

***Delineation and Attribution of
Wrangell Saint Elias Park and Preserve
Off-Road Vehicle Trails and Vegetation***



Pacific Northwest CESU Task Agreement #J8W07080004

GeoSpatialServices



Wrangell – St. Elias, Off-Road Vehicle Trails and Vegetation Mapping

Background:

Off-road vehicles (ORVs) are used as a major means of transportation into roadless areas of Alaska. Small four and six-wheelers and medium sized ORVs (Weasels) are used for personal access to property and mining claims, and subsistence and recreational activities such as hunting and fishing. Heavy ORVs (Bombardier Muskeg Tractors and Caterpillar D-7s are used by industry during mineral exploration and extraction.

The earliest trails in Wrangell – St. Elias Park and Preserve were established along traditional Alaskan Native routes during the 1890's to 1930's by horse drawn sleds and a few steam driven vehicles for mineral exploration and mining access (Bleakley, 1997). Additional trails were created by modern diesel driven bulldozers in the study of seismic activity in the 1950's. During the late 1960's and early 1970's mining activity created additional trails. Homesteads and recreation brought ORVs including rubber tired and tracked vehicles ranging in size from a three-wheeled Honda to a D-9 CAT (Connery 1987). Present day use includes access to in-holdings, subsistence hunting, fishing, trapping, and gathering, and recreational access to hunting, fishing, and general recreation. Currently in the park, approximately 600 miles of trails affect almost 2,000,000 acres of park and preserve land (Ahlstrand and Racine 1990). ORV use is most heavily distributed in the northern area of the Park and Preserve within the Nabesna District, which includes the Nabesna and Gold Hill areas. Within this district, there are over 315 miles of trails directly affecting an estimated 500,000 acres of Park and Preserve land (Beck *et al.* 1985).

Wrangell - St. Elias National Park and Preserve was established in 1980 by the Alaska National Interest Lands Conservation Act (ANILCA). Prior to the establishment of the Park and Preserve, ORV use amplified this network of trails. This legislation established federal regulations to prohibit the use of ORVs in locations other than established roads and parking areas with the following exceptions: 1) on routes or areas designated accordingly; 2) by the establishment of a permit system for ORV use on existing trails in non-wilderness areas if it is found that ORV use would be compatible with the purposes and values of the area; 3) as access to in-holdings if ORV use is the most adequate and feasible method without causing significant adverse impacts on natural or other values of the area or does not go against the management plans for the area; and 4) as access to subsistence resources if this means of surface transportation was traditionally employed and does not pose a threat to public health, public safety or resource protection. Due to terrain limitations and little road development, most in-holder and subsistence access in the Park and Preserve is currently by ORV (P.J. Happe, K. E. Shea, and W. M. Loya, 1998).

Study Area and Mapping Program:

Wrangell - St. Elias National Park and Preserve is located in Southeast Alaska near the communities of Valdez, Copperville, Chitina, and Tetlin Junction. The Park is

approximately 150 miles from Anchorage and 200 miles from Juneau (Figure 1). From Juneau the park can only be reached by air or boat travel. Wrangell – St. Elias covers approximately 13.2 million acres and is characterized by mountain ranges, with the tallest extending up over 18,000 feet, coastlines, glaciers, braided rivers, wetlands, and a mosaic of vegetation communities from early successional to climax.

Figure 1: Location of Wrangell – St. Elias National Park and Preserve



Color infrared (CIR) aerial photography was used to classify vegetation types along ORV trails and to quantify lengths of trails in the study area. Existing knowledge of the amount of ORV use on trails was used to stratify the trails by amount of ORV use. For the Nabesna study area, vegetation of the trails was classified on 1:30,000 photography and verified using helicopter access during the summer of 1994. When money was available for new photography, a contract was established with the Bureau of Land Management, Anchorage, Alaska to shoot 1:6000 CIR aerial photography. Aerial photographs were taken of all trails in the Nabesna District August 2-4, 1994. The 1:30,000 photography and ground truthing notes were used to interpret vegetation on the 1:6000 photography in the spring of 1995. Segment boundaries were established in places where use levels were expected to change, such as at trail junctions, physical barriers (i.e. river crossings), the wilderness boundary (beyond which all recreational use

was banned), or features at which use was expected vary (i.e. the beginning of a lake) (P.J. Happe, K. E. Shea, and W. M. Loya, 1998).

Digital Conversion Methodology:

Digital conversion refers to the process by which a hardcopy aerial photograph and ink delineations of land cover polygons on acetate overlays are transformed into digital images and digital vector data within a Geographic Information System (GIS). This process generally applies five main steps: photo and acetate scanning; georeferencing and orthorectification of scans; raster to vector conversion of delineated polygons from scanned acetates, edge matching and quality assurance and quality control (QAQC), and polygon attribution.

The process established in this project did not require many of these steps. The original base layer was the 1:6000 CIR air photos; however the new polygons would be projected onto IKONOS digital imagery which was already georeferenced and orthorectified. The line work on acetate would not be digitally scanned, but cartographically transposed through image interpretation. These roughed in polygons would be digitized "heads-up" into a feature data class thus bypassing the traditional raster to vector conversion. Edge matching was also done on the fly. Each photo contained a sufficient amount of overlap to be viewed and replicated on-screen. Polygon attribution and QAQC were treated similar to standard digital conversion methods.

The NPS provided 317 photos with associated acetate overlays for digital conversion. Upon receipt of these hardcopy products, the photos were inventoried and recorded into a project management database. The photos were then separated into thirteen sub-project areas based on trail segments: Black Mountain East, Black Mountain West, Boomerang Lake, Caribou Creek, Chalk Creek, Copper Lake, Lost Creek, Reeve's Field, Rock Creek, Pass Creek, Suslota, Tanada Lake, and Trail Creek. The photos were then further ordered by trail splits and flight lines. This was done to associate specific photos with on-screen, collateral data for later delineation stages.

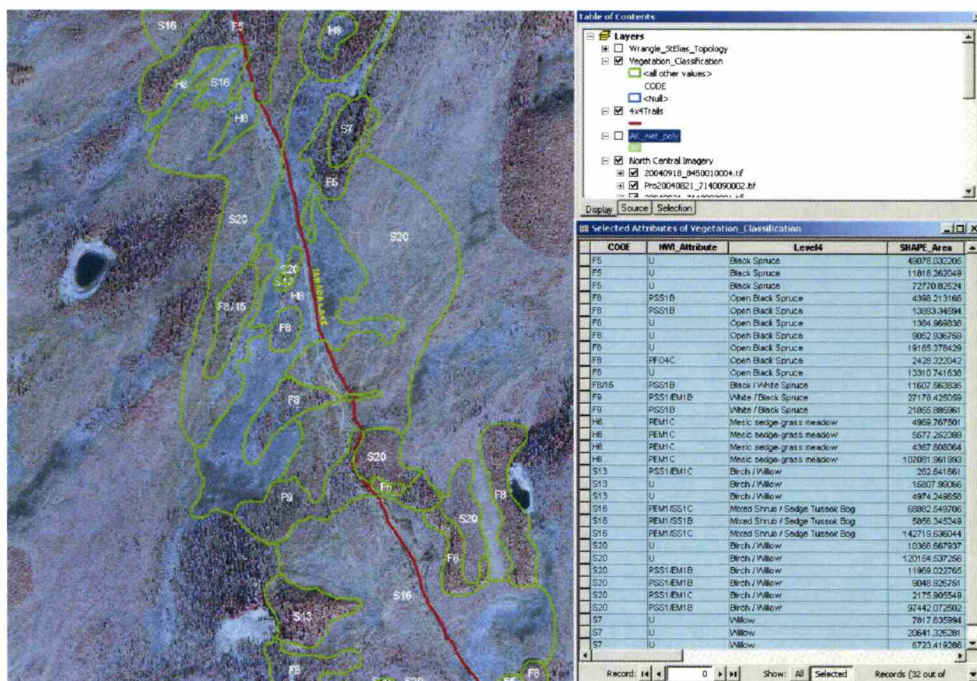
Light Table Delineation:

A standard GIS workstation was set up with two flat-panel monitors and a small light table positioned to the side. The hardcopy air photos overlaid with mylar line work were back lit and viewed on the fluorescent light table (Photo 1). An ArcMap 9.2 map document was set up with IKONOS imagery as the base layer and a new feature class created within a personal geodatabase to digitize and edit polygons. The second screen contained the table of contents, attribute records, and snapping options. Photos along the trail segment and flight line were flipped onto the light table and the polygons pictured were digitized on-screen (Figure 2). The analyst applied signatures and shapes of the IKONOS digital imagery matched to the hardcopy CIR photos. Position and size of each polygon was retained by calculating the length of the trail segment and maintaining a scale 1:6000, the same as the original mylar data.

Photo 1: 1:6000 CIR Air Photo and Acetate Polygons on Light Table



Figure 2: 1:6000 IKONOS Imagery and Vector Polygons On-Screen



The ORV Vegetation Impact personal geodatabase is georeferenced to North American Datum of 1983 (NAD83-CORS96 or CORS94) and is further specified below:

Projection: Albers
False_Easting: 0.000000
False_Northing: 0.000000
Central_Meridian: -154.000000
Standard_Parallel_1: 55.000000
Standard_Parallel_2: 65.000000
Latitude_Of_Origin: 50.000000
Linear Unit: Meter (1.000000)

Geographic Coordinate System: GCS_North_American_1983
Angular Unit: Degree (0.017453292519943299)
Prime Meridian: Greenwich (0.000000000000000000)
Datum: D_North_American_1983
Spheroid: GRS_1980
Semimajor Axis: 6378137.000000000000000000
Semiminor Axis: 6356752.314140356100000000
Inverse Flattening: 298.257222101000020000

Digital Transfer Scope (DTS) Delineation:

A DTS is a hardcopy / softcopy imagery and data viewing and editing machine that works in coordination with a GIS system (Photo 2). This equipment combines a light table, stereoscope, and digitizing tablet that plugs into a computer's video card. A DTS is able to extract the ground information directly into a GIS. This configuration allows stereo photo interpretation of extreme topography, high accuracy digitizing between multiple imagery sets, visual comparison of hardcopy photos and digital imagery, and manual, vector conversion of hardcopy line work on a single desktop workstation.

Photo 2: DTS Machine



The unit is a high performance, zoom stereoscope that allows viewing photos with both eyes, and with a computer monitor display superimposed onto one photo of a stereo pair. A DTS generally contains wide-field objectives, an internal liquid crystal display (LCD) monitor and optics, and the ability to work with different software applications. Some come with their own programs for continuous zooming and panning, warping, rotating, and stretching imagery or line work in order to visually fit one onto another. More

expensive models also have a camera mounted for capturing pictures of what is seen through the instrument's eyepiece (Greene 2002).

Base map scale must closely approximate photographic scale, or else the distortion inherent in a single photograph is increased when enlarging a small-scale photo to fit a large-scale base map. In addition, if an aerial photo's mylar line work is adjusted to fit a particular map projection as represented by a digital data set, the images must either be georeferenced, rectified, or converted into ortho-images. The use of the Albers NAD83, 2004, IKONOS imagery as a digital base map prevented both of these issues. In order to complete the DTS polygon detailing the 1:6000 hardcopy photos were zoomed in at 50 percent. So the projected and referenced IKONOS scale was also set 1:3000. Vector polygons that were roughed in during the light table delineation fell cleanly over the acetate polygons on mylar when viewed by the DTS. In addition, the on-screen imagery matched the air photos on the DTS table to offer a 3D, stereo comparison of signatures. The final vector polygons were edited for precise corrections in shape associated to adjacent polygons and trail segments. This process was completed with the ArcGIS topology tool, reshape edge. Size, location, orientation, position, and attributes of the polygons were accurate with only the light table digitizing.

Existing gaps within the data prevented the analyst from delineating complete coverage of all Nebesna District ORV trails (Figure 3). In some instances there were small gaps of polygons along trails or larger gaps due to missing air photos and acetate overlays. In this case polygons were created and attributed by matching signatures of surrounding features on the IKONOS imagery. In other situations the ORV trails extended beyond the IKONOS boundary and Alaska High-Altitude Aerial Photography (AHAP) was used to interpret vegetation signatures. Polygons delineated on IKONOS imagery, with well defined signatures, where AHAP could be used as collateral acted as a cross reference and a match to signatures where IKONOS imagery was not available (Figures 4 and 5).

Figure 4: 1:10,000 IKONOS

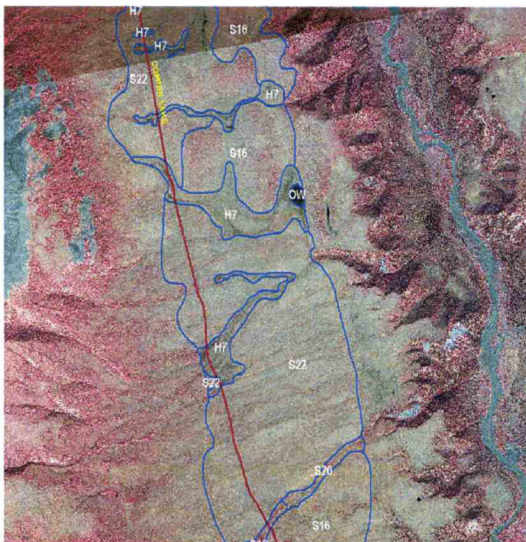
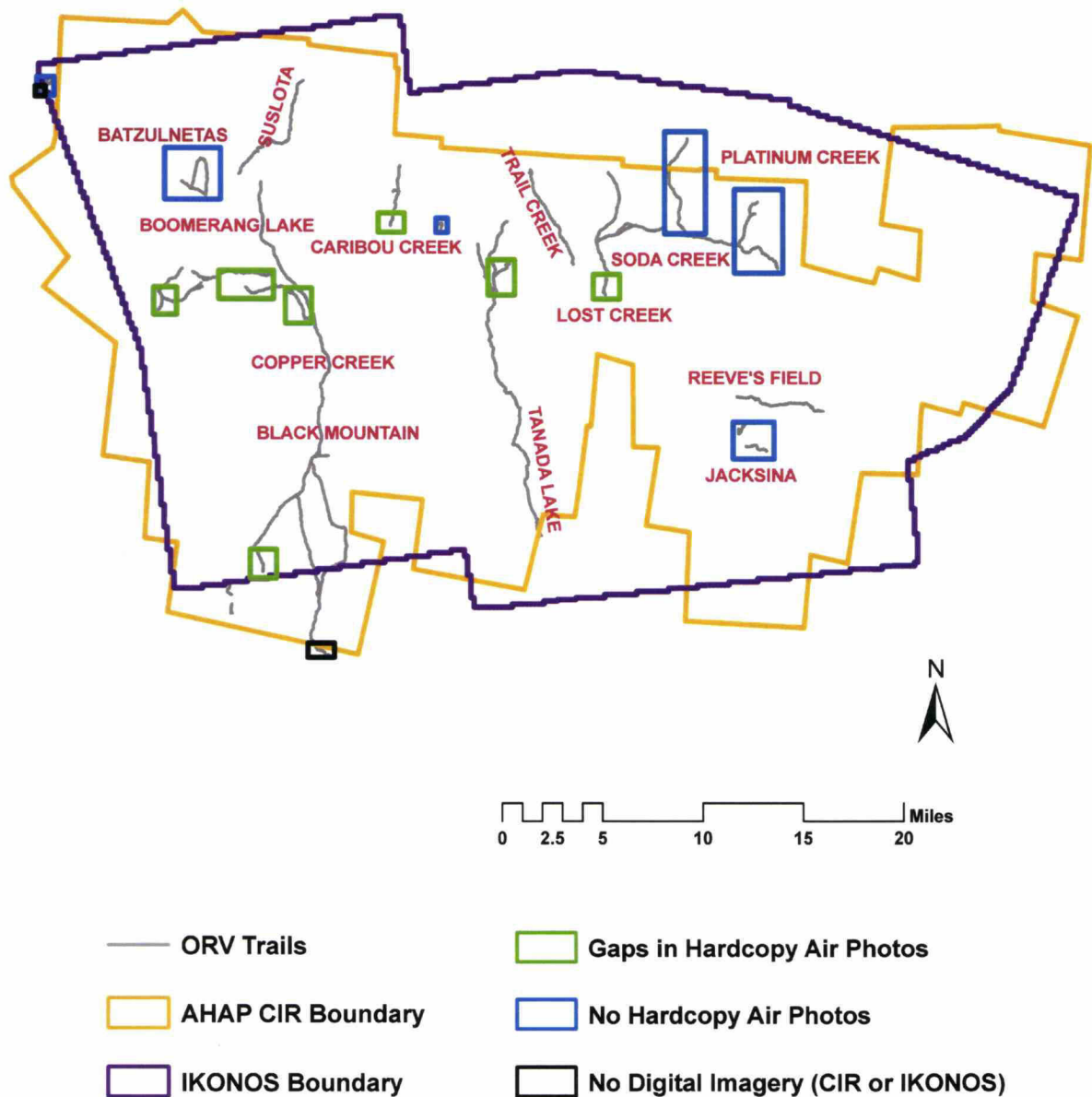


Figure 5: 1:10,000 AHAP CIR



Figure 3: Imagery Availability in Study Area

Nabesna District ORV Trails



Attribution and Vegetation Crosswalk:

Attribution refers to the process of attaching a descriptive identifier to vector polygons so that the spatial data are meaningful to a user. Attributes are typically stored in a database table that is linked directly to the feature geometry (Figure 5). Traditionally, polygons are attributed by opening the vector line work on top of the a raster image such as an air photo or satellite image, selecting a feature, interpreting the signature of a polygon, and typing in the polygon attribute within a database table. This is primarily a manual process in which editors interact with ArcMap in order to type in every polygon attribute. In this project, the polygon attributes have already been coded according to signature on the 1:6000 hardcopy air photos. No signature interpretation was required for the areas of the 317 photos, only database entry. Portions of trails with missing hardcopy photos or gaps in line work did require the addition of on-screen interpretation of IKONOS or AHAP CIR imagery.

Figure 5: Attributes in ORV Trail Vegetation Classification Access Database

Vegetation_Classification		
Personal GeoDatabase Feature Class		
Description	Spatial	Attributes
Details for Vegetation_Classification		
Type of object: Feature Class		
Number of records: 1596		
Attributes		
OBJECTID		
Shape		
Level4		
CODE		
Notes		
NWI_Attribute		
Comments		
Level1		
Level2		
Level3		
Shape_Length		
Shape_Area		

Attribution of the Level I, II, III, and IV vegetation descriptions was completed through a selection and field calculation method called “conditional operations.” For example, all NPS codes starting with F are selected and the Level I field is populated with *Forest*. All

forests with codes from F1 – F9 are selected and attributed with *Needleleaf 75%* in the Level II column. F1 – F3 forests receive *Closed 60-100%* in the Level III field. Only forests in this subset with F3 coding get the attribute of *White / Black Spruce* in the Level IV category.

Completing the NWI classification required the greatest amount of effort and interpretation in this project. An Excel spreadsheet categorizing NPS codes and Level I, II, III, and IV vegetation classifications was opened and saved with an NWI column added (Appendix A). Wetland interpreters reviewed land cover classification polygons, previously mapped 1:40,000 NWI features, IKONOS and CIR imagery, and Wrangell – St. Elias species listings. Then documentation of NWI conventions were compiled to adhere to these standards. A list of possible, but not always applicable, NWI systems, classes, and regimes were cross referenced into the table with the NPS vegetation codes.

Each individual land cover polygon was reviewed for NWI attribution. All upland features and polygons over 50 percent upland received an NWI code of U (upland). All features that appeared to occupy a water regime and were over 50 percent wetland were further inspected for NWI attribution. Vegetation Classification polygons were overlaid on 1:40,000 NWI polygons to compare size, shape, and orientation of features. Then the layer was compared to the CIR and IKONOS imagery. After viewing all collateral data a valid NWI attribute was assigned to the polygon.

A comment field was added to give a user some insight as to how the features were transposed from hardcopy photos to on-screen vector data. There were some discrepancies of polygon shape and labels between overlaps of photos. In addition, some of the polygons were interpreted to fill in gaps or entire trail segments. Below is a list of these comments and a brief explanation. Comments are based on labels and attribution, delineation to digitizing, and QAQC check of wetland criteria.

MULTIPLE LABELS – More than one NPS code between photos, all are listed.

MISLABELED – Interpreted as an incorrect NPS code.

LABELED – At times there were other attributes on the photo and are documented.

NO LABEL – No NPS code listed, the code was interpreted.

CIR – NPS code was digitized or interpreted from AHAP CIR not IKONOS.

GAP – Missing portions between polygons or photos which are interpreted and filled in.

PARTIAL DELINEATION – Polygons which were not closed off on hardcopy.

MULTIPLE DELINEATIONS – Polygons which had multiple shapes and sizes between two or more hardcopy photos.

PONDING – Does not meet wetland criteria, just standing water.

HYDROLOGICALLY CONNECTED – Meets wetland criteria, linked to other wetlands.

SOME UPLAND – A majority of this polygon is wetland, although portions are not.

MOSTLY UPLAND – A majority of this polygon is upland, and portions are wetland.

UPLAND – Does not meet wetland criteria or signature.

Quality Assurance and Quality Control:

The land cover polygons were originally delineated on 317 CIR air photos and through manual, vector transformation are represented as features overlaid on IKONOS digital imagery. Quality control of the final product was managed and verified in three different spatial examinations. Initially, polygon boundaries were checked by displaying them on-screen, side-by-side with the original air photos and mylar line work. This was to ensure that all of the line work was present and matched the original labels. Next, the delineations were checked against the existing land cover layer in order to verify the line work added by the interpreter matched the IKONOS imagery on-screen. Finally, the delineated features received an ArcGIS topology check to guarantee structural integrity in the final dataset. The topology rules that were enforced during this test included must not have gaps and must not have overlaps.

The attributes were transferred from hardcopy pen and ink to a typed code in an Access table and verified between table and multiple photos. At the end of a trail segment the entire flight line was again reviewed for correct attributes. At times there would be differences in vegetation codes between multiple photos in areas called "overlap". In this case the code most listed on that feature was used. If the polygon had a number of different labels a judgment call was made by matching signatures. Multiple labels and their listing are recorded in the Comments field. The final attribution review was completed with queries of the attribute table. Erroneous codes were replaced with correct attributes.

After an internal QAQC review was completed, two preliminary datasets were sent to Wrangell – St. Elias for further evaluation. Copper Lake and Tanada Lake trails were exported to shapefiles and submitted. The features and attributes were assessed at five major points. The first check was how accurately the polygons taken from acetate, hardcopy CIR matched the digital IKONOS imagery based on major landforms and vegetation. The review discovered the presence of same adjacent attributes (SAAs) in the database. These SAAs were present on the hardcopy mylar in original delineation, or created by overlap between multiple photos. These errors were identified by an SAA tool and then corrected by an interpreter.

The second verification also passed. The attributes of Level IV vegetation classification and NPS Code correlated to the digital IKONOS signature.

The third assessment was the correlation of the NWI attribute to the IKONOS imagery and comparison of the collateral data: (CIR imagery, 1:40,000 NWI polygons, and vegetation crosswalk). Based on trail condition, approximately five percent of the polygons were requested to have a second interpretation of wetland properties. All of these polygons were originally classified as upland. Of these second pass polygons approximately 20 percent were changed to a wetland classification. This prompted the need for field verification of polygons in proximity to degraded portions of ORV trails. In some instances the polygon could be misclassified as a wetland when in actuality it is ponded water from trail wear.

Finally a comment field was added to the database describing issues with labeling or delineation of the original mylar line work. This field explains problems and solutions the analyst may have encountered while transposing features. The Comment field holds a text data type where an analyst can answer a user's question. Polygons in question of SAA or NWI attribute are "commented on." The table can be exported to a dBase IV file and may be opened in Excel and viewed as a spreadsheet. The feature identification (FID) was used to indicate what polygons had comments.

The final submission was an imagery availability map (Figure 3). It was discovered that several full trails or portions of trails had missing hardcopy photos, mylar line work, or IKONOS digital imagery. This map depicts where gaps are located between photos and between polygons. It also displays where polygons were not transposed but IKONOS or AHAP CIR signatures were interpreted and delineated.

GPS Vegetation Plots:

In 1994, 623 GPS points were taken to plot vegetation information. These latitude, longitude positions and vegetation data were recorded by hand and later entered into Excel spreadsheets. These points were then loaded as X, Y coordinates in degrees, seconds, and minutes from the table and exported to a point shapefile. The shapefile projected incorrectly even after redefining the layer as NAD83 Albers. It was discovered that updating from ArcGIS 9.2 Service Pack 2 to Service Pack 4 solved projection issues when converting GPS points.

The supplementary vegetation was then combined to the points. The vegetation Excel spreadsheet had the field OBJECTID added as a column and populated 1-623. The vegetation data was then saved as a .dbf (dBase IV) file. This and the GPS points were loaded into ArcMap and joined by their OBJECTID fields. A final shapefile titled Vegetation Plots was exported with latitude, longitude coordinates and all associated vegetation data. Original vegetation columns included underbars (_) as the first character in the field name. These underbars were removed from the column as features in personal geodatabases do not allow this naming structure. The Vegetation Plots shapefile was exported as a feature to the final personal geodatabase.

Final Products:

Final products for the Wrangell - St. Elias ORV Trail and Vegetation Mapping Project include the following:

- 1a. Fully assembled and topologically verified ArcGIS 9.2 personal geodatabase containing polygonal NPS land cover features with NWI attributes for all ORV trail segments in the Nebesna District. This geodatabase included OGC compliant metadata created with the ESRI ArcGIS 9.2 metadata editor following the FGDC-STD-001-1998 format.

- b. The dataset also contains the following features: IKONOS Satellite Imagery Boundary, AHAP CIR Air Photo Boundary, ORV Trails, Vegetation Plots of GPS sampling points, and Vegetation Classification Topology.
2. A vegetation crosswalk table in an Excel spreadsheet listing likely NWI attributes derived from NPS vegetation codes, Level I, II, III, and IV vegetation descriptions, and on-screen, IKONOS and CIR signatures.
3. A final draft in Microsoft Word detailing the background, study area, delineation and attribution, NWI crosswalk, final products, and results and discussion of the Wrangell – St. Elias National Park and Preserve ORV Trails and Vegetation Mapping project.

Results and Discussion:

The National Park Service, in cooperation with Saint Mary's University of Minnesota developed an alternative approach to completing the development of GIS-based vegetation and wetland layers for the Nabesna ORV study area within Wrangell – St. Elias National Park. By incorporating the use of a digital transfer scope for polygon delineation referenced to an orthorectified IKONOS base image, vegetation polygons were digitally converted from hardcopy aerial photos to an accurately georeferenced spatial database. This process successfully eliminated a number of the typical steps required for the digital conversion process including the time consuming steps of individual photo georeferencing and orthorectification.

The purpose of this project was to apply this revised digital conversion methodology across all of the ORV trails in the Wrangell – St. Elias, Nabesna District in order to produce spatially accurate vegetation and wetland layers for use in trail monitoring and assessment programs. It was found that this process results in accurate, cost effective mapping methods of vegetation and wetland signatures across multiple types of digital imagery and maintains or improves the detail of polygon features from the original aerial photo base. As a result, all objectives of this project were successfully met.

Some liberty in interpretation is assumed when identifying vegetation and wetland types using photo interpretation techniques. With regard to hardcopy aerial photo based delineations that formed the input mapping for this project, most polygons were left open, displaying the length of trail that feature occupied. Allowing for judgment calls and closing the ends of a polygon around a signature creates a topologically sound, two-dimensional feature. All digital polygons were delineated to match the original acetate line work, in proper relationship to the ORV trail, and overlay accurately onto the IKONOS imagery.

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Appendix A: Vegetation Classification and NWI Crosswalk, (Vegetation Type Key Levels from *The Alaska Vegetation Classification*, Viereck, 1992.)

Code	Level 1	Level 2	Level 3	Level 4	NWI Attributes
F1	Forest	Needleleaf 75%	Closed 60-100%	White Spruce	
F2	Forest	Needleleaf 75%	Closed 60-100%	Black Spruce	PFO4C (B), PEM1/FO4C (B)
F3	Forest	Needleleaf 75%	Closed 60-100%	White / Black Spruce	PFO4C (B), PEM1/FO4C (B)
F4	Forest	Needleleaf 75%	Open 25-60%	White Spruce	
F5	Forest	Needleleaf 75%	Open 25-60%	Black Spruce	PFO4/SS1B, PSS1/FO4B
F6	Forest	Needleleaf 75%	Open 25-60%	White / Black Spruce	PFO4/SS1B, PSS1/FO4B
F7	Forest	Needleleaf 75%	Woodland 25-60%	White Spruce	
F8	Forest	Needleleaf 75%	Woodland 25-60%	Black Spruce	PSS4B
F9	Forest	Needleleaf 75%	Woodland 25-60%	White / Black Spruce	PSS4B
F10	Forest	Broadleaf 75%	Closed 60-100%	Red Alder	PFO1C (B)
F11	Forest	Broadleaf 75%	Closed 60-100%	Black Cottonwood	PFO1C (B)
F12	Forest	Broadleaf 75%	Closed 60-100%	Balsam Poplar	
F13	Forest	Broadleaf 75%	Closed 60-100%	Aspen	
F14	Forest	Broadleaf 75%	Closed 60-100%	Aspen / Poplar	
F15	Forest	Broadleaf 75%	Open 25-60%	Aspen	
F16	Forest	Broadleaf 75%	Open 25-60%	Poplar	
F17	Forest	Mixed Forest	Closed 60-100%	Aspen / Spruce uplands	
F18	Forest	Mixed Forest	Closed 60-100%	Poplar / Spruce	PSS1/FO4B, PFO4/SS1B
F19	Forest	Mixed Forest	Open 25-60%	Aspen / Spruce	PFO4/SS1B, PSS1/FO4B
F20	Forest	Mixed Forest	Open 25-60%	Spruce / Poplar	
F21	Forest	Mixed Forest	Open 25-60%	Spruce / Birch	PFO4/SS1B, PSS1/FO4B
F22	Forest	Mixed Forest	Open 25-60%	Closed Paper Birch	
F23	Forest	Mixed Forest	Open 25-60%	Open Paper Birch	
S1	Scrub	Dwarf Trees	Open 25-60%	Black Spruce	PSS4/1B, PSS1/4B, or SS/EM1
S2	Scrub	Dwarf Trees	Woodland 25-60%	Black Spruce	PSS1B

S3	Scrub	Tall 5-10ft	Closed 75-100%	Willow	PSS1C (B)
S4	Scrub	Tall 5-10ft	Closed 75-100%	Alder	PSS1C (B)
S5	Scrub	Tall 5-10ft	Closed 75-100%	Alder / Willow	PSS1C (B)
S6	Scrub	Tall 5-10ft	Closed 75-100%	Scrub Swamp	PSS1C (B), PSS1/EMC (B)
S7	Scrub	Tall 5-10ft	Open 25-75%	Willow	PSS1C (B)
S8	Scrub	Tall 5-10ft	Open 25-75%	Alder	PSS1C (B)
S9	Scrub	Tall 5-10ft	Open 25-75%	Alder / Willow	PSS1C (B)
S9a	Scrub	Tall 5-10ft	Open 25-75%	Birch / Willow	PSS1C (B)
S10	Scrub	Tall 5-10ft	Open 25-75%	Scrub Swamp	PSS1C (B), PSS1/EMC (B)
S11	Scrub	Low 20cm-5ft	Closed 75-100%	Birch	
S12	Scrub	Low 20cm-5ft	Closed 75-100%	Willow	PSS1C (B)
S13	Scrub	Low 20cm-5ft	Closed 75-100%	Birch / Willow	PSS1C (B)
S15	Scrub	Low 20cm-5ft	Open 25-75%	Mixed shrub - sedge tussock tundra	PSS1/EM1B, PEM1/SS1B
S16	Scrub	Low 20cm-5ft	Open 25-75%	Mixed shrub - sedge tussock bog	PSS1/EM1B, PEM1/SS1B
S17	Scrub	Low 20cm-5ft	Open 25-75%	Mesic shrub birch - ericaceous shrub	PSS1/EM1B, PEM1/SS1B
S18	Scrub	Low 20cm-5ft	Open 25-75%	Shrub birch - ericaceous shrub bog	PSS1/EM1B, PEM1/SS1B
S19	Scrub	Low 20cm-5ft	Open 25-75%	Ericaceous shrub bog	PSS1/EM1B, PEM1/SS1B
S20	Scrub	Low 20cm-5ft	Open 25-75%	Birch / Willow	PSS1/EM1B, PEM1/SS1B
S21	Scrub	Low 20cm-5ft	Open 25-75%	Willow	PSS1/EM1B, PEM1/SS1B
S22	Scrub	Low 20cm-5ft	Open 25-75%	Willow - sedge shrub tundra	PSS1/EM1B, PEM1/SS1B
S23	Scrub	Low 20cm-5ft	Open 25-75%	Willow - graminoid shrub bog	PSS1/EM1C (B), PEM1/SS1C (B)
S24	Scrub	Low 20cm-5ft	Open 25-75%	Sagebrush / Grass	PSS1/EM1C (B), PEM1/SS1C (B)
S25	Scrub	Dwarf Scrub	Dyas dwarf scrub	Dryas tundra	
S26	Scrub	Dwarf Scrub	Dyas dwarf scrub	Dryas sedge tundra	
S27	Scrub	Dwarf Scrub	Ericaceous dwarf scrub	Bearberry	
S28	Scrub	Dwarf Scrub	Ericaceous dwarf scrub	Vaccinium	
S29	Scrub	Dwarf Scrub	Ericaceous dwarf scrub	Crowberry	PSS1B
S30	Scrub	Dwarf Scrub	Ericaceous dwarf scrub	Mountain heath	
S31	Scrub	Dwarf Scrub	Ericaceous dwarf scrub	Cassiope	
S32	Scrub	Dwarf Scrub	Willow dwarf scrub	Willow tundra	
S33	Scrub	Dwarf Scrub	Willow dwarf scrub	Open low alder - willow	

S34	Scrub	Dwarf Scrub	Willow dwarf scrub	Open low alder	
H1	Herbaceous	Graminoid	Dry	Elymus	
H2	Herbaceous	Graminoid	Dry	Fescue	
H3	Herbaceous	Graminoid	Dry	Midgrass - shrub	
H4	Herbaceous	Graminoid	Dry	Midgrass - herb	
H5	Herbaceous	Graminoid	Mesic	Bluejoint meadow	PEM1B (C,F,H)
H6	Herbaceous	Graminoid	Mesic	Bluejoint - herb	PEM1B (C,F,H)
H7	Herbaceous	Graminoid	Mesic	Tussock tundra	PEM1B (C,F,H)
H8	Herbaceous	Graminoid	Mesic	Mesic sedge - grass meadow	
H9	Herbaceous	Graminoid	Mesic	Mesic sedge - herb meadow	
H10	Herbaceous	Graminoid	Mesic	Sedge - willow tundra	PEM1B (C,F,H)
H11	Herbaceous	Graminoid	Mesic	Sedge - birch tundra	PEM1C (B)
H12	Herbaceous	Graminoid	Mesic	Sedge - Dryas tundra	
H13	Herbaceous	Graminoid	Wet	Wet sedge meadow tundra	PEM1C (B)
H14	Herbaceous	Graminoid	Wet	Wet sedge - herb meadow tundra	PEM1C (B)
H15	Herbaceous	Graminoid	Wet	Fresh sedge marsh	PEM1H
H16	Herbaceous	Graminoid	Wet	Subarctic lowland sedge wet meadow	PEM1H
H17	Herbaceous	Graminoid	Wet	Subarctic lowland sedge bog meadow	PEM1H
H18	Herbaceous	Graminoid	Wet	Subarctic lowland sedge - moss bog meadow	PEM1H
H37	Herbaceous	Graminoid	Wet	Subarctic lowland sedge - herb wet meadow	PEM1H
H19	Herbaceous	Forb	Dry	Seral herbs	
H20	Herbaceous	Forb	Dry	Alpine herb - sedge	
H21	Herbaceous	Forb	Mesic	Alpine herb	
H22	Herbaceous	Forb	Mesic	Mixed herbs	
H23	Herbaceous	Forb	Wet	Fireweed	PEM1H, PEM1/AB3H
H24	Herbaceous	Forb	Wet	Fresh herb marsh	PEM1H, PEM1/AB3H
H25	Herbaceous	Forb	Wet	Subarctic lowland herb wet meadow	PEM1H, PEM1/AB3H
H26	Herbaceous	Forb	Wet	Subarctic lowland herb bog meadow	PAB3H, L2AB3H
H27	Herbaceous	Byroid	Bryophyte	Wet bryophyte	PML1B
H28	Herbaceous	Byroid	Bryophyte	Dry bryophyte	

H29	Herbaceous	Byroid	Lichen	Crutose lichen
H30	Herbaceous	Byroid	Lichen	Foliose and Fruitcose

H31	Herbaceous	Aquatic Herb	Freshwater aquatic	Pondlilly	PAB3H, L2AB3H
H32	Herbaceous	Aquatic Herb	Freshwater aquatic	Marestail	PAB3H, L2AB3H
H33	Herbaceous	Aquatic Herb	Freshwater aquatic	Buttercup	PAB3H, L2AB3H
H34	Herbaceous	Aquatic Herb	Freshwater aquatic	Burreed	PAB3H, L2AB3H
H35	Herbaceous	Aquatic Herb	Freshwater aquatic	Water Milfoil	PAB3H, L2AB3H
H36	Herbaceous	Aquatic Herb	Freshwater aquatic	Fresh pondweed	PAB3H, L2AB3H

Code Notes

F1
F2
F3

F4
F5
F6

F7
F8
F9

F10 Floodplain / gravel bars
F11 Well drained floodplain
F12 Tall and low shrub in understory
F13
F14

F15 Usually small trees
F16 Variable / scattered shrub layer

F17
F18 Floodplain

F19
F20 Low shrub understory
F21
F22 Alder understory
F23

S1
S2 Near treeline - cold, wet, permafrost soils

S3
S4

S5

S6 Usually alder as dominant or co-dominant; standing water, poorly drained, poor exposure

S7

S8

S9 Floodplain, side slopes, near treeline

S9a Wet sites

S10

S11

S12

S13

S15 Eriophorum, Carex bigelowii, Betula, Ledum, Vaccinium, Salix planifolia, arctic and alpine

S16 Eriophorum / shrubs include Potentilla, Alnus; subarctic, below treeline

S17 Betula, Vaccinium, Ledum, Arctostaphylos, Festuca, Carex

S18 Peaty - sphagnum, Carex aquatilis

S19 Empetrum, Ledum, Vaccinium; Maritime

S20

S21

S22 Arctic

S23 Wet stream bottoms, lowland depressions, grasses, and sedges

S24

S25

S26

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