy Assessment

Finally, when we included all choices were included in the analysis the final overall accuracy improved to 82%. Again this is likely a result of very similar classes being listed on the field form. In addition this may resolve some of the difficulties in getting good GPS signals in the mountains. For example if the GPS is off by 20 meters or so, recording all of the other map classes within a 50 meter radius would effectively record the correct target polygons.

Using three levels of accuracy allowed us to help factor in the variability of the vegetation at GRTE and the difficulty of classifying it into discreet classes. These levels of assessment also helped us to gauge the validity of our map classes and the ability to interpret them both from the aerial photography and also to recognize them on the ground. **Table 14** summarizes the results of all three assessments and reports the percent change from the binary to the reasonable level for each map class. By examining this percent change we can see that for some classes the amount of accuracy increased greatly (up to 67% for HWM). This may indicate that the map class is hard to distinguish from other map classes on the ground or was intermixed with other map classes.

USGS-NPS Vegetation Mapping Program
Grand Teton National Park

Table 10. Total acreage and frequency of map units for Grand Teton National Park.

Map Code	Map Unit Name	Park			Total Project Area		
		Frequency	Acres	Hectares	Frequency	Acres	Hectares
DSA	Artic Willow Dwarf Shrubland	222	672	272	312	1,131	458
DSE	Low Sagebrush Dwarf Shrubland	80	2,792	1,130	82	2,807	1,136
FAP	Aspen Forest	947	4,280	1,732	2,266	10,464	4,235
FBS	Blue Spruce Riparian Forest	174	1341	543	239	1,678	6,79
FCW	Cottonwood Riparian Forest	587	3,324	1,345	1,079	5,740	2,323
FDF	Douglas-fir Forest	1,530	14,585	5,902	2,615	25,208	10201
FEP	Mixed Evergreen - Poplar Forest	259	1,792	725	686	3,969	1,606
FJ	Rocky Mountain Juniper Woodland Stand	0	0	0	10	76	31
FLM	Limber Pine Forest	2	9	4	17	93	38
FLP	Lodgepole Pine Forest	2,135	40,073	16,217	4,101	77,765	31,470
FMC	Mixed Conifer Forest	211	6,153	2,490	298	10,364	4,194
FRM	Mixed Conifer - Cottonwood Riparian Forest	185	1,880	761	262	3,326	1,346
FSF	Subalpine Fir - Engelmann Spruce Forest	3,970	43,676	17,675	6,579	81,813	33,109
FWB	Whitebark Pine Forest	1,260	9,280	3,755	1,642	12,127	4,907
HA	Herbaceous Aquatics	15	78	32	19	255	103
HBR	Bracken Fern Herbaceous Vegetation	81	226	91	133	383	155
HDA	Alpine Herbaceous Vegetation	675	7,052	2,854	815	11,547	4,673
HFD	Montane Mesic Forb Herbaceous Vegetation	500	2,708	1,096	1,361	7,206	2,916
HFX	Montane Xeric Forb Herbaceous Vegetation	467	3,424	1,386	1,422	10,365	4,194
HGL	Mixed Grassland Herbaceous Vegetation	1,011	11,247	4,551	2,165	25,873	10,471
HGS	Flooded Wet Meadow Herbaceous Vegetation	975	4,154	1,681	1,476	8,581	3,473
HSA	Subalpine Mixed Herbaceous Vegetation	923	6,022	2,437	1,288	9,159	3,707
HWM	Alpine Mesic Meadows	117	1,046	423	213	2110	854
KRM	Krummholz Woodland	1,288	3,400	1,376	1,543	4,261	1,724
NGS	Perennial Snow - Glaciers	53	1,409	570	55	1,469	594
NID	Irrigation Canals	12	38	16	23	81	33
NIP	Cropland and Pasture	18	689	279	119	8,313	3,364
NLP	Lakes and Reservoirs	276	31,594	12,786	548	32,526	13,163
NRD	Transportation, Communications, and Utilities	11	912	369	15	1,818	736
NRF	Mixed Urban or Built-up Land	182	1,225	496	941	3,763	1523
NRK	Bare Exposed Rock	970	15,038	6,086	1,161	16,427	6,648
NSM	Strip Mines, Quarries, and Gravel Pits	10	74	30	16	108	44
NST	Streams	125	2,705	1,095	144	4,269	1,728

**USGS-NPS Vegetation Mapping Program
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NVS	Non-vegetated Sand Bars	323	1,096	444	472	1,592	644
RAM	Mixed Subalpine Fir - Engelmann Spruce Woodland - Deciduous Shrubland Regeneration	677	4,583	1,855	762	5,107	2,067
RAP	Aspen Woodland Regeneration	279	1,369	554	725	3,896	1577
RLC	Lodgepole Pine - Ceanothus Woodland Regeneration	11	264	107	12	283	115
RLP	Lodgepole Pine Woodland Regeneration	279	4,097	1,658	573	10,319	4,176
RMC	Mixed Conifer Woodland Regeneration	78	551	223	226	1,609	651
SAI	Alder Shrubland	22	109	44	23	110	44
SCV	Ceanothus Shrubland	62	1,779	720	81	2,020	817
SDS	Mixed Deciduous Shrubland	155	734	297	178	808	327
SES	Sagebrush - Antelope bitterbrush Mixed Shrubland	165	7,287	2,949	232	8,654	3,502
SMR	Mixed Tall Deciduous Shrubland	627	3,636	1,472	1,356	7,113	2,878
SSD	Sagebrush Dry Shrubland	1,051	39,957	16,170	2,541	59,274	23,987
SSW	Sagebrush / Shrubby Cinquefoil Mesic Shrubland	323	3,395	1374	724	6,060	2,453
SWL	Willow Shrubland	1,500	10,180	4,120	2,384	14,147	5,725
VCT	Cliff and Talus Sparse Vegetation	1,560	21,587	8,736	2,066	28,742	11,631
VEH	Exposed Hillside Sparse Vegetation	188	1,233	499	834	4,068	1,646
VLP	Limestone Pavement Sparse Vegetation	83	1,884	762	114	3,524	1,426
VRB	Recently Burned Sparse Vegetation	76	4,882	1,976	76	4,942	2,000
VSL	Exposed Lake Shoreline - Stream Deposit Sparse Vegetation	365	1,796	727	578	2,750	1,113
	Total Natural Vegetation Map Units	22,843	247,156	100,021	40,440	435,697	176,321
	Total Sparse Vegetation	2,272	31,383	12,700	3,668	44,025	17,816
	Total Non-vegetated Land-Use	1,980	54,781	22,169	3,494	70,366	28,476
TOTAL		27,095	333,320	134,890	47,602	550,087	222,613

ACCURACY ASSESSMENT CONTINGENCY TABLES AND RESULTS

Instructions on Using the Accuracy Assessment Contingency Tables:

The contingency tables or error matrices found on the following pages present an array of numbers set out in rows and columns corresponding to a particular vegetation map unit relative to the actual vegetation type as verified on the ground. The column headings represent the vegetation classification as determined in the field and the row headings represent the vegetation classification taken from the vegetation map. The highlighted diagonal indicates the number of points assessed in the field that agree with the map label. Conversely, the inaccuracies of each map unit are described as both errors of inclusion (user's or commission errors) and errors of exclusion (producer's or omission errors). By reading across this table (i.e., rows) one can calculate the percent error of commission, or how many polygons for each map unit were incorrectly labeled when compared to the field data. By reading down the table (i.e., columns) one can calculate the percent error of omission, or how many polygons for that type were left off the map. Numbers "on the diagonal" tell the user how well the map unit was interpreted and how confident they can be in using it. Numbers "off the diagonal" yield important information about the deficiencies of the map including which types were: 1) over- mapped - commission errors on the right or 2) under-mapped - omission errors on the bottom.

Table 11. Contingency table for Binary Accuracy Assessment - Level 5.

[illegible]

Table 12. Contingency table for Acceptable Accuracy Assessment - Level 4.

		FIELD SAMPLES – REFERENCE DATA																																	COMMISSION								
																																			Totals	Accuracy	90% Confidence Interval						
																																					-	+					
MAP DATA - PREDICTION DATA	MAP CODES	DSA	DSE	FAP	FBS	FCW	FDF	FEP	FLM	FLP	FMC	FRM	FSF	FWB	HA	HBR	HDA	HFD	HFX	HGL	HGS	HSA	HWM	KRM	RAM	RAP	RLC	RLP	RMC	SAI	SCV	SDS	SES	SMR	SSD	SSW	SWL	12	42%	14%	69%		
	DSA	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	3	19	89%	75%	100%		
	DSE	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	46	76%	65%	88%			
	FAP	0	0	35	0	1	0	3	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	1	0	0	23	87%	73%	100%		
	FBS	0	0	0	20	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	33	73%	58%	87%			
	FCW	0	0	1	0	24	0	1	0	0	0	5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	31	58%	42%	74%		
	FDF	0	0	0	0	1	18	0	0	6	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	28	57%	40%	74%		
	FEP	0	0	1	1	0	0	16	0	1	4	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	2	62	85%	77%	94%	
	FLM	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	27	67%	50%	83%		
	FLP	0	0	0	0	0	0	0	0	53	1	0	1	0	1	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	24	67%	49%	85%		
	FMC	0	0	0	0	0	1	0	0	5	18	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	24	67%	49%	85%		
	FRM	0	0	0	1	2	0	1	0	1	0	16	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	43	72%	60%	85%	
	FSF	0	0	0	0	0	0	0	0	5	5	0	31	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	31	77%	63%	91%		
	FWB	0	0	0	0	0	0	0	0	0	0	0	0	24	0	0	1	0	0	0	0	2	0	1	1	0	0	0	1	0	0	0	0	1	0	0	0	7	86%	57%	100%		
	HA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	36%	17%	56%			
	HBR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	12	0	0	0	24	63%	44%	81%		
	HDA	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	6	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	21	57%	37%	77%		
	HFD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	5	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	23	65%	47%	84%		
	HFX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	15	0	0	2	0	0	1	0	0	0	0	0	0	0	0	2	2	0	0	64	83%	74%	91%	
	HGL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	53	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	74%	63%	85%			
	HGS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	3	37	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	1	50	74%	63%	85%
	HSA	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	28	0	1	0	0	0	0	0	0	0	1	0	1	0	2	37	76%	63%	89%		
	HWM	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	1	12	17%	0	39%		
	KRM	0	0	0	0	0	0	0	0	0	0	0	5	4	0	0	0	0	0	0	0	1	0	20	1	0	0	0	0	0	0	0	0	0	0	0	0	31	65%	49%	80%		
	RAM	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	23	0	0	0	4	0	0	0	0	0	0	0	1	30	77%	62%	91%		
	RAP	0	0	5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	35	0	1	0	1	0	3	0	3	0	0	0	51	69%	57%	80%		
	RLC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	2	0	0	1	0	0	0	0	0	11	73%	46%	99%			
	RLP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	1	0	0	0	0	2	0	0	41	93%	85%	100%			
	RMC	0	0	0	0	0	0	1	0	4	0	0	2	2	0	0	0	0	0	0	0	0	0	0	2	0	1	21	0	1	0	0	0	1	0	0	35	60%	45%	75%			
	SAI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	0	0	0	0	0	0	7	71%	36%	100%			
	SCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	20	1	0	5	1	0	0	30	67%	51%	82%			
	SDS	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	13	0	0	0	0	17	76%	57%	96%			
	SES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	1	0	0	9	89%	66%	100%			
	SMR	0	0	2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	2	0	0	1	2	0	0	0	24	0	2	1	39	62%	47%	76%		
	SSD	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	71	1	0	79	90%	84%	96%		
	SSW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	7	14	0	24	58%	40%	77%		
SWL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	2	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0	1	1	51	61	84%	75%	92%			
OMISSION	Totals	9	20	44	22	29	19	23	2	76	30	23	44	33	13	9	27	17	29	63	43	42	2	25	31	43	8	48	36	13	24	18	12	57	89	20	63	TOTAL SAMPLES = 1106 TOTAL CORRECT = 805					
	Accuracy	56%	85%	80%	91%	83%	95%	70%	50%	70%	60%	70%	70%	73%	46%	89%	56%	71%	52%	84%	86%	67%	100%	80%	74%	81%	100%	79%	58%	38%	83%	72%	67%	42%	80%	70%	81%						
	90% Conf. Interval	-	23%	69%	68%	79%	69%	84%	52%	0	60%	44%	52%	58%	58%	20%	66%	38%	49%	35%	76%	76%	54%	75%	65%	60%	70%	94%	68%	43%	12%	69%	52%	40%	30%	72%	51						

Table 13. Contingency table for Reasonable Accuracy Assessment - Level 3.

MAP DATA - PREDICTION DATA			FIELD SAMPLES – REFERENCE DATA																																	COMMISSION					
																																				Totals	Accuracy	90% Confidence			
																																						-	+		
MAP CODES	DSA	DSE	FAP	FBS	FCW	FDF	FEP	FLM	FLP	FMC	FRM	FSF	FWB	HA	HBR	HDA	HFD	HFX	HGL	HGS	HSA	HWM	KRM	RAM	RAP	RLC	RLP	RMC	SAI	SCV	SDS	SES	SMR	SSD	SSW	SWL					
DSA	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	12	75%	50%	100%
DSE	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	19	89%	75%	100%	
FAP	0	0	40	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	46	87%	78%	96%	
FBS	0	0	0	20	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	23	87%	73%	100%	
FCW	0	0	1	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	33	94%	86%	100%	
FDF	0	0	0	0	1	21	0	0	6	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	31	68%	52%	83%	
FEP	0	0	1	1	0	0	16	0	1	4	1	1	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	28	57%	40%	74%	
FLM	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	50%	0	100%		
FLP	0	0	0	0	0	0	0	0	57	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	62	92%	85%	98%	
FMC	0	0	0	0	0	1	0	0	3	20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	27	74%	58%	90%	
FRM	0	0	0	1	1	0	0	0	1	0	18	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	24	75%	58%	92%	
FSF	0	0	0	0	0	0	0	0	5	1	0	35	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	43	81%	70%	92%	
FWB	0	0	0	0	0	0	0	0	0	0	0	0	24	0	0	1	0	0	0	0	2	0	1	1	0	0	0	1	0	0	0	0	1	0	0	0	31	77%	63%	91%	
HA	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	86%	57%	100%		
HBR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	12	0	0	22	36%	17%	56%		
HDA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	88%	74%	100%		
HFD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	21	62%	42%	82%		
HFX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	17	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	23	74%	57%	91%	
HGL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	59	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4	0	64	92%	86%	98%	
HGS	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	3	43	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	50	86%	77%	95%	
HSA	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	32	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	37	86%	76%	97%	
HWM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	9	0	0	0	0	0	0	0	0	0	0	0	0	0	1	12	75%	50%	100%	
KRM	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	1	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	31	84%	71%	96%	
RAM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	30	100%	98%	100%	
RAP	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	45	0	1	0	0	0	0	0	1	0	0	0	51	88%	80%	97%	
RLC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	11	p	95%	100%		
RLP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	1	0	0	0	0	2	0	0	41	93%	85%	100%		
RMC	0	0	0	0	0	0	1	0	3	0	0	2	2	0	0	0	0	0	0	0	0	0	0	2	0	0	24	0	0	0	0	0	0	0	1	0	35	69%	54%	83%	
SAI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	0	0	0	0	0	0	7	86%	57%	100%			
SCV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	24	1	0	4	0	0	30	80%	66%	94%			
SDS	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	13	0	0	0	0	0	17	76%	57%	96%		
SES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	1	0	0	9	89%	66%	100%		
SMR	0	0	2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	1	2	0	0	0	26	0	2	1	39	67%	53%	80%		
SSD	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	75	0	0	79	95%	90%	100%		
SSW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	5	16	0	24	67%	49%	85%		
SWL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0																						

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Table 14. Summary of map unit accuracies for omission and commission errors.

MAP CODE	Level 5 – Binary		Level 4 - Acceptable		Level 3 - Reasonable		Percent Change from Level 5 to Level 3	
	User's Accuracy	Producer's Accuracy	User's Accuracy	Producer's Accuracy	User's Accuracy	Producer's Accuracy	User's Accuracy	Producer's Accuracy
DSA	44%	31%	44%	31%	90%	75%	46%	44%
DSE	85%	89%	85%	89%	94%	89%	9%	0%
FAP	77%	72%	80%	76%	87%	87%	10%	15%
FBS	78%	78%	91%	87%	91%	87%	13%	9%
FCW	81%	67%	83%	73%	89%	94%	7%	27%
FDF	89%	55%	95%	58%	95%	68%	6%	13%
FEP	62%	46%	70%	57%	89%	57%	27%	11%
FLM	50%	50%	50%	50%	50%	50%	0%	0%
FLP	63%	81%	70%	85%	74%	92%	11%	11%
FMC	39%	44%	60%	67%	77%	74%	38%	30%
FRM	57%	54%	70%	67%	95%	75%	38%	21%
FSF	63%	58%	70%	72%	80%	81%	17%	23%
FWB	68%	74%	73%	77%	80%	77%	12%	3%
HA	46%	86%	46%	86%	60%	86%	14%	0%
HBR	89%	36%	89%	36%	89%	36%	0%	0%
HDA	58%	48%	59%	52%	81%	88%	23%	39%
HFD	53%	48%	71%	57%	93%	62%	40%	14%
HFX	34%	48%	52%	65%	61%	74%	26%	26%
HGL	77%	72%	84%	83%	86%	92%	9%	20%
HGS	86%	72%	86%	74%	90%	86%	4%	14%
HSA	46%	53%	57%	80%	76%	86%	30%	33%
HWM	50%	8%	100%	17%	100%	75%	50%	67%
KRM	75%	58%	80%	65%	93%	84%	18%	26%
RAM	65%	67%	74%	77%	88%	100%	24%	33%
RAP	76%	63%	81%	69%	90%	88%	14%	25%
RLC	89%	73%	100%	73%	100%	100%	11%	27%
RLP	78%	88%	79%	93%	86%	93%	8%	5%
RMC	49%	51%	58%	60%	73%	69%	24%	17%
SAI	38%	71%	38%	71%	55%	86%	16%	14%
SCV	81%	57%	83%	67%	100%	80%	19%	23%
SDS	67%	71%	72%	76%	87%	76%	20%	6%
SES	50%	89%	67%	89%	73%	89%	23%	0%
SMR	38%	62%	42%	62%	50%	67%	12%	5%
SSD	70%	80%	80%	90%	83%	95%	13%	15%
SSW	61%	58%	70%	58%	80%	67%	19%	8%
SWL	77%	82%	81%	85%	88%	85%	12%	4%
Average	64%	62%	72%	69%	83%	80%	18%	18%

Common Map Errors

Of the assessed map units, some had lower than expected levels of accuracy. By carefully examining these discrepancies we found some common issues that seem to explain most of the errors, these include:

1. Perspective: Many of the errors occurred when a polygon was classified with a very similar, but different map unit than the one identified by the field ecologist. This can happen because the photo interpreter and the field ecologist see the vegetation differently. For example, the photo interpreter sees the cover of shrubs and herbaceous vegetation over a large area, while the field ecologist assesses the cover in a much smaller area. Also the field ecologist can thoroughly assess the understory whereas the interpreter may have his view partially or completely blocked by overstory canopy. Different perspectives can lead to different estimates of cover and differing conclusions as to the correct plant association or map unit.
 - Example: Both big sagebrush map classes (SSW and SSD) had commission errors with the grassland type (HGL). This could likely be due to viewing less cover of sagebrush on the ground for a particular area. Conversely on the photography these areas may have appeared to be small and part of a larger sagebrush unit.
2. Rare Types: Some map classes only occurred in a few homogeneous stands that were large enough to map. Consequently not enough accuracy assessment points were acquired resulting in very large confidence intervals. The small sample size of these map classes produced an error that may or may not be indicative of the actual ability of the photo interpreters.
 - Example: Limber pine is found throughout most of GRTE but was only found to occur in a few pure stands that were larger than the minimum mapping unit. Only two accuracy assessment points were taken in this type, one was right and one was wrong. This resulted in 50% accuracy for the FLM map class and confidence intervals of 0 to 100%.
3. Forest vs. Krummholz vs. Regeneration: The forest, krummholz and regeneration map classes often contained the same tree species and were mapped based on both evidence of past disturbance (fire, avalanche) and the size of the trees. Often the difference between trees big enough to be considered forest and those still in an early succession or stunted stage was vague and undefined. This left the choice up to the individuals on the field crews and the photo interpreters. Again due to perspective, a few large trees may have appeared to warrant a forest designation when in fact they were the only survivors in a larger regeneration unit or small pockets of regeneration may have been an inclusion in a larger forest unit. Similarly, relatively tall yet stunted trees may have been labeled forest on the ground but on the aerial photos appeared as krummholz.
 - Examples: The FEP map class was confused 3 times with both the RAP and the RLP regeneration map classes. This is likely a case of being able to see large enough trees on the aerial photos but on the ground they were actually part of an early succession unit. KRM map class was confused 4 times with both the FSF and FWB classes. Again, this was likely due to subtle differences between the tall stunted trees and actual krummholz.
4. Physiognomic and Growth Similarities: To accurately photo interpret vegetation a scientist needs the ability to distinguish obvious growth characteristics for each dominant species. For example spruce and fir trees typically have pointed crowns whereas Douglas firs are usually bushier in appearance. Likewise shrubs are almost taller than herbaceous vegetation and trees are taller than shrubs. By combining these and other photo signatures a photo interpreter can develop a model of the vegetation across a landscape. At GRTE several

common species presented themselves in numerous growth and physiognomic forms that successfully mimicked other vegetation. This led to confusion and mis-classification on the aerial photos.

- Examples: The Douglas-fir map unit (FDF) was confused with the lodgepole pine unit (FLP) six times. This is likely a result of some lodgepole pine at GRTE growing in open meadows. In these situations the lodgepole pines grow bushier and appear on the photos as Douglas-fir trees. Also confusing were herbaceous vegetation and shrublands. At GRTE moisture is a limiting factor. In wet areas forbs can grow lush and tall. Conversely dry areas may support stunted shrubs. This phenomenon is likely evidenced in the confusion of the willow map class (SWL) with four other herbaceous map classes, where the willow was likely short and growing in similarly dry habitats as grasses and forbs. Conversely, forbs growing in wet mountain valleys appeared tall and lush much like willows. This may explain the two times that the HSA map class was confused with the willow.
5. Species Overlap: One of the largest sources of error and a constant issue across all of the map units was the overlap in common species among different map classes. The vegetation at GRTE was diverse and a majority of species occurred across multiple life zones. This was compounded by the high level of disturbance from fire, avalanche, and water erosion. The overall variability in the terrain also created many transition areas containing different mixes of vegetation. The presence of multiple dominant and indicator species caused for confusion when trying to both key the vegetation on the ground and delineating discreet units on the aerial photography.
- Example: The mixed conifer (FMC), mixed evergreen - poplar (FEP) and the mixed conifer - cottonwood riparian forest (FRM) map classes all had numerous errors with themselves and with other forest map classes. This is

likely a result of similar species occurring in various degrees across all of the forest map classes.

4. DISCUSSION

Grand Teton National Park is truly a special place combining a near pristine mix of alpine mountains, lush valleys, and arid plains. Across this vast landscape a wide array of plant and plant communities thrive in habitats typical of Northern Rockies and the Greater Yellowstone Area. During this project we found it very challenging to both classify and map the vegetation into meaningful context for all levels of interest (local, regional and national). However, with patience and persistence we feel that we were fairly successful as evidenced by the 40 new plant associations documented for GRTE, the high level of detail (over 40,000 polygons), and the initial accuracy of more than 82%. Now that it is done, we are proud of our efforts and hope that they will be used and improved upon in the future.

—A few thoughts and suggestions:

4.1 Field Survey

The extreme terrain at GRTE made for very strenuous and difficult data collection. Thankfully the field crews were up to the task and were able to hike into almost all areas of the park. Considerable planning by dedicated coordinators was essential to this effort on many levels. First they were able to maintain moral and put together compatible people that could effectively work together. Second they were also able to strategically plan back-country overnight trips and rotate these among the crews including securing permits for back-country cabins and camp sites. Third they were able to maintain control over the data collection, adjusting work where needed. Finally they were able to coordinate with the other cooperators and contractors in order to make sure the project was on track and on time.

Another aspect of the field work that made this project successful was the comprehensive training. At the beginning of every field season GRTE staff would conduct a training session that would go over the park rules and regulations, how to use the

GPS, how to use the radio, and back country safety instructions. This was in addition to the normal plot and AA data collection training. For GRTE we also gave the field crews instructions on how to collect detailed fire fuels data and record the presence of exotic species. All of this training made for very prepared and highly skilled field crews.

The special opportunity to collect vegetation data in Grand Teton National Park created a difficult juggling act of trying to get as much data as possible while still being productive and getting the project completed on time. During the first field season in 2002, WYNND collected very detailed plot data using a Modified-Whittaker technique. In addition very detailed fire fuel data was also collected. This information, although very useful and precise, slowed production to around 2 plots per day on average for each field crew. As a result the amount of plots collected during the entire year did not meet expectations. This was adjusted for the next field season by using NPS staff, collecting project specified macro plots and backing off on the amount of fire fuels data collected. This combination effectively righted the ship putting the project back on track.

Overall, the plot data collected during this project was extensive, with plots, observation points, and AA points combining to total over 1800 newly sampled sites with vegetation, environmental and fuels data and ground photos. This rich dataset creates a new "baseline" from which to evaluate past and future management policies and will be useful for years to come for various planning and resource management activities including fuels and fire management.

4.2 NVC Classification

While it may appear there are a large number of associations described for a study area of this size, each association was sampled at least three times in GRTE. The majority of the associations were already existent in the NVC, with many additional associations described by previous authors or acknowledged as seral stages of known habitat types. Some of the lower elevation communities occur in the study area environs, but not within the park boundaries.

The addition of 1100+ data points through the accuracy assessment data collection process

added several associations that had not been sampled in the original 600+ plots used to classify the vegetation. In several cases one plot of an association had been recorded in the original data collection, but the presence of the association on the landscape was substantiated by having numerous AA points for these types. This was largely due to the fact that the AA points were randomly selected and as such the crews navigated to them without bias in determining sample location. In the end, having the abundance of accuracy assessment points helped complete and verify the classification.

The initial data collection may have been somewhat biased by the preliminary list of associations and target numbers of samples in each association. For example krummholz and aspen-conifer mixed forests types were not included in the preliminary classification so 2002 field crews did not sample these types. These were later added as map units and consequently, showed up in the AA data. The 2003 field season was less influenced by the preliminary associations. Future projects may want to place less emphasis on the preliminary associations and instead collect more observation points (similar to AA data).

There are still some unresolved classification issues that will need additional survey work to further define various plant associations. For example some remaining sparse vegetation types need clarifying and vegetation types identified in the AA point data could be classified with more plot data. Also, anthropogenic disturbance of many of the lowland riparian vegetation types created challenges in classifying them. More data collection might increase our understanding of these types.

4.3 Aerial photos and Orthophotos

The acquisition of new orthophotos in addition to the aerial photography was critical to our mapping efforts at GRTE. We found that these not only saved time in the digitizing and transfer stage but also aided tremendously with map verification. The true color orthophotos provided the utility of a map with the functionality of an aerial photo. In other words, we could easily prepare and plot draft maps that contained both our polygon outlines and a true color representation of the vegetation. In the past we would have had to either plot polygons on less-

clear black-and-white orthophotos or use a clumsy combination of non-rectified aerial photos and simple color plots. Further, as a digital product they afforded us the capability of easily reproducing them for multiple users.

We would suggest that future projects strongly consider purchasing new orthophotos in addition to the aerial photography for the following reasons: 1.) It reduces the amount of time needed for digital transfer or digitizing of the line work; 2.) It helps minimize shadows and scale distortion in areas with large changes in elevation; 3.) It increases the accuracy and thoroughness of the mapping by having *recent*, true-color basemap imagery; 4.) It allows for more useful and easier dissemination of draft products to field crews, mappers, ecologists, etc., and 5.) It is a great stand-alone product that can be used in many other applications.

4.4 Photo-interpretation and Map Units

Inherent to vegetation mapping projects is the need to produce both a consistent vegetation classification and a comprehensive set of map units. Typically the systems are very similar, but when using a national classification such as the NVC there is usually not a strict one-to-one correspondence. This is due to the remote sensing nature of photographic interpretation and its ability to only delineate map units based on complex photo signatures. Subtle vegetation characteristics that can be seen on the ground are not necessarily the same as those apparent on the photos. Canopy closure, shadows, and timing of the photography can also distort or obscure photo signatures.

For a highly diverse park such as GRTE we suggest that a completed (or nearly completed) classification be in place before the actual interpretation begins. This will avoid having to revisit or, worst case, redo the photo-interpretation based on classification changes. Ideally, plot sampling should begin early in the project, followed by analysis of the vegetation data to tie it to the NVCS. The resulting nearly completed list of NVC associations could then be used to construct meaningful map classes before any ground-truthing or interpretation of the aerial photographs. Also critical is deciding early in the process how to characterize and describe common types that are widely

distributed but highly variable in species composition.

In the future it is recommended that ecologists produce a draft classification after the first field season is completed. This classification can be used to target additional data collection in poorly understood types and/or geographic areas. We also recommend that preliminary map units be developed prior to the first field season and used to help allocate samples to map units not well represented by NVC associations. This will help insure mappers have a minimum number of training site data to begin mapping.

To ensure effective mapping, more map verification or ground-truthing needs to occur at GRTE. We feel that this project in many ways should be viewed as an initial effort that needs to be refined and periodically updated. To do this, GPS points, mapping, surveying, or field checking the existing aerial photography and map on the ground could greatly improve the quality and accuracy of this project.

4.5 Accuracy Assessment

The accuracy assessment at GRTE consisted of three levels using fuzzy logic parameters. This range of accuracy allows us to look not only at where the error occurred but also how the accuracy improved as we decreased our tolerances. We believe that this is an important tool for examining how well the map units can be recognized on the ground and how well they can be mapped. Vegetation types that improved dramatically from the binary to the reasonable level may indicate types that are hard to split from one another.

Also by incorporating the three fuzzy levels we were able to document all of the subjective processing of the AA points. In other words, the binary level results represent the initial accuracy without any manipulation. The acceptable level reports the first round of combining the initial field calls with the field crews' second and third choices. Finally the reasonable level shows the accuracy of the map when factoring in all possible choices along with any over-rulings. Future users of this product might find that one level of accuracy more useful than the others for certain projects.

4.6 Future Recommendations

Park Specific

In summary, this project represents the best efforts put forth by one group of people over a relatively short period in time. In order to create the best possible “long-term” vegetation classification for GRTE and the most accurate and detailed GIS layer, this project should be viewed as a place to start rather than an end product. In other words, present and future NPS staff should be encouraged to scrutinize this project, building from its strengths and bolstering its weaknesses. By keeping in mind that this project was only a snapshot in time, future efforts can help complete our understanding of the vegetation at GRTE and how it changes over time. We hope that the products presented here will help focus and direct future efforts. We propose the following recommendations:

1. The high diversity of plant species and inaccessibility of the park warrants periodic **field surveys** to various remote locales by experienced ecologists. In this way new plant associations could be discovered and existing types could be updated.
2. Remote sensing does not replace on-the-ground knowledge provided by GPS linked plots, observations and ground verification. Time limitations curtailed the amount of **ground-truthing** done with the map. As opportunities arise, maps should be sent into the field to be verified by competent crews. Also GPS data and other GIS layers should be used to improve and update the spatial data. We feel strongly that this product should not be static but change with current and accurate information.
3. To better understand the limitations of the map, the **accuracy assessment** data presented in **Tables 11-13** should be thoroughly reviewed by the park staff. Map classes with low accuracy should be examined to see if they could be improved with future studies using ground-truthing or other remote-sensing formats (i.e. color infrared, hyperspectral, etc). Also, landscape modeling may help to tease out the location of specific types based on specific habitat information. Finally for some applications it may make sense to combine map classes into higher units, such as

alliances or ecological systems to improve their accuracy.

4. For monitoring purposes, **change over time** could be addressed by similar remote sensing projects. New aerial photos or compatible digital imagery taken 5, 10, 20+ years from now would capture this change. This new imagery could then be used to create up-to-date vegetation layers and compare changes in both specific vegetation stands and across the entire park.
5. In the future, resource management personnel could link the habitat for **species of concern** to specific associations and map units. This would allow them to locate potential sites by using vegetation map and environmental variables (e.g. Subalpine-spruce forest on north slopes, or whitebark pine on granitics).

Program Specific

Accuracy Assessment

Over the course of many projects, and again at GRTE, we have witnessed the difficulty of classifying complex plant assemblages into discrete associations. Although subjectivity is inherent to the work we still strive for a balance between impartiality and accuracy/precision. Nowhere is this task more difficult than in the accuracy assessment stage. During this process we test the map in unfavorable spots by placing stratified random points in heterogeneous and non-uniform areas. Points fall on what are described as “ecotones”, “mosaics”, “edges of multiple associations” and “species gradients”. These difficult sites test the ability of the field ecologists to be consistent and the complex mixing of species is difficult to pigeon hole into the National Vegetation Classification System. As a result we usually spend untold hours cleaning and processing the AA data before we ever use it. This reduces our efficiency and erodes our confidence in the final map products even before it yields a lower than expected map accuracy. To partially correct these short-comings we ultimately enter into an impromptu cycle of assessing the assessment, making corrections, redoing the assessment, assessing the second assessment and so on.

To break this sequence we propose that the national program adopt multi-level accuracy

assessments with fuzzy logic and incorporate these into the entire AA process. Specifically we recommend that the national program adopt the Level 3 Acceptable Accuracy we presented in this report as the standard. We would also urge that distinct guidelines be created for implementing this process using feedback from cooperators and the end users of the products.

At GRTE we found the following steps to be extremely useful for conducting a multi-level AA:

1. **Field Crew Discussion:** We realized that discussing the AA process at length up-front with the field crews before the data collection allowed them to better understand the process and what was expected from them. This provided an opportunity to demonstrate how to analyze difficult sites and record all possible choices. Our goal was to have the crews make as many of the tricky classification calls in the field as possible rather than having to do this later in the office.
2. **AA Form and AA Key Modifications:** In the past the field key (used to determine the plant associations) and the field data form lacked any reference to the actual map codes or map classes. Instead the data was processed in the office and each form had to be cross-walked from the associations back to their respective map classes. Needless to say, this was a time consuming step that also introduced subjectivity; especially if the plant association occurred within multiple map classes.

At GRTE we addressed this by including all possible map codes for each association in the key along with a brief description (**Appendix C**). We also gave the field crews definitions and descriptions of each map code. Further we also added blanks on the field form for recording the primary, secondary, tertiary map codes and space for two others that might be in the surrounding area (**Figure 11**). In this manner the field crews were the ones primarily responsible for analyzing an AA site and determining **both** the association(s) and the map classes present.

3. **Automating the AA Process:** We found a tremendous benefit to having the map codes recorded on the field forms during both the

processing stage and when it came time to determine the different levels of accuracy. First, by having the map codes on the form and then entered into the database we could quickly convert the points into GIS overlay files without having to recode. The resulting layers exactly matched the attributes on the map, allowing us to produce contingency tables and calculate the kappa index almost effortlessly.

We also used the multiple map codes recorded on the forms to help determine the three levels of accuracy. For binary we simply used the primary (1) map code choice, for reasonable we used the primary along with any correct secondary (2) and tertiary choices (3) and for acceptable we used any of the first three choices along with any recoded in the adjacent map code blanks (**Figure 11**). By weeding out the correct matches directly off the form we were left with a smaller set of incorrect points to thoroughly review.

Research Opportunities

At GRTE, the NPS staff, cooperators and contractors working on this project viewed the classification and mapping of the existing vegetation to be such an important component of the ecosystem that this project was used as a springboard for further research. A few examples follow:

Fire modeling: A major component of this project was documenting the fire fuel data at the sample plots. This was in addition to the standard plant species cover and environmental information normally collected. Analysis of the fire fuel data revealed limitations in the distribution of the sample sites in timbered areas. In other words, not enough fuels data was collected. This led to a cooperative agreement between GRTE, BOR and Colorado State University (CSU). Through this agreement a graduate student was funded to collect more fire fuels data in areas that had similar vegetation but different fuel loadings. For example a very large stand of homogenous lodgepole pine might have multiple levels of dead and down fuel in the understory but only one sample plot.

By collecting more fire fuels data researchers at CSU hope to create a landscape model that would give an accurate representation of the fuels across GRTE. This digital GIS layer when coupled with the vegetation data could be directly imported into existing NPS fire modeling software such as FARSITE. Having these layers gives the fire professionals very useful and powerful prediction tools to plan and predict the growth of both prescribed and wildland fires. In addition, not only are the products themselves valuable so too are the protocols that were used to develop them. It is anticipated that the fire fuel methods developed for GRTE will set the standard and be used in vegetation mapping projects at other National Parks.

Rare plants: Another issue for National Parks is inventorying and monitoring rare plant populations. When a new population of a rare plant is located habitat information collected at that site can be extrapolated to this map to find other potential locations. This should help botanists determine other sites with the same existing vegetation. In this manner, research efforts could be tailored to high probability areas and new populations could be found. On the monitoring side, this project will provide baseline acreages of the rare plant habitat along with those of its neighboring plant communities. Similar studies in the future when compared to this project would yield change over time and answer questions about whether this habitat is expanding or being encroached on by other vegetation.

Exotic Plants: The presence of noxious and exotic weeds in National Parks is a constant

threat to their biodiversity. It has been shown that non-native invasive plants can displace native vegetation and seriously lower diversity in plant communities. By combining this map with known locations of weedy plants researchers should be able to predict their establishment and spread, find other vulnerable areas, and prioritize eradication efforts.

Habitat for animals: Analysis using this project could determine areas that are being used by animals as grazing/browsing sites, hiding areas, nesting sites, or movement corridors. This project when combined with wildlife studies such as radio collaring or GPS tracking could also reveal important home range, feeding and migration patterns. Overall, it is hoped that this project will help correlate the plant communities to wildlife and the ways they interact with the landscape.

General Plant Ecology: Having an existing vegetation map provides a very powerful tool for examining ecological processes. In a GIS other layers such as geology, hydrology, elevation, and soils could be overlain and compared to the vegetation. Complex interactions between these layers could yield important information about growth rates, regeneration after disturbance, biomass distribution, avalanche acreage, stream morphology, etc. In the future other GIS layers will be created and improved. There are numerous other interactions worth studying, including: the relationship with soil, pollution, archeological sites, weather patterns, fire, human impact, etc.

Figure 11. Example of the modified AA field form used at GRTE.

Field Point Code 04	Database Point Code	Surveyors:
Date ____/____/2004	Quad Name	Aerial photo #
Plot Pictures Taken (Y/N)	State <u>WY</u>	Park Name <u>GRTE</u>
Park Site Name	Dominant Association 1)	
Alternate Association Name 2)	Alternate Association Name 3)	
Map Code 1)	2)	3)
Adjacent Association within 50m 1)		
Adjacent Association within 50m 2)		
Adjacent Map Codes within 50m 1)	2)	

The highlighted blanks were used in the following levels of accuracy assessment: Map Code 1) = Binary, Map Codes 1) + 2) and 3) = Acceptable, and Map Codes 1-3 + Adjacent Codes within 50m 1) and 2) = Reasonable.



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