MAPPING LAND COVER TO ESTIMATE SAGE GROUSE HABITAT WITHIN THE CEDAR CREEK ANTICLINE AND SURROUNDING STUDY AREA

FINAL REPORT OCTOBER 2008

Prepared by

Patrick Wright & Dave Wegner
Science Applications International Corporation
Under Contract with the Bureau of Reclamation

Technical Memorandum No.86-68211-09-02
Remote Sensing and GIS Team
Technical Service Center
Bureau of Reclamation
Denver, CO

DATE DUE

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WATER RESOURCES MANAGEMENT.....FOR THE FUTURE

RECLAMATION'S MISSION

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

DEPARTMENT OF THE INTERIOR'S MISSION

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering wise use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. Administration.

The Remote Sensing and Geographic Information Team, organized in 1975, provides assistance and advice regarding the application of remote sensing and geographic information systems (GIS) technologies to meet the spatial information needs of the Bureau of Reclamation and other governmental clients.

This report was prepared for the United States Bureau of Land Management, Miles City Field Office by the Remote Sensing and GIS Team of the Bureau of Reclamation's Technical Service Center, Denver, CO as Technical Memorandum

No. 86-68211-09-02

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EXECUTIVE SUMMARY

In 2008, the Bureau of Reclamation's Remote Sensing and Geographic Information Team (RSGIT) in collaboration with the Bureau of Land Management Miles City Field Office mapped sagebrush and other land cover in a study area in and around the Cedar Creek Anticline within the Williston Basin. The study area fell within portions of NW South Dakota, SW North Dakota and SE Montana representing approximately 1,126,000 acres. The project utilized a methodology developed from a collaboration between the Bureau of Reclamation and the South Dakota Department of Game, Fish & Parks designed to research the effectiveness of combining the newer technologies high resolution multi-band color infrared digital imagery along with object oriented image processing for the identification and mapping of sagebrush over a large area in a cost effective manner. The objective of the project was to cost effectively collect and analyze imagery to determine the extent of sagebrush vegetation communities at a level of detail to assess vegetation community relationships (Wright, P., Wegner D. 2007). To this end the South Dakota mapping project was a success. The costs incurred by using the methodology represented in the Cedar Creek project to map 11 land classes have been estimated at $.40 to $.80 per-acre compared to the $2.00 to $3.00 per-acre using the traditional methodology of photo-interpretation of hard copy aerial photography, transfer and digitizing the classified data into a geo-referenced format.

Sagebrush represents an important ecosystem to the study area, especially for sage grouse and other associated obligate plant and animal species that depend on this vegetation assemblage. The big sagebrush shrub community is considered the most threatened of all communities in Montana, mainly due to the fragmentation and degradation of habitats including fire, grazing, harvest and noxious weed management, mining and energy development, power lines and generation facilities, recreation, roads and use of motorized vehicles, and agricultural conversion, Montana Sage Grouse Working Group (2005). Within the study area *Artemesia* species vary from the herbaceous sageworts and wormwoods to two woody species, silver sagebrush (*A. cana*) and Wyoming big sagebrush (*A. tridentata*).

The ADS40 digital imagery was acquired in early October, 2007. Processing and delivery of the final image product took 4 months, with a delivery date of February 2008. The imagery was provided as a series of 6 individual tiles in ERDAS .img format. Each image tile was composed of the infrared, red and green spectral bands. From October 29, 2007 through November 2, 2007, 145 representative locations distributed throughout the study area were visited and ground truthed. Coordinates were monumented using a hand held real-time differentially corrected global position system unit (GPS) along with landcover information pertaining to land cover composition and estimated canopy cover density.

BUREAU OF LAND MANAGEMENT, MCFO SAGE MAPPING

Dominant land cover types within the study area including areas representing sage, sage riparian, grasses, sparse vegetation, agriculture, conifers, developed, energy related, open water, wetland and riparian assemblages were mapped, quantified and provided to the BLM along with the ADS40 imagery to be used in geospatial analysis of potential habitat for sage grouse and obligate species.

The sum acreage calculated for each class within the study area:

1) Wetland - 430 polygons = 760 acres
2) Open Water - 2,839 polygons = 3,907 acres
3) Riparian – 11,020 polygons = 36,163 acres
4) Sage Riparian – 11,562 polygons = 35,699 acres
5) Sage – 94,649 polygons = 479,726 acres
6) Agriculture – 2,421 polygons = 260,886 acres
7) Conifers – 3,845 polygons = 10,036 acres
8) Developed – 2,466 polygons = 15,185 acres
9) Energy – 1,175 polygons = 4,708 acres
10) Sparse Vegetation – 39,896 polygons = 112,971 acres
11) Grasses – 10,462 polygons = 166,265 acres

TOTAL ACREAGE = 1,126,306

TOTAL # POLYGONS = 180,765

INTRODUCTION

The Bureau of Reclamation's Remote Sensing and Geographic Information Team (RSGIT) in collaboration with the Bureau of Land Management, Miles City Field Office has successfully completed the mapping of sagebrush and 10 other land covers within in a defined study area in and around the Cedar Creek Anticline within the Williston Basin. This project utilized a methodology developed from the 2006-2007 research collaboration between the Bureau of Reclamation and the South Dakota Department of Game, Fish & Parks to study the effectiveness of combining the newer technologies high resolution multi-band color infrared digital imagery along with object oriented image processing for the identification and mapping of sagebrush over a large area in a cost effective manner. The South Dakota mapping project successfully completed the mapping of sagebrush and other land cover within and intersecting publicly owned lands found in a study area representing the western portions of Butte and Harding Counties in South Dakota. The objective of the South Dakota mapping project was to cost effectively collect and analyze imagery to determine the extent of sagebrush vegetation communities at a level of detail to assess vegetation community relationships and provide land and resource managers the information required to make decisions regarding future conservation actions. To this end the South Dakota mapping project was a success. In retrospect, by only mapping publicly owned lands within the study area (due to cost constraints) the data was limited in the analysis of connectivity. The Cedar Creek mapping effort covers both private and public land within the study area.

1.1 PROGRAM BACKGROUND

Vegetation is a sensitive indicator of multiple environmental factors, including precipitation, temperature, soil, geology, water quality, and wind. In summary, vegetation affects a number of important processes, including snow accumulation, soil moisture depletion, surface runoff, infiltration, and erosion (Lewis, 2004). Vegetation input to streams (coarse- particulate organic material) and inputs of chemicals applied to vegetation are additional factors affecting stream quality.

The Montana Sage Grouse Working Group (2005) delineated sage grouse ecotypes in an effort to identify geographic areas that have similar capabilities and potential for management of habitats occupied by sage grouse. Ecotypes are based on soils, climate, vegetation patterns, and sage grouse distribution. There are two major Sagebrush ecotypes found in Montana, the Mountain Foothills Mixed Sagebrush and the Wyoming Big Sagebrush-Silver Sagebrush. This studies project area falls within the Wyoming Big Sagebrush- Silver Sagebrush ecotype (MSGWG 2005).

Healthy, properly functioning sagebrush communities support sage grouse and a variety of other native wildlife and vegetation species. Sagebrush communities in Montana are generally classified into 2 primary ecotypes (MSGWG 2005) which are influenced by a variety of environmental variables. Among these variables are soil texture, moisture regime, past fire, past herbicide spraying, topography, grazing history, grazing accessibility, and recent weather patterns (MSGWG 2005).

The characteristics of vegetation and vegetation distribution at any particular site are the result of superimposed environmental variables. Functional sagebrush vegetation communities are defined by having a heterogenous matrix/patches of shrubs, grasses, and forbs of varying heights, canopy coverage, and species. Sage grouse have evolved with and adapted to and require a heterogenous patchwork of vegetation communities to meet their life history requirements and ultimately their survival (Connelly et al. 2000). Contiguous large blocks of healthy sagebrush-grassland are best suited for sage grouse survival (MSGWG 2005). Sagebrush distribution is a limiting factor for sage grouse.

Characteristics of the Wyoming Big Sagebrush – Silver Sagebrush ecotype in the project area is defined as sagebrush steppe ranging from elevation 2000-3500 ft (607-1067m) on nearly level landscape or gentle slopes except for locally steep dissected river breaks. Stands of ponderosa pine are found at higher elevations and are intermixed with prairie across the landscape (MSGWG 2005). Major drainages include the Tongue, Powder, and lower Yellowstone rivers. Mean annual precipitation across the ecotype is 13.1 inches (33.3 cm). Wyoming big sagebrush (*Artemesia tridentate wyomingensis*) is found on fine textured soils. Silver sagebrush (*Artemesia cana viscidula*) is found in more medium textured, non-saline soils where moisture is higher. The other major shrub species found in this ecotype is greasewood (*Sarcobatus vermiculatus*) which occurs in dense clay saline or alkaline soils. Dominant understory species include western wheatgrass (*Agropyron Smithii*), prairie junegrass (Koleria cristata), needle-and-thread (Stipa comata), and green needlegrass (S. viridula) (MSGWG 2005).

Sagebrush Distribution

Sagebrush taxa occur on an estimated 109 million hectares in the region (Beetle 1960, McArthur and Plummer 1978). Most of the more than 25 million ha of Montana rangeland contain at least 1 sagebrush taxon (Wambolt, C.L. and M.R. Frisina 2002). Within Montana there are 12 taxon of Artemesia tridentatae and 4 taxon of Artemesia non-tridenatae 9 subshrubs and shrubs. Within the study area *Artemesia* species vary from the herbaceous sageworts and wormwoods to two woody species, the silver sagebrush (*A. cana*) and Wyoming big sagebrush (*A. tridentate ssp. wyomingensis*).

Opinions differ on historic sagebrush distribution. Vale (1973, 1975) concluded that intermountain rangelands were generally dominated by big sagebrush. His research concluded major areas of the intermountain west were covered by "thick stands of brush" when the first Europeans arrived. Gruell (1983) compared early (1870s) and present day photos of areas in Montana and observed a variety of coverages ranging from increased sagebrush density to a decrease in other situations.

Sagebrush has been demonstrated to be a critical food source for several wildlife species during various seasons of the year, particularly fall, winter and spring (sagebrush pub). Cole (1955) found three different species of sagebrush comprised 93% of the winter diet of antelope in Montana. Studies by Wilkins (1956) determined the importance of sagebrush to mule deer feeding and Wambolt (1996) found similar use of the species by elk.

Wallerstad et al. (1975) determined that sagebrush comprised 62% of the yearlong diet of adult sage grouse and essentially 100% of their winter diet in Montana.
Sagebrush provides an important ecosystem service in Montana. In other Great Plains sagebrush habitats, Richards and Caldwell (1987) identified the ability of *Artemesia tridentata* to hydraulically lift water from deep in the soil into the upper soil profile; capture snow (Tweit 2000); hold soil from erosion (Lewis 2004); and provide forage for pronghorn antelope (*Antilocapra Americana*), mule deer (*Odocoileus hemionus*), pygmy rabbits (*Brachylagus idahoensis*), and sage grouse (Lewis 2004). Additional ecosystem services include cover for all of the above species, and nesting sites for sage grouse and other obligate birds including Sage Thrasher (*Oreoscoptes montanus*), Brewer's Sparrow (*Spizella breweri*), and Sage Sparrow (*Amphispiza belli*) (Paige and Ritter 1999). Sagebrush has other assets for wildlife in addition to forage and cover. Sagebrush's thick canopy protects understory vegetation from livestock grazing (MSGWG 2005). Understory vegetation can be a valuable food source for wildlife. Additionally, the crowns of sagebrush plants tend to breakup and weaken hard crusted snow on winter ranges making it easier for big game to access understory plants for foraging.

Spatial patterns of natural sagebrush recruitment are generally unrelated to proximity of a potential seed source, suggesting that occasional events in the tail of the seed dispersal curve are disproportionately important in influencing patterns of seedling abundance. Furthermore, seedlings tended to occur in clumped distributions at small spatial scales. These combined results support a "nucleation" pattern of sagebrush reestablishment, in which a small amount of seed reaching microsites appropriate for germination and establishment are far more important in influencing recovery than a large amount of seed dispersed adjacent to an unburned edge or island. Future efforts at accelerating big sagebrush reestablishment can likely be improved by ensuring the successful establishment of fewer individuals across the burned landscape, rather than planting large islands or mass seeding for individuals unlikely to survive germination and establishment (Forman et al. 2007).

Summary of Definitions for Vegetation Survey

For our analysis, we separated the vegetation in the study area into classes. A brief description is provided here with a more details description provided in Section 2.4.

Sage = primarily sage (greater than 5 %) of mixtures of sage taxon. On fine textured drier soils big sagebrush dominates. On medium textured wetter soils silver sage is more abundant. Dominant understory species include western wheatgrass, prairie junegrass, and varieties of needle grass.

Riparian = usually along a river or stream course. Dark red on the image. May be planted groves of trees associated with a farm or ranch if located in proximity to other sage grouse habitat. Vegetation commonly found include willows, cottonwoods, cattails and other small shrub species. Identified as dark red in color.

Sage- Riparian = mix of sage and riparian vegetation. May or may not be associated with a perennial water source. May include mix of willows, ash, juniper/pinon pine and sage & grasses. Typically shaded red or pink with definitive shrub signatures. Stream course obvious in some situations.

Open Water = reservoirs, stock ponds or streams. Upper ends or edges may exhibit characteristics of wetlands.

Wetlands = definitive vegetation (usually cattails and sedges) associated with ponds or at the upper section of reservoirs. Some seasonal grasses may be associated as wetlands dried up during the summer season.

Sparse Vegetation = limited vegetation, white reflection from image which may be rock exposures or alkaline deposits

Agriculture = clear tractor/equipment or combine tracks on fields. May include all irrigated lands and none irrigated agricultural fields. Often associated with "developed" lands and "energy" polygons.

Grasslands = lighter in color and no visible signs of sage or shrubs. May include meadows surrounded by vegetation. No definitive signs of machinery or trailing by irrigation spigots. These lands may have been planted as Conservation Reserve Program and used for periodic grazing of stock animals.

Conifers = definitive higher elevation forests. Usually ponderosa pines and other conifer species. Generally are not located in association with drainages.

Developed = definitive houses and structures, roads, human induced impacts.

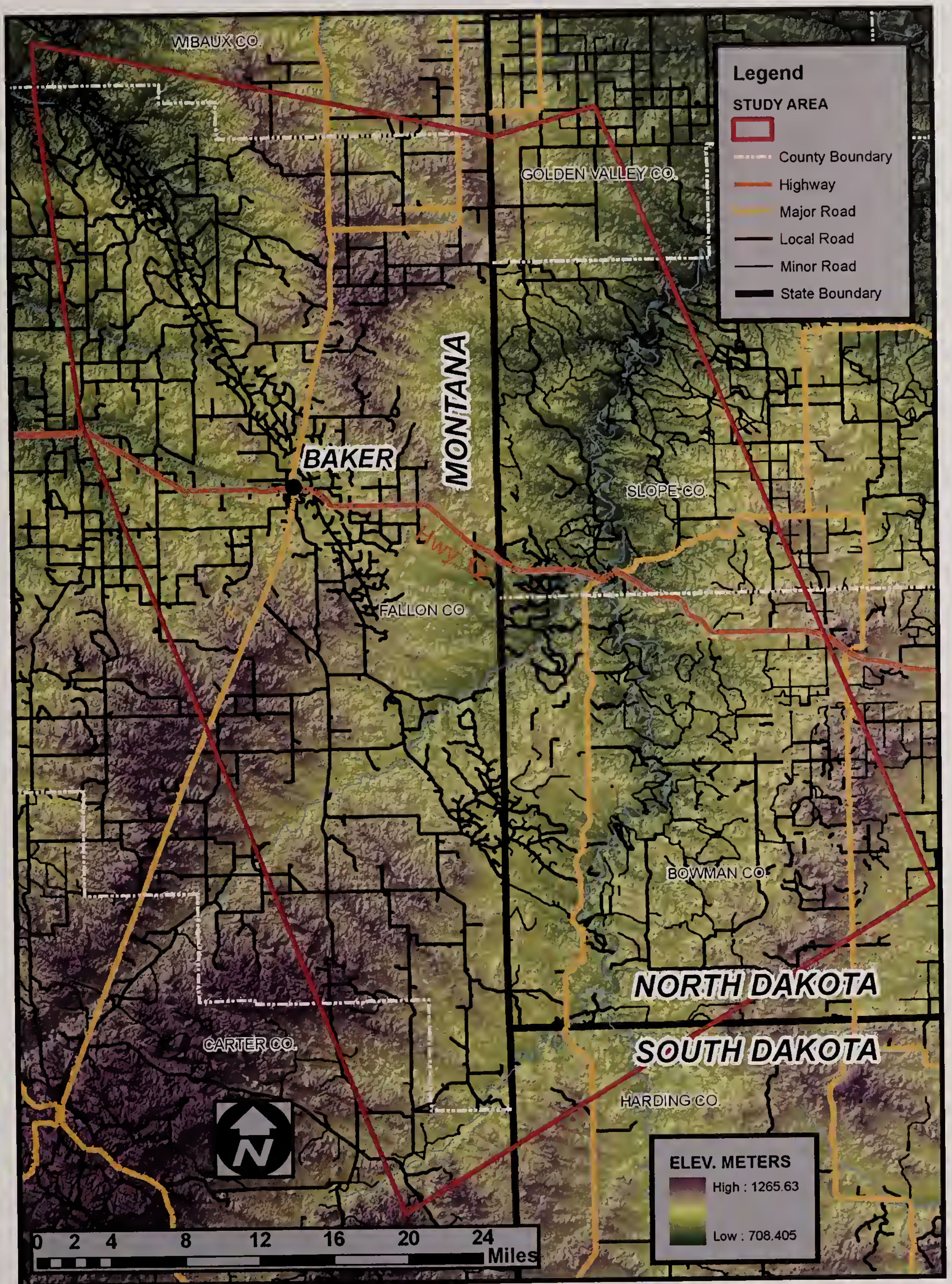
Energy = well heads, compressor stations, refinery plants and energy specific access roads where oil and gas is processed.

Understanding the relationships of the sage steppe community within the study area is important in order to put into context the results of the study and the potential changes that may occur to this area as a result of adjacent agricultural conversion, climate change, and land management activities.

Study Area

The study area surrounds the Cedar Creek Anticline beginning at the southwest corner of North Dakota running northwest into the southern portion of Wibaux County Montana, encompassing approximately 1,126,000 acres (figure 1).

FIGURE I


WIBAUX CO.
Legend
STUDY AREA
County Boundary
Highway
Major Road
Local Road
Minor Road
State Boundary
GOLDEN VALLEY CO.
MONTANA
BAKER
SLOPE CO.
Hwy 12
FALLON CO.
BOWMAN CO.
NORTH DAKOTA
SOUTH DAKOTA
CARTER CO.
HARDING CO.
N
ELEV. METERS
High : 1265.63
Low : 708.405
0 2 4 8 12 16 20 24
Miles

1.2 PROGRAM PURPOSE

This project is the result of a research effort that was completed in 2007. We analyzed the South Dakota mapping effort and developed a cost effective approach to collect and analyze imagery to determine the extent of vegetation communities at a level of detail to assess vegetation relationships focusing primarily on sage grouse habitat. The objective of the current mapping effort is to utilize the newly developed methodology to create a land cover GIS data set that can determine the extent of sagebrush vegetation communities in and around the Cedar Creek anticline. The 2007 high resolution color infrared orthophotography and the 10 meter digital elvation model (DEM) a byproduct of generating the orthophotography can also be used by researchers in many different ways to quantify and analyze the biodiversity of the study area. For example:

1) The orthophotography can be used a high resolution base map to calculate two dimensional distance and area values of photographically referenced elements or to develop an even more detailed land cover data base representing a sub-area within the original study area.
2) The 10 meter DEM can be used to generate such products as slope, aspect, three dimensional perspectives and distances.

DATA DEVELOPMENT

At the onset of the sage mapping project it was determined that the methodology developed in the South Dakota mapping effort would be used to identify and map sagebrush employing an automated technique that would replicate the traditional photo interpretation and digitizing approach at a reduced time and cost with acceptable reductions in accuracy and level of detail. The two specific new technologies identified in the South Dakota project used for this project to achieve our mapping goals are, (1) the high resolution ADS40 digital color infrared photography and (2) the Definiens object oriented image processing software.

The ADS40 sensor platform, a product of Leica Geosystems, is a relatively inexpensive way to develop high resolution georeferenced imagery. The all digital ADS40 image acquisition and production process can reduce ground control requirements, processing, and production costs when compared to traditional methodologies.

The review of the technical research literature indicated that high resolution (0.3 meter) color infrared imagery derived from the ADS40 platform would provide the best opportunity to identify and map sagebrush. Langs (2004) study finding a high correlation ($R2 = 0.7404$) between classifying sagebrush in the field compared to classifying sagebrush through image processing using 0.3 meter color infrared imagery supported our findings.

Cogan and Ode (2005) concluded that, "Recent developments in image processing and map spatial modeling techniques show promise in helping to cost-effectively and consistently map sagebrush and sage grouse habitat. Of particular interest is the development of software that can identify land cover information by creating objects and examining their relationships to one another. At the forefront of this discipline is Definiens, a German software program that moves beyond classifying pixels to working with image objects created by segmentation algorithms. The advantage of this program is that it allows consistent, homogeneous image object extraction at any desired resolution and scale with results that mimic manual photo interpretation. Definiens also features a set of interfaces which make information about image objects, features and classification transparent and accessible."

The data development for this project involved eight separate phases. Phase one, the collection of ground truth data was performed to be used as training data for image processing. Phase two, the ADS40 digital imagery was acquired and processed by the aerial photography contractor. Phase three, the ADS40 imagery was segmented and classified with the Definiens software generating a first cut classified polygon data base. Phase four, the classified polygon data base was assigned the coarse classes of agriculture and developed land using existing landcover data in a geospatial selection process. Phase five, heads-up photo interpretation was performed Definiens on classified data to refine the initial Definiens classification. Phase six, a random field check was performed to assess the thematic accuracy of the data development process. Phase seven, development of canopy densities for sage classes. Phase eight, post processing, finalizing and delivery of geospatial landcover data base.

2.1 GROUND TRUTHING

Ground truthing is defined as the process of collecting land cover information in the field in order to correlate imagery data to actual features and land cover on the ground. Ground truth data facilitates the calibration of digital imagery data, and aids in the classification and analysis of what is being remotely sensed. When the identity and location of land cover types are known through a combination of field work, maps, and personal experience, the spectral characteristics of these areas are used to train the image processing software using decision rules to classify the entire image.

From October 29, 2007 through November 2, 2007 in excess of 145 accessible locations, evenly distributed throughout the study area were visited and ground truthed. Coordinates were monumented using a hand held real-time differentially corrected global position system unit (GPS) along with landcover information pertaining to land cover composition and estimated canopy cover density. Our ground truth effort focused on collecting information on the dominant land cover types within the study area, such as, areas representing sage, grasses, sparse vegetation and riparian zones, open water, developed and energy related. Approximately 82 ground truth data points were also collected from October 2007 through July 2008 using a modified "Daubenmire Method" by Bureau of Land Management and Forest Service staff Daubenmire (1968)(figure 3). The field objective was to identify vegetation classes within the study area. We accomplished that objective and also identified sage brush distribution and its relationship to other landscape characteristics.

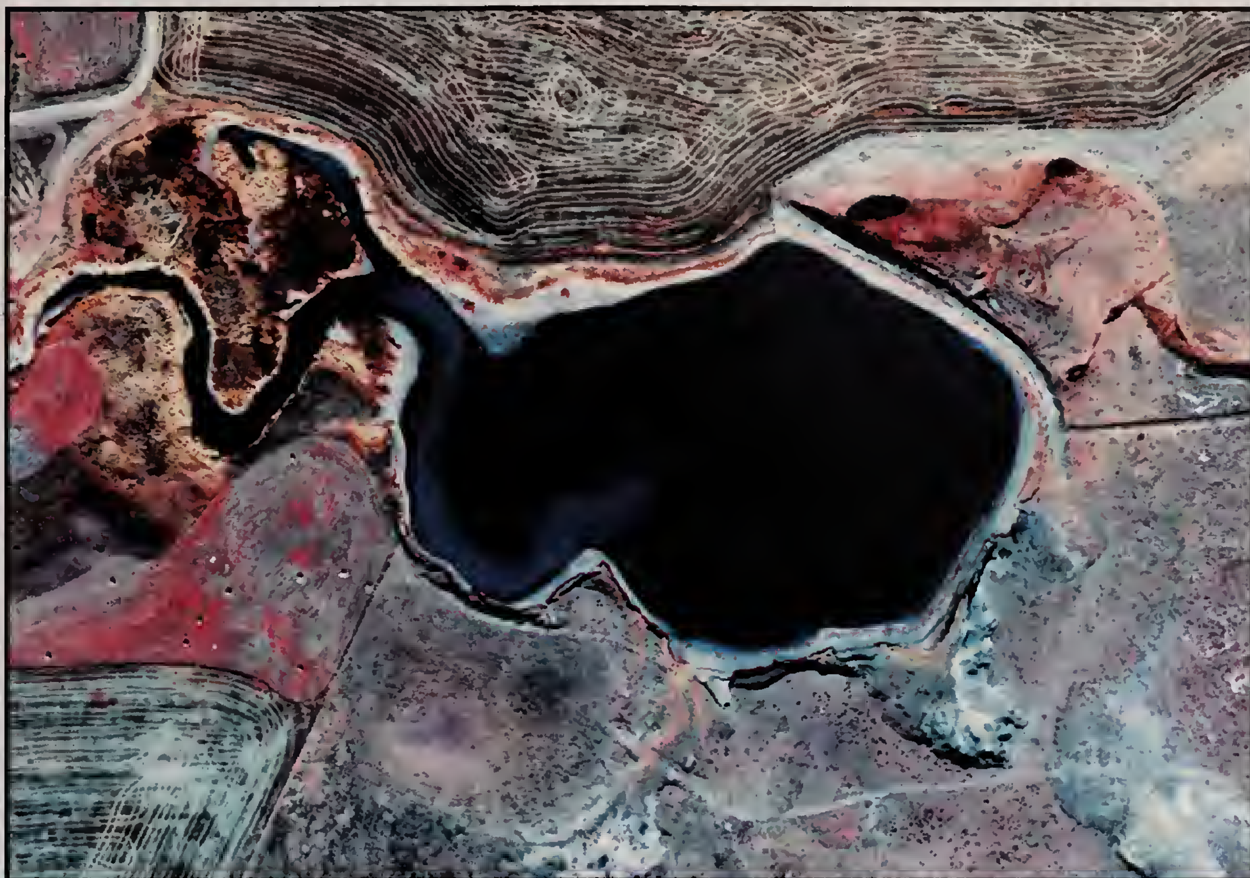
2.2 IMAGE ACQUISTION

The ADS40 digital imagery was acquired between 10/02/07 and 10/10/07 by Horizons Inc., Rapid City, South Dakota. Processing and delivery of the final image product took 4 months, with a delivery date of February 2008. The imagery was delivered as a series of 6 tiles in ERDAS .img format. Each image tile was composed of the infrared, red and green spectral bands and was between 28 and 50 gigabit in size (figure 2).

Upon delivery the imagery was inspected for smears, unusual color variations, positional accuracy, study area coverage and other contractual specifications. Minor color variations were found between North/South flight lines, but were deemed as an acceptable byproduct of the ADS40 data collection methodology. To achieve the resolution required by this project the ADS40 imagery is collected at low altitude in swaths by a fixed winged aircraft, thus the data was collected at different times of the day and sometimes different days, which equates to variability in the spectral reflectance introduced by dissimilar sun angles and atmospheric distortions. It is this variability in spectral reflectance that account for the aforementioned minor color variations.

FIGURE 2

ADS40 HIGH RESOLUTION CIR IMAGERY



2.3 IMAGE PROCESSING

The processing of the ADS40 imagery was composed of several steps to generate a final classified object/polygon file. 6 individual color infrared image tiles in ERDAS .img format were received from the photogrammetric contractor at a resolution of .3 meters, ranging from 28 to 50 gigabits in file size. The South Dakota mapping study discovered that for analytical efficiency, the ADS40 imagery needed to be degraded to a lower resolution of .9 meters to be compatible with the image size limitations of the Definiens software. The risk with this option is that spectral information that might be invaluable in the classification process could also be reduced in quality or lost to the analysis. A series of tests that were run in the South Dakota study comparing the spectral values and homogeneity of object files created from the original .3m x .3m imagery to a degraded .9m x .9m image revealed no significant difference within the object spectral values between the compared resolutions. Therefore the six original images received from horizons were degraded to 0.9m x 0.9m images (Site #1 through Site #6) to be used in the subsequent image processing (figure 4).

FIGURE 3

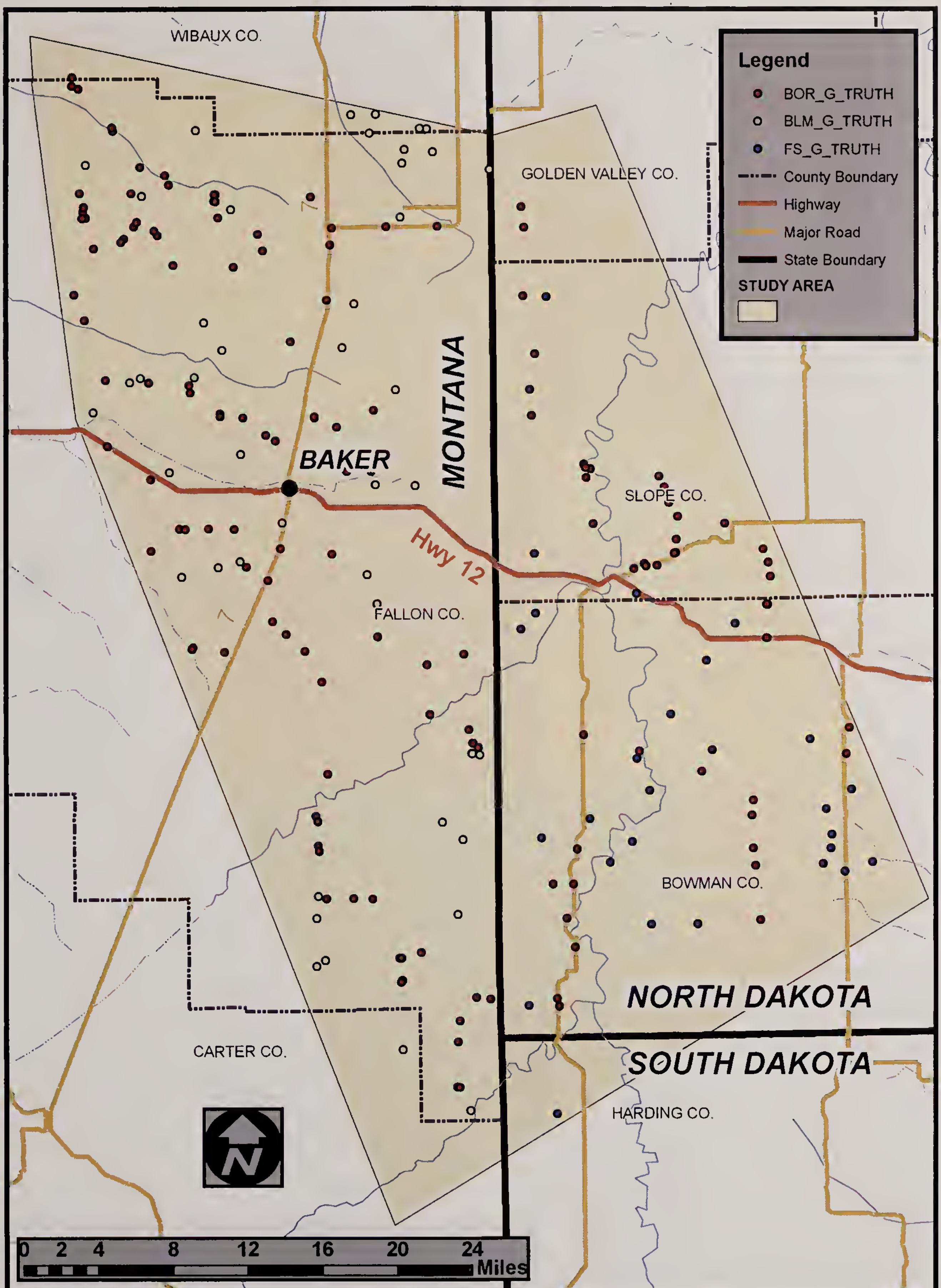
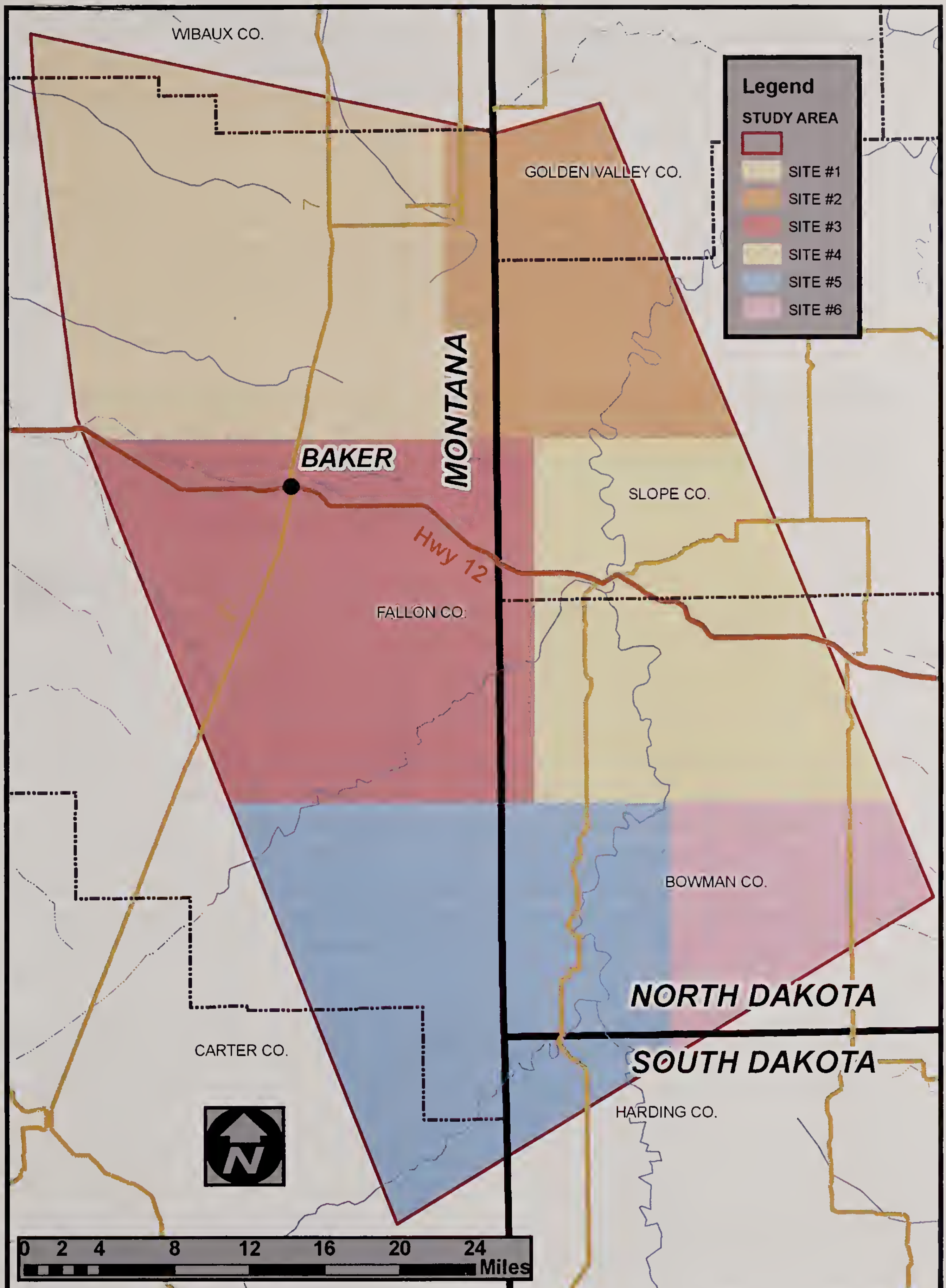

WIBAUX CO.
Legend
BOR_G_TRUTH
BLM_G_TRUTH
FS_G_TRUTH
County Boundary
Highway
Major Road
State Boundary
STUDY AREA
GOLDEN VALLEY CO.
MONTANA
BAKER
SLOPE CO.
Hwy 12
FALLON CO.
BOWMAN CO.
NORTH DAKOTA
SOUTH DAKOTA
CARTER CO.
HARDING CO.
N
0 2 4 8 12 16 20 24
Miles

FIGURE 4


WIBAUX CO.
GOLDEN VALLEY CO.
Legend
STUDY AREA
SITE #1
SITE #2
SITE #3
SITE #4
SITE #5
SITE #6
MONTANA
BAKER
SLOPE CO.
Hwy 12
FALLON CO.
BOWMAN CO.
NORTH DAKOTA
SOUTH DAKOTA
CARTER CO.
HARDING CO.
N
0 2 4 8 12 16 20 24
Miles

2.3.1 Normalized Vegetation Index

As a matter of practice and well supported by our literature review a Normalized Difference Vegetation Index (NDVI) band was derived from each of the 6 images by calculating the ratio between the red and infrared bands. An NDVI is a spectral feature that exploits the strong differences in plant reflectance and has been shown to be directly related to the photosynthetic capacity (Sellers 1985 and Myneni et al. 1995). The NDVI data set is a vital input into to both the segmentation and classification model.

2.3.2 Segmentation

The next step in the progression of the image processing procedure was segmentation. Segmentation is the generation of homogeneous image objects (polygons) from user defined parameters, at this point the image processing transitions from pixel base process to an image object process. It is this step that separates Definiens from most other image processing software.

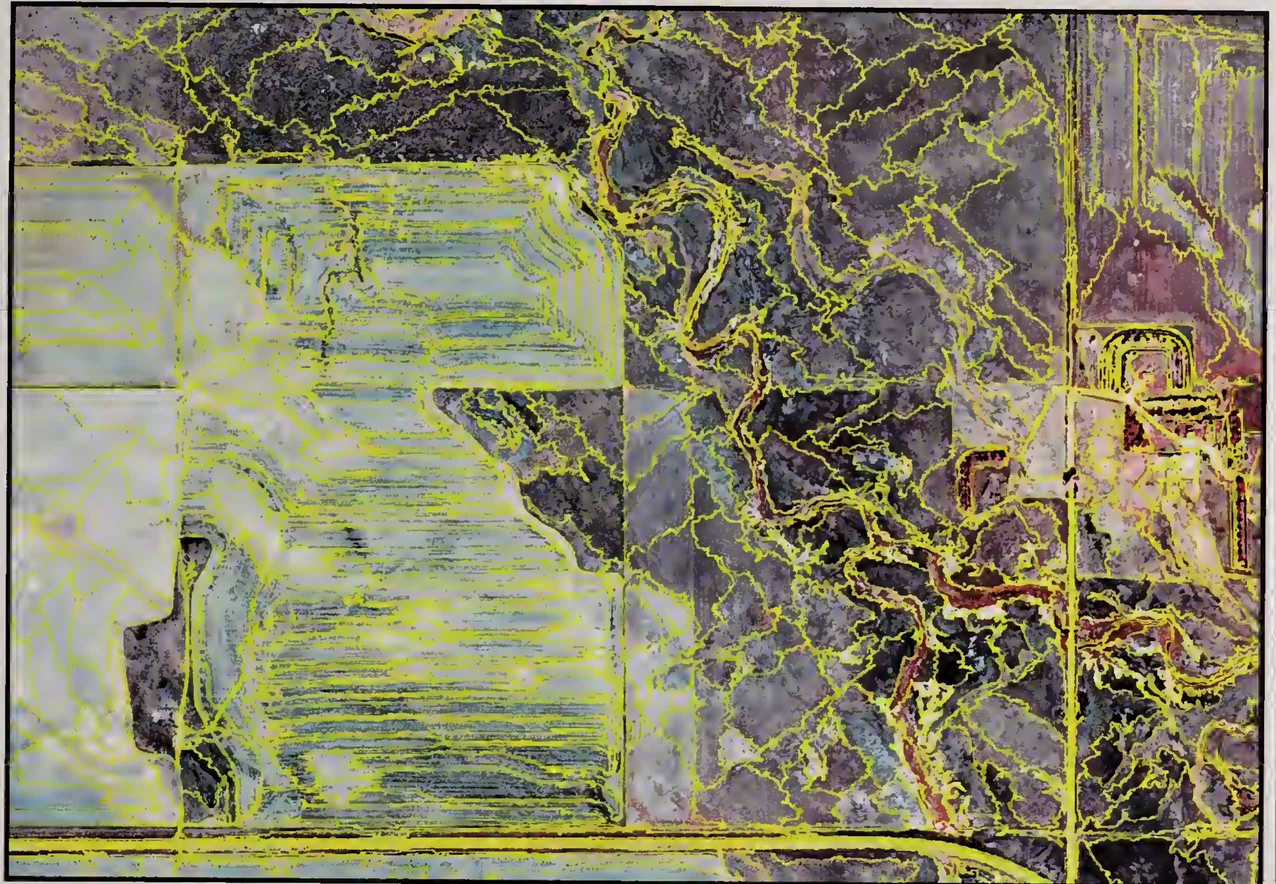
The initial advantage of generating image objects is that it automates the polygon drafting and transfer stage of the traditional photo interpretation process. This equates to an estimated 60% to 70% savings in processing time and costs. Note, the thematic accuracy achieved through the Definiens process is most likely less than what would be achieved through the traditional photo interpretation process.

Using segmentation parameters documented in the Bureau of Land Management (BLM) research report "Mapping Sagebrush/Grasslands from Landsat TM-7 Imagery: A Comparison of Methods" (Fisher et al. 2002) as a baseline for our segmentation parameter selection, a series of segmentation tests were performed on a representative sample image to define the segmentation parameters that would produce an object file that represented the homogeneity and detail required for this study (figure 5). As was found in the BLM report and the South Dakota mapping work, weighting the IR and Red bands equally as 1.0, the green band as 0.5 and the NDVI layer as 2.0, along with lower compactness weights and higher smoothness weights produced an object file that captured the detail necessary for this study. The final scale parameter used in our segmentation increased by a factor of 10 compared to the BLM study, it is assumed that this is a result of differences in image resolutions. Segmentations were performed on all six site images, creating 6 object files unique to each site, using the following weighted parameters:

SCALE	COLOR	SHAPE	COMP.	SMOOTH	IR	RED	GREEN	NDVI
100	0.8	0.2	0.1	0.9	1	1	0.5	2.0

FIGURE 5

DEFINIENS SEGMENTATION



2.3.3 Classification

Prior to classification, it is essential to recognize that the ADS40 imagery by the nature of the methodology used to collect the imagery is cumbersome to use in an automated classification process. The ADS40 imagery is collected in swaths by a fixed winged aircraft. The orthophotography collected for a large study area is collected at different times of the day and sometimes different days, which equates to variability in the spectral reflectance introduced by dissimilar sun angles and atmospheric distortions. It is this variability in spectral reflectance that limits the automated classification process and promotes the implementation of combined automotive and manual classification techniques.

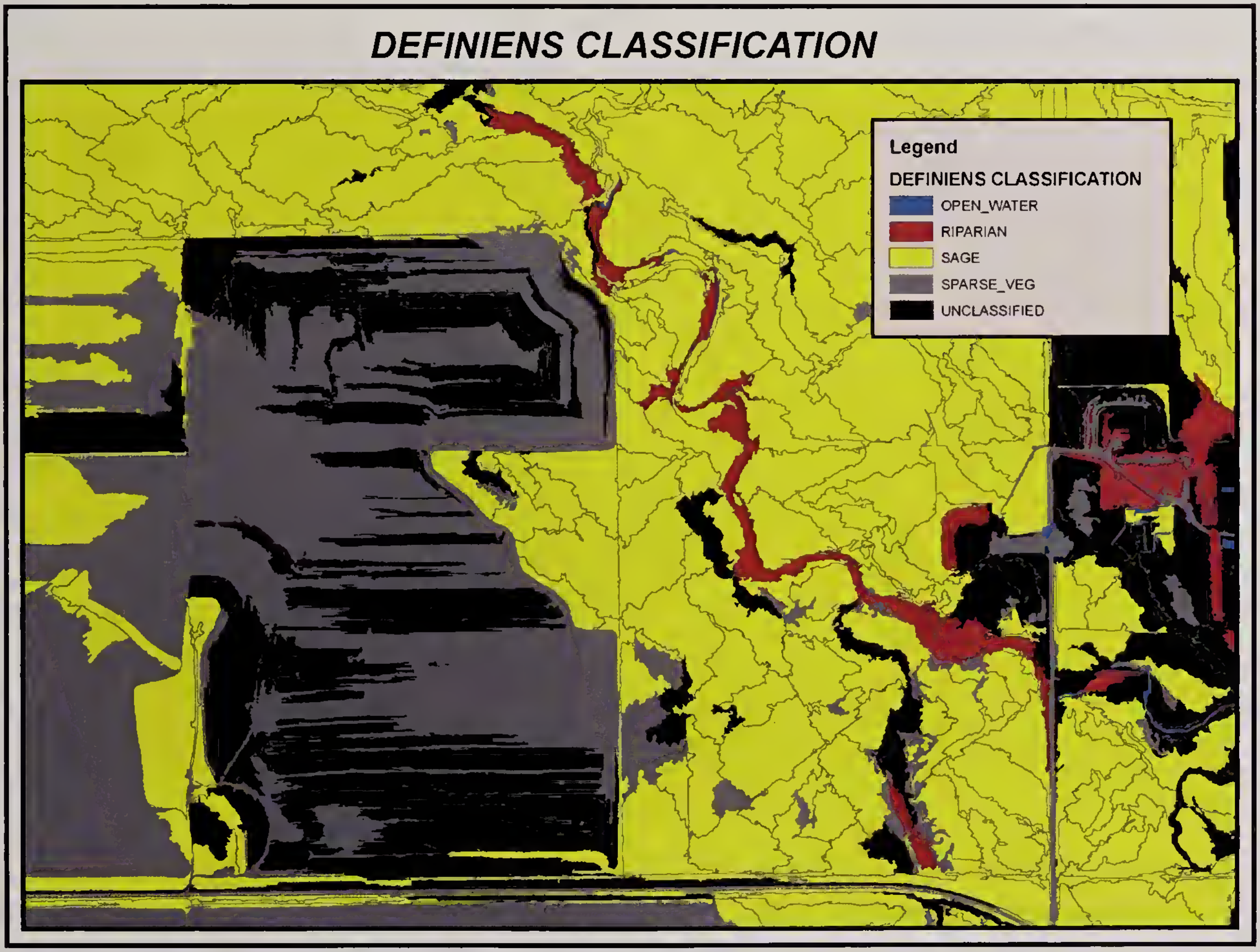
Three individual classification methods were employed assigning the objects one of eleven landcover types. Each classification method was applied in a stepwise fashion increasing the number of classes and refining the thematic accuracy of the landcover data set with each iteration. The initial classification method took advantage of the Definiens suite of visual classification tools that promote interaction between user and software. This automated classification method was essentially an interactive hybrid of a rules based and a supervised classification process.

By combining Definiens visualization tools, ground truth data and the spectral values associated with the object polygons, including the unique band selection, band width and statistical operatives, we were able to identify an estimated 65% of the land cover classes of sage, riparian, open water and sparse vegetation throughout the study area data set. This analytical process was performed on each of the 6 site image sets to compensate for any spectral variation between sites. In general the rules applied follows:

CLASS	BAND/LAYER	STATISTICAL OP.
SAGE	NDVI	Mean
RIPARIAN	NDVI	Mean
OPEN WATER	Infrared	Mean
SPARSE VEGETATION	ALL	Sum-Brightness

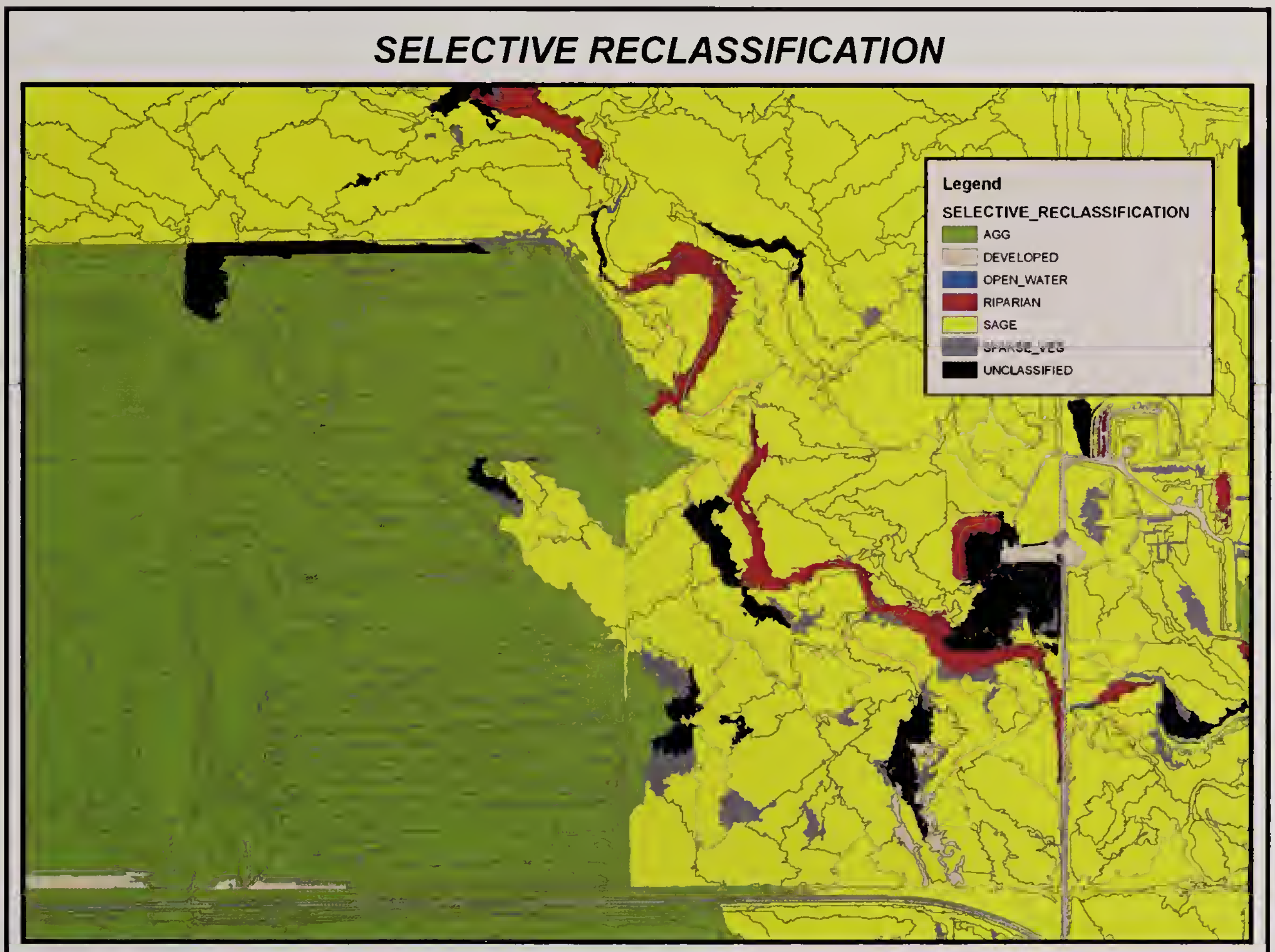
Once the classification parameters were identified, each representative site object file was classified (figure 6).

FIGURE 6

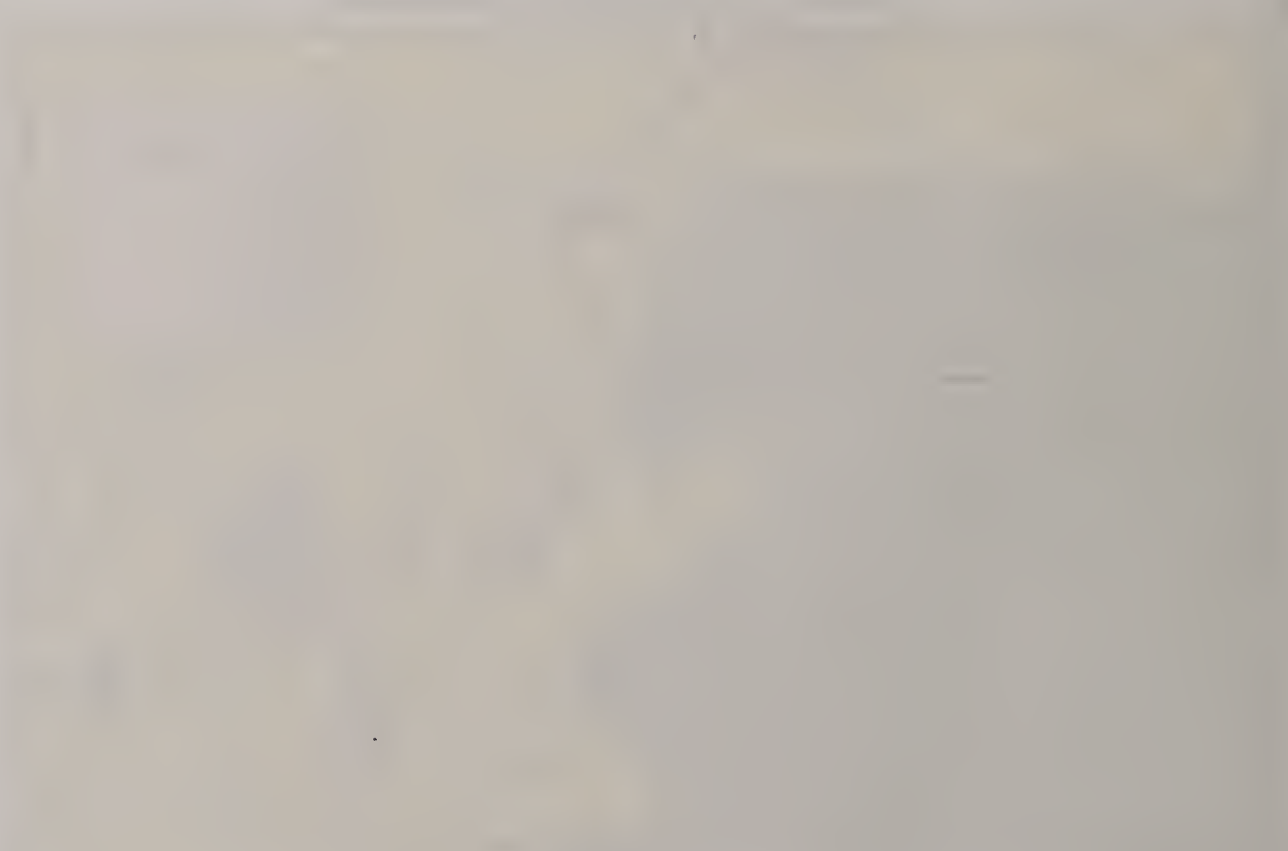


The second classification technique used existing landcover data to spatially select and classify representing agriculture and developed landcovers. The landcover classes of "Pasture/Hay" and "Cultivated Crops" within National Land Cover Data (NLCD) set were used to spatially identify and reclassify polygons within our project data set that share common geographic space to agriculture. The same process was followed using NLCD "Developed" classes to reclassify objects within our project data set that share common geographic space to developed. Specific iterative rules were used in the selection process to avoid misclassifying accurately classified data. Note, it is estimated that at this point in the classification process the project data is approximately 70% thematically accurate (figure 7).

FIGURE 7



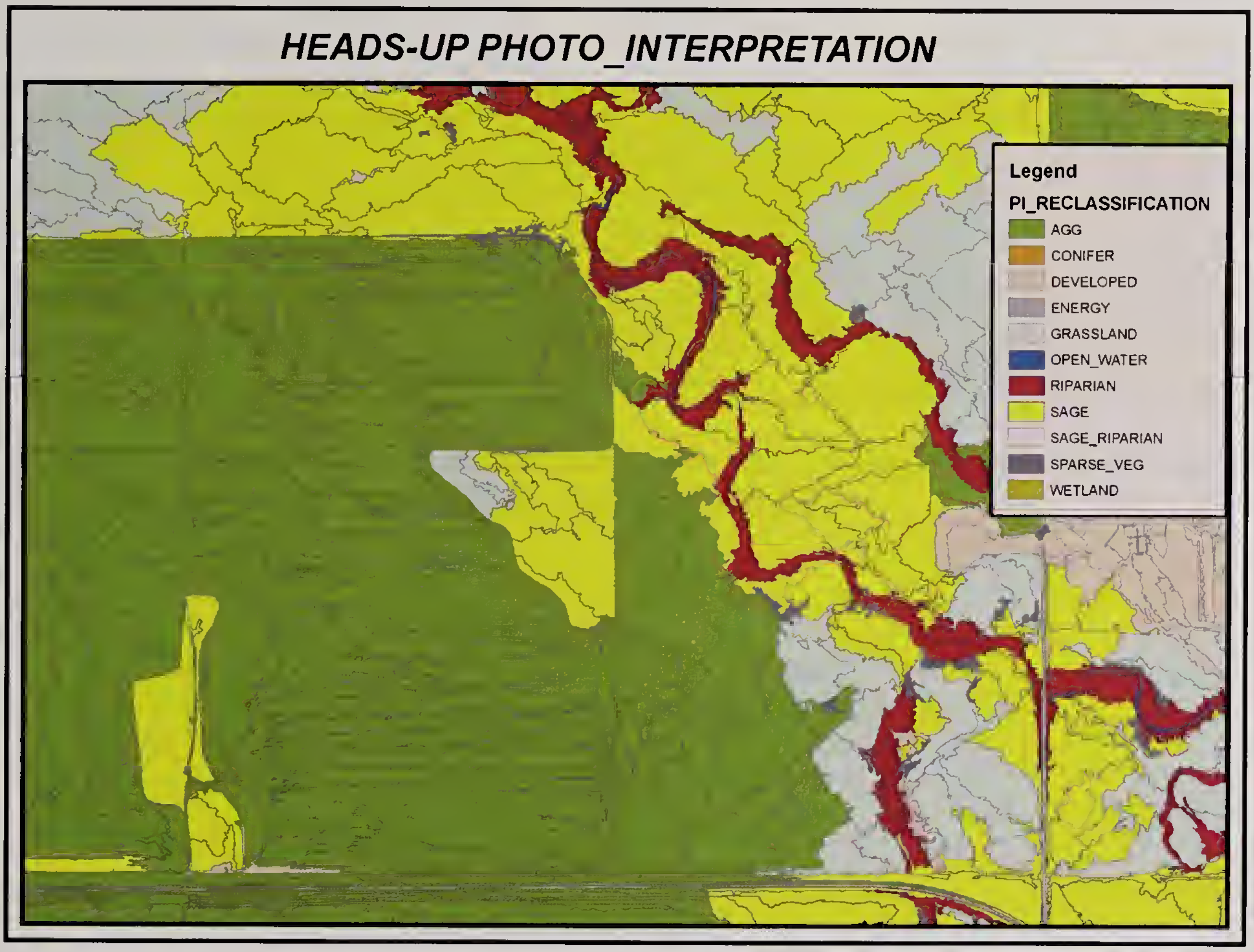
The third and final iteration of the classification process is called of heads-up photo interpretation. Heads-up photo interpretation process involves panning through the classified object data overlaying the ADS40 imagery and subjectively interpreting and, if necessary, re-classifying objects mis-classified by the Definiens and the selective processes, thus refining the thematic accuracy of the project data to an estimated 80% or higher. A user driven GIS interface was designed to pan through the data at a designated scale of 1:5,000 and re-classify the object data with a click of the mouse.



At the onset of the photo-interpretation process we realized that four classes needed to be added to the overall classification to complete the landcover data set:

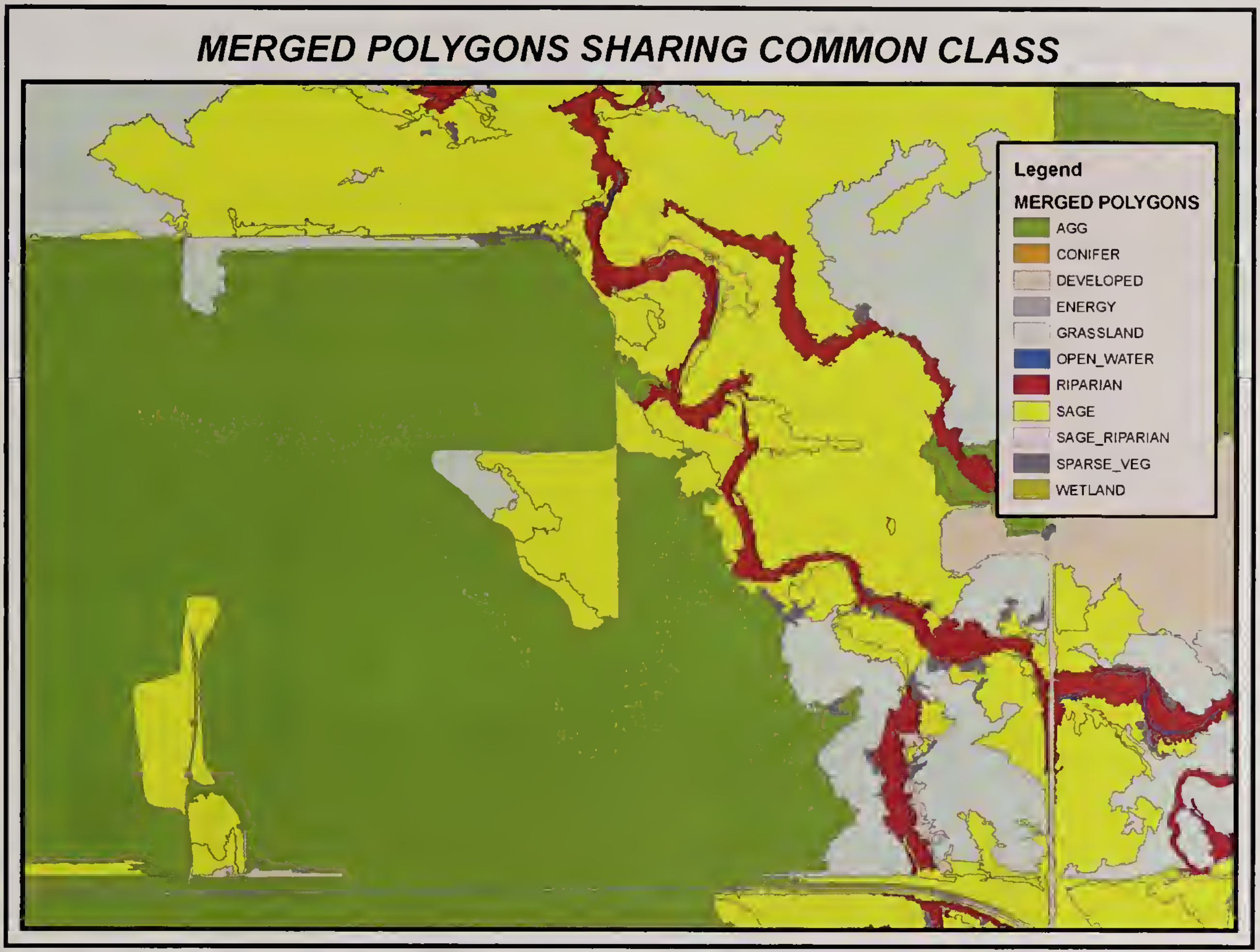
1) Wetland areas interpreted as containing wetland species, frequently found as a perimeter to reservoirs and stock ponds was added to the classification schema.
2) Sage-Riparian was added to the classification schema. It was found that in some cases objects classified as riparian included patches of sage or areas identified as sage also included patches of riparian, this is essentially an artifact of the segmentation process.
3) Conifers, ponderosa pine, juniper and other conifer species was added to the classification schema.
4) Energy, infrastructure associated with energy development was added to the classification schema (figure 8).

FIGURE 8



Post processing of the final classified data merged multiple objects (polygons) sharing common class attributes and boundaries into single objects (figure 9).

FIGURE 9



The gray polygon boundaries seen on figure 9 represents the sub-classification of canopy density attributed to the "Sage and Sage-Riparian" classes.

2.4 CLASS SIGNATURE AND COMPOSITION

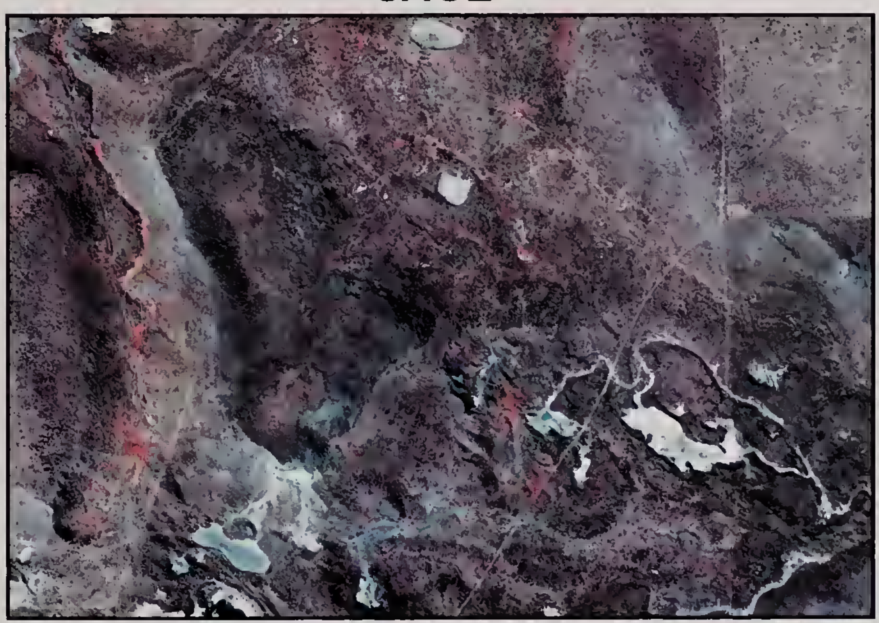
A description of the spectral signature and the general composition of the final land cover classes mapped in this project are as follows:

1) Sage

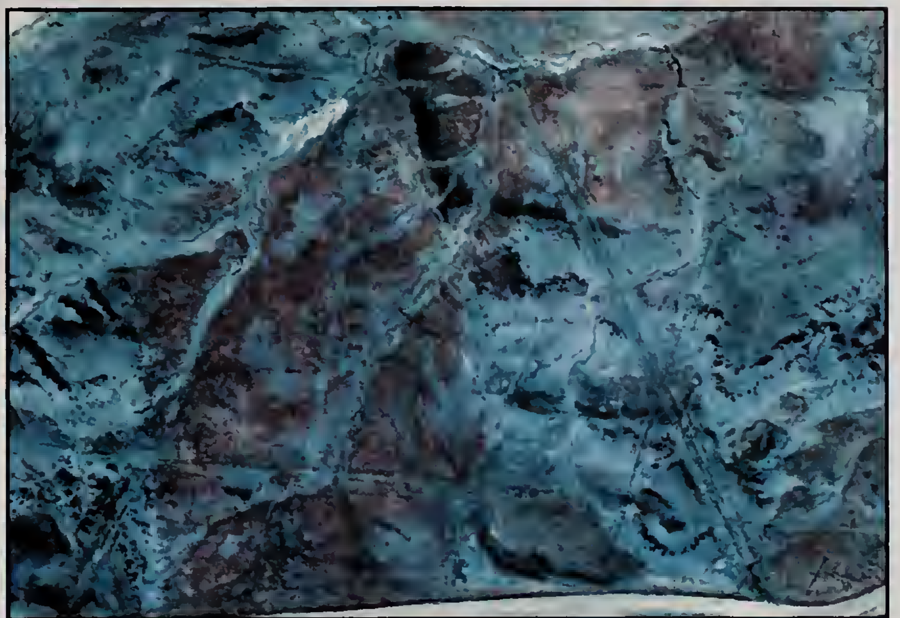
Signature – The spectral signatures presented by sage are different inside and outside of the Cedar Creek anticline area. Outside of the anticline sage is represented as brown in color and has a granular texture. Inside the anticline area sage is represented as brown in color but with less texture than the later.

Composition - Throughout the study area, Wyoming big sagebrush (*A. tridentate ssp. wyomingensis*) may be intermixed with herbaceous sageworts and wormwoods, along with Silver sage (*A. cana*). Native grasses, including western wheatgrass (*Pascopyrum smithii*) and needle-and-thread grass (*Stipa* spp.) in this vegetation class is being overtaken by the invasive annual cheatgrass (*Bromus tectorum*).

SAGE



ANTICLINE SAGE

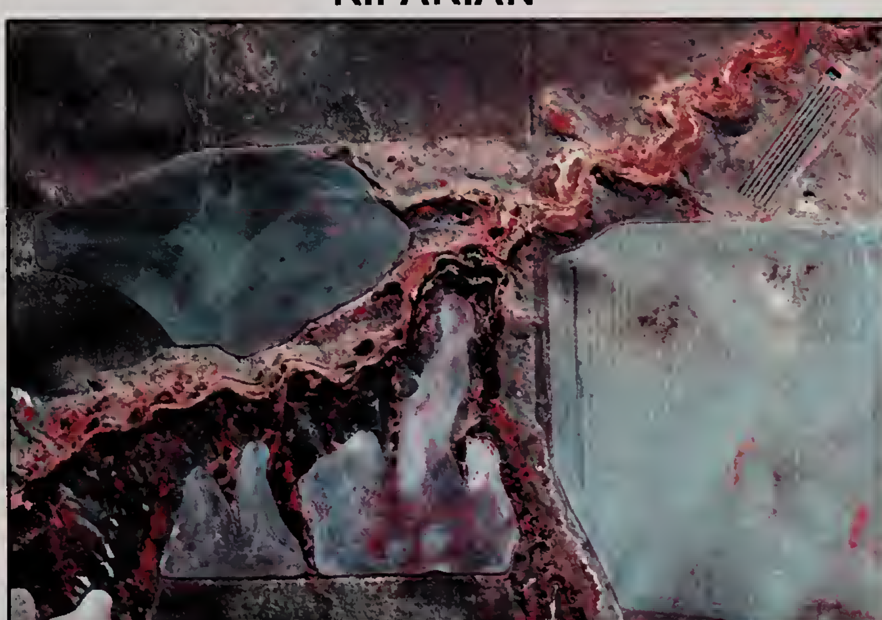


2) Riparian

Signature – The spectral signature of the riparian class is represented as medium to bright red in color, linear in shape and fine to course in texture.

Composition – Riparian stands are found on stable bars in floodplains and along stream banks in rolling hills and foothills adjacent to upland plateaus and mesas where the water table is still high but flooding may occur occasionally. Substrates are typically relatively recently deposited alluvium with a stream gradient that is typically gentle with soils sandy to sandy and silt loam. Vegetation commonly found include willows, cottonwoods, cattails and other small shrub species. Note, only areas identified as vigorous riparian vegetation were mapped, dry drainages were classified with the appropriate class.

RIPARIAN



3) Sage-Riparian
Signature – The sage-riparian class is a function of the segmentation process in which the polygon generated includes both sage and riparian classes, the spectral signature is the same as the individual class as described.

Composition – In areas associated with drainages in the study area, environmental gradients provide habitats that are associated with a mix of sage-riparian vegetation. Along the drainage, more typical riparian vegetation, such as cottonwoods (*Populus fremonti*) and willow (*Salix exigua*) grade into silver sage (*A. cana*) on the floodplain steppe grading up to Wyoming big sage (*A. tridentate ssp. wyomingensis*) on the drier soils higher in elevation. Common associated plants include rabbitbrush (*Chrysothalmus* sp.) and *gutterezia*

SAGE RIPARIAN

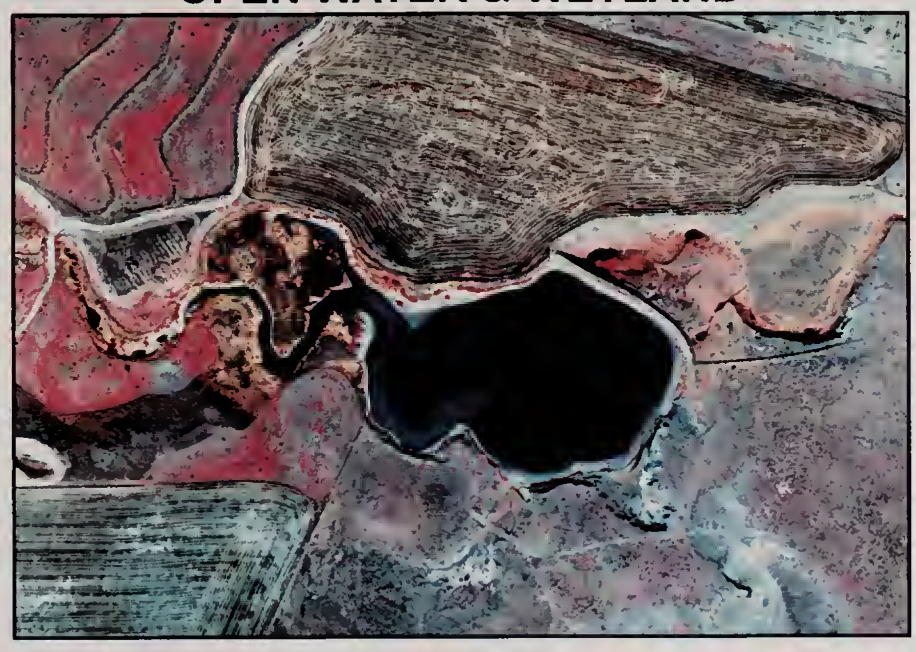
4) Open Water
Signature – The spectral signature of the open water class is represented as light blue to black in color, round (ponds) or linear (rivers) in shape and smooth in texture.

Composition - areas of standing water, farm ponds, reservoirs and streams located in the study area typically supported cattails (*Typha latafolia*) and a variety of sedges along the edges of the wetted perimeter. These open water areas typically support algae blooms in the summer as they warm. The majority of these open water areas are formed by small earthen dams

5) Wetland
Signature – The spectral signature of the wetland class is represented as medium to bright red in color, varies in shape, fine to course in texture and usually located in or adjacent to waterbodies.

Composition – natural areas of seasonal standing water found in drainages that are located in the study area typically support cattails (*Typha latafolia*) and a variety of sedges and wetland grasses. These areas are seasonally wetted and are often associated with areas of silt and clay.

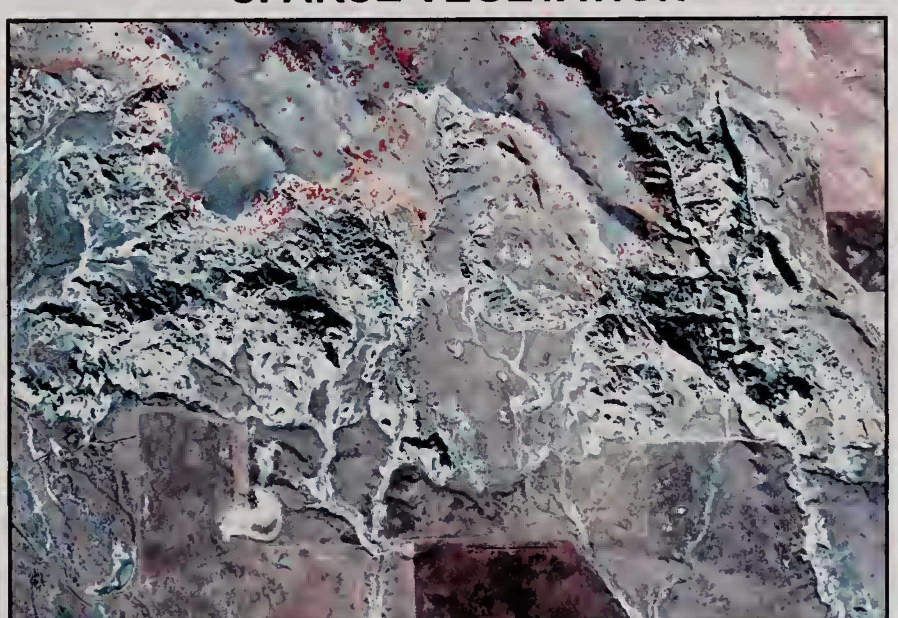
OPEN WATER & WETLAND



6) Sparse Vegetation
Signature – The spectral signature of the sparse vegetation class is represented as grey to bright white (monochrome) in color, varies in shape and fine to course in texture.

Composition – limited vegetation, consisting of barren soils and or rock

SPARSE VEGETATION



7) Agriculture
Signature – The spectral signature of the agricultural class varies in color, rectilinear in shape and has a fine to medium texture that runs parallel in structure..

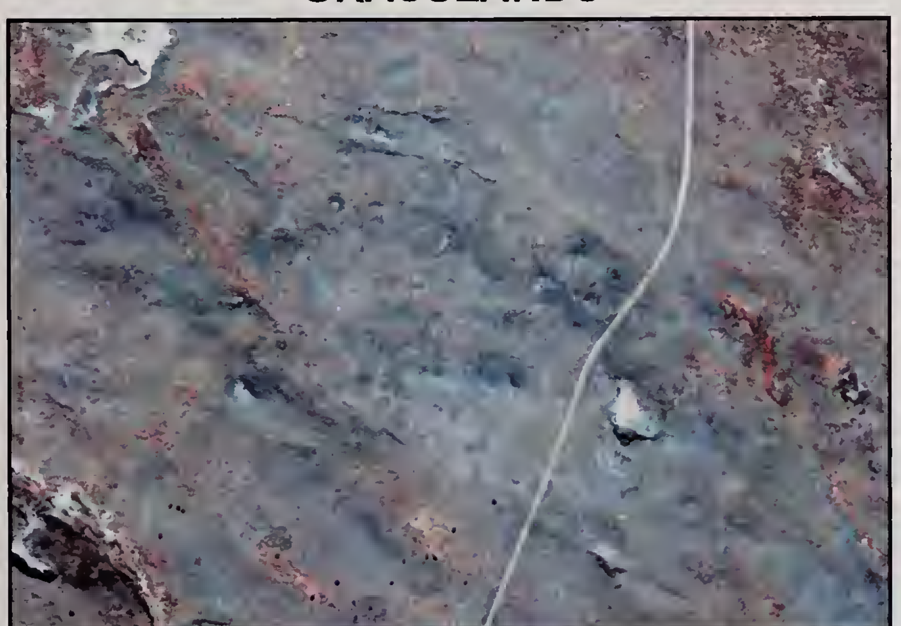
Composition - both irrigated and none irrigated agricultural fields

AGRICULTURE

8) Grasslands
Signature – The spectral signature of the grasslands class is represented as light to dark blue/gray in color, varies in shape and fine in texture.

Composition – native grasses

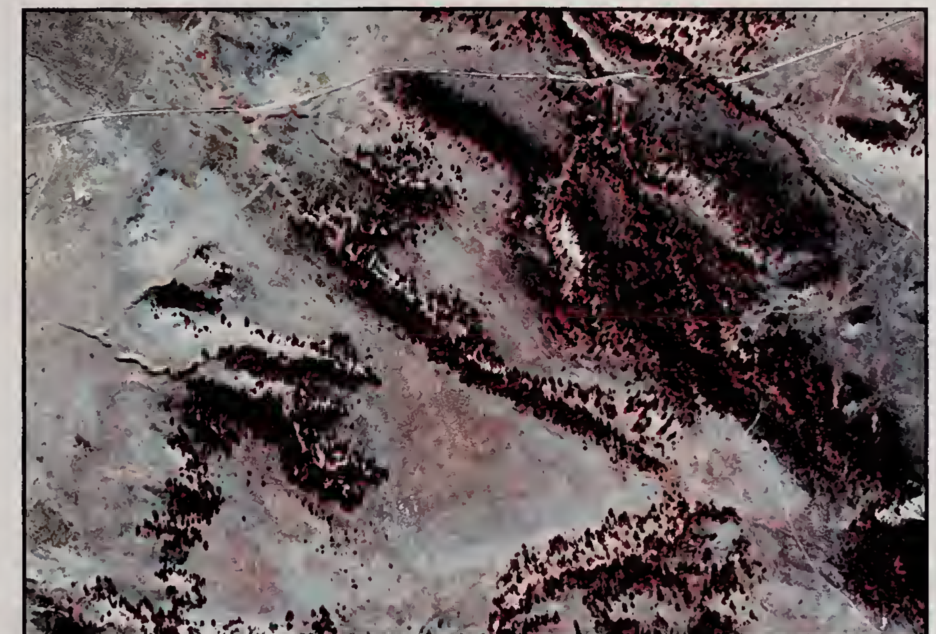
GRASSLANDS



9) Conifers
Signature – The spectral signature of the coniferous class is represented as medium to bright red in color, varies in shape and fine to course granular texture not located in riparian zones.

Composition – usually extensive ponderosa pines and or junipers

CONIFERS



10) Developed
Signature – The spectral signature of the developed class varies in color, rectilinear in shape and course in texture. This class is mostly identifiable by its composition.

Composition – definitive houses or structures, roads, human induced impacts

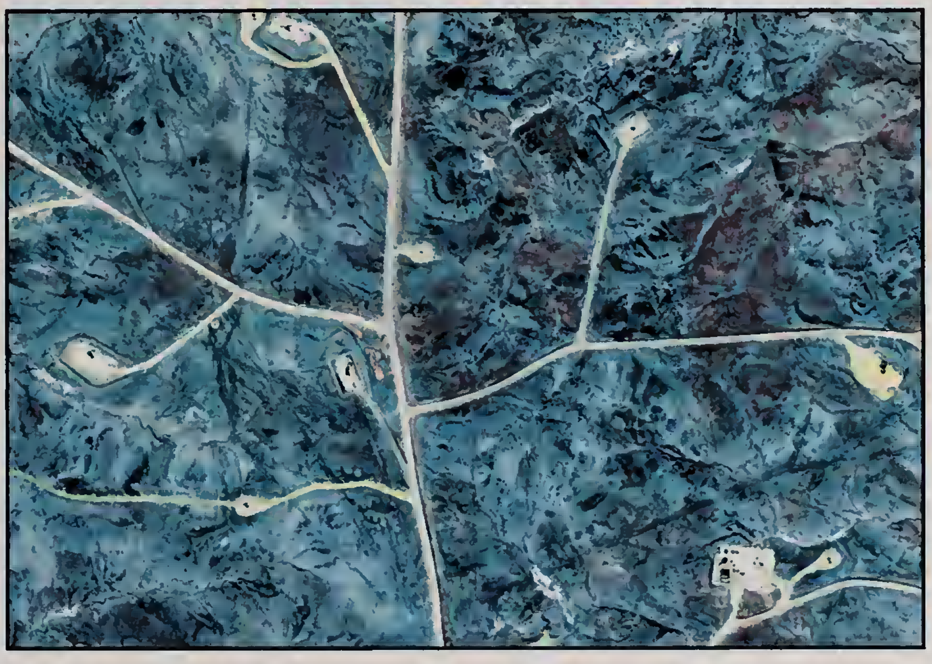
DEVELOPED

11) Energy

Signature - The spectral signature of the energy class is represented as light grey to bright white in color, rectilinear in shape and fine in texture and primarily located in the Cedar Creek anticline area.

Composition – well pads, compressor stations, access roads and other energy specific land cover

ENERGY



2.5 RANDOM FIELD CHECK

A random field check was performed to assess the quality of the classification process after the initial classification was completed.

Sixty nine accessible sites (points) out of one hundred randomly selected sites were field checked, five sites were found to be mis-classified, approximately 8%. Out of the five misclassified sites, no reason for the misclassification could be found for two, one misclassified site fell on the border of two classes and two misclassified sites were classified as "Sparse Vegetation" and were found to be heavily grazed areas (figure 10). Due to cost constraints, no formal accuracy assessment was contracted or completed for this study, and in no way this field check constitutes a statistically sound accuracy assessment.

2.6 CALCULATING CANOPY COVER DENSITY

To enhance the value of the land cover data, canopy density was generated for both the sage and sage riparian classes. Normally, in a project like this, density values are assigned to polygons by subjectively comparing the density represented on the base imagery to a standard density chart. The traditional method would be cost intensive due to the time it would take to make a density call on approximately 106,000 polygons. Fortunately an automated methodology was developed through the South Dakota mapping project. Using pixel based ERDAS image processing software we performed an unsupervised classification on the 6 site image mosaics, specifying 60 classes. By specifying such a large number of spectral classes to identify a very detailed breakdown of segregated spectral values was produced. The classified image output was then inspected to identify the classes unique to areas of shrubbery. The classified imagery was "Recoded" assigning a pixel value of 0 to none-shrub classes and a pixel value of 2 to classes identified as shrubs. At this point a "Zonal Attribute Function" was performed calculating the number of pixels identified as shrubbery within each classified Sage or Sage riparian polygon and with the pixel size known, calculating the percent canopy cover for each polygon. Polygons classified as sage or sage riparian were then attributed with the calculated canopy density (figure 11).

This methodology was checked by comparing canopy densities derived from the traditional methodology to canopy densities based on the automated methodology. Out of the 40 randomly selected polygons checked, the average difference between the two methodologies was 5%.

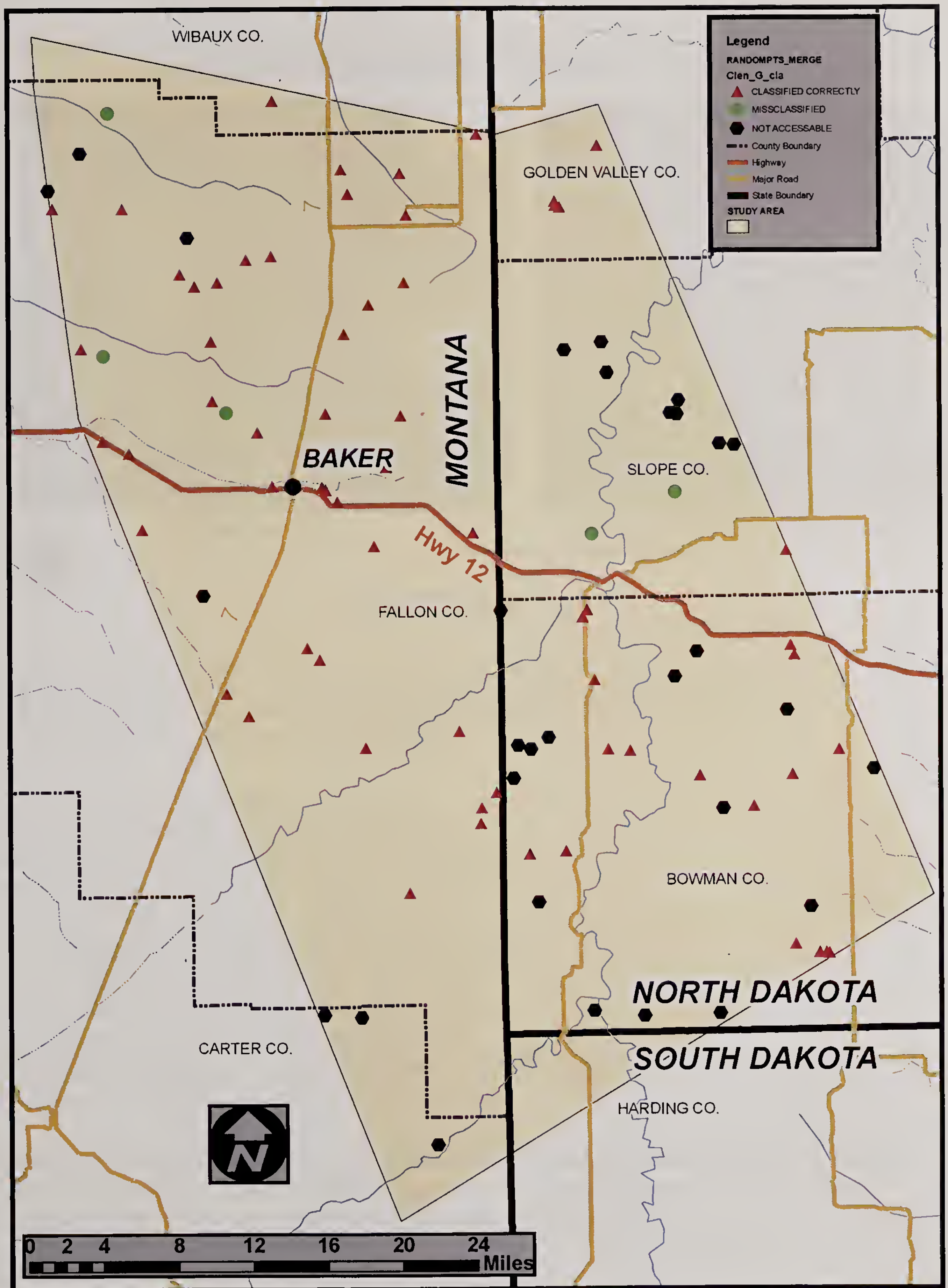
Because the accuracy of the canopy densities for the sage and sage riparian classes could not be not formally assessed it was decided to attribute the final data by four density ranges providing room for error:

1) 1% to 10%
2) 10% to 20%
3) 20% to 30%
4) > 30%

2.7 POST PROCESSING

Several editing steps were needed to finalize the sage data set. All six classified polygon data sets representing the individual sites were merged. Seams between merged sites were edited for inconsistencies. Polygons sharing common boundaries and attributes were dissolved into one. A final thematic accuracy assessment was performed by mimicking the heads-up photo interpretation process described in section 2.3 throughout the entire study area. A sample plot representing the final classified GIS polygon data set, "Land Cover Mapping Within the Cedar Creek Anticline and Surrounding Study Area" can be found as a foldout at the back of this report.

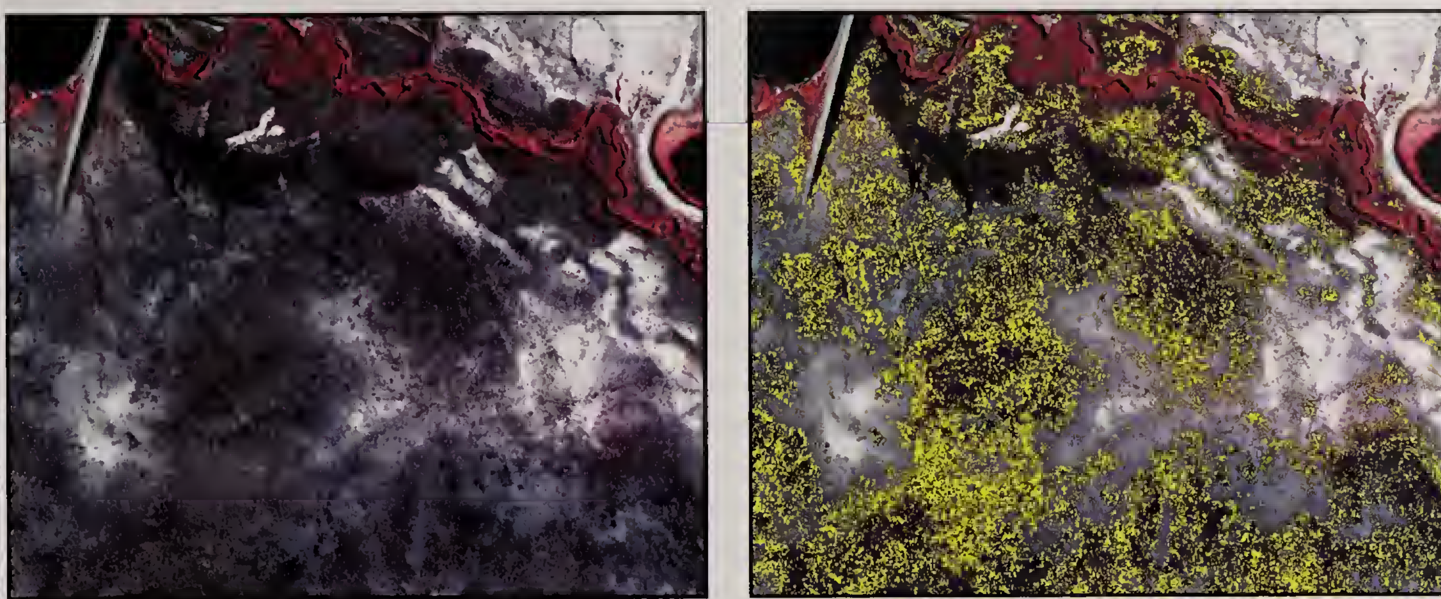
FIGURE 10



WIBAUX CO.
GOLDEN VALLEY CO.
Legend
RANDOMPTS_MERGE
Clen_G_cla
CLASSIFIED CORRECTLY
MISSCLASSIFIED
NOT ACCESSABLE
County Boundary
Highway
Major Road
State Boundary
STUDY AREA
MONTANA
BAKER
SLOPE CO.
Hwy 12
FALLON CO.
BOWMAN CO.
NORTH DAKOTA
SOUTH DAKOTA
CARTER CO.
HARDING CO.
N
0 2 4 8 12 16 20 24
Miles

FIGURE 11

SAGEBRUSH DENSITY / AUTOMATED CALCULATION



ADS40 IMAGERY | *PIXELS REPRESENTING SAGE COVER*

RESULTS

Acreages were calculated for each class polygon and added as an attribute to the final GIS data set. The sum acreage calculated for each class within the study area (approximately 1,126,306 acres in total)include:

1) Wetland - 430 polygons = 760 acres
2) Open Water - 2,839 polygons = 3,907 acres
3) Riparian – 11,020 polygons = 36,163 acres
4) Sage Riparian – 11,562 polygons = 35,699 acres
5) Sage – 94,649 polygons = 479,726 acres
6) Agriculture – 2,421 polygons = 260,886 acres
7) Conifers – 3,845 polygons = 10,036 acres
8) Developed – 2,466 polygons = 15,185 acres
9) Energy – 1,175 polygons = 4,708 acres
10) Sparse Vegetation – 39,896 polygons = 112,971 acres
11) Grasses – 10,462 polygons = 166,265 acres

The final GIS data set in ESRI *File Geodatabase* format can be found on the CD attached to the back cover of this report. A hard copy of the metadata associated with the final GIS data set can be found in Appendix I at the back of this report.

DISCUSSION

Healthy, properly functioning sagebrush communities support sage grouse and a variety of other native wildlife and vegetation species. Sagebrush communities in Montana are generally classified into 2 primary ecotypes (MSGWG 2005) the Mountain Foothills Mixed Sagebrush and the Wyoming Big Sagebrush-Silver Sagebrush. This study area falls primarily within the Wyoming Big Sagebrush- Silver Sagebrush ecotype (MSGWG 2005). Functional sagebrush vegetation communities are defined by having a heterogenous matrix/patches of shrubs, grasses, and forbs of varying heights, canopy coverage, and species.

The Montana Sage Grouse Working Group (2005) delineated sage grouse ecotypes in an effort to identify geographic areas that have similar capabilities and potential for management of habitats occupied by sage grouse. Ecotypes are based on soils, climate, vegetation patterns, and sage grouse distribution. Sage grouse have evolved with and adapted to and require a heterogenous patchwork of vegetation communities to meet their life history requirements and ultimately their survival (Connelly et al. 2000). Contiguous large blocks of healthy sagebrush-grassland are best suited for sage grouse survival (MSGWG 2005). In Montana, sagebrush distribution is a limiting factor for sage grouse poulations.

Recent advances in imagery acquisition and processing technology present opportunities for mapping and evaluating vegetation in a cost effective manner. The results presented in this report identify an effective integration of new technologies with existing computer digitizing methods and field expertise. This effort integrated high resolution multi-band color infrared digital imagery along with object oriented image processing to identify and map sagebrush and other vegetation classes in the BLM Miles City study area.

The ability to automate much of the traditional mapping and classification process allowed a large area to be rapidly evaluated for potential sage grouse habitat in the Miles City BLM project area. The costs incurred by using this methodology are estimated at $0.80 per-acre compared to the $3.00 per-acre using traditional methodologies. The results of this study are encouraging and it should be noted that the thematic accuracy obtained in this study is likely less than the accuracy of a similar product produced by more traditional methods.

The primary objective of this study was to collect and analyze imagery of the study area that would allow for the determination of sagebrush vegetation communities at a level of detail that would provide land and resource managers the information required to make decisions regarding future conservation and management actions in the BLM Miles City study area.

Seven vegetation assemblages and four other classes were identified through the study process. The vegetation assemblages include: Grassland; Conifer; Wetlands; Open Water; Riparian; Sage-Riparian; and Sage.
The remaining classes include: Energy; Agriculture; Developed; and Sparse Vegetation.

Polygons of each classification and vegetation assemblage were delineated through the Definiens process and verified through both a Heads-Up analytical analysis and a refined field check.

Application and use of the Study Results

Utilization of the results of this study are outlined below along with issues that have been identified as important by the BLM Miles City Office. Recent completion of a classification of the major vegetation species in the project area (Hansen et al. 2008) provides the ability for the BLM to combine this study with a more rigorous vegetation classifications to develop site-specific resource management and reclamation programs that focus on the specific needs and opportunities in the project area. Specific areas of discussion are addressed below.

Density of Sage Brush in Study Area.

The aerial imagery for this study focused on several factors: (1) collected at a scale comparable to the imagery collected in 2006 for the South Dakota study area located adjacent to the BLM study area; and (2) collected in the fall to allow comparison of similar seasonal vegetation signatures. The imagery allows for analysis of sage densities that were defined as being important for sage grouse use. These densities were defined as:

- Densities greater than 30 percent coverage
- Densities of 20 to 30 percent
- Densities 10 to 20 percent
- Densities 1 to 10 percent

The ability for the software to differentiate sage densities ranges less than 10 percent is diminished due to background vegetation communities and the limits of the process. Estimates of sage density ranges less than 10 percent can be made on a site-by-site visual assessment and should be backed up with a field survey to ensure that the vegetation densities represent sage brush species.

Shrub Associations within the Study Area

In southwest Montana other shrub species are found in association with big and silver sage communities, particularly in drainage areas and in areas of higher soil moisture content. On higher, drier and more exposed slopes and elevations, we occasionally found patches of greasewood (*Sarcobatus vermiculatus*) in association with big sagebrush. Greasewood typically grows in soils that are more alkaline and are often associated with dried lakebeds or playas.

In drainages and flood plain benches and areas with higher soil moisture content, common snowberry (*Symphoricarpos albus*) in association with silver sage and periodically with big sage occurred in the study area.

Snowberry does well on soils derived from limestone and not well on soils derived from granitic sources. It does best on well-drained soils range from warm dry slopes and open forests (where it can be used as an indicator species)to warm moist slopes to riparian benches and terraces

Application of the Aerial Photography and Methodology to other areas

This methodology utilized in this study can be applied to other areas and different vegetation classes. Critical to quantitative analysis is the occurrence of adequate vegetation densities to allow for the methodology to capture density differences and vegetation types. As the vegetation density diminishes (at higher elevations) it becomes more difficult, and hence less accurate, for capturing and assessing differences in vegetation and distribution.

Qualitative and quantitative assessments of other vegetation communities would require additional and adequate ground truthing. At higher elevation study sites, due to the reduced density, it is necessary to ensure that the data that is being collected accurately reflects the species, distribution and density of the vegetation classes being analyzed.

Integrating Studies for Land Management Plans

Vegetation varies across the BLM study area ranging from grasslands of relatively monotypic species to highly diverse and heterogeneous associations of plants. Developing reclamation plans for areas impacted by natural and anthropogenic causative agents requires understanding the relationships of geology, geography, soils, native and non-native plant distributions and topography.

Hansen et al (2008) have provided the BLM with a definitive description on the vegetation types and their classification throughout the Miles City Area. The Hansen study can be used to augment this study and provide an ability for BLM to develop site specific management and land restoration programs. We do know that we can determine where the two major species of sage brush common to the study area can be found. Silver sage typically is common on old alluvial terraces along streams and rivers while big sage *Artemisia tridentata* subsp. *tridentata* (basin big sagebrush) typically occupies shallower soils and soils with large amounts of clay and silt. It does not do well on coarse-textured soils.

In order to appropriately integrate the Hansen et al. (2008) study with this study it is important to understand the different objectives the two studies had. The Hansen study had the following objectives:

1. Develop one single vegetation -based ecological <u>site classification and management document for all lands</u> (i.e., uplands, riparian sites, and wetlands) within the administrative boundary of the USDI Bureau of Land Management's Miles City Field Office.

The work would build from the earlier regional works of Pfister and others (1977), Hansen and others (1984), Cooper and Pfister (1985), Hoffman and Alexander (1987), Hansen and Hoffman (1988), Hansen and others (1995), Thompson and Hansen (2001), and Thompson and Hansen (2002), in addition to collecting new data to supplement these earlier works.
2. Relate the various types to the soils and climate of the area.
3. Present management information (where applicable) for the various habitat types and community types, including forage productivity, timber productivity, wildlife information, response to fire, rehabilitation/restoration considerations, and recreational uses and considerations.
4. Determine successional relationships for the habitat types and major seral community types.
5. Relate the work to similar studies in this and adjacent regions.

Our study focused on quantifying the relative amounts and densities of the various vegetation types across a portion of the Miles City BLM area of management and was not intended to directly integrate with the Hansen et al. (2008) study. In essence this study looked at the broad distribution and density of public and private lands while the Hansen study focused on more detailed site classification effort. These studies combined with field vegetation monitoring and sampling studies being conducted by the Miles City BLM Office and the Forest Service can provide the BLM with a unique data base from which to evaluate and develop site and landscape specific restoration and monitoring programs. It was beyond the scope of this study to complete this analysis however the following discussion should help to focus your thinking as you contemplate these future efforts.

Succession of Vegetation Communities in Study Area.

The succession of vegetation communities and eventually to climax vegetation communities occurs in both riparian/wetland and upland environments throughout the study area. However, primary succession (Hansen et al. 2008) is more prevalent in riparian and wetland situations than in upland sites. Primary succession, as defined by Hansen et al (2008) represents the initial invasion of vegetation on barren sites lacking soil or pedogenic processes. Primary succession may be evident on previously unoccupied bedrock, on recent colluvial or alluvial deposits, or in areas where severe fire or flood has removed surface soil layers. Primary succession usually develops slowly, especially in the early stages as pioneer species gradually colonize and modify infertile sites over time (Clements 1920). However, in riparian zones this process may be much more rapid. Locally adapted pioneer species usually abound ready to establish on alluvial deposits of fine materials with good moisture supply. Secondary succession generally proceeds after disturbances resulting in the loss of the vegetation component, but where the soil layer remains intact. Revegetation may occur rapidly since the growth medium and nutrients remain primarily in place (Clements 1920). The result of succession in either context is climax vegetation, defined by self-replicating populations of vegetation that, barring disturbance, will persist on a site (Daubenmire 1968).

Hansen et al (2008) goes through a description of the different types of climax vegetation that presently exists in the BLM management area. The important conclusion to be drawn is that based on the work presented in this report, a distribution and density description of the existing vegetation communities were delineated throughout the defined study area and can be used in combination with the Hansen (2008) descriptions as a first cut to determine the type of restoration vegetation communities that may be appropriate for the location of the desired program. It would be appropriate for the BLM to utilize the information presented in this report with the more detailed vegetation classification scheme defined in the Hansen et al (2008) to determine the site specific restoration plan appropriate.

Of particular interest in this study was the distribution and density of sagebrush in the study area. We focused our attention on sagebrush distribution and associations. *Artemisia tridentata* subsp. *wyomingensis* (Wyoming big sagebrush) is one of the most important shrub species on western North American rangelands. It is a key species across a variety of Western landscapes, and a critical component in complex ecosystem processes ranging from localized soil processes, to large-scale herbivore interactions. *Artemisia tridentata* subsp. also provide critical seasonal habitat for a variety of species of importance, including sage grouse, deer, antelope and many avifauna.

Across the mid-elevation areas of the study area *Artemisia tridentata* subsp. *wyomingensis* (Wyoming big sagebrush) is the dominant species and generally represent late seral to climax stages on the landscape. According to the Hansen et. al (2008) study, Wyoming big sagebrush can be further separated into two habitat types:

- *Artemisia tridentata* subsp. *wyomingensis/Agropyron smithii* (Wyoming big sagebrush/western wheatgrass) habitat type, a common type typically found in valleys and on gentle slopes with finer soils; and,
- *Artemisia tridentata* subsp. *wyomingensis/Agropyron spicatum* (Wyoming big sagebrush/bluebunch wheatgrass habitat type typically found on moderate to steep hill slopes and ridges with coarser soils.

Traditional range management belief holds that sagebrush is an invader on rangelands believed to be historically dominated by herbaceous vegetation. The primary cause associated with this perceived expansion of range and increase in canopy cover is overgrazing, widespread burning, and mechanical clearing for crop production and rangeland alteration and conversion for livestock production (Welch 2005).

Artemisia cana subsp. *cana* (plains silver sagebrush). *Artemisia cana* subsp. *cana* (plains silver sagebrush) is an important shrub on western North American rangelands. Of the *Artemisia* (sagebrush) genus, its distribution is second only to *Artemisia tridentata* (big sagebrush) subspecies (Monsen 2004). It is a native, fragrant, evergreen shrub, typically found on floodplains, along drainages, and on alluvial terraces. It tolerates imperfect drainage, and grows well in mesic areas with a fluctuating water table, including areas that may experience periodic flooding (Hansen and others 1995).

Artemisia cana subsp. *cana* (plains silver sagebrush) is the dominant shrub (and in some situations is thc climax vegetation) on large areas in eastern and central Montana where soil, ground water, and climatic conditions are optimal for its growth and development. It is the primary woody component in the *Artemisia cana* subsp. *cana/Agropyron smithii* (plains silver sagebrush/western wheatgrass) habitat type.

According to Monsen and others (2004), *Artemisia cana* subsp. *cana* (plains silver sagebrush) has been used successfully in re-vegetating mine disturbances in southern Idaho and Wyoming. It may be useful in re-vegetating some degraded wetland sites. It is useful for soil stabilization as it is well adapted to newly exposed soils and tolerates short periods of flooding.

Unlike *Artemisia tridentate*, *Artemisia cana* is often found on edge habitats where other types of vegetation associations are occurring, specifically along drainages and riparian areas, proximity to wetlands, and where soil conditions are moving towards higher salinity soils. In these cases the climax vegetation association will likely include other types of vegetation including snowberry, alders, willows, and annual grasses for the wetter, loamier soils to greasewood (*Sarcobatus* sp.) which is typically found on more saline soils.

Can The Different Shrub Species be Differentiated in this Study?

In general the different types of shrub vegetation cannot be accurately differentiated from the aerial photography and analysis of this study. That was not an objective of this study. Instead the results of this study can be used to differentiate the distribution and density of the different vegetation associations over large areas of the BLM managed areas. With additional analysis a delineating of the different species types within the vegetation associations can be made. This would require:

- Integrating the Hansen et. al (2008) study with our vegetation associations
- Integrating additional transect assessments within different vegetation associations throughout the study area.
- Conducting additional vegetation field assessments to verify classifications

Summary

We believe that the results presented and developed through this study will provide the BLM with a product that can be integrated with other studies and data, applied to specific management questions and aid the agency with making more definitive and scientifically based decisions.

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APPENDIX I

Metadata

BUREAU OF LAND MANAGEMENT, MCFO SAGE MAPPING

Identification_Information:
Citation:
Citation_Information:
Originator: Patrick Wright, Contractor for the Bureau of Reclamation
Publication_Date: 09/2008
Title: LandCover
Geospatial_Data_Presentation_Form: vector digital data
Online_Linkage: \\IBR8PWRIGHTD2\C$\mt_sage\final\CedarC_LC.gdb
Description:
Abstract: These data were generated as a cooperative project between the, Bureau of Land Management and the Bureau of Reclamation for the purpose of mapping sage brush and other land cover in a defined study area in and around the Cedar Creek Anticline within the Williston Basin. The study area falls within portions of NW South Dakota, SW North Dakota and SE Montana representing approximately 1,132,000 acres.
Purpose: The importance of sagebrush for many obligate species including sage grouse (Centrocercus urophasianus) is well documented. The objective of the current mapping effort is to utilize the newly developed methodology to determine the extent of sagebrush vegetation communities at a level of detail to assess community relationships in and around the Cedar Creek anticline. The 2007 high resolution color infrared orthophotography and the GIS compatible land cover land use map produced from the orthophotography can be used by researchers in many different ways to quantify and analyze the biodiversity of the study area.
Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 10/2007
Currentness_Reference: October 2007
Status:
Progress: Complete
Maintenance_and_Update_Frequency: As needed
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -104.568230
East_Bounding_Coordinate: -103.551659
North_Bounding_Coordinate: 46.719070
South_Bounding_Coordinate: 45.796226
Keywords:
Theme:
Theme_Keyword_Thesaurus: REQUIRED: Reference to a formally registered thesaurus or a similar authoritative source of theme keywords.
Theme_Keyword: SAGEBRUSH
Theme_Keyword: Land Cover
Theme:
Theme_Keyword: SAGEGROUSE

Place:
  Place_Keyword: Cedar Creek
  Place_Keyword: Anticline
  Place_Keyword: Montana
Access_Constraints: To be determined by the Bureau of Land Management
Use_Constraints: To be determined by the Bureau of Land Management
Point_of_Contact:
 Contact_Information:
  Contact_Person_Primary:
   Contact_Person: Patrick Wright
   Contact_Organization: Bureau of Reclamation
  Contact_Position: Environmental Scientist / Contract Task Lead
  Contact_Address:
   Address_Type: mailing address
   Address: USBR Denver Federal Center, MC 86-68260,POB 25007
   City: Denver
   State_or_Province: Colorado
   Postal_Code: 80225
   Country: USA
  Contact_Voice_Telephone: 303-445-2288
  Contact_Facsimile_Telephone: 303-445-6337
  Contact_Electronic_Mail_Address: pwright@do.usbr.gov
  Hours_of_Service: 7:00am to 6:00pm
Security_Information:
 Security_Classification_System: To be determined by the Bureau of Land Management
 Security_Classification: Unclassified
 Security_Handling_Description: To be determined by the Bureau of Land Management
Native_Data_Set_Environment: Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 2; ESRI ArcCatalog 9.2.5.1450
Cross_Reference:
 Citation_Information:
  Originator: Bureau of Reclamation Tech Memo
  Publication_Date: 10/2008
  Title: Mapping Land Cover to Estimate Sage Grouse Habitat Within the Cedar Creek Anticline and Surrounding Stucd Area
Data_Quality_Information:
 Attribute_Accuracy:
  Attribute_Accuracy_Report: No formal thematic accuracy check has been performed on data set. An informal check of 69 random polygons identified 5 miss-classified polygons.
 Logical_Consistency_Report: 1) Repair Geometry
 Completeness_Report: Data set represents land cover polygons that fall within proposed study area.

Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report: The data set was generated from ADS40 imagery at a relative scale of 1:12,000
Quantitative_Horizontal_Positional_Accuracy_Assessment:
Horizontal_Positional_Accuracy_Value: 33 feet
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report: NA
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Title: Horizons Inc. Rapid City S.D.
Source_Scale_Denominator: 1:12,000
Type_of_Source_Media: ADS40 CIR Imagery
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: Sept. 2006
Source_Currentness_Reference: Flight Date
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Process_Description: Data development described in detail in project write up "MAPPING LAND COVER TO ESTIMATE SAGE GROUSE HABITAT WITHIN THE CEDAR CREEK ANTICLINE AND SURROUNDING STUDY AREA"
Source_Used_Citation_Abbreviation: C:\sage_grouse\sample_data\SHAPEFILES\SITE4_CLIPPED_SB_Dissolve.shp.xml
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Process_Description: Metadata imported.
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Cloud_Cover: NA
Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: G-polygon
Point_and_Vector_Object_Count: 180765

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: 13
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.999600
Longitude_of_Central_Meridian: -105.000000
Latitude_of_Projection_Origin: 0.000000
False_Easting: 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000100
Ordinate_Resolution: 0.000100
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222
Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: LandCover
Entity_Type_Definition: Thematic land cover class defined initially by image processing and refined by photo interpretation
Entity_Type_Definition_Source: Image processing for entire study area and detailed photo interpretation
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Attribute_Label: Shape
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
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Attribute_Label: Acres
Attribute_Definition: Acreage of individual polygon
Beginning_Date_of_Attribute_Values: 10/2007
Attribute:
Attribute_Label: OBJECTID
Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI

Attribute_Domain_Values:
Unrepresentable_Domain: Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: CLASSFINAL
Attribute_Definition: Land cover Class
Attribute_Definition_Source: Images processing and photo interpretation
Attribute:
Attribute_Label: DENS_CLASS
Attribute_Definition: % canopy cover for sage and sage riparian classes
Attribute:
Attribute_Label: Shape_Length
Attribute_Definition: Length of feature in internal units.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Positive real numbers that are automatically generated.
Attribute:
Attribute_Label: Shape_Area
Attribute_Definition: Area of feature in internal units squared.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Positive real numbers that are automatically generated.
Distribution_Information:
Distributor:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Jen Nagy
Contact_Organization: Bureau of Land Management
Contact_Address:
Address_Type: mailing address
Address: 111 Garryowen Road
City: Miles City
State_or_Province: Montana
Postal_Code: 59301-0940
Contact_Voice_Telephone: 406-233-2800
Contact_Electronic_Mail_Address: Jennifer_Nagy@blm.gov
Resource_Description: To be determined by the Bureau of Land Management
Distribution_Liability: To be determined by the Bureau of Land Management
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Transfer_Size: 375.721
Fees: To be determined by the Bureau of Land Management
Ordering_Instructions: To be determined by the Bureau of Land Management
Turnaround: To be determined by the Bureau of Land Management
Custom_Order_Process: To be determined by the Bureau of Land Management

Technical_Prerequisites: To be determined by the Bureau of Land Management
Metadata_Reference_Information:
Metadata_Date: 20081025
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Patrick Wright
Contact_Organization: Bureau of Reclamation
Contact_Address:
Address_Type: REQUIRED: The mailing and/or physical address for the organization or individual.
City: REQUIRED: The city of the address.
State_or_Province: REQUIRED: The state or province of the address.
Postal_Code: REQUIRED: The ZIP or other postal code of the address.
Contact_Voice_Telephone: 303-445-2288
Contact_Facsimile_Telephone: 303-445-6337
Contact_Electronic_Mail_Address: pwright@do.usbr.gov
Hours_of_Service: 6:00am to 7:pm
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Access_Constraints: To be determined by the Bureau of Land Management
Metadata_Use_Constraints: To be determined by the Bureau of Land Management
Metadata_Extensions:
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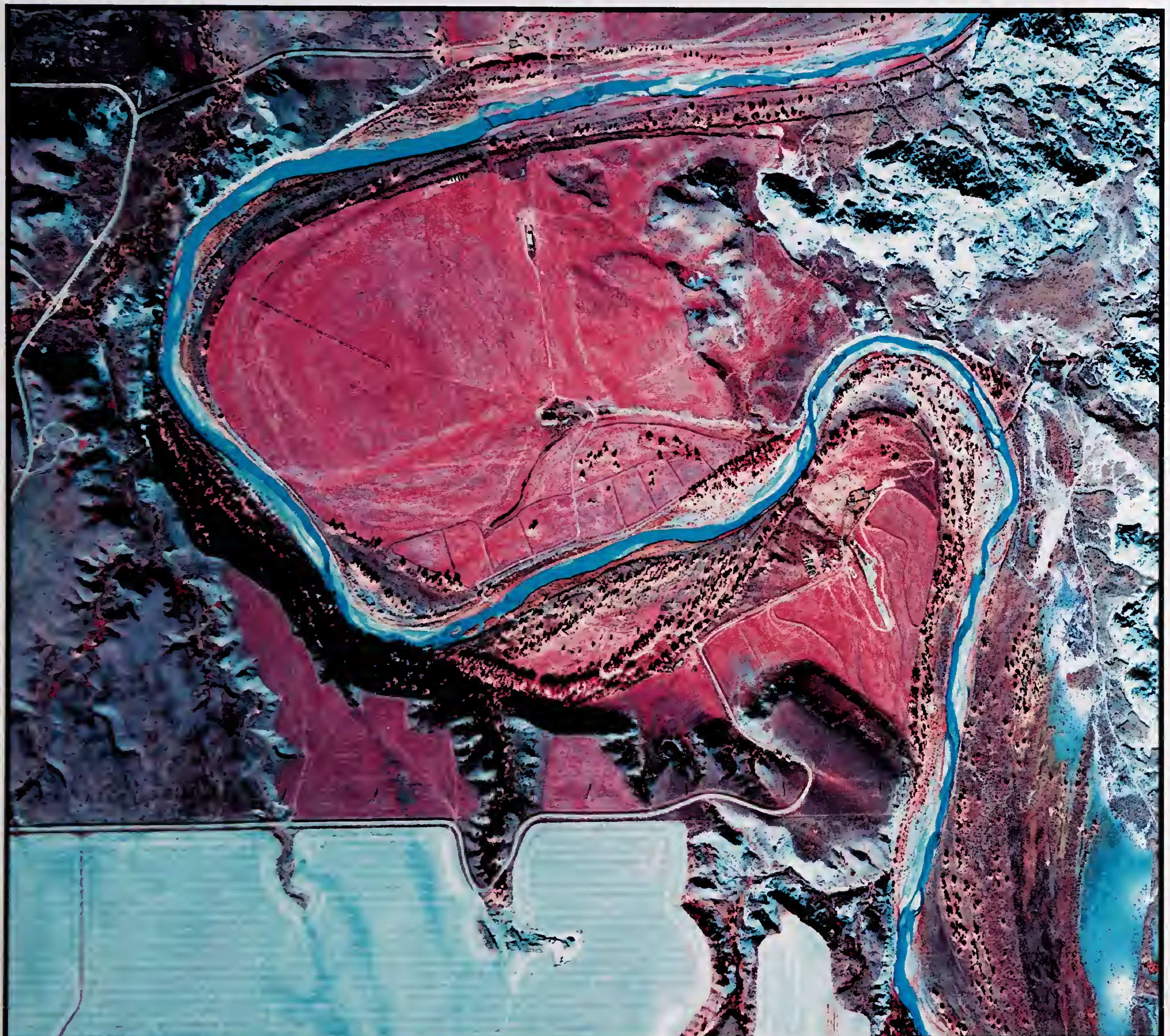
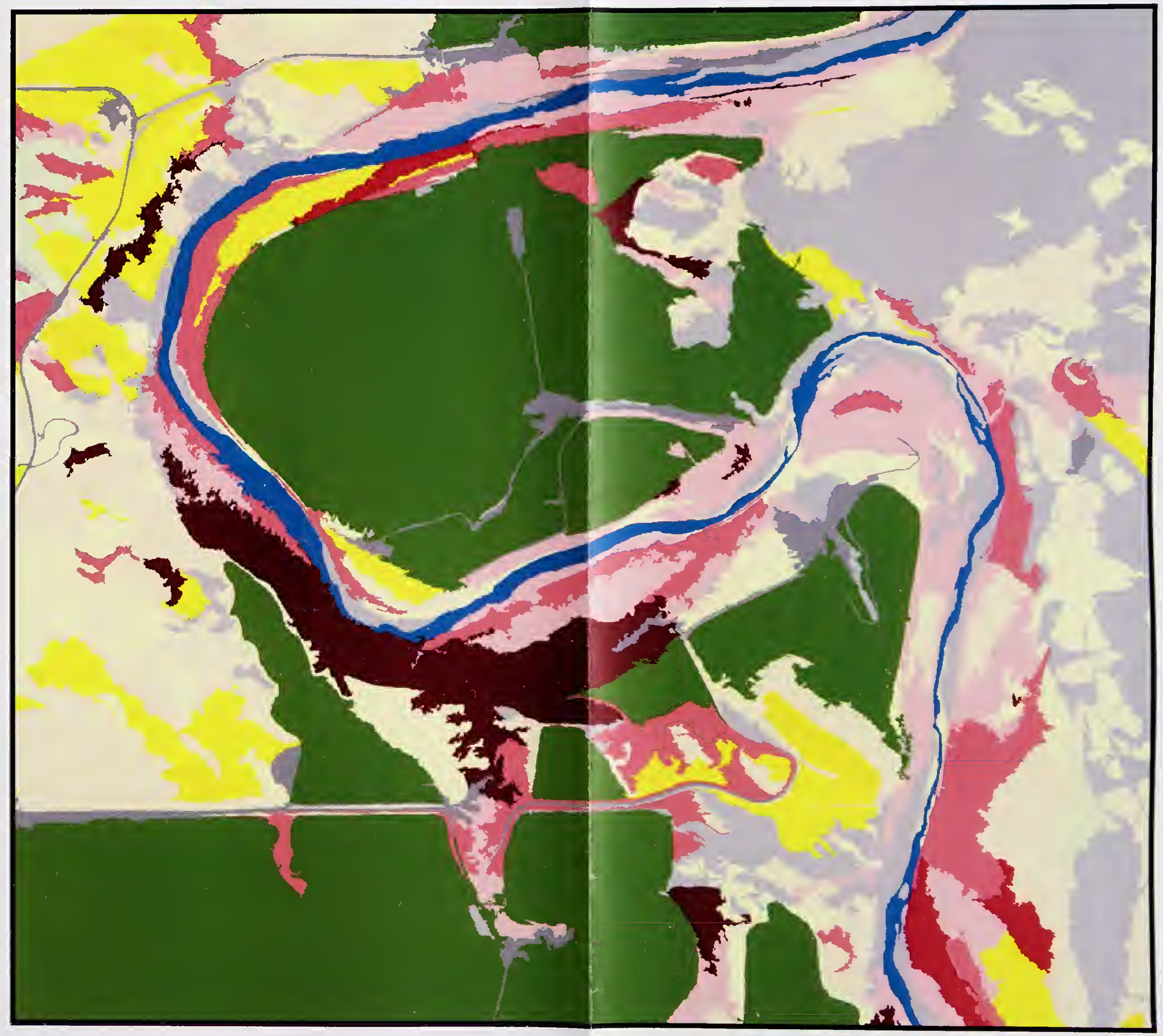
LAND COVER MAPPING WITHIN THE CEDAR CREEK ANTICLINE AND SURROUNDING STUDY AREA



ADS40 IMAGERY



CLASSIFIED POLYGON DATA

N
W E
S

0 125 250 500 750 1,000
Meters

Legend

LAND COVER
- AGG,
- CONIFER,
- DEVELOPED,
- ENERGY,
- GRASSLAND,
- OPEN_WATER,
- RIPARIAN,
- SAGE, 1% TO 10%
- SAGE, 10% TO 20%
- SAGE, 20% TO 30%
- SAGE, >30%
- SAGE_RIPARIAN, 1% TO 10%
- SAGE_RIPARIAN, 10% TO 20%
- SAGE_RIPARIAN, 20% TO 30%
- SAGE_RIPARIAN, >30%
- SPARSE_VEG,
- WETLAND,

This plot represents a cooperative effort between the Bureau of Reclamation's Remote Sensing and Geographic Information Team and the Bureau of Land Management, Miles City Field Office. This effort successfully completed the mapping of sagebrush and 10 other land covers in and around the Cedar Creek Anticline within the Williston Basin using ADS40 imagery and Definiens image processing software.

Project Contacts: Dave Wegner (970) 259-2510, emiwegner@aol.com and Patrick Wright (303) 445-2288, pwright@do.usbr.gov, under contract with the Bureau of Reclamation Remote Sensing and GIS Team P.O. Box 25007 M.S. 86-68211 Denver, Colorado 80225

PEER REVIEW DOCUMENTATION

(Typical Form)

Project and Document Information

Project Name Mapping Land Cover / Cedar Creek Anticline WOID OG950

Document Technical Memorandum

Document Date 10/2008 Date Transmitted to Client 10/2008

Team Leader Patrick Wright (SAIC Contractor) Leadership Team Member M. Pucherelli
(Peer Reviewer of Peer Review/QA Plan)

Document Author(s)/Preparer(s) Patrick Wright, Dave Wegner

Peer Reviewer Mike Pucherelli Peer Reviewer ____________

Peer Reviewer ____________

Review Requirements

(Part A: Document does not require Peer Review)

Explain ____________

(Part B: Document require Peer Review: **SCOPE OF PEER REVIEW**)

Peer Review restricted to the following items/section(s): ____________

Reviewer ____________

Review Certification

Peer Reviewer: I have reviewed the assigned items/sections(s) noted for the above document and believe them to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

Reviewer Michael J Pucherelli Date reviewed 10/23/08
(Signature)

Preparer: I have discussed the above document and review requirements and believe that this review is completed, and the document will meet the requirements of the project.

Team Member Peter Wright Date signed 10/23/08
(Signature)