Orthorectification and Automation

of

Glacier Bay Park and Preserve

Landcover Mapping

Pacific Northwest CESU Task Agreement #J8W07070002

GeoSpatialServices

Saint Mary's University
OF MINNESOTA

Glacier Bay Orthorectification and Digital Conversion

Background:

The National Park Service's Alaska Landcover Mapping Program is funded through the inventory portion of the NPS Inventory and Monitoring Program (I&M) and has as its goal the provision of basic vegetation information on a park-wide basis for all national parks in Alaska. Landcover mapping is intended to provide data that are useful for the design and implementation of other I&M Programs as well as facilitate general resource management decision making within parks.

In fiscal year 2005/06, the NPS landcover mapping program undertook a Glacier Bay National Park and Preserve (GLBA) mapping project in cooperation with the U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI). Under this agreement, NPS provided for the fieldwork and manual interpretation of aerial photography for landcover and wetland types while NWI provided for the automation of the manual interpretation to produce a GIS dataset. NWI worked with Saint Mary's University of Minnesota (SMU) in completing their part of the project.

NPS review of the final product received from NWI determined that horizontal error in the digital GIS data set often exceeded 200m in areas of significant terrain relief. NWI specifications for these products are typically 1:63,360 national map accuracy standards (NMAS). The final product from the original NPS/USFWS Glacier Bay project did not meet this specification. The horizontal error associated with the NWI product was the result of using the existing Alaska National Elevation Dataset digital elevation model for orthorectification and the failure to use camera calibration corrections during the ortho correction of the line work. Neither the camera calibration reports nor a more accurate digital elevation model were provided to SMU by the USFWS. Manual transfer of line work could have been used to build a more accurate GIS dataset however this was not part of the original contract specifications.

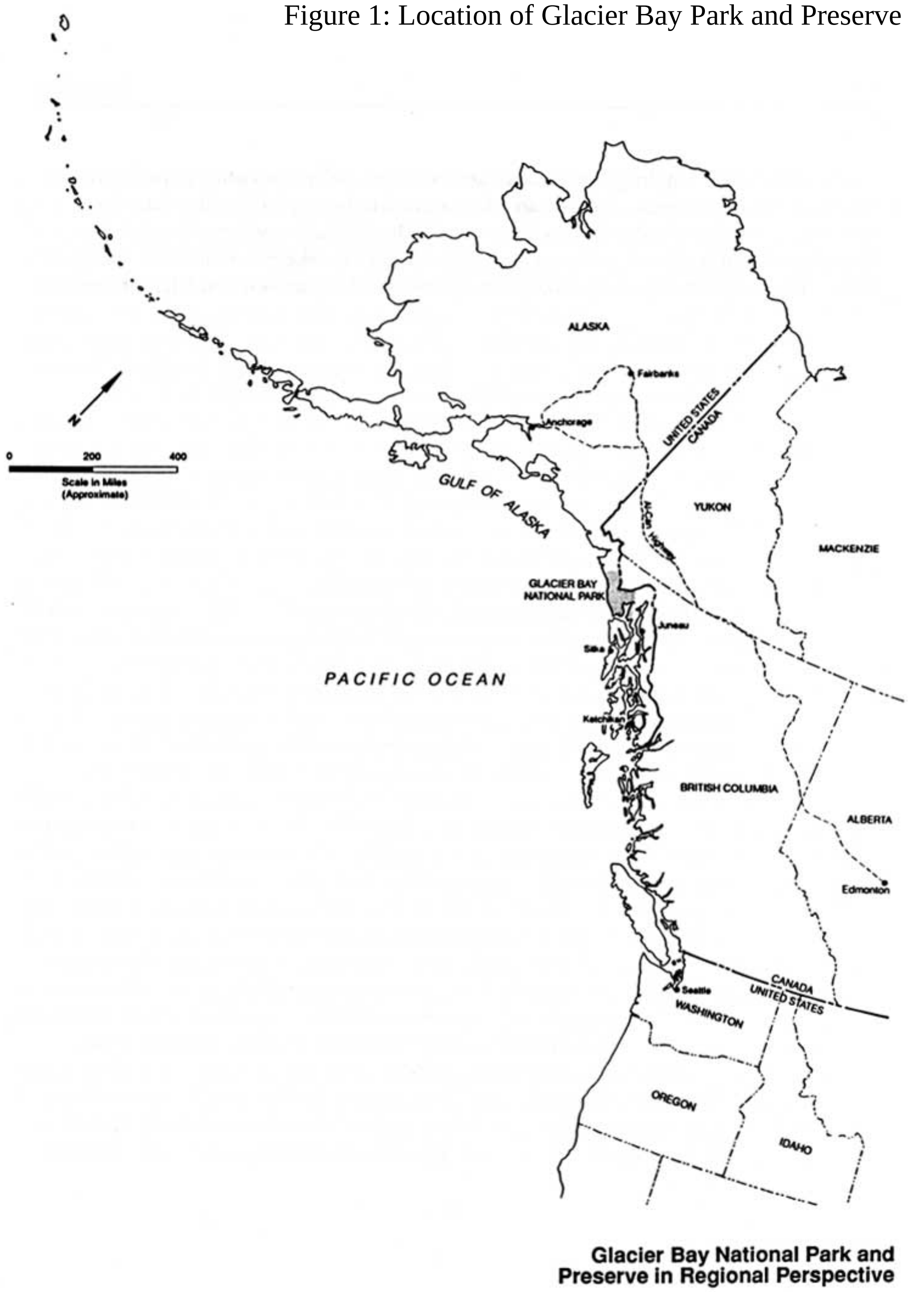
In order to improve the quality of the Glacier Bay landcover dataset, NPS worked with the SMU to develop a different methodology for automation that made use of an alternative digital elevation model (DEM), camera calibration reports as well as control points taken from the existing black/white orthoimagery. SMU produced test images that were corrected using this approach and they have shown horizontal error of approximately 20-30 meters, thereby, meeting the NMAS 1:63,360 (32m).

The purpose of this project, therefore was to reprocess the original GLBA line work using this new methodology with the expectation of developing a landcover map with significantly higher positional accuracy as well as orthorectified CIR photography that match the landcover GIS dataset. All edits and corrections made to the prior GIS dataset by NWI and NPS have been incorporated into this new geodatabase. NPS worked collaboratively with SMU to identify and resolve problems associated with the revised processing methodology.

Study Area and Mapping Program:

Glacier Bay National Park and Preserve is located in Southeast Alaska near the communities of Juneau, Haines, Skagway, Gustavus, and Yakutat. The Park is approximately 600 miles from Anchorage and 90 miles from Juneau (Figure 1). It can only be reached by air or boat travel. Glacier Bay covers approximately 3.3 million acres of land and is characterized by mountain ranges extending up over 15000 feet, coastal beaches, deepwater fjords, glaciers, and a mosaic of vegetation communities from early successional to climax.

Figure 1: Location of Glacier Bay Park and Preserve



The Inventory and Monitoring Program of NPS is designed to provide reliable and consistent information for assessing the status and trends in the condition of Alaska's National Park ecosystems including Glacier Bay. Vegetation mapping is conducted under the inventory portion of the program in order to provide basic information readily useful for making resource management decisions, and to collect data that can be aggregated on a service-wide level for designing monitoring programs.

NPS, in cooperation with the US Forest Service, undertook an aerial photography flying mission that covered all of Glacier Bay National Park and Preserve plus surrounding areas. The mission was flown on

July 27 and 28, 1996 using a Wild RC30 aerial camera equipped with a Wild Universal Aviogon 4-S lens (calibrated focal length of 152.752 mm). The product of this mission was a series of 1:65,000 scale, color infra-red aerial photographs for the Park. The photographs were flown so as to provide 60% overlap between each frame allowing for stereoscopic viewing and detailed image interpretation.

Aerial photo interpreters from The Alaska Natural Heritage Program were contracted by NPS to complete landcover mapping and National Wetlands Inventory classification on these photographs through the use of traditional photo interpretation techniques. The results of their work were a series of 182 individual aerial photograph frames with acetate overlays on which landcover and NWI polygons were delineated and classified using a fine point, Rapidograph drafting pen and india ink.

Digital Conversion Methodology:

Digital conversion refers to the process by which the hardcopy aerial photographs and ink delineations of landcover and NWI polygons on acetate overlays were transformed into digital images and digital vector data within a Geographic Information System (GIS). This process had 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 control; and, polygon attribution.

Photo and Acetate Scanning:

NPS provided 182 photos with associated acetate overlays for digital conversion. Upon receipt of these hardcopy products, the photos were inventoried and logged into a project management database in order to ensure that all materials had been received. The photos were then separated into four sub-project areas (Mt. Fairweather, Juneau, Skagway and Yakutat) based on the USGS 1:250,000 quad sheet boundary within which the photos were located. This was done so as to be able to associate specific photos with specific collateral data for later processing stages.

Once sub-divided the acetate overlays, which had been attached to the photos using drafting tape, were physically separated from the aerial photographs for scanning. Each photo and acetate pair was scanned using a desktop Epson Expression 1640 XL flatbed color image scanner to the user defined specifications listed below. During the scanning process, care was taken to ensure that all fiducial marks and overlay tie points were visible on each scan as they were required for later orthorectification and image processing. The scans were then saved using the file naming convention of <photo#>P.tif for photographs and <photo#>L.tif for polygon linework.

Scan Specifications - Photography:

- Scan resolution: 1200 dpi (21 microns)
- Pixel Depth: 16 bit
- File Format: TIFF
- Resampling Method : Nearest Neighbor
- Multi-band (red-green-blue)

Scan Specifications - Acetate Overlay:

- Scan resolution: 1200 dpi (21 microns)
- Pixel Depth: 1 bit
- File Format: TIFF
- Single band black and white

Georeferencing and Orthorectification:

Georeferencing or photogrammetric control is the process by which known ground control points are used to provide geographic reference to a scanned aerial image and/or graphic. Orthorectification is the process by which a digital elevation model and a camera calibration report are used to correct image displacement caused by terrain variation and camera lens aberrations. On the Glacier Bay project, these processes were used to create georeferenced aerial photography for use as a backdrop GIS product and to create georeferenced, terrain rectified raster versions of the delineated acetate scans that could be further processed into landcover and NWI polygons. The software package used for georeferencing and orthorectification on this project was OrthoMapper rev. 3.18 from Image Processing Software Inc.

The aerial photography and associated acetate overlays for the Glacier Bay project were georeferenced using two different data sources. For much of the park area (approximately 80%), NPS provided up to date black and white digital ortho photography (flown in September 2000) which was used for the selection of high quality control points (Figure 2). For areas of the park where this imagery was not available, ground control points were selected from digital copies of the appropriate USGS 1:63,360 15 minute quadrangles for Alaska (Figure 3). A minimum of 5 georeference control points were required for every photo, however, in most cases between 15 and 20 points were used in order to improve the accuracy of the referencing process. For every photo, a text file was generated in order to document the approximate error of the georeferencing process. Typical Root Mean Square (RMS) error for areas georeferenced to the black and white orthophotography was between 5 and 10 meters. Areas that were georeferenced using the USGS quadrangles typically had RMS errors of between 15 and 30.

All aerial photographs and acetate overlays were georeferenced to North American Datum of 1983 (NAD83-CORS96 or CORS94) and as further specified below:

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PROJCS["NAD_1983_UTM_Zone_8N",
GEOGCS["GCS_North_American_1983",
DATUM["D_North_American_1983",
SPHEROID["GRS_1980",6378137,298.257222101]],
PRIMEM["Greenwich",0],
UNIT["Degree",0.017453292519943295]],
PROJECTION["Transverse_Mercator"],
PARAMETER["False_Easting",500000],
PARAMETER["False_Northing",0],
PARAMETER["Central_Meridian",-135],
PARAMETER["Scale_Factor",0.9996],
PARAMETER["Latitude_Of_Origin",0]
UNIT["Meter",1]]
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Figure 2: NPS Supplied Black and White Orthophotos

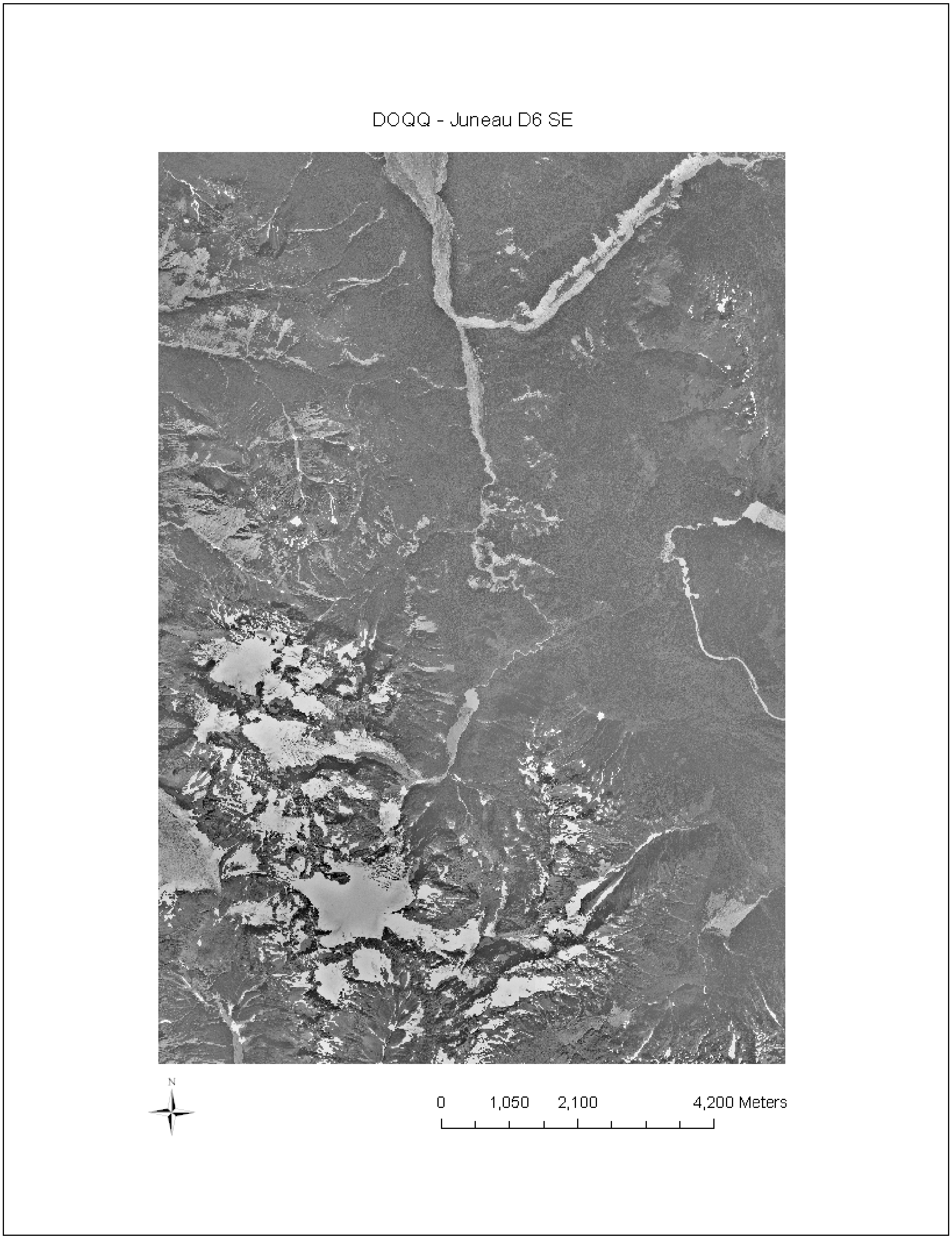
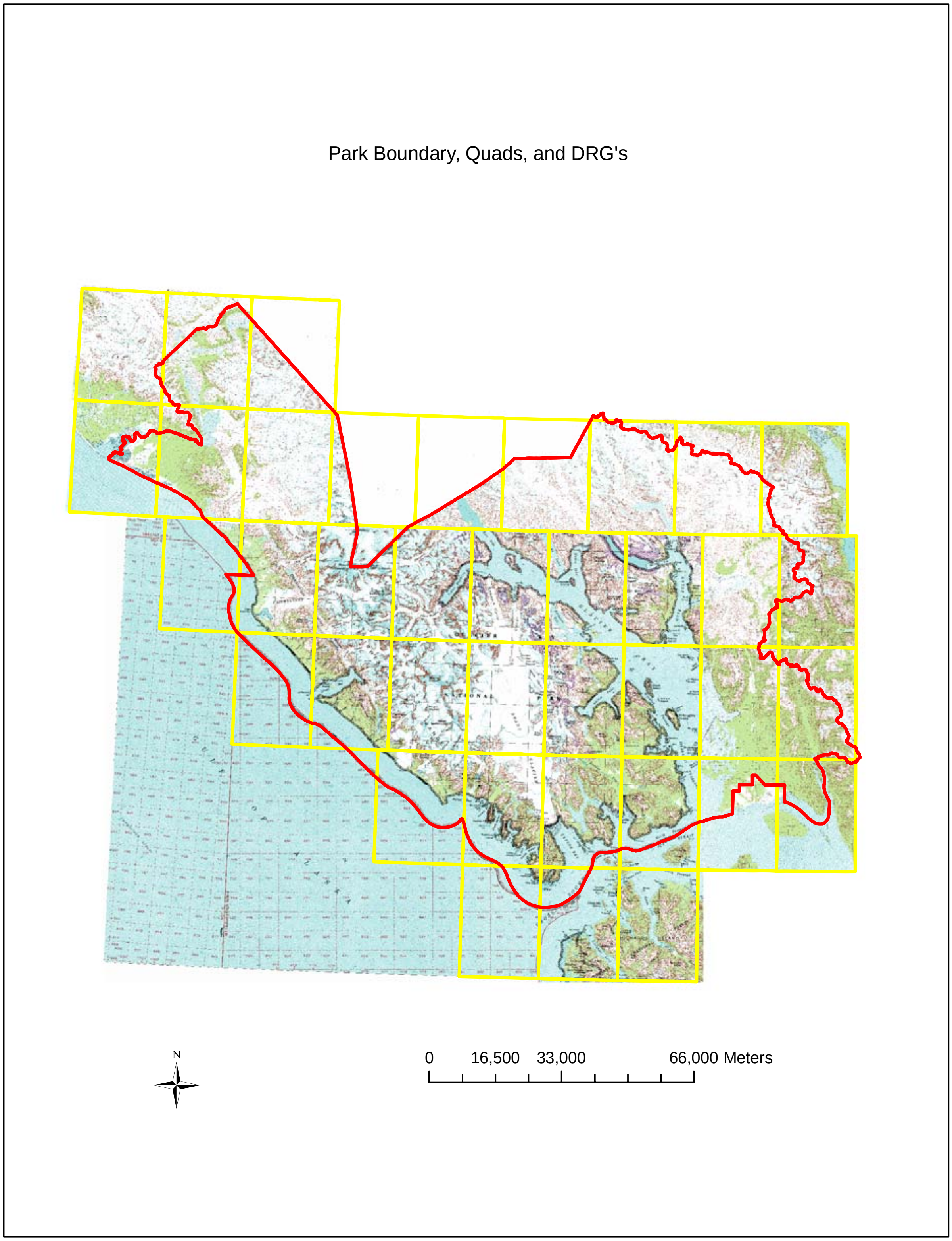
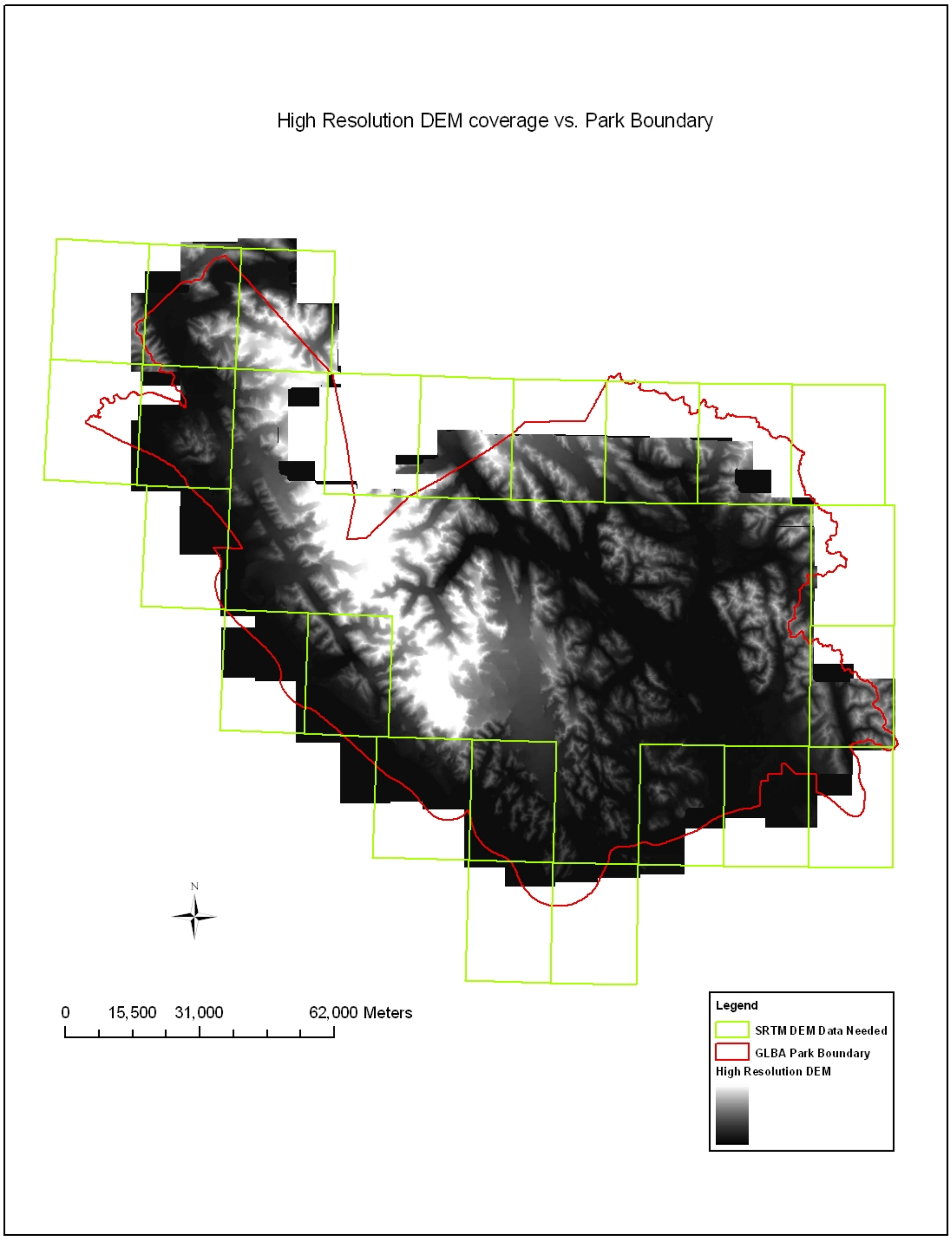


Figure 3: Park Boundary, Quads and DRG’s



As with the georeferencing, orthorectification of the scanned products for Glacier Bay was completed using two different Digital Elevation Models (DEM). For areas where there was up to date black and white digital ortho photography provided by NPS, there was also an enhanced DEM that was built for the orthorectification of the September 2000 black and white photos referenced above. This DEM was developed through a photogrammetrically controlled auto-correlation process. This 30 meter resolution terrain elevation product was provided by the NPS in quad based ArcGIS GRID format files referenced to NAD27. These files were converted to TIFF format, projected to NAD83 (using the projection definition above) and mosaiced into 1:250,000 scale blocks for use in the orthorectification process.

Figure 4: NPS Supplied DEM



For areas where there was no enhanced DEM available, NPS provided a composite DEM created from a merge of NASA Shuttle Radar Topography Mission (SRTM) DEM data and the enhanced NPS DEM. The SRTM DEM is a 30 meter resolution elevation product derived from data captured during an 11 day space shuttle mission in 1999. This data covers the entire Glacier Bay study area, however, it is not as consistently accurate as the NPS DEM. As a result, the SRTM DEM was only used to orthorectify areas where the NPS DEM was unavailable. The SRTM data was provided by NPS already projected to UTM Zone 8, NAD83.

Figure 5: Orthorectified Photos

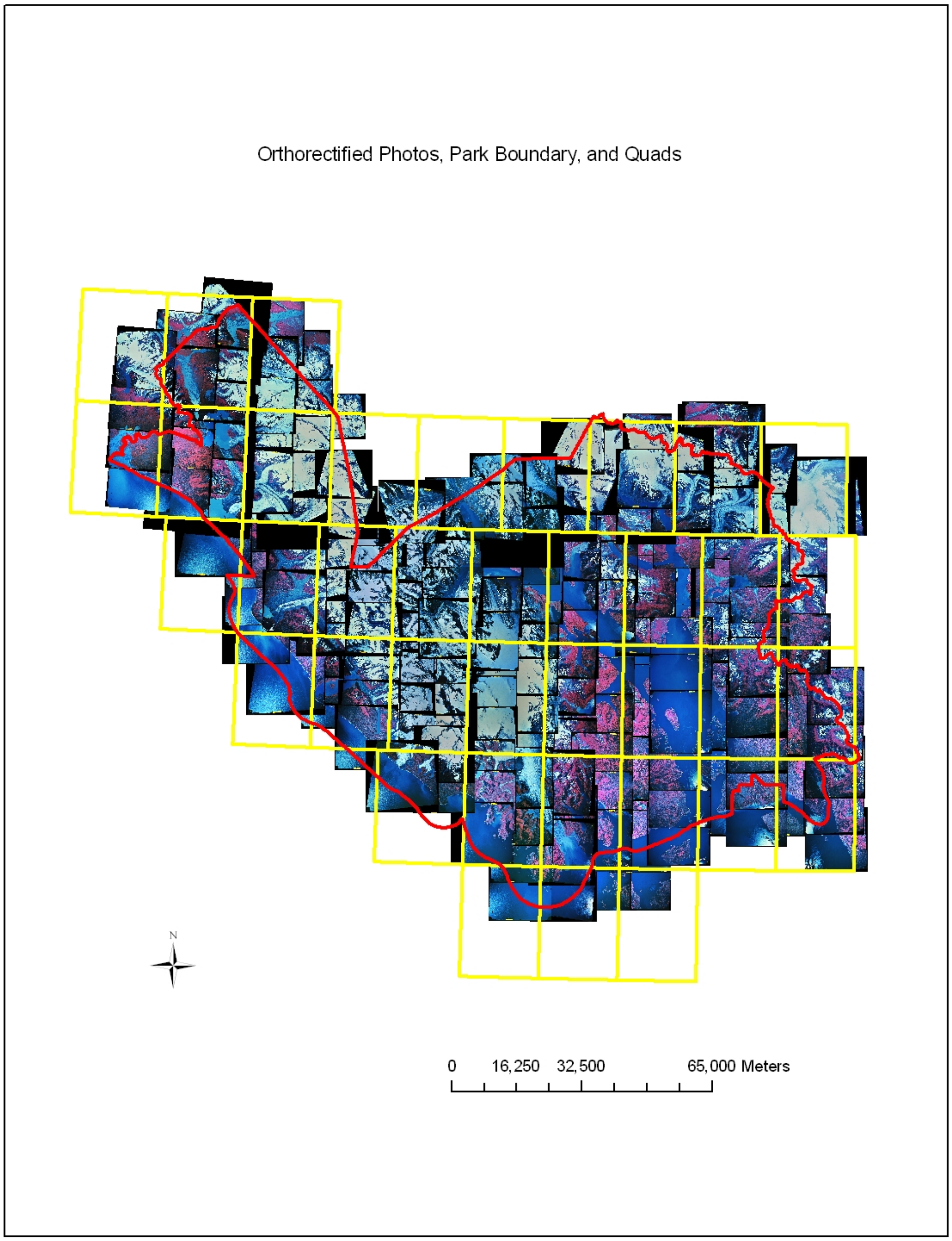


Figure 6: Sample Scanned Photo

Scanned Photo 35-218

Figure 7: Sample Orthorectified Photo

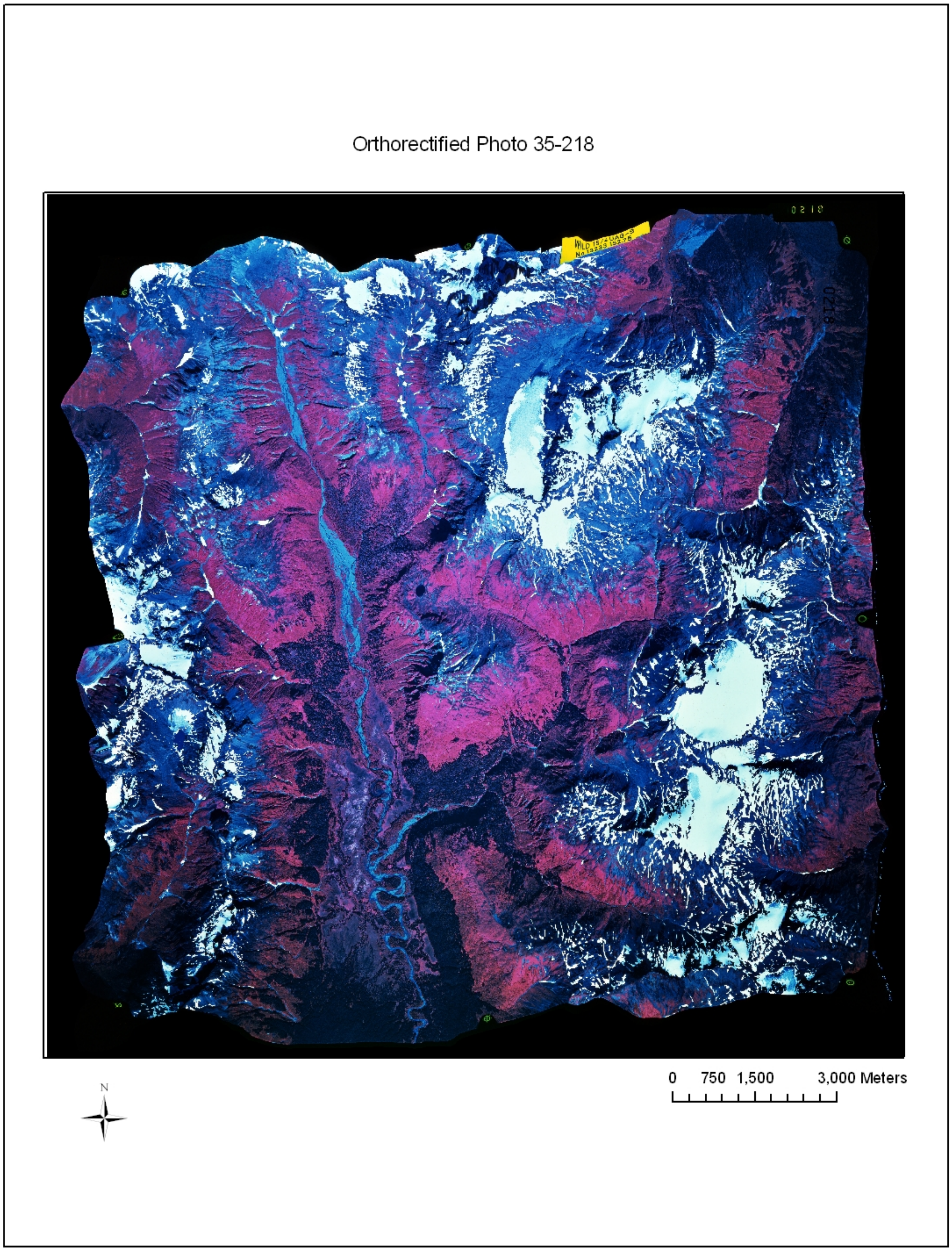
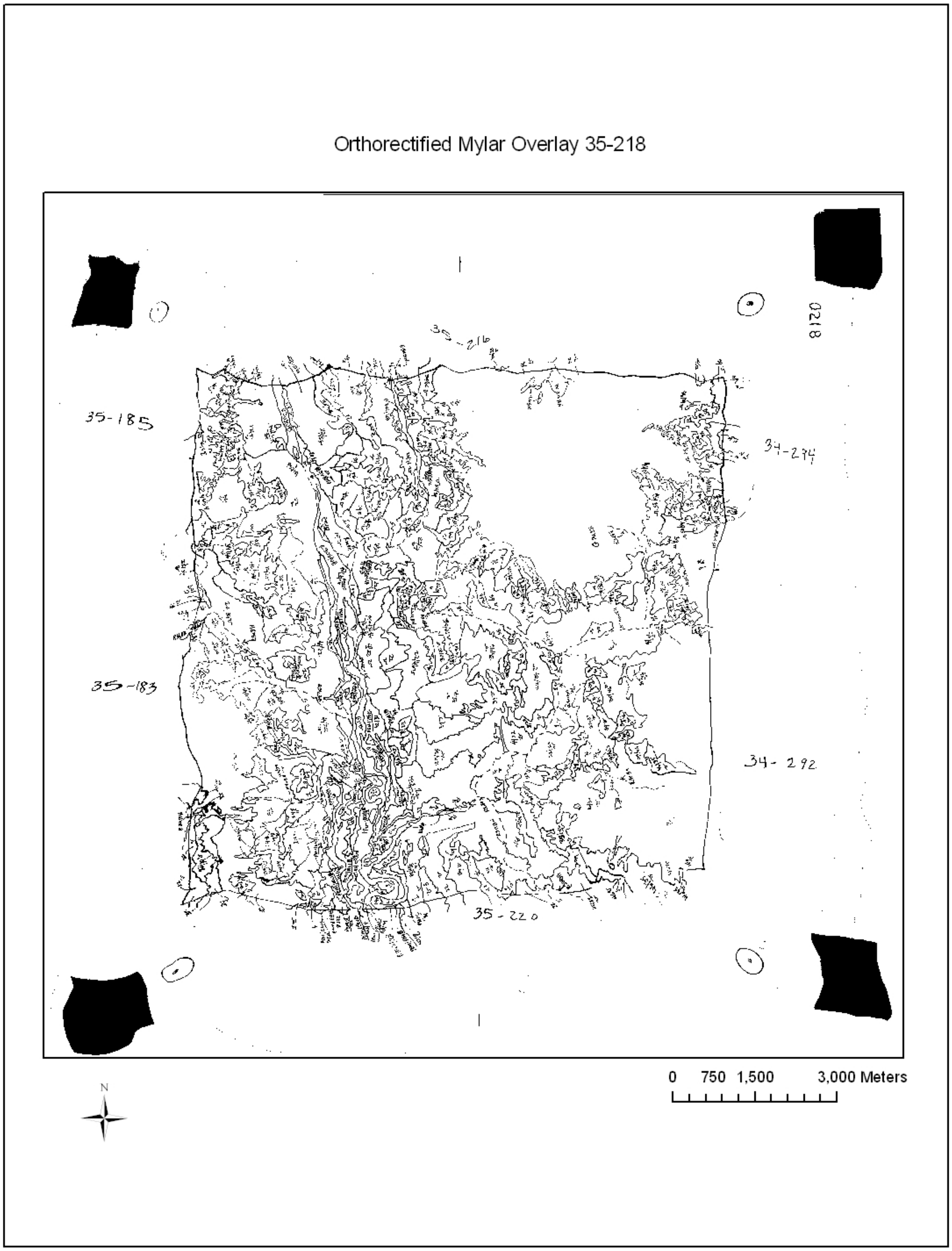


Figure 8: Orthorectified Acetate Overlay



Raster to Vector Conversion:

The next step in the digital conversion process was to take the georeferenced and orthorectified acetate overlays and convert them from raster to vector format. This step was required so that the landcover and NWI data could be represented as polygon data in ArcGIS as opposed to grid cells. This conversion was accomplished using the ArcScan extension in ArcMap. ArcScan is a suite of software tools that provides raster-to-vector conversion and raster editing capabilities in ArcGIS. ArcScan includes capabilities to perform interactive raster editing, raster geometric correction and noise removal, and interactive raster-to-vector conversion.

The most time intensive task in the vector conversion process is “noise cleanup”. Noise refers to the fact that the scanned acetate overlays typically contain more information than just the polygon boundaries which will form the final vector product. These artifacts include such things as: hand written polygon attributes, arrows, dashed lines, and tag lines. All of these features must be edited and removed from the raster image prior to vector conversion so that only the actual polygon boundaries are vectorized. Noise cleanup is basically a manual process in which every part of the scan must be reviewed and, if necessary edited, to ensure that only valid polygon boundaries remain.

Once the scans have been cleaned, vectorization is an automated process that is handled by the ArcScan software. The user is required to set certain parameters in order to achieve the best vector output. The parameter settings that were used on the Glacier Bay project are shown in Figure 10 below. These settings have been determined to provide the most consistent raster to vector conversion through various conversion projects.

Figure 9: Dirty vs. Cleaned Acetate Overlay

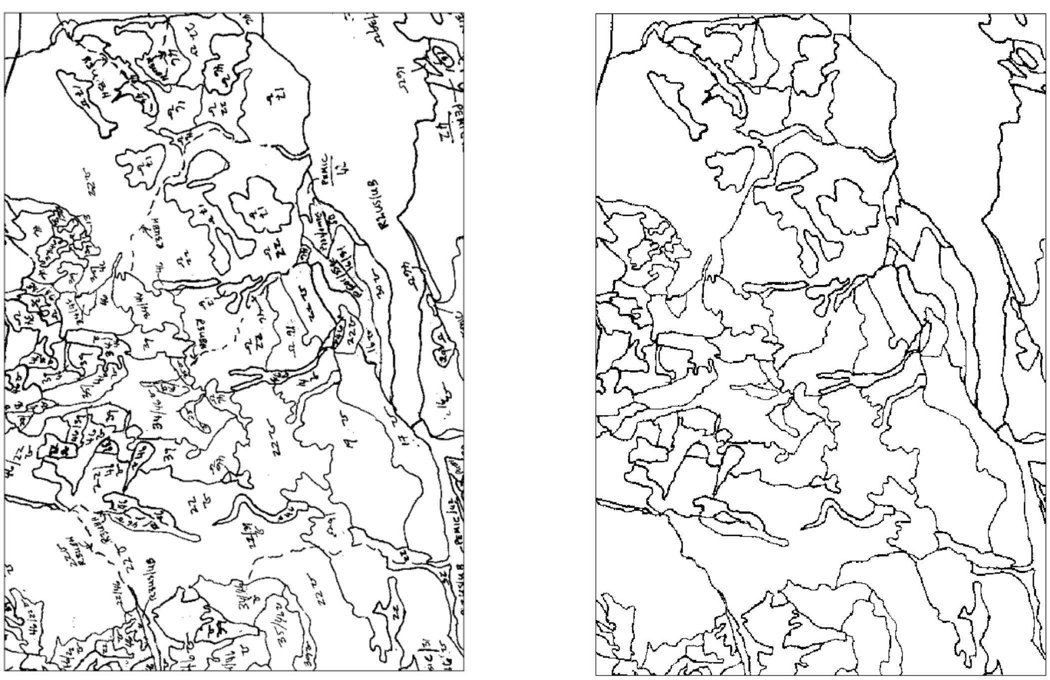
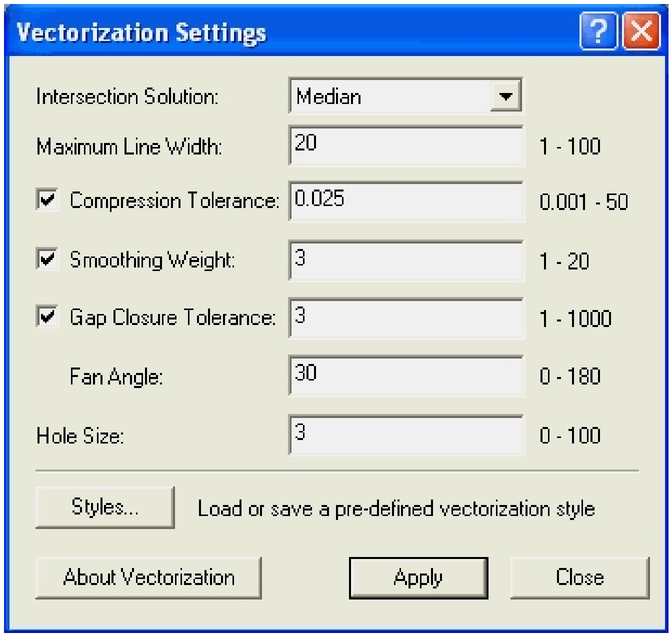


Figure 10: ArcScan Vectorization Settings



Attribution:

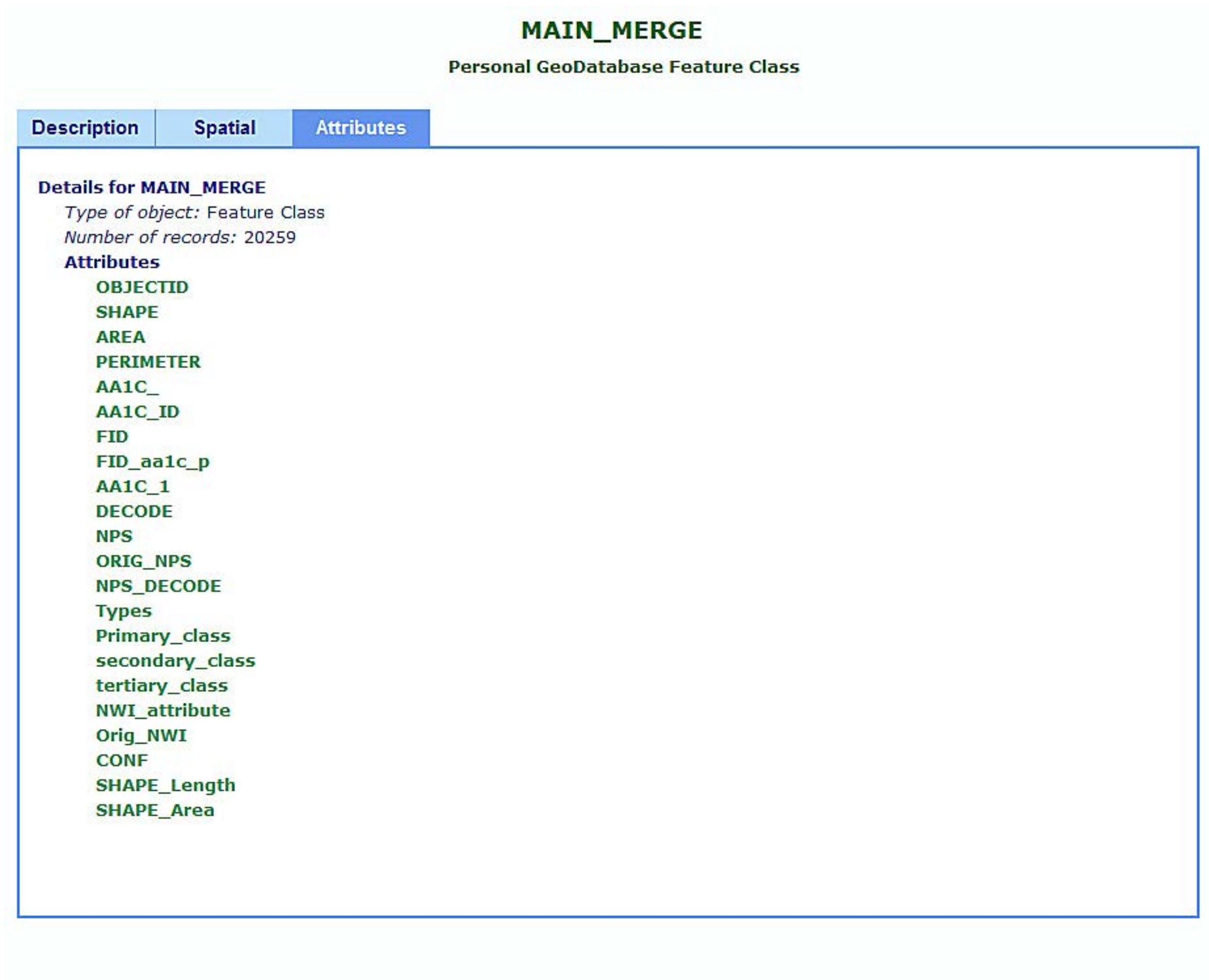
Attribution refers to the process of attaching a descriptive identifier to vectorized polygons so that the data have meaning to an end user. Attributes are typically stored in a database table that is linked directly to the feature geometry. Traditionally, polygons are attributed by opening the cleaned vectorized line work on top of the original georeferenced raster scan, pointing at the polygon on the screen to select that feature, opening the database table and typing in the polygon attribute as it is displayed from the raster scan on the screen. This is primarily a manual process in which editors interact with ArcMap in order to type in each and every polygon attribute.

In the case of the Glacier Bay project, because there was a pre-existing polygon landcover and NWI layer, the intent was to complete the attribution phase using a different approach. The proposed work flow was to take the polygon centroids (including attributes) from the pre-existing layer and combine those with the new polygon layer through an intersect operation thus populating the landcover and NWI attributes automatically. Unfortunately, this approach proved to be impractical because the spatial location and alignment of the new polygon layer was significantly different than the pre-existing layer due to the improved DEM data that was used for orthorectification. In fact, there were many cases in which the centroids from the pre-existing layer did not even fall within the correct polygon during the intersect process. In addition, NPS had made a number of edits to polygons in the pre-existing layer in order to correct photo interpretation ambiguities. These edits needed to be incorporated in the attribution phase of the project because this was the only time in which the editors went through the layer polygon by polygon.

In addition to the polygon delineation changes that were made by NPS, there were also attribute updates and changes that resulted from their review. As a result of the need to accommodate these updates, the final attribution work flow involved using the Attribute Transfer Tool within ArcScan to copy all the information, polygon by polygon, from the correctly attributed polygon in the pre-existing layer into the empty polygon in the new that was created in the raster to vector conversion process. This involved having the editor point at every polygon that had to be attributed, however, it did not involve re-typing the attribute value as that was copied from the previous layer.

Since the polygon attributes were copied from the pre-existing layer, most of the values in the attribute table were not updated as part of this project. Updating occurred primarily to the NPS field which is where the final landcover code for each polygon was stored. In addition, the attribute CONF was added to the table as per an NPS request. This field was intended to indicate the level of confidence that the attribute editor had concerning the accuracy of the NPS code assigned to a particular polygon. Valid values for this field were H, M, and L representing high, medium or low confidence in an attribute assignment. These codes were only assigned to polygons where there was a question concerning what the attribution should be. These questions arose due to either an inability to clearly read the attribute from the scanned acetate or an inability to clearly match the polygon from the pre-existing layer to the same polygon in the new layer during the attribute copy procedure. For all polygons that were clearly identifiable in the new geodatabase the value of this attribute was null.

Figure 11: List of Landcover Geodatabase Attributes



Edgematching and Quality Control:

As mentioned above, the landcover and NWI polygons were delineated on 182 individual photos for this project. In order to create a seamless final polygon layer covering the entire park, the polygon data had to be “stitched” together through the process of edgematching. This process involved having the editor review all of the seams where the data from one photo joined with another photo in order to ensure that polygons matched geometrically and shared the same attribute. Any artificial neat lines that were used to close polygons on individual photographs were removed at this point and polygon edges were reshaped and snapped as necessary to achieve geometric coincidence with the adjacent data. Individual photos were first edgematched in blocks of 6; approximately equivalent to the extent of a USGS 1:63,360 15 minute quadrangle. These blocks of 6 photos were then edgematched together to create the seamless park wide dataset. The orthorectified photos were used as a background layer to aid in edge match decision making.

Quality control of the final product was managed in several different ways. During the orthorectification phase, the amount of error associated with the selection of individual georeferencing control points was monitored and points that had too much error were eliminated from the final rectification. An average of 15 to 20 control points were chosen per photo in order to ensure that final georeferencing and orthorectification generally had an average RMS error of less than 10 meters.

With regard to the raster to vector conversion phase of the project, final delineations were checked multiple times against three different sources. Initially, polygon boundaries were check by overlaying them with the original orthorectified raster scan. This was to ensure that all of the line work was present and matched the original data. Next, the delineations were checked against the pre-existing land cover layer in order to identify line work that had been edited or changed by NPS during review of the original product. Finally, the delineated boundaries were superimposed on the black and white ortho photos provide by NPS in order to ensure concurrence between the land cover layer and the photo base that most users will be viewing it on. An ArcGIS topology check was also run on the final dataset to ensure topological integrity. The topology rules that were enforced during this check included: must not have gaps and must not have overlaps.

Quality control of the attribution phase of the project was managed in three ways. First of all, when the attribute transfer tool in ArcScan was being used to copy over attributes from the pre-existing layer to the new layer, the line work was viewed on top of the scanned acetate overlay in order to visually compare the attribute assigned in the layer table to the attribute on the scanned map. Secondly, approximately 20% of the polygons across the study were randomly chosen and reviewed against the scanned acetate by a separate editor as further verification of attribute accuracy. Finally, attribute codes were check for legitimacy by searching the entire database for values that did not match a master list of codes provided by NPS. This was completed by running a series of SQL queries against the final database.

Final Products:

Final products for the Glacier Bay orthorectification project included the following:

1. 182 scanned aerial photos and acetate overlays as per the specifications listed above.
2. Orthorectified aerial photos delivered as 8 bit pixel depth, 1 meter pixel resolution, full color TIFF format files. These files all included OGC compliant metadata created with the ESRI ArcGIS 9.2 metadata editor following the FGDC-STD-001-1998 format. This metadata indicated which base data set and DEM were used to orthorectify each photo and corresponding acetate overlay.
3. Orthorectified acetate overlays delivered as 1 bit pixel depth, black and white TIFF format files.
4. Text reports for each photo orthorectification summarizing the average horizontal Root Mean Square inherent in the rectification process.
5. Fully assembled and topologically verified ArcGIS 9.2 personal geodatabase containing polygonal NPS landcover features for the entire project study area. This geodatabase included

OGC compliant metadata created with the ESRI ArcGIS 9.2 metadata editor following the FGDC-STD-001-1998 format.

Results and Discussion:

As mentioned previously, NPS and the USFWS had originally partnered on a project to create and NWI and landcover dataset for Glacier Bay National Park and Preserve. When this product was delivered, it was found to contain considerable horizontal error in various portions of the final polygon data layer when compared to existing black and white digital orthophotography for the Park. NPS, in cooperation with Saint Mary's University of Minnesota developed an alternative approach to completing the development of a landcover layer for Glacier Bay by incorporating camera calibration report and a new auto-correlated DEM in the orthorectification process to improve spatial accuracy of the final product. The purpose of this project was to apply this methodology across the Glacier Bay Park study area in order to produce a higher quality landcover layer for use in park planning activities.

In short, the objectives of this project were successfully met. The use of the higher quality auto-correlated DEM and the incorporation of the camera calibration report in the rectification process generally led to horizontal RMS errors of between 5 and 10 meters. In addition, the selection of between 15 and 20 control points per photo and the care taken by editors when selecting these points definitely contributed to improved georeferencing. The entire digital product now meets the 1:63,360 National Map Accuracy Standard of +/- 32 meters horizontal accuracy for areas where the auto correlated DEM and black and white digital ortho photos were available.

In areas of the Park where the USGS 15 minute quadrangles were used for georeferencing and the SRTM DEM was used for rectification, there was still significant horizontal error in final polygon data. The application of the camera calibration report during orthorectification and the more careful selection of ground control points for georeferencing allowed for a better product than in the original Glacier Bay project, however, horizontal accuracy in many of these areas still ranged between 10 and 30 meters. Unfortunately, it was not possible to achieve better results in areas where the auto correlated DEM was unavailable.

Another technique that could have been employed to improve the match between the land cover polygons and the orthophoto base map was spatial adjustment. This approach, also called rubber sheeting, involves isolating small areas of spatial data that are displaced from a known correct base layer and then selecting and moving them until they line up with the base. While this approach results in a superior visual product, it is very difficult to quantify because the amount that a given spatial data element is moved to improve its alignment is completely subjective. As a result, it is almost impossible to replicate this type of processing. This approach was not used on the Glacier Bay project.