Airboat/ORV Trail Inventory for the East Everglades Addition Lands

Final Report

by

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Airboat/ORV Trail Inventory
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Summary

In conjunction with the National Park Service-Everglades National Park (ENP), the University of Georgia's Center for Remote Sensing and Mapping Science (CRMS) conducted a study entitled, "Airboat/ORV Trail Inventory for the East Everglades Addition Lands" (Cooperative Agreement H5000-03-5040). This study was designed to produce detailed mapping, classification and inventory of airboat and off-road vehicle (ORV) trails in the ENP East Everglades Addition Lands, otherwise known as the East Everglades Expansion Area. A baseline inventory of trails was produced from U.S. Geological Survey (USGS) Digital Orthophoto Quarter Quads (DOQQs) created from aerial photographs acquired in the winter of 1999 at a scale of 1:40,000. A subsequent report will detail the results of a follow-on study of historical trends in airboat trails based on photographs recorded in 1984/1985, 1994 and 2003.

The 1-m resolution 1999 USGS color infrared DOQQs provided evidence of substantial airboat activity and potential impacts in the northern half of the ENP East Everglades Expansion Area, while fewer ORV trails and thereby reduced impact was observed in the southern half of the Expansion Area, beginning approximately 0.5 km south of Grossman's Ridge. Helicopter and airboat surveys provided ground truth data needed to develop a classification system of trail types and perform manual interpretation of trails from the 1999 DOQQs. Observations recorded in the helicopter surveys also were reserved for future use in assessing the accuracy of the 2003 airboat/ORV trail database produced in a follow-on study.

Heads-up digitizing techniques of ArcMap 9.1 GIS software were used to manually interpretate airboat/ORV trails from the 1999 DOQQs. In this process, trails were delineated and classified as Class 1 [wide (≥10 m)], Class 2 [medium (3 – 10 m)] or Class 3 [narrow (≤ 3 m)]. Additional areas containing Class 3 trails too numerous to delineate individually were designated as High Impact polygons and areas of Open Water were mapped that included both naturally open areas and areas of deep, open water and sparse vegetation along major airboat trails. A conversion factor to compute the linear equivalent of Class 3 trails within High Impact areas was determined by mapping individual trails within four 500 by 500 m sample areas and calculating the average trail length to be 1,138.82 m per ha.

Summary statistics tallied to quantify the total length of individual airboat/ORV trail types within the East Everglades Expansion Area in 1999 revealed a total of 10,639 km of trails. Over 87 km of these trails were designated as wide Class 1 trails and 18 km were medium width Class 2 trails. Narrow Class 3 trails totaled 10,368.4 km and included 2,845 km of individually delineated Class 3 trails and the linear equivalent of 7,523 km of Class 3 trails within 6,606 km of High Impact polygons. An additional 232.5 km of Open Water areas was used by airboats. Reviewing these results, Class 1 and 2 trails represented only 2.5% of the total length of trails in 1999, compared to 97.5% of Class 3 trails. Since narrow Class 3 trails are generally associated with lower frequency airboat travel, these data may indicate a high level of impact in the northern half of the Expansion Area in 1999 from "free-range" airboating, or private airboat use off major trails. The area mapped as wide Class 1 and Class 2 trails, along with Open Water

routes, on the other hand, may provide information on impacts by larger, commercial airboats that regularly travel along consistent routes.

In addition to the complete mapping of trails in East Everglades from the 1999 DOQQs, the CRMS mapped trails in three 2 by 2 km study areas using aerial photographs taken in 1994, 1999 and 2003. These areas were selected to be representative of areas of mainly commercial airboat use, a mix of commercial and private airboat use and mainly private airboat/ORV use. Visual inspection of trails mapped and classified in these study areas, along with summary statistics of trail length indicate Class 3 trails have decreased remarkably by an average of 82% in all three study areas over the nine-year period. Conversely, Class 1 and Class 2 trails were generally evident in the same locations from year to year and experienced only a slight decrease in total length from 1994 to 2003. This reflects the photographic and ground truth evidence that narrow, single pass trails appear to be ephemeral in nature, while there is a stable network of wide trails. The extended study of the 1984/1985, 1994 and 2003 photos will provide an historical airboat/ORV trail inventory for the entire East Everglades Expansion Area and ultimately assist in the assessment of impacts for developing policies on continued airboat use.

Introduction

The Everglades National Park (ENP) located in South Florida is one of the oldest National Parks in the United States, granted that designation on 6 December 1947. It encompasses roughly 607,000 hectares (1.5 million acres) of wetlands that are unique in the world and have been designated a World Heritage Site, International Biosphere Reserve and a Wetland of International Importance (NPS 2006). Throughout its history, the park has been subject to urban encroachment as people have settled around the park, constructed canals for hydrologic diversion and engaged in recreational activities such as hunting, fishing and frogging within and adjacent to the Park boundaries. Included in this area is the East Everglades Addition Lands, also known as the East Everglades Expansion Area, consisting of individual parcels buffering the Park from agricultural lands adjacent to the northeast corner of ENP that have been purchased by the National Park Service (NPS) over the past fifteen years. The ENP, as a unit of NPS, has a mandate of restoration and preservation of lands for which it is responsible, and part of this mandate includes taking stock of current commercial and private airboat activities and assessing their impacts on the land. Remote sensing and geographic information system (GIS) and Global Positioning System (GPS) techniques can be used to create a digital database and hardcopy maps and images of airboat and off-road vehicle (ORV) trails from current and historical aerial photographs acquired over the East Everglades Expansion Area (Welch and Madden, 1998; Welch et al., 1999, 2001, 2002). The resulting airboat/ORV database and maps can be spatially analyzed to assess airboat impact over time and propose management guidelines for future airboat use.

The NPS completed the acquisition of lands in the East Everglades Expansion Area in 1999 and consequently began to institute management changes to the area. This area was traditionally used for hunting and camping with access to private camps being primarily by airboat (Figure 1a). In addition, several commercial firms located along U.S. Hwy 41, the Tamiami Trail, operate ‘ecotourism’ businesses with tours of the area in large airboats typically seating as many as 25 customers (Figure 1b). The mapping project described in this report was designed to

provide a data set for the 1999 season that can be used as a baseline for comparing airboat trail impacts over a multiyear period from 1984/1985 to 2003 (Madden, et al., 2005).

Figure 1: Small private-size airboats (a) and large commercial airboats (b) used in the East Everglades Expansion Area.

Study Area

The East Everglades Expansion Area, covering roughly 44,000 hectares (109,000 acres), was purchased from many private landholders on the north end of the ENP and east of the Big Cypress National Preserve (Figure 2). It is bounded on the north by U.S. Hwy 41/Tamiami Trail and on the east by various private holdings in Homestead and Miami. The northern portion of the Expansion Area, extending roughly from Grossman's Ridge to the northern boundary, is part of the natural flow of water from Lake Okeechobee toward the Gulf of Mexico. This area, known as Shark River Slough, is characterized by slow-moving water (30 m per day) from mere centimeters to 1 m deep over a bed of limestone and its resulting eroded soils (Myers and Ewel, 1990; NPS, 2006a). The water flows through primarily a marsh of sawgrass, the density and height of which are dictated by water depth. Also located throughout the slough are tree islands, originally formed by bits of organic matter that could not be suspended by the slow-moving water and instead settled and provided an obstruction which collected more organic matter. Eventually these obstructions built up detritus and organic soils upon which a wide variety of shrubs and trees grew to produce tear drop-shaped islands. Although the major axis and elevation of these islands grow as the tree island ages, they are generally on the order of hundreds of meters long and a meter tall (Davis and Ogden, 1994). The tree islands provided a home for land mammals such as deer, were inhabited by Native Americans and in recent times were used by hunters for hunting camps. The area has traditionally been used by private airboat owners for hunting, camping and recreational purposes, except when low water levels prevented airboat access. Commercial operators also have used this area, providing ecotourism opportunities with larger versions of the standard private airboats. On the east side and southern end of the East Everglades Expansion Area, known as the Freshwater Marl Prairie, the elevation is slightly higher. Because of the shallow water depth, and especially in the dry season, airboats are replaced by wheeled ORVs.

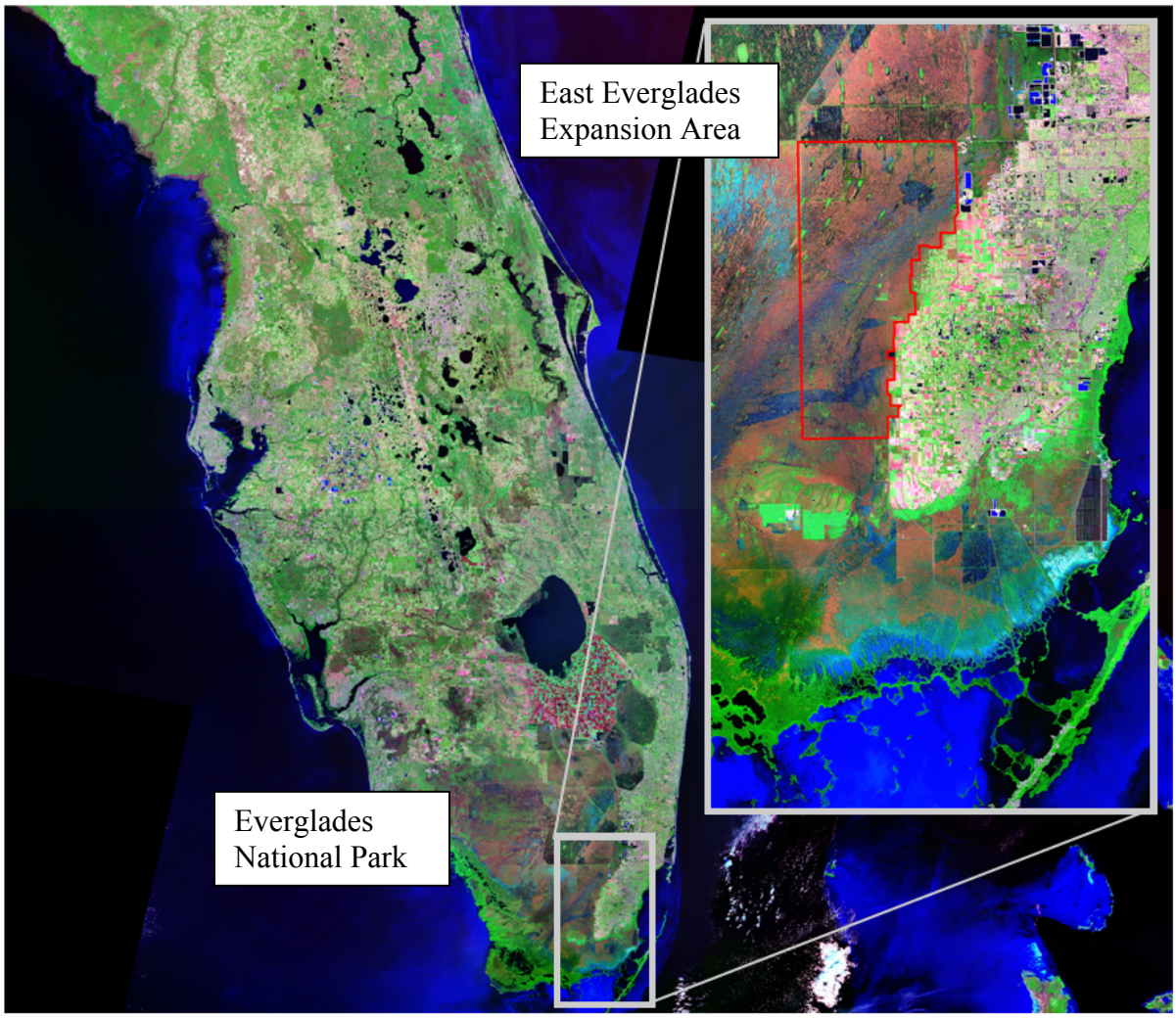

Figure 2. Location of the East Everglades Expansion Area within Everglades National Park in south Florida.

Objectives

The overall goals of this project were 1) to visit the area and develop a classification system for mapping airboat/ORV trails from aerial photographs; and 2) to develop a GIS database in ESRI ArcGIS format that delineates and classifies airboat and ORV trails in the East Everglades Expansion Area. The data set selected for this purpose was the U.S. Geological Survey (USGS) Digital Orthophoto Quarter Quads (DOQQs) prepared from 1:40,000-scale color infrared aerial photographs recorded during the winter of 1998/1999. The resolution of the digital DOQQs is 1 m and is suitable for detecting and delineating the vast majority of the airboat and ORV trails in the area. Color infrared images also enhance distinctions between vegetation and water in airboat trails due to the absorption and relatively high reflectance of infrared radiation by water and vegetation, respectively (Figure 3; Lillesand et al., 2004). Additional datasets acquired for this historical study include aerial photographs from 1984/1985, 1994 and 2003/2004 (Table 1).

Figure 3. Typical airboat trail in the East Everglades Expansion Area.

Table 1: Aerial Photographs and Digital Data for the Historical Airboat Study

	1984-85	**1994**	**1999**	**2003**
Source	USGS NHAP	USGS DOQQ	USGS DOQQ	SFWMD
Scale	1:58,000	1:40,000	1:40,000	1:24,000
Color	CIR	CIR	CIR	True Color

Methodology

Field Surveys

Personnel from the CRMS visited Everglades National Park two times in the winter of 2004/2005 for the purposes of conducting ground truth surveys: November 2004 (Marguerite Madden, Thomas Jordan and Louis Manglass) and March 2005 (Madden, Jordan and Cheryl McCormick). During the first visit, an initial background briefing was held with park managers Brien Culhane, Fred Herling and Skip Snow, followed by three-hour orientation airboat tour of the East Everglades Expansion Area. Two airboats driven by Park Rangers were employed for the tour during which many of the major airboat trails and tree islands were visited (Figure 4). Goals of the orientation tour included: 1) stops at several of the tree islands to observe airboat trails leading to and surrounding camps and structures; 2) discussion of the social and physical history of airboat use in the area; and 3) inspection and identification of the different types of airboat trails to develop a trail classification system. Digital photographs and GPS coordinates were recorded of each observation during the tour.

Upon completion of the airboat survey, an initial airboat trail classification system was developed that included 10 classes of trails (Table 2; Figure 5). These classes were reviewed for logic and consistency and approved by Herling and Snow in a subsequent meeting at the Park Headquarters. These classes included three general trail-type classes based on vegetation community type (i.e., open water, wet prairie and sawgrass) with trail-width sub classes (i.e., $\geq$ 10m, 3-10 m and $\leq$ 3m), as well as roads, canals and off-road vehicle (ORV) trails. Each class was assigned a number for use in identifying the trails during the helicopter survey.

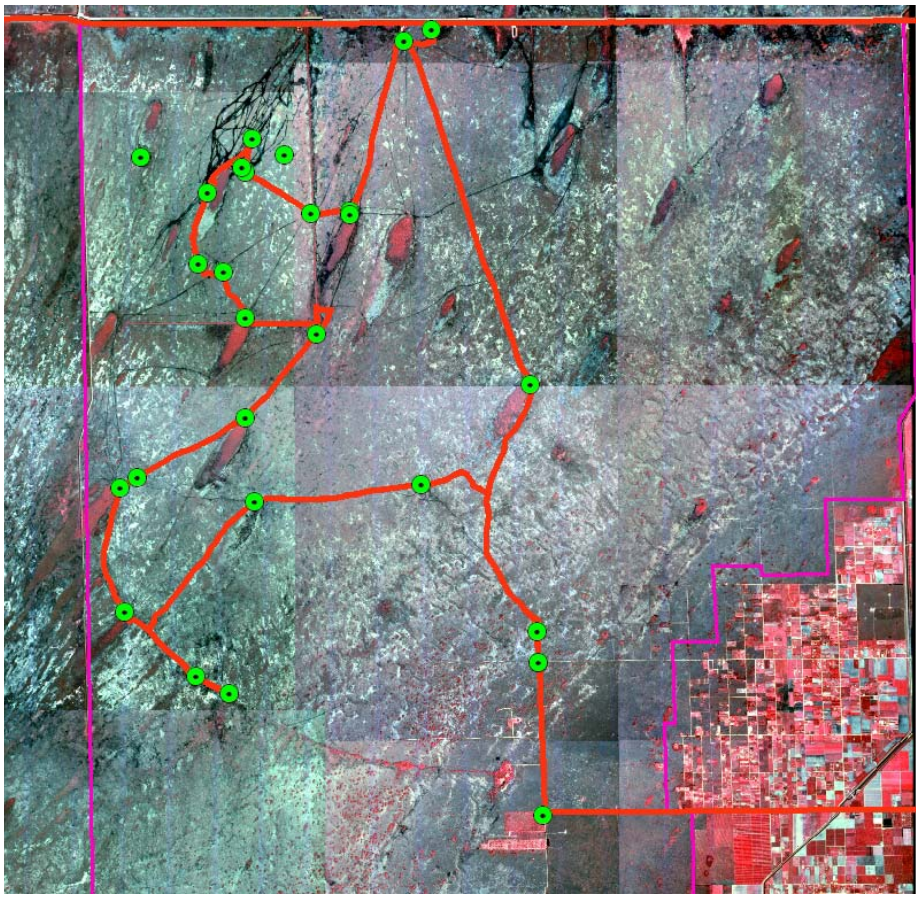

Figure 4. Color infrared aerial photo mosaic showing the route of the airboat survey (red line) and points visited (green dots).

Table 2: Field-Based Airboat/ORV Trail Classification System

1	Open water ≥ 10 m wide
2	Open water 3–10 m wide
3	Open water ≤ 3 m wide
4	Wet prairie ≥ 10 m wide
5	Sawgrass/Wet prairie 3–10 m wide
6	Sawgrass ≤ 3 m wide
7	Sawgrass, medium ≤ 3 m ht.
8	Sawgrass, tall > 3 m ht.
9	Canal
10	ORV trail
11	Old ORV trail
12	Road

a.

b.

c.

d.

e.

Figure 5: Airboat trail types: a) Class 6 – Sawgrass $\leq$ 3 m wide; b) Class 5 – Sawgrass/Wet prairie 3–10 m wide; c) Class 8 - Sawgrass, tall > 3 m ht.; d) Class 2 - Open water 3–10 m wide; and e) Class 9 – Canal.

Helicopter Surveys

Viewing the region from the air was the most appropriate and efficient way to conduct a ground truth survey and determine classes of airboat trails that were most likely to be visible and discernable from the aerial photographs. After CRMS personnel participated in an eight-hour helicopter safety training class held at the ENP Daniel Beard Research Center during the November 2004 field visit, helicopter surveys were conducted over a three-day period.

A series of 18 parallel, east-west flight lines were defined *a priori* to best cover the area within a four-hour flight day. Latitude-Longitude GPS coordinates for the flight line end points were provided to the pilot who flew the aircraft at an average speed of approximately 45-50 mph and altitude of 152.4 m (500 ft) above ground level. The doors were removed to increase visibility of the landscape by the observers. The crew on-board the helicopter consisted of the pilot, two CRMS personnel and one NPS personnel. The CRMS trail observer (Madden) sat in the front passenger seat to observe the trails below and on the left side of the helicopter, the NPS trail observer sat on the right side of the rear passenger seat to observe trails on the right side of the helicopter and the GIS specialist (Jordan or Manglass) sat in the rear seat with a laptop computer connected to a Trimble Pro XRS GPS (Figure 6). The GPS antenna was placed in the front left portion of the windshield for optimal visibility of satellites.

Figure 6. Helicopter survey seating configuration showing the pilot and observer in the front seats, the Trimble Pathfinder Pro XRS GPS antenna (visible through the front window), and GIS specialist and Park observer in the back seat.

As the helicopter flew along the transect flight line, Madden would observe a trail beneath the helicopter and call out a class number (1-12). The GIS specialist in the back seat would monitor the progress of the survey using real-time display of the aircraft GPS position on a map of the region displayed in ArcGIS software and the NPS observer could confirm Madden's observation. When a trail was identified, its location would be marked by entering a point feature and the class number into the database. A total of 600 points were collected in this manner during the November 2004 field trip (Figures 7 and 8). The survey along the east-west transects required two flight days to complete. On the third day, north-south flight lines were flown and trail data

collected as an independent check of helicopter observations. In addition, we visited specific points of interest in order to obtain photographs from the air of features such as hunting camps, tree islands and commercial airboat enterprises.

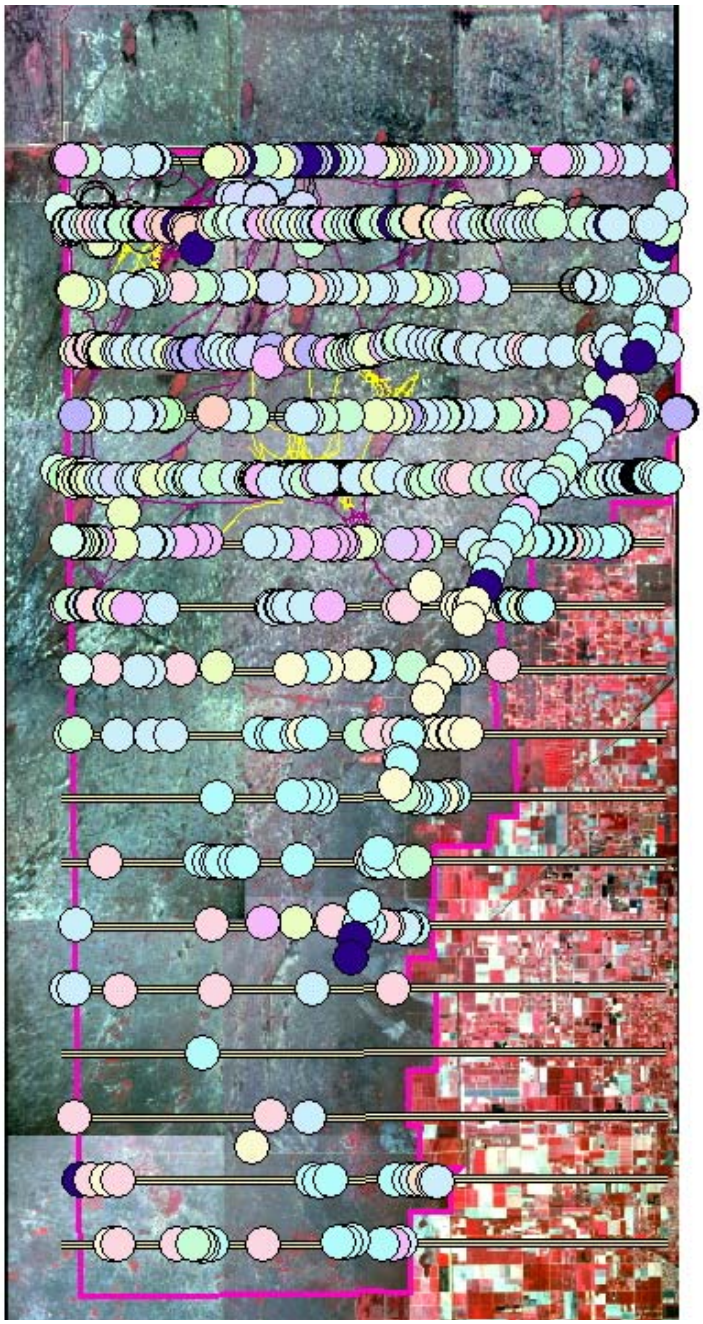

Figure 7. East Everglades Expansion Area helicopter survey showing 18 parallel flight lines and approximately 600 observations from the November 2004 field visit.

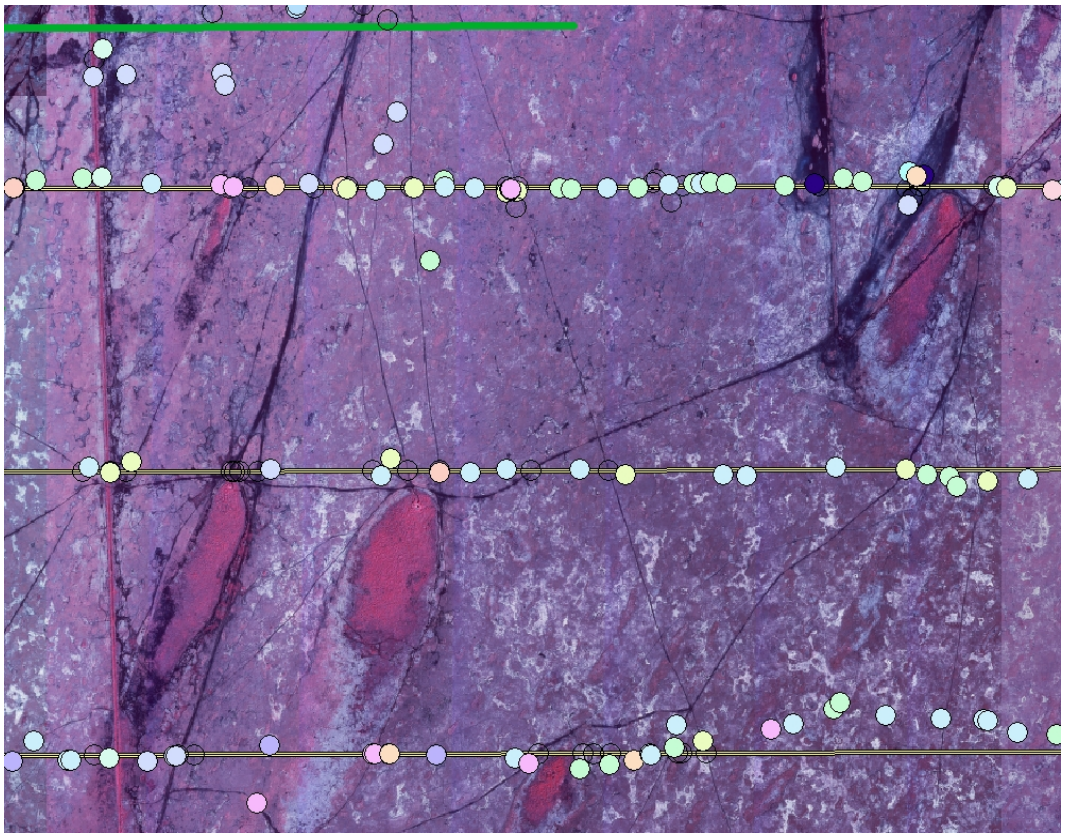

Figure 8. Closeup of a portion of the helicopter survey record.

Although a considerable amount of valuable information was recorded during the first helicopter data collection mission, several problems with the procedures were initially identified including difficulties in seeing the computer screen in the glare of the sunlight, the awkwardness of operating the computer mouse and keyboard while wearing fireproof gloves and the speed with which a point could be entered into the database. Entering a point required three steps: 1) monitoring the location of the aircraft on the computer screen and marking the point indicated by the GPS cursor location; 2) opening the attribute table and entering the correct class number; and 3) saving the point to the database. This operation required about 6-9 seconds per point and was frequently too slow for areas with very dense trail networks. At an air speed of 45 mph, the aircraft is moving over the ground at a speed of 20 meters per second. Thus, the time lag between the observation and recording could potentially introduce a positional error of up to about 200 m. To abrogate this, the GIS specialist would track the GPS position of the aircraft on the map using the mouse and record the position immediately upon hearing the observation called out. The trail class value would then be entered into the database. Even with this technique, however, there was typically a one to three second delay between the observation call and recording of the point, leading to potential error of up to 60 m. In addition, because of the time required to record each point, it was extremely difficult to record every point that was observed in areas of very dense trails. In these areas, it was not unusual to cross an airboat trail at a rate of up to one trail per second.

These problems were addressed during the second field visit and helicopter survey in March 2005. A new computer program for data collection was written specifically for this purpose in which the GPS coordinates were read directly into the program and saved as a record of the flight path. The user interface was designed to fill the computer screen and consisted of 18 programmable buttons with large numbers that could easily and quickly be selected using the mouse (Figure 9). Upon clicking the button for a given airboat trail class, the coordinate, class number and class name were recorded directly into a database file. This new method was extremely successful and permitted the helicopter to fly faster, resulting in over 950 points being recorded in one flight day during the second survey. The accuracy of the positional locations of observations was tested against 22 points where the helicopter flight line crossed a road. For the 22 test points, the average positional accuracy was 37.8 m, which is approximately equivalent to the forward motion of the aircraft of 35.6 m/sec (80 mph) as measured from the GPS track log recorded during the second survey. This positional error could be reduced further by flying more slowly (e.g. 45-50 mph as was done during the first survey), but it would also result in extended flight time to cover the study area.

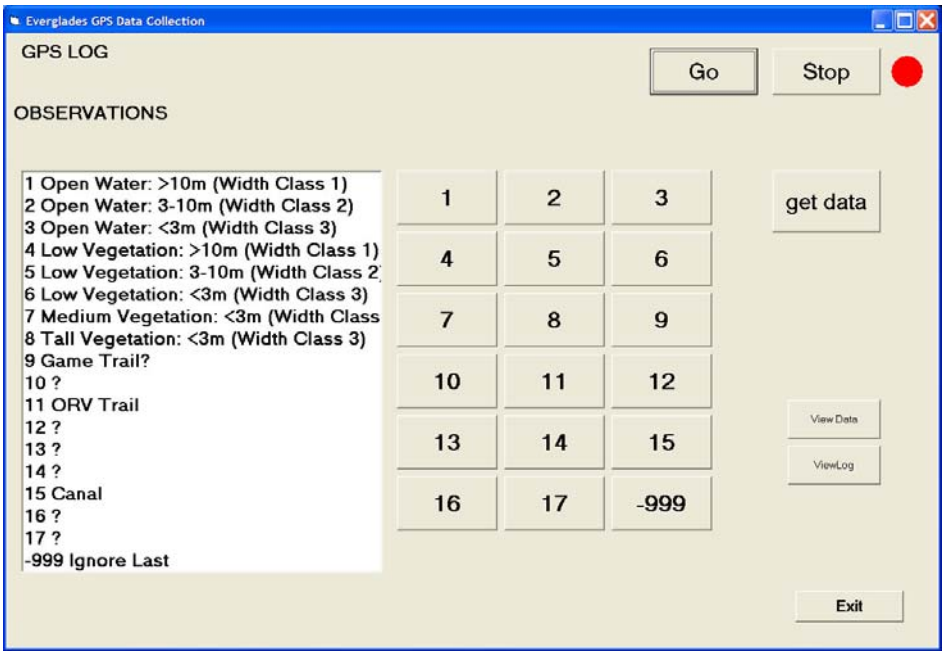

Figure 9. Protoype user interface of data collection program.

Photo Interpretation and GIS Database Development

Interpretation of the airboat trails and associated features was performed using heads-up digitizing methods in the ESRI ArcGIS 9.1 GIS software. To accomplish this task, several analysts were assigned specific areas of the East Everglades Expansion Area to map corresponding sections of the USGS topographic quadrangles and DOQQs. The analysts zoomed in on a portion of the DOQQ so that the airboat trails in the area were clearly and individually visible. Feature delineation and editing tools within the ArcMap module were then employed to trace the airboat trials visible in the photo and capture their locations as a series of line segments (Figure 10). Finally, class numbers of the trail type were entered into the associated attribute database.

Figure 10. Trails were digitized from CIR DOQQs using heads-up digitizing techniques in ArcMap 9.1.

Once the mapping effort began in earnest, it was found that it was difficult to discriminate the eight initial airboat trail classes identified on the ground from the aerial photographs. The width of trails, however, were clearly evident. As a result, the original classes were collapsed into three general classes based on width. These trail classes, along with the additional feature types of Open Water and High Impact (explained further below) were used by the photo interpreters (Table 3).

Table 3: Generalized Airboat Classes for Photo Interpretation

Class	**Description**
1	Airboat Trail $\geq$ 10 m wide
2	Airboat Trail 3–10 m wide
3	Airboat Trail $\leq$ 3 m wide
4	High Impact Trails (equivalent density of 1139 m per ha)
5	Open Water

While it was often difficult to interpret the subtle vegetation type differences from the aerial photographs, the width of the evident trails were not difficult to discern. Thus, for the photo interpretation efforts, trails were classified as wide ($\geq$10 m), medium (3 – 10 m) or narrow ($\leq$ 3 m). The narrowest trails are roughly equivalent to the width of a single airboat and represent limited use by a few airboats. These trails may be more ephemeral in nature while still being evident on the air photos. Wider trails representing multiple and repeated passes of airboats impact a wider swath of vegetation and may prove to have a greater, more permanent impact on the ecology of the Everglades. Large swaths of dense, intertwined and narrow Class 3 trails that were difficult to separate into individual trails were outline by a polygon and classed as High Impact areas. These polygons signify areas where intense airboat activity is evident. All Class 1 and Class 2 trails were mapped separately, even if they fell within a High Impact polygon. Open

Water polygons represent areas that appear to be naturally open or are potentially created by intensive airboat forming deep water routes.

The trails, areas of High Impact and Open Water features digitized in ArcMap 9.1 were stored in a geodatabase with a feature dataset bounding the extent of the Everglades Expansion Area. To avoid confusion and versioning issues, each analyst collected data for their portion of the study area into a separate copy of the master geodatabase for which they were responsible. The trail data geodatabases were then managed through ArcCatalog 9.1 by a single database manager (Manglass).

The final step in creating the GIS database was to merge all of the results of the individual interpreters into a single database and then to perform edge-matching between sections. In this operation, trails that appeared to extend across the boundary between DOQQ sections were joined into single trails. Joins and intersections between trails were edited and snapped together when appropriate to create a clean database and to ensure connections that will be utilized during a network analysis later in this project.

Results

This document reports primarily on the results of mapping airboat trails from DOQQs generated from 1:40,000-scale color infrared aerial photographs recorded during the winter of 1999. Additional work is on-going to create similar datasets from aerial photographs recorded in 1984/85, 1994 and 2003. This 19-year span of photographic data will be used to analyze trends in airboat use over time, establish longevity of trails and identify trails that are more or less stable and permanent in the landscape. To-date, the majority of the mapping from the 1994 and 2003 photographs has been completed. Therefore, it is appropriate to report on preliminary analyses of the changes in trail length and density over this time period.

Each of the trails stored in the database has attributes for class number and length. The areas of all polygon features (High Impact and Open Water areas) are calculated and stored in the database. These attributes permit the trails to be summarized in terms of total length and class. In order to derive a conversion factor for calculating effective Class 3 trail length per area of High Impact polygons, all of the visible Class 3 trails evident within four 500 x 500 m sample areas of high impact were delineated. The total length of trails within the polygons was then converted to a length per unit area for deriving the linear summary statistics. This conversion factor is 0.113886 linear meters for every 1 square meter of High Impact area polygon, or 1138.86 m per ha.

East Everglades Trail Summary Statistics - 1999

The final summary statistics for the 1999 trail database for the entire East Everglades Expansion Area are given in Table 4. It can be seen that the vast majority of trails are Class 3 trails, with 2845.2 km of individually delineated Class 3 trails and 7,523.2 km of Class 3 trails within 6605.9 ha of High Impact areas. The combined length of Class 3 trails is 10,368.4 km. There also were 87.7 km of Class 1 trails and 183 km of Class 2 trails. Open Water represented 232.5 ha of the

total area. The total length of all trails mapped in East Everglades from the 1999 photographs was 10,639.1 km, of which 97.4% were Class 3-type trails.

Table 4: Summary Statistics for East Everglades Airboat Trails: 1999

Feature Type	**Total Length / Area**
Class 1: >10 m wide	87.7 km
Class 2: 3 – 10 m wide	183.0 km
Class 3: ≤ 3 m wide	2,845.2 km
High Density: ≤ 3m wide	7,523.2 km
Total Class 3	10,368.4 km
Total Trails	10,639.1 km
High Density polygons (1138.86 m/ha)	6,605.9 ha
Open Water area	232.5 ha

Trail Changes from Three Sample Areas: 1994-2003

Interpretation of the additional years (1984/1985, 1994, 2003) of aerial photographs is on-going and, in fact, is nearly completed. In order to give a preliminary indication of changes and trends over time, three 2 x 2 km sample areas (SA) with the East Everglades Expansion Area were selected and mapped for 1994, 1999 and 2003 (Figure 11). These three areas represent: 1) an area of predominantly commercial airboat use (SA1); 2) an area of mixed commercial and private airboat use (SA2); and 3) an area of predominantly private airboat use (SA3). Complete mapping was performed in each of the three areas for three years of aerial photographs and the results of this work provide an indication of airboat usage trends over a nine-year period from 1994-2003.

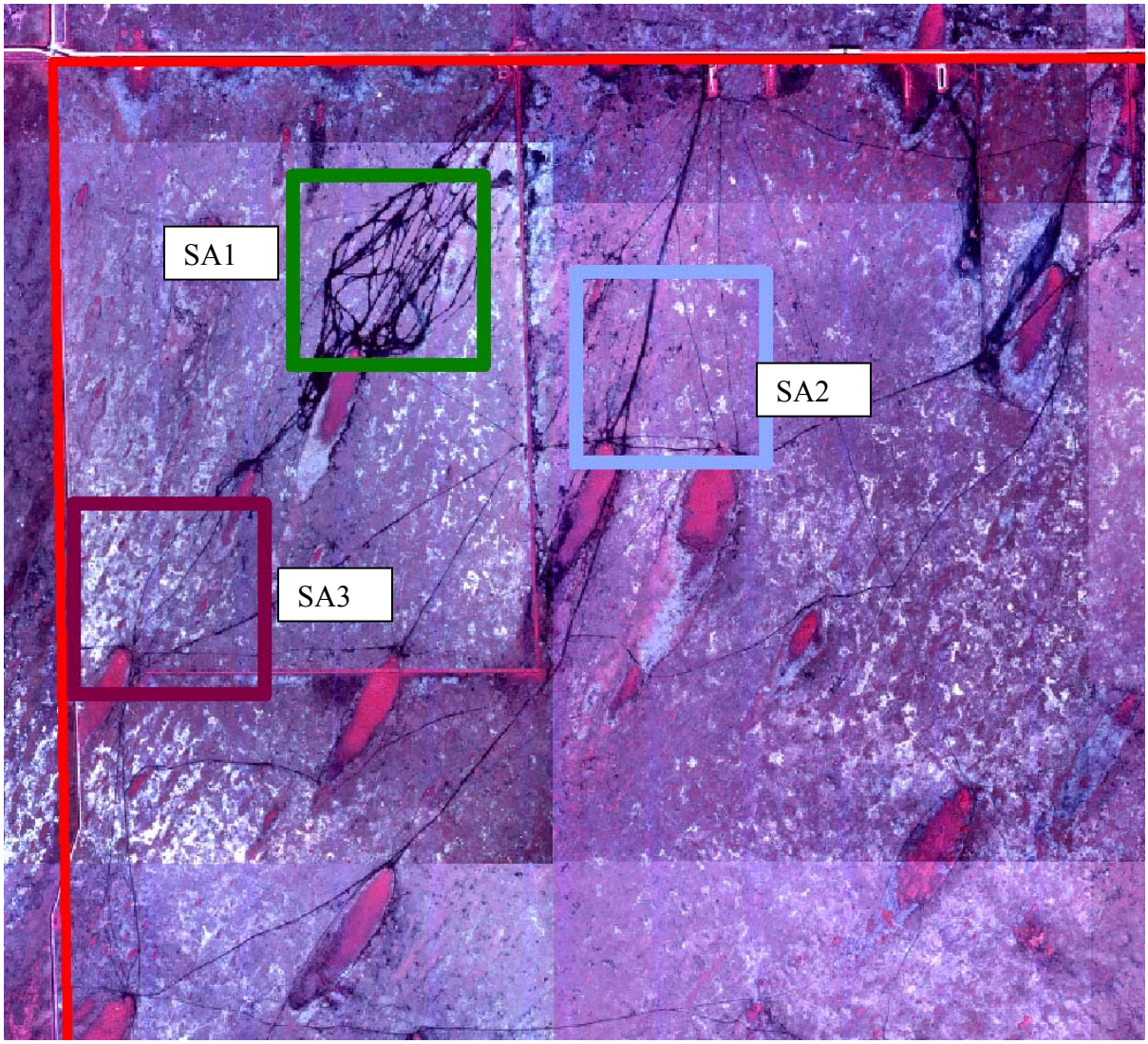

Figure 11. Three representative study areas (SA) were selected for this initial historical study. SA1 (green box) is typical of an area where commercial airboats operate; SA2 (blue box) is used by both commercial and private airboat users; and SA3 (red box) is used mostly by private operators. Each SA is 2 x 2 km in size.

Study Area 1 (SA1) – Commercial Airboat Use

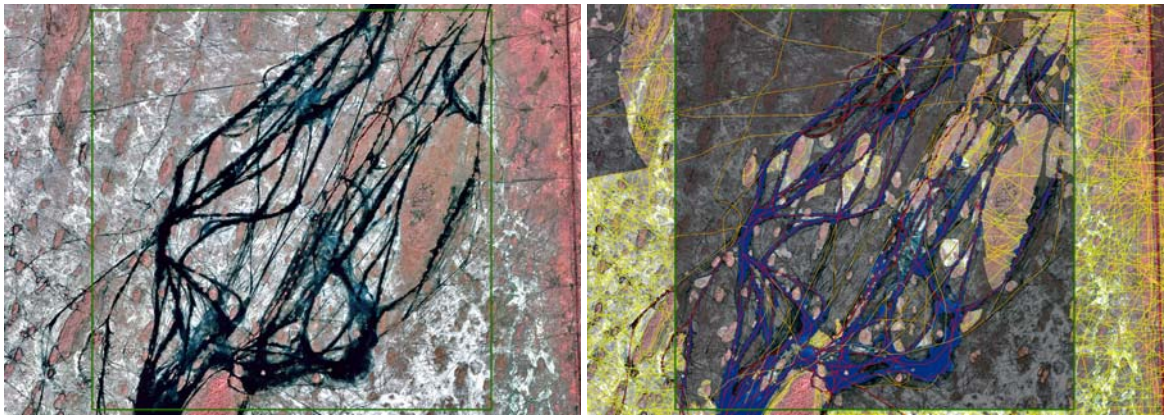

Figure 12. SA1 1994 (left) image and (right) trail map. The area is predominantly High Impact polygons (shaded grey) with Open Water routes (shaded blue) and Class 3 trails (yellow).

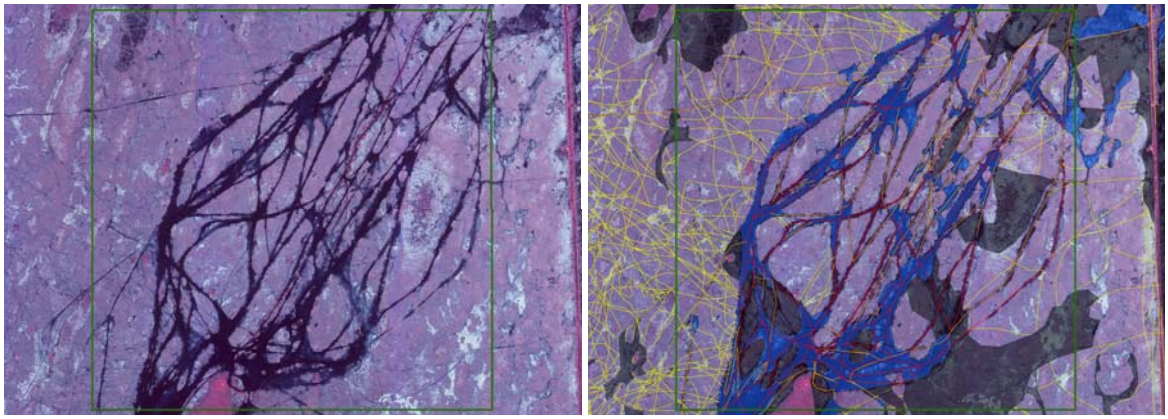

Figure 13. SA1 1999 (left) image and (right) trail map. The Open Water network is still obvious, but not as prominent, and the High Impact areas are much smaller.

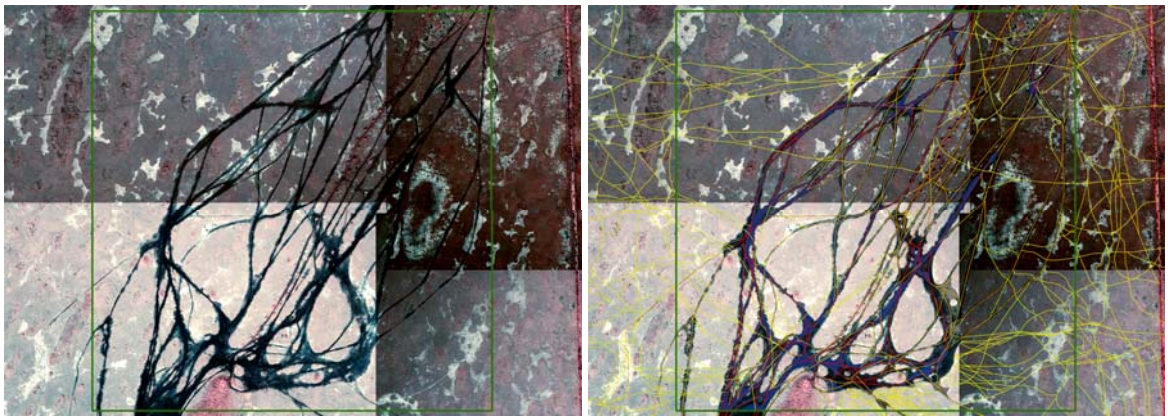

Figure 14. SA1 2003 (left) image and (right) trail map. The Open Water and High Impact areas have decreased in size.

Table 5. Trail Summary Statistics for SA1

	1994 (km)	1999 (km)	2003 (km)
Class 1	39	22	21
Class 2	32	23	34
Class 3	213	36	48
High Impact	293	87	28
Total	577	168	131
	1994 (ha)	**1999 (ha)**	**2003 (ha)**
High Impact	2580	765	242
Open Water	61	57	24

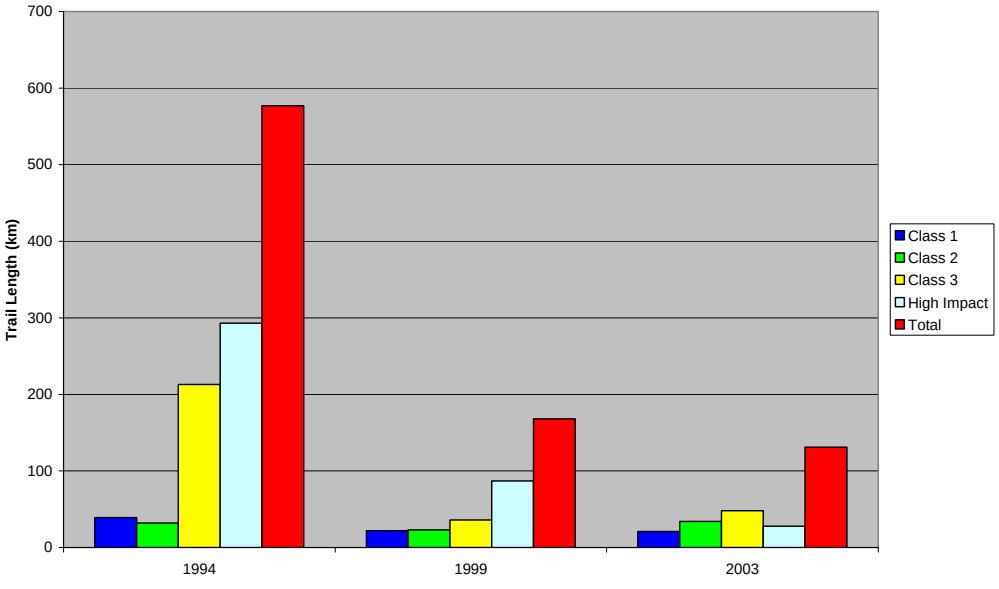

Figure 15. Total trail length by class for 1994, 1999 and 2003 within SA1.

Image subsets and delineated trails for SA1 depicted in Figures 12-14 show a high level of potential impact by wide trails (Class 1) and Open Water areas, possibly due to the commercial airboat tours that travel extensively and frequently in this area. The 1994 photos also show a high density of Class 3 trails, indicating a large amount of potential impact beyond the main routes. The overall airboat use in SA1, however, appears to be decreasing over time. There was a 77% reduction in total length of trails between 1994 and 2003 (Figure 15). The total length of Class 3 trails, (213 km of individually Class 3 trails plus 293 km of Class 3 trails within High Impact areas) in 1994, fell dramatically (Table 5). In 1999, there was a 76% decrease (to 123 km) from 1994, followed by an additional 38% decrease to 76 km from 1999-2003. The overall decrease in Class 3 trail length was 85% in nine years. The Class 1 and Class 2 trails, on the other hand, decreased 46% (39 km to 22 km) and increased 6% (32 km to 34 km), respectively. It appears that some of the former Class 1 trails from 1994 became Class 2 trails in 1999, while some Class 2 trails varied between Classes 2 and 3 in 1999. This indicates that the Class 1 and 2 trails may recover over time and appear to be more stable in the landscape than Class 3 trails.

Study Area 2 (SA2) – Mix of Commercial and Private Airboat Use

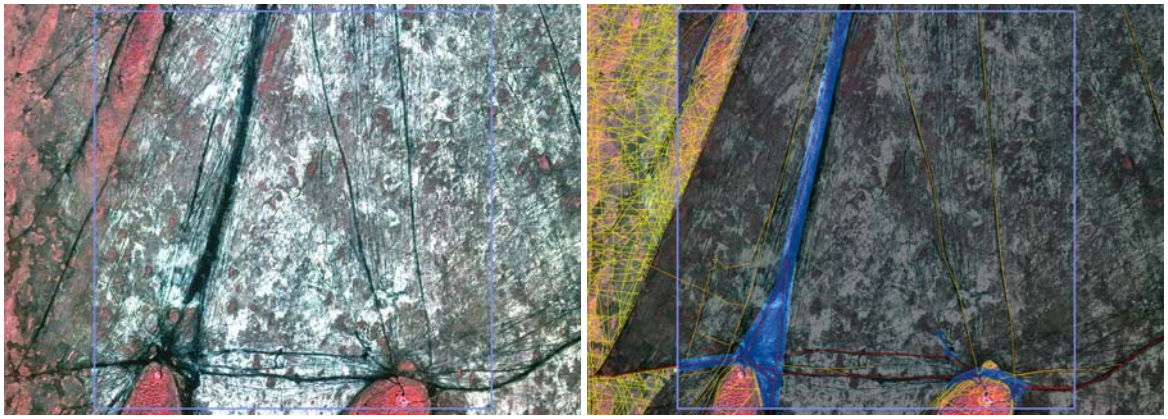

Figure 16. SA2 1994 (left) image and (right) trail map. This SA shows extensive airboat use and is almost completely delineated as a High Impact polygon.

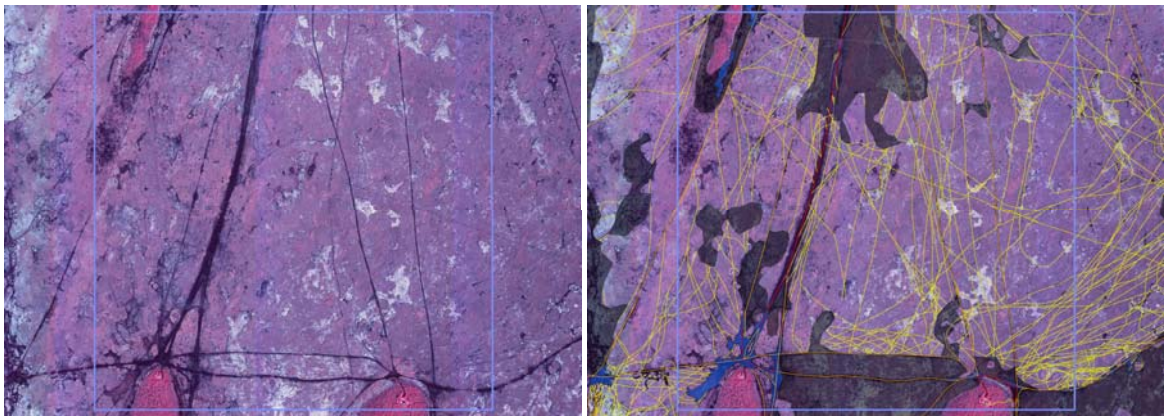

Figure 17. SA2 1999 (left) image and (right) trail map. There is a large decrease in visible trails reflected by a reduction in High Impact polygons.

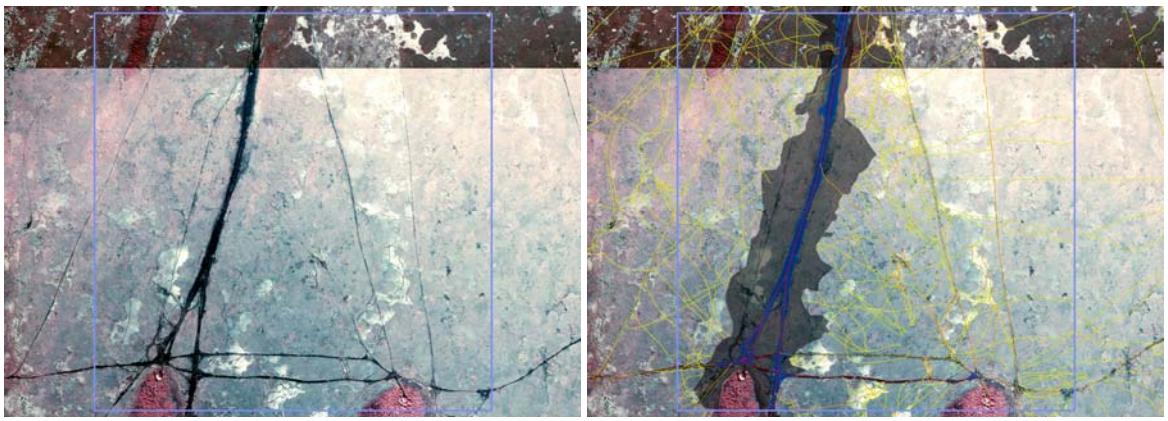

Figure 18. SA2 2003 (left) image and (right) trail map. A High Impact area surrounds the main Open Water route, but elsewhere airboat trails have markedly decreased.

Table 6. Trail Summary Statistics for SA2

	1994 (km)	1999 (km)	2003 (km)
Class 1	6	3	4
Class 2	13	11	13
Class 3	50	68	57
High Impact	417	94	76
Total	486	176	150
	1994 (ha)	**1999 (ha)**	**2003 (ha)**
High Impact	3658	825	667
Open Water	24	6	12

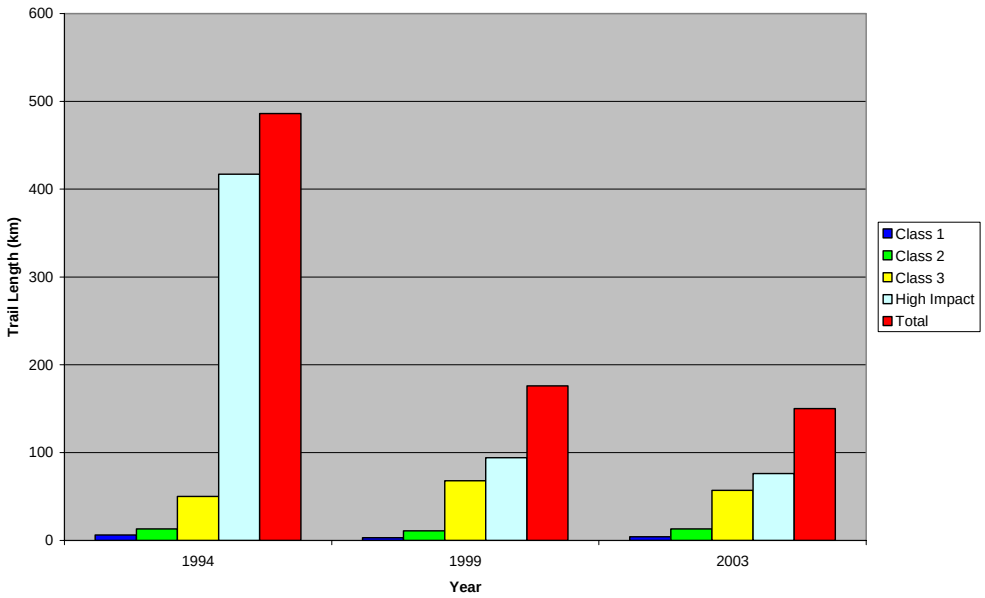

Figure 19. Total trail length by class for 1994, 1999 and 2003 within SA2.

Study Area 2 is located at the south end of a major airboat trail known locally by airboat users as the "Autobahn" for its heavy airboat traffic. Again, the area is characterized by heavy use in 1994, with decreasing impact by 1999 through 2003 (Figures 16 – 18). Overall, there was a 69% reduction in total length of trails in nine years for SA2 (Figure 19). The total length of individually mapped Class 3 trails and Class 3 trails in High Impact areas in 1994 was 467 km, which dropped markedly by 65% to 162 km by 1999 (Table 6). This area may also have experienced reduced impact by Class 3 trails and possible recovery. The total length of Class 3 trails fell an additional 18% to 133 km in 2003, a total decrease of 72% over nine years. Again, there was as great a change in the length of Class 1 and Class 2 trails during this same period. The total length of Class 2 trails stayed roughly level, while the number of Class 1 trails decreased 33% from 6 km to 4 km total length over the nine-year period. The total length of trails for this study area decreased by 69% over nine years (from 486 km to 150 km). The total area of High Impact also decreased from 3658 ha in 1994 to 667 ha in 2003.

Study Area 3 (SA3) – Private Airboat Use

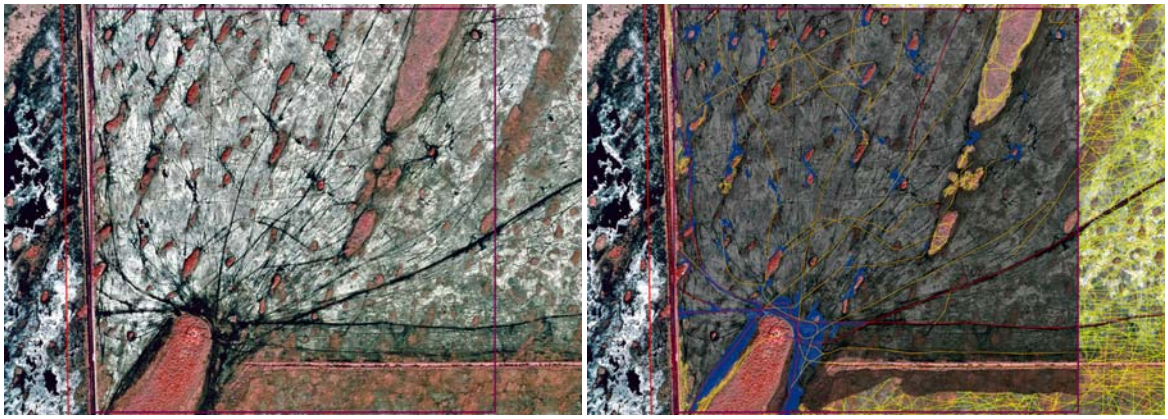

Figure 20. SA3 1994 (left) image and (right) trail map. The entire area is predominantly delineated as a High Impact polygon (shaded grey) with some Open Water areas (blue).

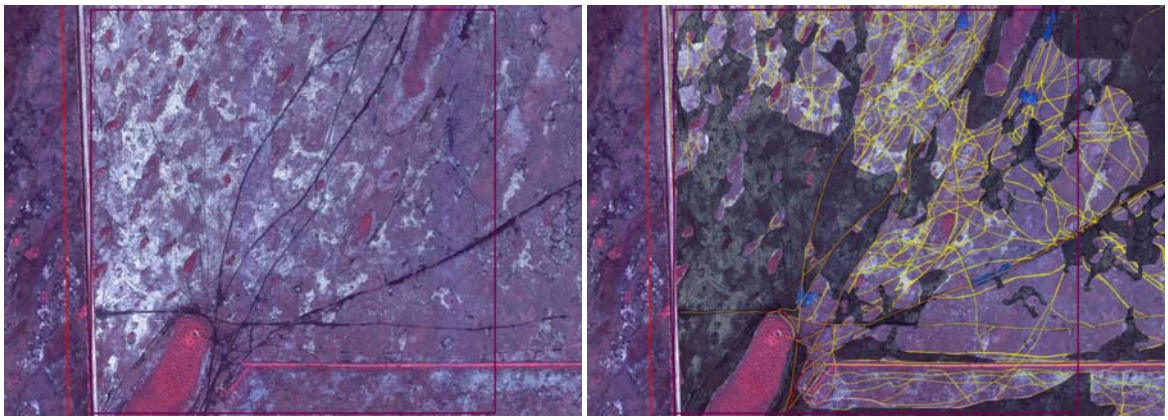

Figure 21. SA3 1999 (left) image and (right) trail map. The areas of High Impact and Open Water are reduced in size and distribution, while the network of Class 3 trails is more open.

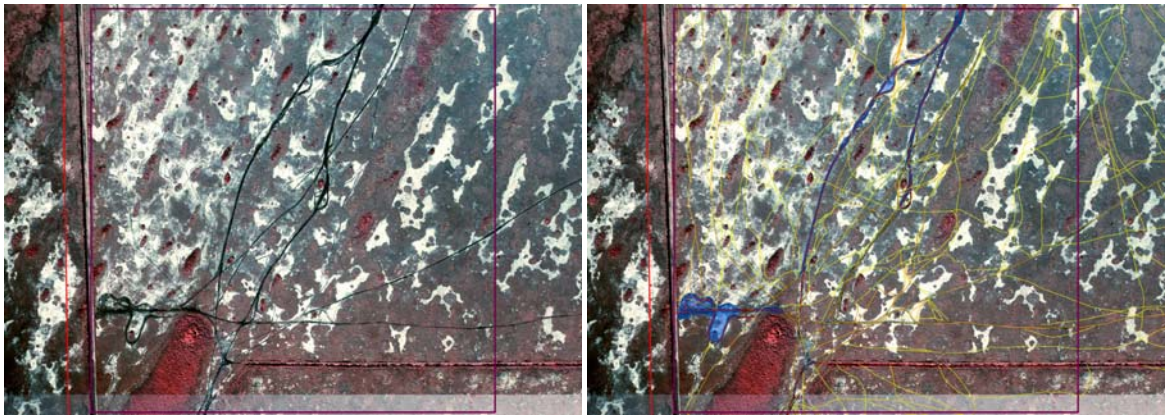

Figure 22. SA3 2003 (left) image and (right) trail map. The areas of High Impact polygons are essentially gone.

Table 7. Trail Summary Statistics for SA3

	1994 (km)	1999 (km)	2003 (km)
Class 1	9	1	6
Class 2	20	9	21
Class 3	79	48	42
High Impact	390	184	0
Total	497	242	69
	1994 (ha)	**1999 (ha)**	**2003 (ha)**
High Impact	342	161	0
Open Water	17	3	10

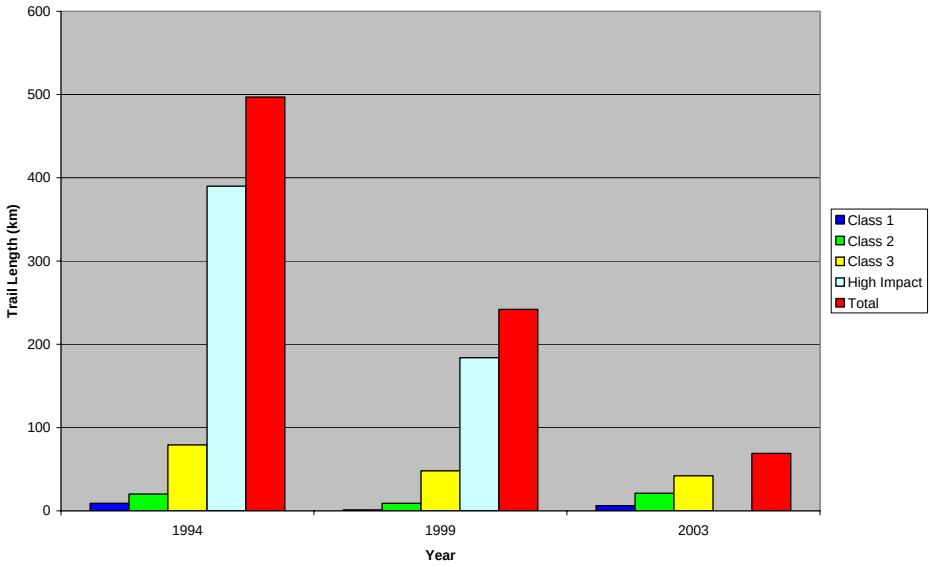

Figure 23. Total trail length by class for 1994, 1999 and 2003 within SA3.

Study Area 3 is characterized by some Class 1 and Class 2 trails connecting to the head of a tree island. In SA3, we again see evidence of heavy impact in 1994 by the definition of High Impact polygons throughout most of the study area (Figures 20-22). It did not experience as dramatic a decrease in High Impact areas by 1999 as the other Study Areas but still shows marked changes in Class 3 trail length. Overall, there was an 86% reduction in total length of trails in nine years within SA3 (Figure 23). The total Class 3 trail length, including High Impact polygon trail length conversions, was 469 km in 1994 (Table 7). This decreased by 51% to 232 kilometers by 1999 and by an additional 82% (90 km) by 2003, for a total decrease of 91% (469 km to 42 km). No High Impact polygons were delineated on the 2003 photographs. The Class 1 and Class 2 trails decreased from 1994 to 1999 by 66% from 29 km to 10 km, then experienced a 170% increase in length back up to 27 km. Most of this trend can be seen in the images as Class 2 trails in 1994 shrinking to Class 3 trails in 1999 then disappearing in 2003. Overall, the total length of Class 1 and Class 2 trails is more stable than Class 3 trails. Total High Impact areas decreased from 342 in 1994 to 0 in 2003.

Summary and Conclusions

Airboat activity, especially evident in the northern half of the ENP East Everglades Expansion Area, was mapped from 1-m resolution 1999 USGS color infrared DOQQs. Helicopter and airboat surveys provided ground truth data for developing an airboat/ORV trail classification system and manually interpreting trails from aerial imagery. Heads-up digitizing techniques of ArcMap 9.1 GIS software were used create an airboat/ORV trail database with trails delineated and classified as Class 1 [wide (≥10 m)], Class 2 [medium (3 – 10 m)] or Class 3 [narrow (≤ 3 m)]. Additional areas containing Class 3 trails too numerous to delineate individually were designated as High Impact polygons and areas of Open Water were mapped that included both naturally open areas and areas of deep, open water and sparse vegetation along major airboat routes. A conversion factor to compute the linear equivalent of Class 3 trails within High Impact areas was determined by mapping individual trails within four 500 by 500 m sample areas and calculating the average trail length to be 1,138.82 m per ha.

High Impact areas were observed to be primarily located around tree islands, especially radiating away from the northeast (head end) and in areas between tree islands in relatively close proximity to one another. Dense areas of explicitly mapped Class 3 trails occur in the northwest portion of the ENP Expansion Area and around areas of High Impact polygons. The spatial frequency of such trails generally decreases radially away from the High Impact polygons. Class 1 and Class 2 trails also are more prevalent in the north, especially the northwest connecting commercial airboat establishments and particular tree islands.

Summary statistics tallied to quantify the total length of individual airboat/ORV trail types within the East Everglades Expansion Area in 1999 revealed a total of 10,639 km of trails. Over 87 km of these trails were designated as wide Class 1 trails and 18 km were medium width Class 2 trails. Narrow Class 3 trails totaled 10,368 km and included 2,845 km of individually delineated Class 3 trails and the linear equivalent of 7,523 km of Class 3 trails within 6,606 km of High Impact polygons. An additional 232.5 km of Open Water areas was used by airboats. Reviewing these results, Class 1 and 2 trails represented only 2.5% of the total length of trails in 1999, compared to 97.5% of Class 3 trails. Since narrow Class 3 trails are generally associated with lower frequency airboat traffic, these data may indicate a high level of impact in the northern half of the Expansion Area in 1999 from "free-range" airboating, or private airboat use off major trails. The area mapped as wide Class 1 and Class 2 trails, along with Open Water routes, on the other hand, may provide information on impacts by larger, commercial airboats that regularly travel along consistent routes.

In addition to the complete mapping of trails in East Everglades from the 1999 DOQQs, the CRMS has completed mapping in three 2 by 2 km study areas based on photographs taken in 1994, 1999 and 2003. This provides an opportunity to examine the changes in representative areas of the East Everglades Expansion Area over the nine years from 1994 to 2003. In general, the presence of Class 3 trails decreased remarkably by 85%, 72% and 91% in SA1 (commercial airboat use), SA2 (mixed commercial and private airboat use) and SA3 (mainly private airboats), respectively, over the nine years studied. In all three study areas, the presence of Class 3 trails in 1994 was predominantly in the form of High Impact polygons, with a few outlying areas classified as individually delineated Class 3 trails. By 1999, most of the High Impact polygons

were replaced with individually mapped Class 3 trails, though they were often still dense in places and comprised most of the trail length in each study area. By 2003, most of the remaining High Impact polygons had disappeared and many of the dense tangles of Class 3 trails left no remaining visible impact. SA3 did not exhibit the same marked rate of change as the other two study areas, and though it ended with the same dramatic result over nine years, it did not drop as sharply from 1994 to 1999. The Class 1 and Class 2 trails were generally more stable trails being evident in the same locations from year to year and experiencing a slight decrease in total length from 1994 to 2003. This reflects the photographic and ground truth observations that these trails are, in many cases, established trail networks in the northern portion of the East Everglades Expansion Area. Looking closer at the trails, it is clear that there are two types of Class 2 trails: those whose impacts are very evident through the years studied (relatively stable) and those whose impacts vary over time or whose impacts are not visible in the intermediate year of 1999 (more ephemeral). The ephemeral trails appear in larger number in 1994 and 2003, but many are either not visible or categorized as Class 3 in 1999. This shows that even some wider trails can show evidence of recovery. Since these ephemeral trails are also often trails that cross main avenues of travel or are accessible only by Class 3 trails, they are presumably less frequently traveled and that may explain this phenomenon. Extended study of the 1984/1985, 1994 and 2003 photos should provide further information on these trends and ultimately facilitate a study of airboat/ORV impacts on the Everglades ecosystem. This information is vital to the development of policies on airboat use and the preservation of natural resources within the ENP East Everglades Expansion Area.

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Contents of the Accompanying CD

Documents

1. UGA Airboats 1999 Final Report.pdf – digital version of this document.
2. Assessing impacts on Everglades Ecosystems.pdf – copy of Madden, et al., 2005

Data

1. 1999 DOQQs of East Everglades Expansion Area in MrSID format
2. ArcView/ArcGIS Shapefiles for trail data and boundaries
3. ArcView project file (.apr) and ArcGIS MapDocument (.MXD) for the GIS data

Maps

1. Photomap.pdf – 1999 DOQQs only
2. Trail Network Photomap.pdf – 1999 DOQQs with trail network overlaid
3. Trail Network.pdf – Trail network only