ASSESSING BURN HISTORY, FIRE SEVERITY, AND MAPPING FUELS MITIGATION TREATMENTS IN THE WILDLAND URBAN INTERFACE OF NORTH CENTRAL FLORIDA

By

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To you

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TABLE OF CONTENTS

page

ACKNOWLEDGMENTS 4

LIST OF TABLES 6

LIST OF FIGURES 7

LIST OF ABBREVIATIONS 10

ABSTRACT 11

CHAPTER

1 WILDFIRE BURN SEVERITY: DOES BURN HISTORY DETERMINE SUBSEQUENT WILDFIRE BURN SEVERITY IN NORTH FLORIDA 13

Introduction 13
Methods 18
The Study Site 18
The Fires 19
Techniques 19
Results 21
Discussion 23

2 RETROACTIVELY MAPPING WORK AREA: A GIS CASE STUDY OF WILDLAND URBAN INTERFACE FUELS MITIGATION PROJECTS IN NORTH CENTRAL FLORIDA 36

Introduction 36
Current Practices 39
Methods 41
Results 42
Case Studies 43
Discussion/Recommendations 45

APPENDIX

A MAPS OF WUI FUELS MITITGATION TRETATMENTS 54

B MAPS OF WUI FUELS MITITGATION TRETATMENTS II 68

LIST OF REFERENCES 83

BIOGRAPHICAL SKETCH 87

LIST OF TABLES

Table page

1-1 A Kolmogorov-Smirnoff test for the 2004 Impassable Bay Fire NBR histogram and the 2007 Bugaboo Fire NBR Histogram..... 26

1-2 A Kruskal-Wallis test for 2004 Impassable Bay Fire and 2007 Bugaboo Fire severity classes. 27

1-3 A change matrix of how hectares changed severity classes between the 2004 Impassable Bay Fire and the 2007 Bugaboo Fire..... 28

1-4 Normalized Burn Ratio (NBR) thresholds for severity classes' developed using Composite Burn Index (CBI) protocol 28

2-1 State level fuels treatments from Master Database, January 2004 to December 2007. 49

LIST OF FIGURES

Figure page

1-1 The location of the Impassable Bay Fire and the Bugaboo Fire in north central Florida. 29

1-2 The 2004 and 2007 NBR values for the overlapping area set within their respective perimeters 30

1-3 The 2004 and 2007 burn scars with official fire perimeters: unclassified and classified 31

1-4 The Palmer Drought Severity Index for January 2001-December 2007. 32

1-5 The 2004 Impassable Bay Fire severity classification derived from the Normalized Burn Ration (NBR) 32

1-6 A comparison of 2004 Impassable Bay Fire and 2007 Bugaboo Fire NBR histograms for the overlapping area 33

1-7 Area (ha) per severity class for 2004 Impassable Bay Fire and 2007 Bugaboo Fire for the overlapping area. 33

1-8 A map of the severity change trajectory between 2004 Impassable Bay Fire and 2007 Bugaboo Fire.. 34

1-9 Locations and year of occurrence for prescribed fires near and within the perimeter of Bugaboo Fire. 35

2-1 Florida Department of Agriculture and Consumer Services Division of Forestry Regions. 49

2-2 A summary of DOF wildland-urban interface fuels reduction accomplishments from January 2004 to December 2007. 50

2-3 The process for developing maps. 50

2-4 A distribution of existing records and located project sites respective to Florida DACS Division of Forestry Regions 51

2-5 Total projects completed in FDACS DOF Region 2 during 2004- 2007. 51

2-6 Taylor Community's firebreaks and Bugabbo Fire 52

2-7 The Lamplighter Estates Mitigation Project. 53

A-1 Alachua Forever 54

A-2 Balu Forest. 55
A-3 Louis Hill Tower Project 56
A-4 Blues Creek. 57
A-5 Dowling Project. 58
A-6 Lakewood Project 59
A-7 Manning Cemetery Project 60
A-8 Mitigation Park Project. 61
A-9 Morning Side Project. 62
A-10 Nassau Oaks Project. 63
A-11 Rhymes Airport Project. 64
A-12 SRWMD Spray Field Project. 65
A-13 Ron Weiss/Turkey Creek Project. 66
A-14 Valentine Project. 67
B-1 Bevill Project. 68
B-2 Fire Tower Project. 69
B-3 Job Corps Project. 70
B-4 JR Davis Project. 71
B-5 Lake Butler Project. 72
B-6 LSA Project. 73
B-7 Mason Road Project. 74
B-8 Maxwell Food Tract Project. 75
B-9 Moody Project. 76
B-10 Pinkoson Gladstone Project. 77
B-11 Putnam EOC Project. 78
B-12 Rath Project. 79

B-13 Seminole Electric Project. 80

B-14 Whisham Seal Lane Project. 81

B-15 Whispering Pines Project. 82

LIST OF ABBREVIATIONS

AVIRIS	Airborne Visible/Infrared Imaging Spectrometer
dNBR	Differenced Normalized Burn Ratio
FAS	Forest Area Supervisor
FDACS	Florida Department of Agriculture and Consumer Services
FDOF	Division of Forestry (Florida)
GIS	Geographic Information System
GPS	Global Positioning System
GRS1980	Geodetic Reference System 1980
MRLC	Multi-Resolution Land Characteristics Consortium
MTBS	Monitoring Trends in Burn Severity
NAD 1980	North American Datum
NBR	Normalized Burn Ratio
NED	National Elevation Dataset
NIR	Near-Infrared
NLAPS	National Landsat Archive Production System
NWCG	National Wildfire Coordinating Group
ONF	Osceola National Forest
USGS	United States Geological Survey
WUI	Wildland-Urban Interface

Abstract of Thesis Presented to the Graduate School
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ASSESSING BURN HISTORY AND FIRE SEVERITY, AND MAPPING FUELS MITIGATION TREATMENTS IN THE WILDLAND URBAN INTERFACE OF NORTH CENTRAL FLORIDA

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The pyrogenic forest ecosystems of north central Florida were historically maintained by frequent low severity fires. Portions of two wildfires burned the same area in 2004 and 2007 in Osceola National Forest and these were tested to see if the second fire experienced lower severity as a result of the earlier fire. This was done using remotely sensed images enhanced with the Normalized Burn Ratio, classified, and compared. The second fire was more severe than the first showing no contribution from the 2004 fire in reducing the 2007 fire. Drought conditions contributed to the severity of the 2007 fire, but cannot be concluded to be the only driver of severity as fuel loads, stand ages, and management are not accounted for. During this same time period, the Florida Division of Forestry Region Two Wildfire Mitigation Team conducted fuels reduction treatments on private property throughout north central Florida. Spatial record keeping was analyzed and it was determined that 46 of the 272 projects in the 18 county region had location specific data. Prototype maps were developed to improve the understanding of where and what type of work was performed and format them in ways that could be useful to decision makers in wildfire suppression situations. Working

directly with mitigation personnel, 22 additional project locations were identified. During the 2007 season, four wildfires impacted mitigation projects and fire fighters did attribute the ease of containment to fuels reduction. Factors that contributed to lack of spatial data are addressed and suggestions for improving the institutional structure of data management in the future are given.

CHAPTER 1
WILDFIRE BURN SEVERITY: DOES BURN HISTORY DETERMINE SUBSEQUENT WILDFIRE BURN SEVERITY IN NORTH FLORIDA

Introduction

There is a belief in fire management that maintaining the historical fire regime is critical in reducing the occurrence and severity of large wildfires where the historical fire frequency was high and severity low. Despite the interest of land mangers and others in the fire science community, little research has been done to identify the effects burn history has on wildfire severity. The absence of these studies results from the limited number of study sites where wildfires overlap with well documented older fires or prescribed burns (Pollet & Omi, 2002; Finney, 2005; Martinson & Omi, 2003 & 2006; Outcalt & Wade, 2000; Thompson et. al., 2007). Understanding the relationships between recent fire history and old fire severity patterns is critical to evaluating the efficacy of fire as a wildfire risk reduction strategy.

Historical fire regimes would maintain themselves by spreading through overgrown forests burning what fuel was available and inevitably reoccurring when subsequent growth accumulated and fire-supporting weather conditions prevailed. The time interval between fires created conditions for fires of fairly consistent severity overall, but with pockets of higher or lower severity as well. Prescribed burning is a tool land managers use to attempt safe mimicry of this natural disturbance and is most often performed with minimal severity as an objective.

This remote sensing study is of two overlapping wildfire scars in north central Florida: one from 2004 and one from 2007. This situation is ideal for evaluating re-burned land and contributions earlier severity effects contribute to sequential fires. Land managers believe fuels reduction, i.e. prescribed fire, is a tool that can lead to a

reduction in forest fire severity. The situation where wildfire is responsible for the change in fuel load should present an ideal case study for evaluating historical wildfire events as wildfire regimes are maintained inherently by the changes they contribute to forest structure, i.e. fuel reduction, at regular return intervals. The occurrence of the 2007 wildfire within a historical return interval of the 2004 fire creates a situation where the severity of the second fire could be reduced in overlapping acreage.

Martinson and Omi (2003) conducted a thorough literature review that yielded only three studies assessing the effect prescribed fire had on fire severity. The most recent study occurred in 1979. A 2006 study updates their literature review and reiterates the lack of evidence for fuels treatments mitigating wildfire events, in spite of strong theoretical and anecdotal beliefs (Martinson & Omi, 2006). Their 2006 study of a prescribed fire's impact on wildfire severity was complicated by recognition that the prescribed fire may have been more severe than the wildfire (Martinson & Omi, 2006). Indeed it is possible for prescribe fires that get out of control to become wildfires. With this in mind, land managers typically write burn plans (prescriptions) which they hope will contribute to the fire being easier to control.

Prescribed fire is seldom intended to contribute high or even moderate severity changes to forest structure and is typically applied to isolated units on a much smaller scale than large wildfire events. Other studies addressing this topic suggest that prescribed fires both reduce the severity of wildfire and alter the progression of wildfire spread (Finney et. al., 2005). Regardless of how studies measure the success of fuels mitigation, any reduction in fuel loads from prescribed fire will be a short-term gain

dependant on the time since the burn and fuel accumulation rates (Pollet & Omi, 2002; Fernandes & Botelho, 2003).

A 10,000-hectare fire, in Osceola National Forest (ONF) in 1998, overlapped recent prescribed fire treatments. Natural stands treated with prescribed fire 1.5 years earlier experienced 15% mortality while units treated with prescribed fire two or more years earlier experienced 44% mortality (Outcalt & Wade, 2000). Planted stands treated with prescribed fire 1.5 years earlier experienced mortality of 5% while stands with two or more years since the time of burning had mortality of 54% (Outcalt & Wade, 2000). Upland areas experienced nearly two–thirds fewer tree kills than wetlands. The Outcalt and Wade (2000) study of how these fuels reduction treatments contributed to mitigation of wildfire severity determined their benefits were short term, but did reduce tree mortality even during conditions of extreme drought.

Fuels modification by prescribed fire may change wildfire behavior, but might not modify severity during extreme drought and high winds (Finney et. al., 2005; Pollet & Omi, 2002). This seems to be the common theme many scientists recognize; prescribed fire does reduce fuel loads but weather conditions can trump any benefit reduction in fuel loads might contribute towards severity. These same observations would hold true for natural fires in an idealized historical fire regime.

When fire burns the vegetation of a landscape, it can consume 100% or less of plant matter. Fire can kill plants without full combustion of materials. When a fire burns across a landscape, scorching and combustion of plant materials can vary widely depending on flame heights and the story through which the fire travels. The result is a mosaic of plant mortality and scorching typically scaled in remote sensing studies as

low, moderate, and high severity. This may include canopy consumption, charring of the soils, and other morphological change attributed to the physical, chemical and biological changes resulting from burning (White et. al.,1996). The alteration in spectral response is dependent on vegetation and soil changes resulting in a decrease of near infrared wavelengths and increased mid infrared wavelengths with burn severity (White et. al., 1996).

The National Wildfire Coordinating Group defines fire severity as the "degree to which a site has been altered or disrupted by fire; loosely, a product of fire intensity and residence time (National Wildfire Coordinating Group, 2006)". It has also been defined as "a function of physical and ecological changes caused by fire (Cocke et. al., 2005). Key and Benson define it as "a scaled index gauging the magnitude of ecological change caused by fire (Key & Benson, 2006)." Remote sensing is an important tool in determining the impact of wildfires through quantifying the extent and degree of severity (Sunar & Ozkan, 2001; Escuin et. al., 2008; Thompson et. al., 2007; Miller & Yool, 2002; Hammill & Bradstock, 2006; Robichaud, 2007; Wimberly & Reilly, 2007; Duffy et. al., 2007; Miller & Thode, 2007; Cocke et. al., 2005).

The change in spectral response of a landscape from unburned to burned is a result of multiple factors. These include the change in magnitude of solar reflectance due to defoliation and the relationship this change has with the quantity of defoliation (White et. al., 1996; Patterson & Yool, 1998). Specifically, disturbances responsible for decreased chlorophyll absorption and leaf tissue damage generate a greater reflectance of visible electromagnetic wavelengths and a decreased reflectance of the near-infrared (NIR) region (Jensen, 2000). Near Infrared wavelengths are sensitive to the moisture

content of plants and are an indicator of physiological damage from fire (Rogan & Yool, 2001).

White et al. (1996) determined Landsat band 7 to be effective for delineating burn severity. Miller and Yool (2002) used a combination of Landsat bands 4 and 7 to measure severity with a high accuracy. van Wagtendonk (2004) used AVIRIS hyperspectral data to determine that the portions of light spectrum which Landsat bands 4 and 7 encompass experience the most dramatic changes due to fire occurrence. Key and Benson (1999) developed an index that has become the standard for enhancing burn scars to classify severity. This ratio is the normalized burn ration (NBR) and is calculated with Landsat bands as (4-7)/(4+7). NBR is increasingly correlated to field severity measurements when it is differenced between pre and post fire images as differenced NBR (dNBR).

An application of 13 remote sensing image enhancements for severity classification purposes were evaluated against each other over four different Alaskan fire scars and NBR(dNBR) was determined to be the overall highest ranked (Epting 2005). A study in the southern Appalachians showed NBRs applicability in the southeast (Wimberley & Reilly, 2007). An ongoing study by Tall Timbers Research Station evaluated the 2007 Bugaboo Fire using the Composite Burn Index and determined NBR (dNBR) thresholds for severity within ONF (Picotte, Personal communication).

The objectives of this work were to address the following questions. Did the severity of the 2004 fire reduce the severity of the 2007 fire? Is three years a fire return interval that will support the low severity ecosystem benefiting fire effects that are

believed to have supported the pyrogenic nature of forests in this area of the Southeast? Are factors such as weather more important in determining severity than time since previous burning?

Methods

The Study Site

Osceola National Forest lies in Baker and Columbia counties in North Central Florida and is made up of pine flatwoods, dry prairies, swamps, and bays (Fig. 1-1). Topography is fairly uniform with only slight elevation changes leading to shifts in hydrology and the establishment of vegetation. The overstory is predominantly composed of Pinus palustris and Pinus elliotii with understories of Serenoa serrulata, Ilex glabra, Lyonia lucida, Myrica cerifera and Aristida beyrichiana among others. Quercus virginiana, Quercus nigra, Acer rubrum, Fraxinus americana, and Liquidambar styraciflua occur in isolated stands. Sandy soils are generally sandy, acidic and low in organic matter. They are characterized as imperfectly to poorly drained (Brown et. al., 1990).

Florida's climate is subtropical and humid. Spring has extreme variability in temperatures ranging from -5°C to 39°C. Drought often occurs in spring and occasional frosts persist late into the season. Summer has a mean temperature of 33°C with temperatures above 38°C not uncommon. Autumn has maximum high temperatures of 30°C during the day, but experiences cool to cold nights as temperatures may drop as low as –3°F. Winter mean temperature is 19°C, but in isolated days temperature may drop as low as -10°C. Frequent thunderstorms during summer months are responsible for major rainfall and lightning activity. Frontal systems in winter often precede cold

snaps. If the fall and winter are dry, a dry spring will perpetuate conditions for wild fire activity (Chen & Gerber,1990).

The Fires

The Impassable Bay Fire (Figs. 1-1,1-2 & 1-3) burned 13, 760 hectares of Osceola National Forest during April of 2004. The fire was driven with strong westerly winds across terrain with dry fuels, but moderate soil moisture. Severity levels spanned from low to high in heterogeneous patterns across the forest. The majority of the Impassable Fire burn scar was re-burned in May 2007 within the perimeter of the Bugaboo Fire (Figs. 1-1, 1-2, & 1-3). This fire burned from north to south during a period of extreme drought where fuel moisture content and soil moisture were at record lows (Fig. 1-4). Like the Impassable Bay Fire, the Bugaboo Fire encompassed heterogeneous landscape however the latter fire experienced more homogeneous fire effects resulting in a different pattern of severity (Fig. 1-5).

Techniques

Two Landsat 5 Thematic Mapper images were used for this study. Both were acquired from United States Geological Survey Multi-Resolution Land Characteristics (MRLC, 2001, 2006) Consortium/Monitoring Trends in Burn Severity (USGS MRLC/ MTBS) scientific archive. The image of Impassable Bay Fire is from April 10, 2004 and the image for Bugaboo Fire were acquired on May 21, 2007. MRLC metadata verify geometric and radiometric corrections have been made by USGS Earth Resources Observations and Science Center using the Multi-Resolution Land Characteristics Image Processing Procedure (MRLC, 2001, 2006). Digital numbers (DN) are first converted to at satellite radiance and then to at satellite reflectance using the earth-sun distance, mean solar exoatmospheric irradiance for the day of year, and sun elevation

angle for time of image acquisition. Geometric correction uses the one-arc second National Elevation Dataset (NED) to correct geo-location errors and then cubic convolution re-sampling to 30m spatial resolution is performed on bands one through five and seven. The image is projected as Albers Conical Equal Area using the spheroid GRS1980 and the datum NAD 1980 (MRLC, 2001, 2006).

Clouds and cloud shadows that coincide in both the 2004 and 2007 image were removed to avoid analyzing non-overlapping areas. The cloud cover removal was done by first separating the 2004 image into single bands of the spectrum. A criteria model was applied to band 1 to separate digital number values that make up cloud cover from both smaller and larger values that did not. An iterative process showed the digital numbers 29 through 50 made up clouds and these were then assigned one value. All digital numbers above and below this were lumped together as a second value. This resulted in two values: clouds and not clouds. These clouds were then extracted to remove background, and expanded by one pixel to compensate for edge effects. Next, the cloud shadow removal was performed by compositing TM bands 5, 3, and 2 to create an image with distinct shadows. Using Erdas Imagine v9.3, an Area of Interest (AOI) was grown in each shadow area adjusting threshold settings with each iteration to achieve a precise fit. The AOI layer as a whole was then used to create a raster layer of cloud shadows. These cloud shadows were expanded by one pixel. The cloud shadows and cloud cover layers were merged. The lines dividing the clouds and cloud shadows were dissolved and the resulting features were saved as a single class value which was used as an extraction mask to isolate and remove the clouds and cloud shadows from the 2004 image and the corresponding area of the 2007 image (Fig. 1-3).

USFS GIS polygon vector files for each fire perimeter, created by the National Forest Service, were used to define the burn scars and identify the area of overlap between the Bugaboo Fire and the Impassable Fire (Fig 1-1).

The NBR enhanced version for both images were derived using the calculation [(4-7)/(4+7)]*1000 leaving a value range of (-1000 to 1000). This leaves a gray scale image with values approaching –1000 assigned to pixels of increasing burn severity and values approaching 1000 assigned to unburned pixels. Using NBR thresholds (Table 1-4) developed by Tall Timbers Research Station for the 2007 Bugaboo Fire, areas in both the Bugaboo Fire and Impassable Bay Fire were classified as High, Moderate-High, Low-Moderate, and Unburned (J. Picotte, Personal communication). The low-moderate and high-moderate were combined into a single moderate class to avoid the small area within the low-moderate category and make analysis between images straight forward. The thresholds are averages developed using Composite Burn Index protocol for the fieldwork with sampling stratified over three vegetation types and dormant, early, and late growing season with multiple assessments during the growing season (Picotte, Personal communication). The relationship between thresholds in the field and NBR enhanced imagery for 2007 are assumed to be the same for 2004 as this study analyses only area burned in both fires. With the overlapping area of the fires isolated and the areas of cloud and cloud shadows removed from both NBR images, analysis of the two images was performed.

Results

The NBR histograms of the study area for both fires are compared (Fig. 1-7). The scaled fire severity of each fire is compared (Fig. 1-8). A change trajectory was made to

show how each pixel changed in severity from one fire to the next with all results reported in hectares and these changes were plotted on a map (Table 1-3, Fig. 1-9).

The 2007 Bugaboo Fire had many more hectares of land within pixels trending towards the portion of the scale that indicates high severity. The comparison of these two classified images reveals how the severity of the Bugaboo Fire exceeded that of the Impassable Bay Fire (Fig. 1-5, Fig. 1-7). It is clear that the NBR histogram of the Bugaboo Fire is skewed towards the portion of the NBR range which indicates higher severity in 2007 than 2004 (Fig. 1-7). Table 1-1 shows a Kolmogorov-Smirnoff Goodness of Fit Test applied to the observed values yielded a D-statistic of 0.304 with 99.4% confidence interval showing a strong dissimilarity between the two histogram means. This verifies that the two fires did indeed experience distinct differences in severity with mean hectares falling in different ranges along the –1000 to +1000 NBR spectrum for the two samples of equal area.

The two fires differed strongly in number of hectares per severity class (Fig. 1-8). A Kruskal-Wallis One-way Analysis of Variance (KW Test = 20.57; $p << 0.001$, for the Impassable Bay Fire and 22.23; $p << 0.001$ for the Bugaboo Fire; df = 3 for both) showed the sums of severity class areas strongly skewed in 2007 as high severity and strongly skewed as moderate severity for 2004 (Table 1-2). This robust test of equal sample sizes shows that the data behaves the same whether it is classified into severity categories or compared quantitatively.

The change trajectory shows areas that fell into the same category of classification between the two fires. Table 1-3 shows that 41 percent of the area was classified the same in 2007 as in 2004, and 59 percent changed from one classification to another.

The 57 percent of area that increased in severity from 2004 to 2007 and the two percent of area that decreased in severity are shown in Figure 1-9. The area that decreased in severity is so small and dispersed as to be nearly impossible to see at this scale. The most dramatic of which was a change of 43 percent of total area moving from less severity in 2004 to high severity in 2007.

Discussion

The hypothesis that the 2007 Bugaboo Fire study site should show low severity as a condition of having been previous burned by the 2004 Impassable Bay Fire is shown to be rejected. The 2007 area of overlap is markedly higher in severity than in 2004 and is not significantly different from the remainder of the 2007 fire outside the overlapping area. This indicates that either too much time elapsed between fires for any resulting factors of the primary fire to affect the secondary fire, or other conditions nullified the fuel reduction the primary fire may have provided to the second.

Fire severity is tied to historical fire regime, fuel accumulation rates, stand management, weather, topography, and vegetation type. In this scenario both topography and vegetation type remain constant, fuel loads and stand management are not accounted for, but we do see that climate played a significant role. The 2007 drought was more extreme than the 2004 drought (Fig. 1-4). This supports the findings of both Finney (et. al., 2005), and Pollet and Omi (2002) that severe weather creates fire conditions independent of other factors. Both of their studies were for ponderosa pine forests in western terrain with high topographic relief that are maintained by low severity fires in similar fashion to this study site. The Finney (et. al., 2005) study site was a fire that burned during record drought much like the Bugaboo Fire. When frequent low severity fire is necessary to maintain a fire regime, all conditions for limiting

severity must be met or wildfire can easily become more intense than historical expectations.

We also see in Figure 1-4 that years 2005 and 2006 had high rainfall between the two wildfires that would have resulted in plentiful vegetation growth in the forest. The length and quality of vegetation growth in-between fires outweighs any impact previous fuels mitigation may have had (Pollet & Omi, 2002; Fernandes & Botelho, 2003; Outcalt & Wade, 2000). In 1998, wildfires in the Osceola National Forest burned at high severity despite previous fuels mitigation. Research determined that fuels reduction for this area had little impact in influencing fire severity after two years since treatment (Outcalt & Wade, 2000), but this may have been a result of the drought severity their study site experienced in 1998. This study involved two fires three years apart, but it is difficult to hypothesize what level of severity would have resulted in the absence of extreme drought that served to drive the conditions for the Bugaboo Fire. Future research examining how the fuel loads prior to each fire affected the outcome of each fire would also be helpful in understanding the relationship each of these fires has with each other.

Historical fire occurrence is thought to have maintained a balance in the Southeast that perpetuated the pyrogenic ecosystems. While prescribed fire is used to mimic the natural occurrence of wildfires and is applied ideally at two to three year intervals in many areas of Florida, it is rare to have two overlapping wildfires at just such a time interval. The Impassable Bay Fire can generally be characterized as a moderate severity burn, which implies an additional degree of mortality and canopy fire that is seldom contributed from managed prescribed fires. This mosaic pattern of

heterogeneous fuels reduction may have created conditions that thwarted the spread of fire had such extreme drought conditions not been present. While studies examining wildfire overlap are nearly non-existent, the contribution of other studies showing fuels treatment impacts on wildfire severity is heavily dependent on combinations of mechanical treatments with prescribed fire. The literature base could be improved by increasing the number of prescribed fire only fuels mitigation studies. More emphasis on understanding stand management impacts, fire weather, fire progression, and vegetation are needed to identify where the greatest contribution to severity lies (Wimberly et. al., 2009; Thompson et. al., 2007, Collins et. al., 2007).

Further study of the additional smaller prescribed fires conducted by USFS prior to the Bugaboo Fire would be worthwhile. These included burn units during 2004, 2005, 2006 and 2007 that fall along the southern terminus of the containment line for the Bugaboo fire (Fig. 1-10). It is apparent that these burn units fall on both sides of the burn scar and could have made containment in this area possible do to fuel reduction which was the intention and result of those prescribed fires.

The belief that maintaining the historical fire regime through fuels reduction will reduce fire severity is incomplete. Indeed the periodic fuels removal of the historic fire regime is only one of several factors that affect wildfire burn severity. Climate (or weather) in between fires is a major one and the outcome of severity in a wildfire is often dependant on multiple factors that are unable to be mitigated.

Table 1-1. A Kolmogorov-Smirnoff test for the 2004 Impassable Bay Fire NBR histogram and the 2007 Bugaboo Fire NBR Histogram.

Kolmogorov-Smirnoff Two Sample Test Results	
D -statistic	0.321
Confidence Interval	0.006

Table 1-2. A Kruskal-Wallis test for 2004 Impassable Bay Fire and 2007 Bugaboo Fire severity classes.

2004 Impassable Bay Fire Severity		2007 Bugaboo Fire Severity	
Severity Groups	Rank Sum	Severity Groups	Rank Sum
Unburned	301	Unburned	133
Low	66	Low	72
Moderate	797	Moderate	610
High	432	High	781
Kruskal-Wallis Test Statistic: 20.574		Kruskal-Wallis Test Statistic: 22.233	
p-value<<<0.001	df=3	p-value<<<0.001	df=3

Table 1-3. A change matrix of how hectares changed severity classes between the 2004 Impassable Bay Fire and the 2007 Bugaboo Fire (Northing and Easting of pixels are the same for each year).

		2007 Bugaboo Fire Severity Classes				
		High	Moderate	Low	Unburned	Total
2004 Impassable Bay Severity Classes	High	1816	80	2	1	1899
	Moderate	2671	1019	41	20	3751
	Low	216	273	48	23	560
	Unburned	376	707	107	216	1406
	Total	5079	2079	198	260	7616

Table 1-4. Normalized Burn Ratio (NBR) thresholds developed using Composite Burn Index (CBI) protocol stratified for sandhill, flatwood, and swamp vegetation over dormant, early, and late growing season (Picotte, Personal communication).

Classification	NBR Average
Unburned	1000 to 519
Low	519 to 407
Moderate	407 to -66
High	-66 to -1000

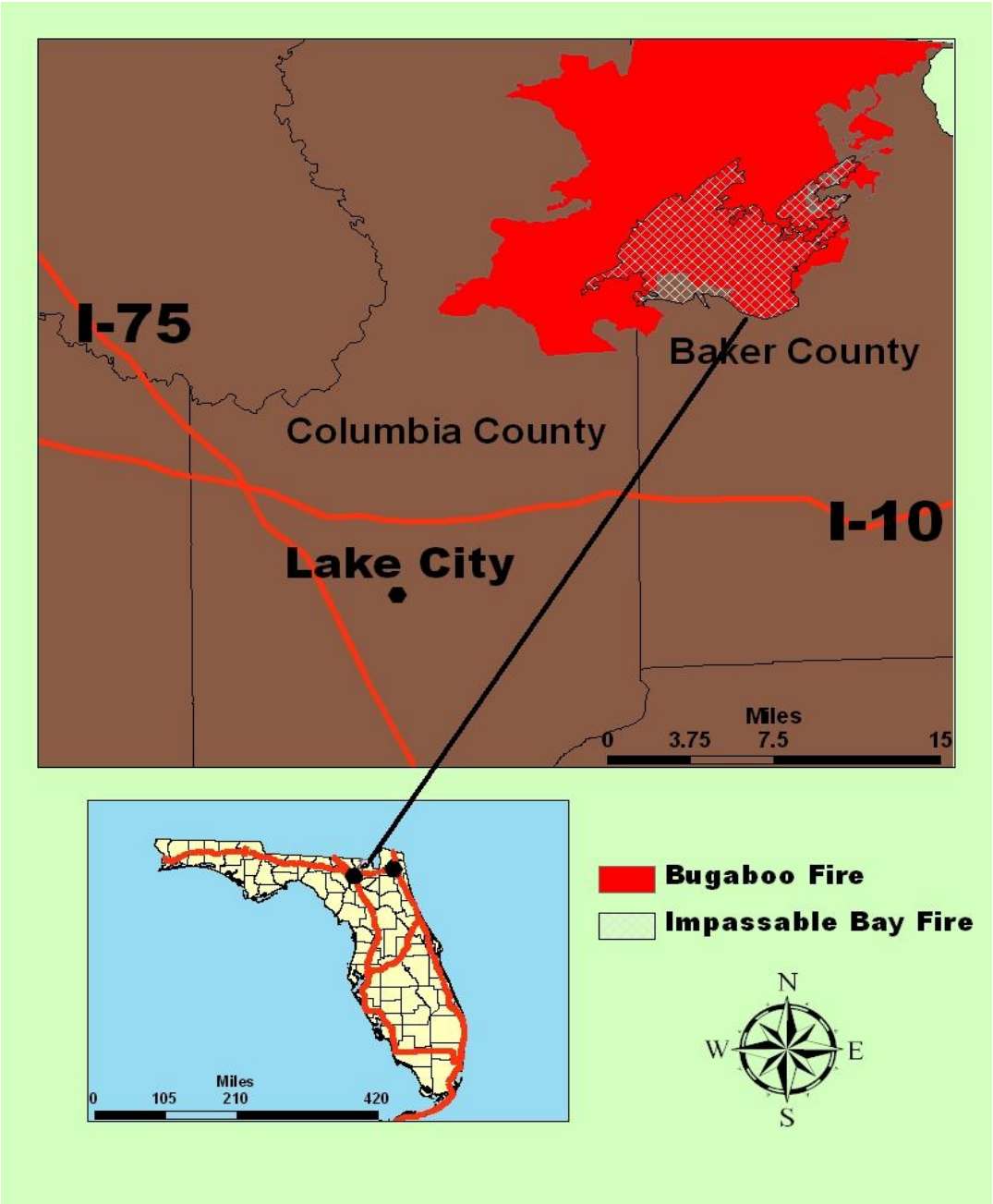


Figure 1-1. The location of the Impassable Bay Fire and the Bugaboo Fire in north central Florida.

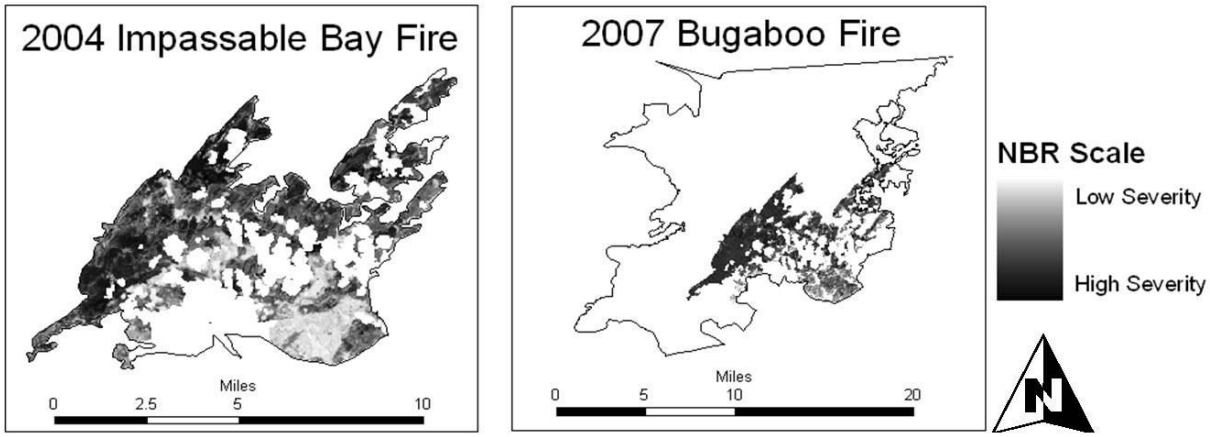


Figure 1-2.The 2004 NBR values for the overlapping area set within the perimeter of the Impassable Bay Fire (Excluding areas of cloud cover and cloud shadows). The 2007 NBR values for the overlapping area set within the perimeter of the 2007 Bugaboo Fire (Excluding those areas covered by clouds and cloud shadows in the 2004 image).

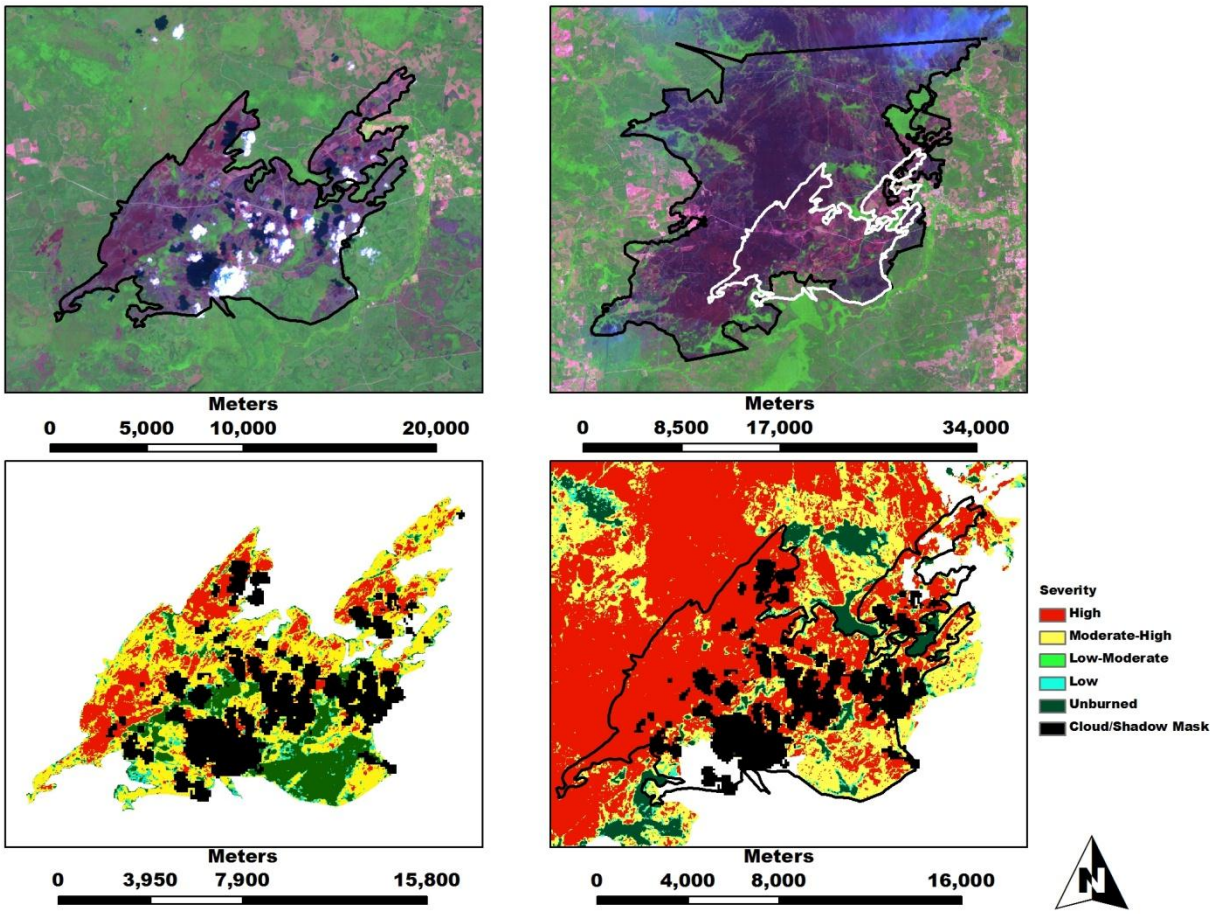


Figure 1-3. The 2004 and 2007 burn scars with official fire perimeters: unclassified and classified. A. The 2004 Impassable Bay Fire (5-4-3=RGB) with perimeter in black. Note Clouds and shadows. B. The 2007 Bugaboo Fire (5-4-3-RGB) with perimeter in black. Impassable Bay Fire perimeter is in white. C. The 2004 Impassable Bay Fire classified for severity. Clouds and cloud shadows are blacked out. D. The 2007 Bugaboo Fire classified for severity with close up of study area. 2004 clouds and cloud shadows are blacked out.

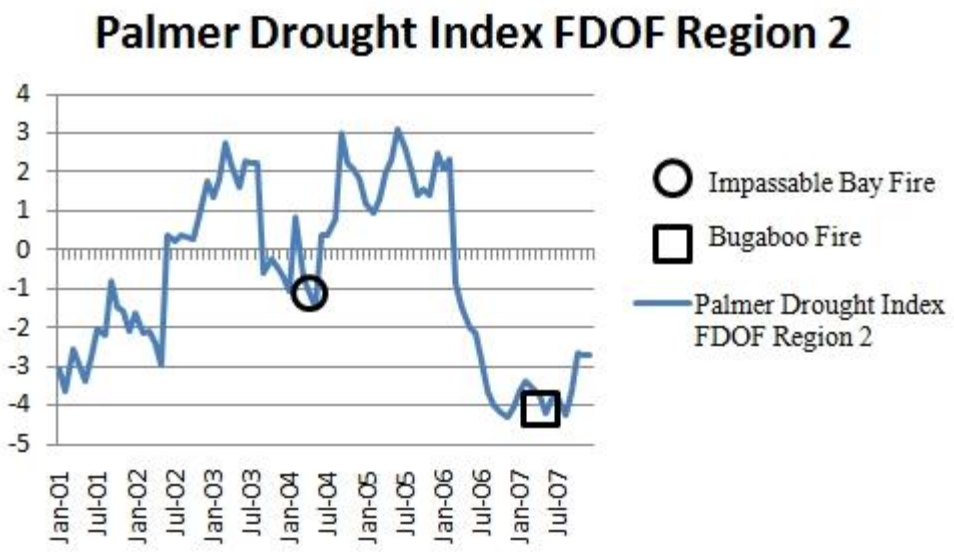


Figure. 1-4.The Palmer Drought Severity Index for January 2001-December 2007. 0=normal, -2=moderate drought, -3=severe drought, and -4=extreme drought. Positive numbers correspond, e.g. +2= moderate rainfall, etc.

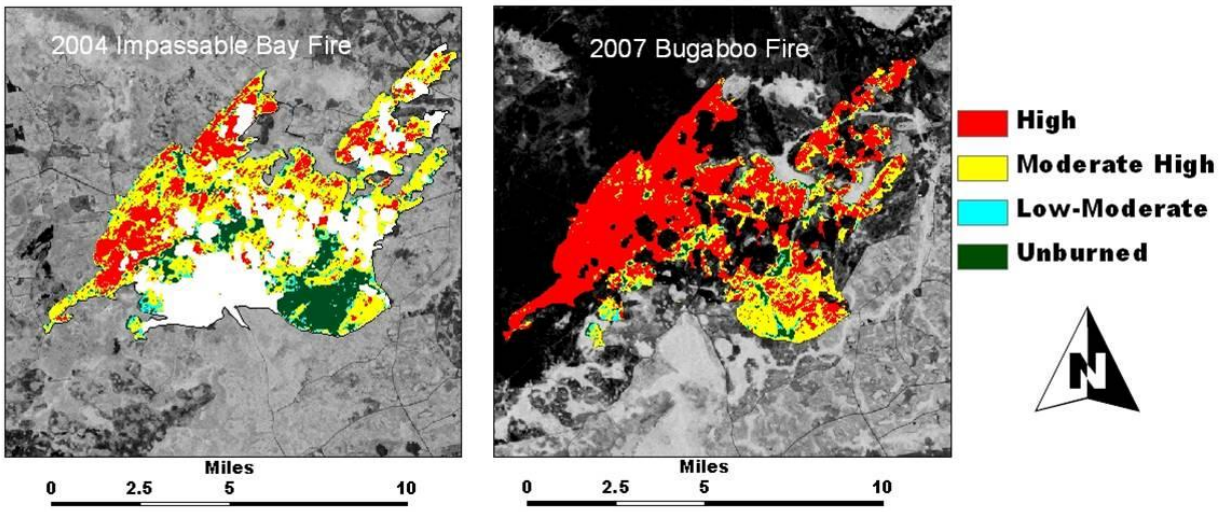


Figure 1-5. The 2004 Impassable Bay Fire severity classification derived from the Normalized Burn Ration (NBR) for the overlapping area shared with the Bugaboo Fire. The 2007 Bugaboo Fire severity classification for the overlapping area shared with the impassable Bay Fire.

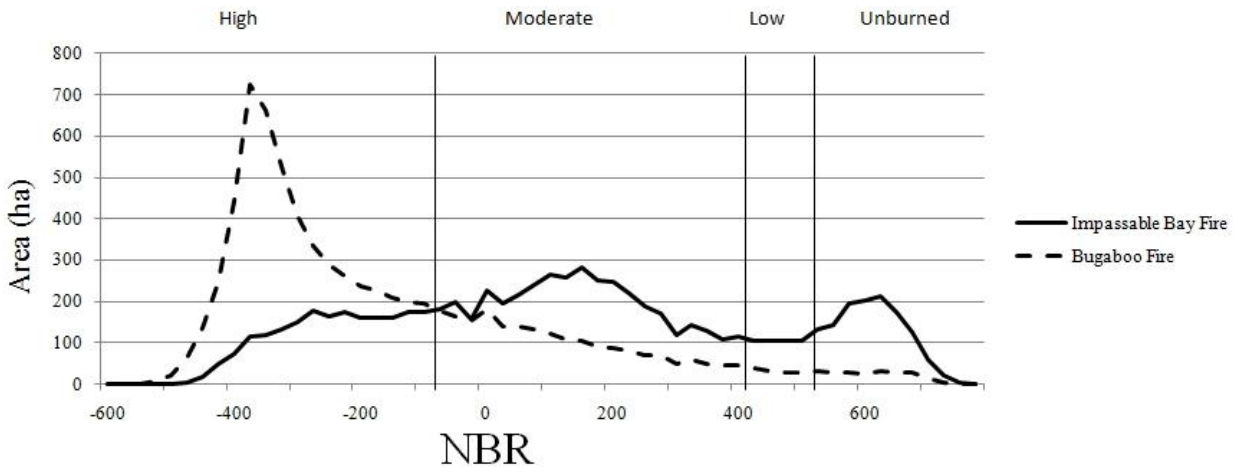


Figure 1-6. A comparison of 2004 Impassable Bay Fire and 2007 Bugaboo Fire NBR histograms for the overlapping area they share.

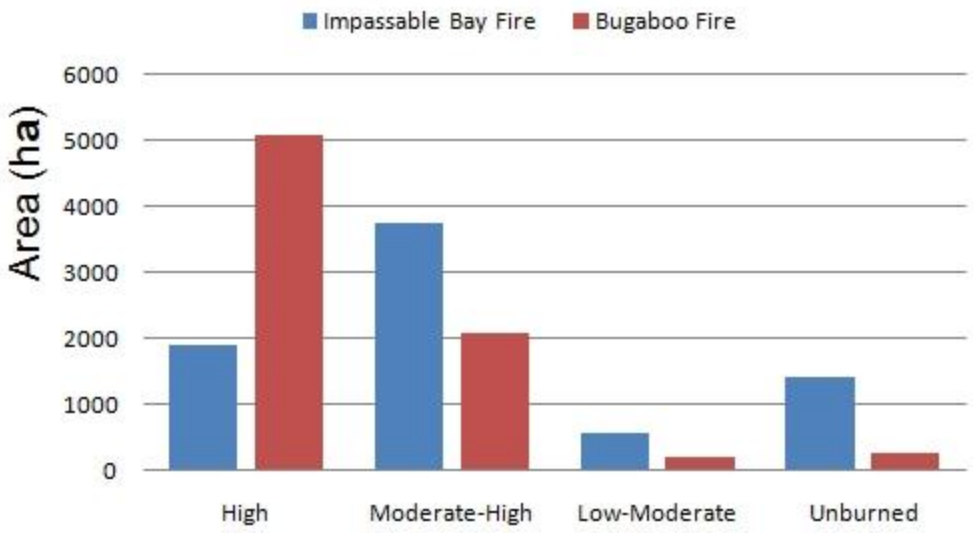


Figure 1-7. Area (ha) per severity class for 2004 Impassable Bay Fire and 2007 Bugaboo Fire for the overlapping area they share.

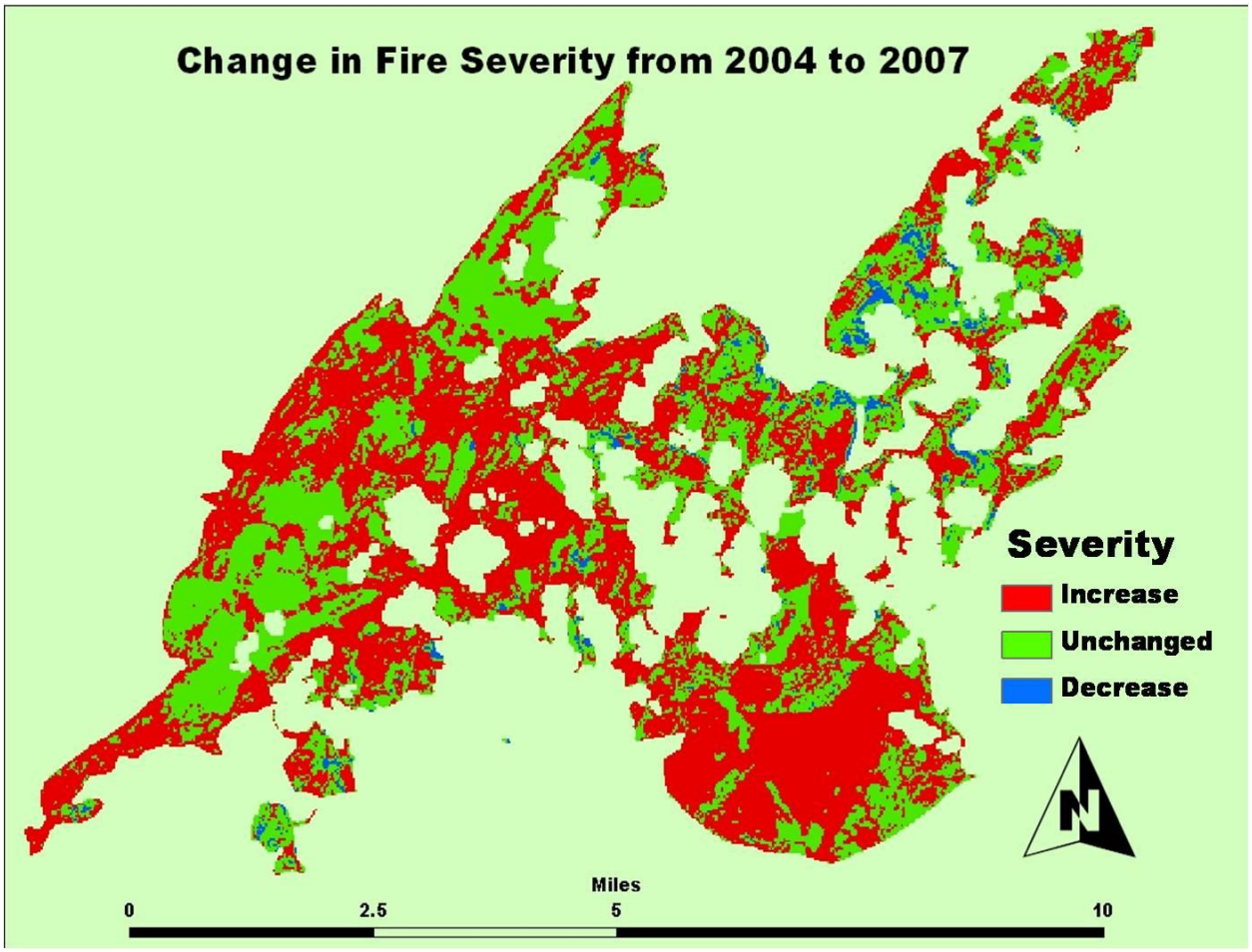


Figure 1-8. A map of the severity change trajectory between 2004 Impassable Bay Fire and 2007 Bugaboo Fire. Change is specific to location.

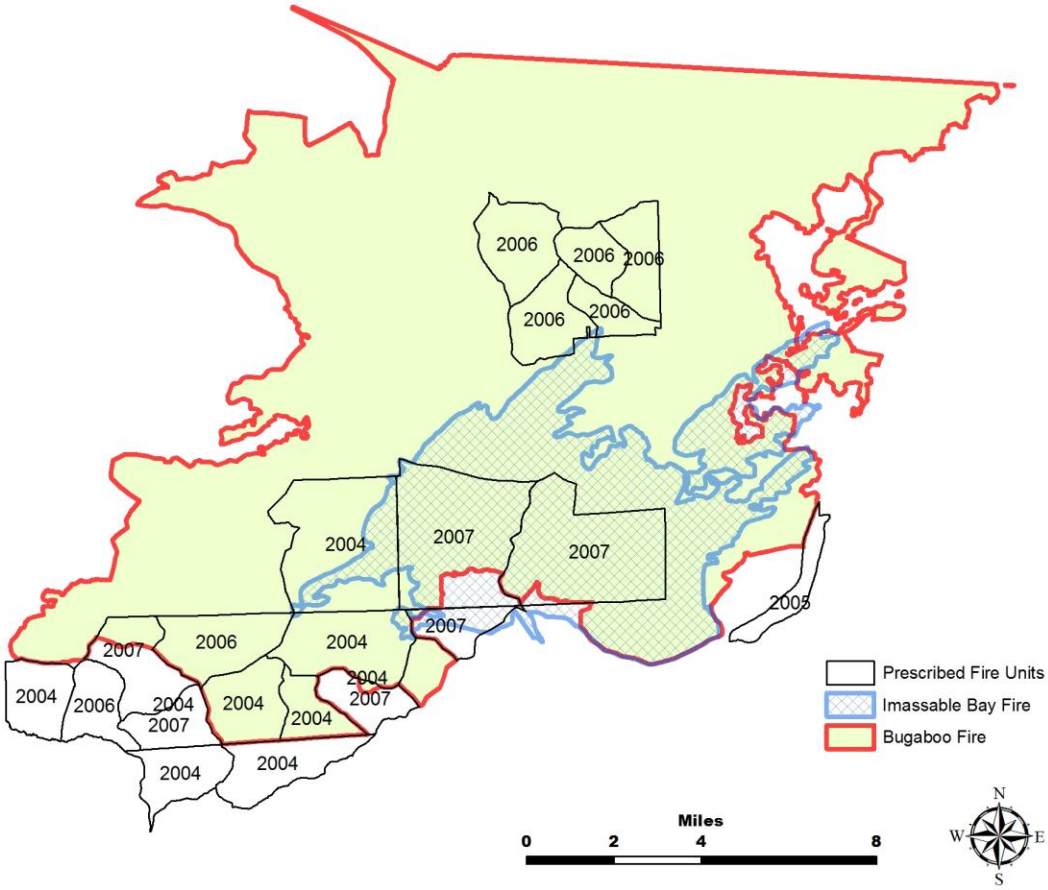


Figure 1-9. Locations and year of occurrence for prescribed fires near and within the perimeter of Bugaboo Fire. Reference map: Figure 1-1.

CHAPTER 2
RETROACTIVELY MAPPING WORK AREA: A GIS CASE STUDY OF WILDLAND URBAN INTERFACE FUELS MITIGATION PROJECTS IN NORTH CENTRAL FLORIDA

Introduction

Fire exclusion along the wildland-urban interface (WUI) and years of fire suppression have resulted in unnaturally high fuel loads that have caused an increase in wildfire size, adverse behavior, total number of wildfires, and cost of suppression (Conard, 2001). Substantial resources are spent on fuel treatments and little is known concerning their effectiveness (Martinson, 2003).

Federal, state, and local agencies have responsibility for protecting homes in the wildland-urban interface during prescribed fire and wildfire events (Cohen, 1999). Fuel mitigation is performed with an understanding that the outcome will influence the size and severity of wildland fires and/or enable increased suppression response (Finney, 2001) and increased home defensibility. Fuels mitigation options for the most part involve surface fuels reduction by mechanical means or prescribed fire. Prescribed fire reintroduces ecological processes and mechanical manipulating of forest structure broadens the toolset for achieving hazard mitigation (Johnson, 2007).

The research question that this paper addresses is: What is the state of spatial record keeping of fire mitigation in north Florida, and what can be done to make if more useful for fire control efforts? Ten years of data exist on Florida's mitigation efforts but spatial records are practically non-existent. Knowledge about the location of fuels reductions may help in suppression situations and increases the value of performing mitigation. The information must be available and in a format accessible to fire fighters. Knowledge of project locations, parcel boundaries, and the time of and extent of prior

fuels reduction enables decision makers to make informed choices on where and how resources are deployed. There is a need to evaluate fuels management options to effectively address local, regional, and national priorities. Remote sensing and Geographical Information Systems are spatial tools that managers can use in their effort to mitigate fire hazards and reduce risks to public well-being (Conard, 2001).

Fire exclusions effects on ecosystem function and fuel reduction are two separate issues. (Cohen, 1999). To reach desired outcomes in fuel reduction and ecological improvement, land managers and fire planners need a variety of techniques to apply including stand thinning, surface fuel roller chopping/mastication, chemical treatment, and grazing (Fernandes, 2003; Johnson, 2007; Kalabokidis, 1998). The effectiveness of fuels reduction treatments may be improved when they are conducted with ecological restoration in mind (Martinson, 2003). Prescribed fire is only one of a handful of fuels mitigation options that results in ecological restoration (Miller, 2003). The use of prescribed fire is limited to days where management of smoke, control, and severity are judged to be safe.

Prescribed fire may reduce wildfire severity and provide various benefits for wildfire control operations. These include decreasing the quantity and type of fire fighting resources that would otherwise be needed, influencing the overall suppression strategy, reduction in the risk of back-burn operations used in indirect attack, decreasing the amount of mopping-up, and providing better access and anchor points for suppression activities (Fernandes & Botelho, 2003).

When planning for the threat of wildfire, agencies realize that pre-suppression activities directly impact suppression response (Cohen, 1999). Finney (2001) states

that treatments are often based on local hazards, ecological objectives, convenience, cost, land ownership, or accessibility. However, weather influences fire behavior in ways that may ultimately nullify any benefits accrued from fuels manipulations (Fernandes & Botelho, 2003). The spatial patterning of firebreaks, prescribed burns, and past wildfires is correlated with the growth and behavior of wildfire events and should be a focus of concern for fuels specialist and fire managers. In addition, knowledge of the distribution of fuels across a landscape influences the options for suppression response (Salazar, 1987). Martinson and Omi (2003) conducted an extensive literature review of fuels treatment effectiveness and found only 14 articles describing treatments burned over by wildfire.

The ability of a structure to survive wildfire situations is dependent upon how well designed it is to avoid ignition from firebrands (Cohen, 1999). The WUI presents a unique area where ignitions are more frequent and protecting “at risk” resources is more difficult. The inability of the state to address home construction increases the necessity for effective fuels manipulations to mitigate wildfire risk (Kalabokidis, 1998). Designing or modifying structure exteriors to resist ignition from fire brands is an effective strategy and is increasingly effective when complemented by the creation of defensible space in the immediate area to prevent direct ignition from flames and from which to conduct immediate suppression when the need arises. Should wildfire occur and needs for defensible space arise, having treatments in place or a plan for swift implementation is important. Older breaks that become overgrown can be plowed more easily than new lines can be created. Reductions in fuel loads make back burns easier to manage.

Reduced fire behavior in low fuel areas adjacent to communities gives suppression activities a greater chance of preventing home losses.

The following statement by a resident of the wildland-urban interface illustrates the perspective that land management is expected if not obligated to reduce fuel loads that are threatening to communities on the fringe. In reference to the fire danger of a swamp in drought adjacent to his house, his neighbors house and the community he resides in at large, he goes on to say:

"I'm scared to death. Why don't yall just clear cut it? That's a fire hazard and a snake den. Yall won't find a householder down here that's not worried about it. That boy down there is worser for it. It's not that I want to be an asshole, I'm just scared. That's a bad swamp. It's got trees in there higher than you all banked up with pine straws."

Current Practices

Florida Department of Agriculture and Consumer Services (DACS) Division of Forestry (FDOF) implements WUI treatments in close proximity to homes and utilizes widespread public/private partnerships throughout the state of Florida. Homeowners and private landholders often agree to maintain treatments when entering into the public private partnerships that form the basis of WUI fuels manipulations. The FDOF then performs their portion of work by implementing the initial reduction in fuel loads at each site. Seldom do homeowners conduct follow-up fuel reductions. Without continual maintenance, the ability of fuel mitigation to meet its objectives steadily decreases.

FDOF currently has criteria for recording the number of structures protected and the total value of structures protected for each mitigation project. Cost categories are created from average housing values in the immediate area and all structures within a

quarter mile of the project site are placed in one of those categories. The sum of structural values in all categories becomes the total value of structures protected in a given year. While FDOF keeps track of property values it protects, regional mitigation teams do not decide to protect communities based on housing values. Workloads are designed to meet mitigation objectives in areas with ignition probability, dangerous fuel loads, and in the presence of residential structures.

Florida FDOF has divided the state into districts comprised of counties, and into four regions comprised of districts (Fig. 2-1). Every district is composed of different number of counties, state forests, and number of offices. Mitigation work is often performed on a regional level, but hard copies of service reports and landowner agreements are often kept at the district level. Each district in turn deals with paperwork by its own methods. This results in extremely decentralized records. Some districts keep hardcopies of service reports at the local forest area supervisor's (FAS) office and some centralize them with their Wildfire Mitigation Specialist. The result is that no one is quite able to pinpoint the location of all hardcopy records at any given time. An electronic database is created at the local level once work is completed. These are then sent to the Fire Mitigation Specialist Coordinator in the DOF Forest Protection office at the state level where they are compiled. Both types of records were used in this project.

Regional mitigation team leaders and their crews decide on where to implement fuels reduction projects based on recognizable needs. There are no quotas or guidelines limiting decision-making. The chief mandate being that projects must have six or more homes located within a quarter mile. Once this criteria is satisfied, team

leaders try to address as many fuel issues within their jurisdiction as they are able. This causes workloads to fluctuate from season to season. Accomplishments regularly filter up according to fiscal accountability (Fig. 2-2, Table 2-1). The state is generally concerned with validating the mitigation efforts from the outset and the type of data that is included in reports reflects this. The inability to know whether fuels reduction efforts ever do reduce wildfire spread, severity, costs, and other losses makes it all the more necessary to know the location of fuels treatments should wildfire burn them over.

We use both types of records described above: hard copy records from FAS offices and digital data from the state office, to describe the current state of spatial record keeping and its utility for addressing fire fighting needs. Then digital maps that could serve as a prototype for improving the system were created from what information was contained in the records. A case study was designed in collaboration with regional wildfire mitigation team personnel to compile as much first hand information as possible to develop maps of fuel reduction projects. This process resulted in additional information not found in either the hard or digital files. This process included mapping the extent of project by parcel identification, projects identified from internal hard copy reports, and firsthand knowledge. Based on fire regime characteristics and rapid fuel accumulation rates, only projects implemented since 2004 were reviewed. Florida's mitigation team leaders have all held their respective positions prior to 2004 and have a wealth of knowledge concerning their respective areas and mitigation accomplishments.

Methods

This initial process was performed with one of the four, regional team leaders. The mitigation team leader used the list of project names from his region to pinpoint sites on Google Earth satellite imagery. These were marked with the "add placemark"

function and where possible the extent of a given project was delineated using the “add polygon” function. The absence of parcel boundaries and varying age of Google Earth imagery were obstacles at this point. A folder within Google Earth was used to store information for each project recorded using original project names.

All GIS processing was done with ArcGIS 9.2. USGS 2004 color infrared digital orthophotos acquired from labins.org were used as base layers. County tax parcel files for 2007 were obtained for all counties from the Florida Department of Revenue and used to map property boundaries. Project extents were depicted over the aerial photos layered with the parcel boundaries on a map. Where only a parcel had been identified, a map was made showing this with the hope that the project extent might be filled in at a later time. All of the GIS maps were then reviewed and edited by the Regional Team Leader and his Senior Ranger. Subsequently, the edits were incorporated and a final version was produced. The set of final maps are available as hard copies and jpegs for DOF (Fig. 2-3).

Results

The Master Database does not indicate the spatial location of many of the treatments. The Master Database includes categories for reporting unit, district number, project name, ownership, county, completion date, acres, treatment type, miles mowed, structures protected, structures total value, treatment cost, grant project, and team/district project. The county and DOF district are always noted, but geographic coordinates are not listed. Hardcopies contain landowner agreements that include addresses, but these typically refer to an offsite home or business address and not to the project parcel. Frequently, hardcopies have a section, township and range designation, but with a coarse description not suitable for identifying the parcel.

Geographic coordinates that most clearly identify project locations have seldom been acquired in the past, but are increasingly being recorded and noted in the documentation.

The spatial information on the digital master database was limited to county name. One district used section, township and range numbers as substitutes for project names, but these were not explicit locations. Of the hard copies reviewed, where township and range were not provided with enough detail to identify the parcel, that sample was not included in the analysis. A small percentage of hard copies contained geographic coordinates reflecting the limited number of personnel using GPS units in the field. More recent projects however, increasingly record locations with latitude and longitude in the hard copies. These were the only samples specific enough to begin mapping at the parcel level.

Hard copy reports of mitigation projects provided 46 locations for fuels reduction treatment sites. Working collaboratively with a wildfire fire fuel mitigation team leader, an additional 22 were identified. The maps created from these two efforts account for only 23 percent of projects accomplished during the study time frame. Figure 2-4 shows the breakdown of known projects per county, how many projects were located via reports in each county, and how many additional mitigation projects were located in each county by searching Google Earth. Figure 2-5 shows the projects that could be mapped as a percentage of total projects.

Case Studies

Four fires occurred within or adjacent to fuels mitigation treatments during the wildfire seasons of 2007 and 2008. Of these four sites, one fuels mitigation project was an extensive collaborative effort between the DOF, USFS, and the local fire department.

Three were exclusively DOF projects. One of these projects had been initially mitigated prior to the window for mapping fuels reductions, but had been maintained until 2008.

Taylor, in Baker County, Florida, is a rural community surrounded by a national forest, a wildlife refuge, state forest and private timberlands. This mosaic of fuel loads has threatened the community many times with the occurrence of large wildfires. A Community Wildfire Protection Plan was put into place in 2006 that involves interagency cooperation to mow and till fire breaks around the perimeter of the community (Fig. 2-6). Shortly after the completion of the initial project in 2007, the Bugaboo Fire burned to the edge of the community. Fuel breaks on the eastern and northern edges of the community were used as anchor points to ignite back burns in an effort to keep the fire at bay. Weather conditions were so extreme that several spot-overs could not be prevented, but the mitigation efforts dramatically enhanced the ability of the suppression response to protect Taylor households. None of the 200 evacuated homes burned.

The Lamplighter Estates trailer park sits on the northern edge of the City of Gainesville in Alachua County and is separated by a large patch of woods from the south side of the Gainesville Regional Airport. The woods between the airport and the park have a dense understory with many ladder fuels that caused concern for the landowner. In fall 2006, FDOF agreed to conduct understory mowing on the west, north, and east edge of the park (Fig. 2-7). The $5394.75 project was estimated to protect 270 structures valued together at $22,950,000. A fire on May 10, 2008 within and adjacent to the mowed area was responded to by FDOF and easily contained. Firefighters believed the mitigation work performed a year and half earlier was effective

in aiding them when they responded to the incident. Again, no structures were lost to the fire (Bond, Unpublished results).

The cone property in Duval County has had several mitigation projects on it, including a prescribed burn many years ago and most recently 10 acres worth of mowed buffer in 2003. The 72 structures deemed to be protected have an estimated value of 4 million dollars and the 2003 buffer cost the DOF only $1, 968 to create. The landowner was active in maintaining this work and on May 15, 2008 a fire that started up was easily contained to a very small footprint and suppressed without incident by the local fire department. The maintained buffer proved itself more than four years after its initial implementation (Winter, Unpublished results a).

In 2004, DOF prescribe burned 30 acres of heavily wooded lot to the SE, East and along a strip to the North of the Brandy Branch Baptist Church in Nassau County. The $420 dollar burn was estimated to protect fifty-four structures valued at 3.4 million. A wildfire on March 19, 2008 on the north side of the property threatened the Church and a close residence. The mitigated acreage had not been maintained by the landowner, but still had reduced fuel loads relative to the surrounding landscape. The fire crept across the old fire line into the churchyard, but the responding FDOF crew was able to re-plow existing breaks and relatively easily contain the fire which was exhibiting manageable behavior in the light fuel bed. All structures within proximity to the fire were able to be protected (Winter, Unpublished results b).

Discussion/Recommendations

Each regional mitigation team is independent of the others. They are funded with different budgets and both crew sizes and available resources vary. The composition of the WUI in Florida is dependent on the history and scale of local development and

varies significantly within and between each region. Thus treatment costs vary between regions. Additionally the transfer of geospatial technology to local and regional offices has been slow. Most district offices are not equipped with technology, training or personnel to effectively collect spatial data or produce usable products.

One step towards improving the collection of spatial data for fuels reduction projects should be the use of GPS units by each mitigation crew to record geographic coordinates. Personnel need to be trained in the proper operation of GPS units. Additionally, personnel capable of performing GIS analysis need to be retained at either the district, regional, or state level. FDOF needs computers sufficiently powerful for operating GIS software. Potentially, a single employee could create GIS maps for the entire state. Maps took an average of three hours to create. With three hundred mitigation projects state wide per year on average, this represents 900 man hours. Standard methods of data collection in the field and streamlined channels for transmitting the data in detail to a state level analyst would need to be instituted. Once maps are created, the centralized information could be available to anyone planning or implementing projects, or instantaneously on the fireline via Wi-Fi or mobile phone internet access.

Hard copies of project paperwork contain the only indication of project locations. The decentralized storage of these documents is a major obstacle in their use for locating project sites. Each district should centralize hardcopies of service reports and landowner agreements in the office of that district's mitigation specialist and Regional Team leaders should retain the paperwork. Districts without mitigation specialists would send their hardcopies to the office of the Regional Team leader.

Although personnel responsible for project completions since 2004 are knowledgeable and available, specifics and details are not easily recalled. Workin directly with personnel produced an additional 8% of projects that could be mapped. Not only were these projects that otherwise would not have been located, but in most cases, when a parcel was located by the team leader, additional details on the extent of fuels reduction were immediately recalled.

The 2004 USGS color infrared digital orthophotos were not available as base layers for a small portion of the state. The 2004 imagery used for base layers does not necessarily reflect the landcover as it existed at the time the mitigation project was implemented or since. In some instances, these details could mislead map users.

The task of developing a spatial database encompassing projects from previous fiscal years has difficulties, which may not make it worthwhile. To collect such spatial data after the fact when a lack of equipment and GIS trained personnel still exists is to add a burden to a system already dealing with many responsibilities. If efforts are costly and no wildfires immediately occur, then treatments become ineffective within a few years. Treatments are a type of calculated gamble. Florida will always be a fire prone landscape and homes along the WUI will periodically be exposed to danger. Resources could be better utilized by improving the capacity for DOF crews to meet in-house goals on collecting spatial data for the near and ongoing future.

To facilitate wildfire suppression operations, locations and maps of treatments need to be developed and available. If the case that fuel reductions are effective as an aid to suppression operations is significant, then it is significant to have information concerning them available to decision makers dealing with wildfire occurrence. There

exists a disconnect between the work performed for fuel reductions out of fire season and the work performed to suppress numerous fires during wildfire periods. This disconnect exists in spite of DOF personnel often being involved with both operations and is due chiefly to the way data are managed, processed and disseminated internally within the organization.

Fuel manipulations coupled with measures to improve structural resistance to ignition are the best defense. It is necessary to work from the home outwards. Accomplishing goals establishing connectivity between preventative fire management options and the accessibility of relevant information to suppression operations is a fundamental step in optimizing FDOF's existing resources. An approach to management that establishes a communications link throughout the hierarchy within witch work is performed is necessary. Integrating links between field work, data management, and decision making in the field, results in the generation of relevant data sets (including spatial) available to enhance the decision making capacity of higher ups. With strategy in place for performing work, developing maps, and then disseminating maps in real time to responsible agencies during wildfire situations, additional benefit is derived from pre-suppression fire operations.

Table 2-1. State level fuels treatments from Master Database, January 2004 to December 2007.

Masterfile	
Total Records	1204
Privately Owned	900
City Owned	16
Federally Owned	2
State owned	157
Publicly Owned	2
Other	23
Section Township and Range Given	43
Titles Containing Specific Parcel Identifier	29

Figure 2-1. Florida Department of Agriculture and Consumer Services Division of Forestry Regions.

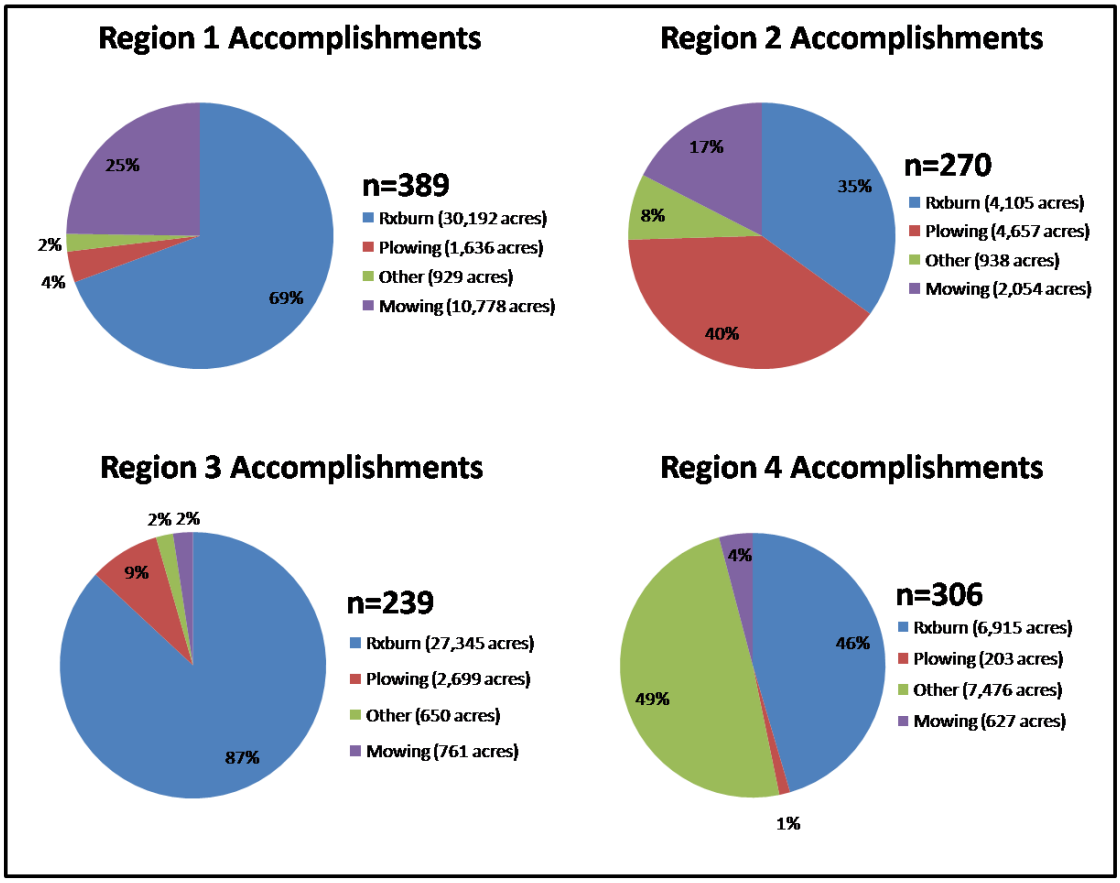


Figure 2-2. A summary of Division of Forestry wildland-urban interface fuels reduction accomplishments from January 2004 to December 2007.

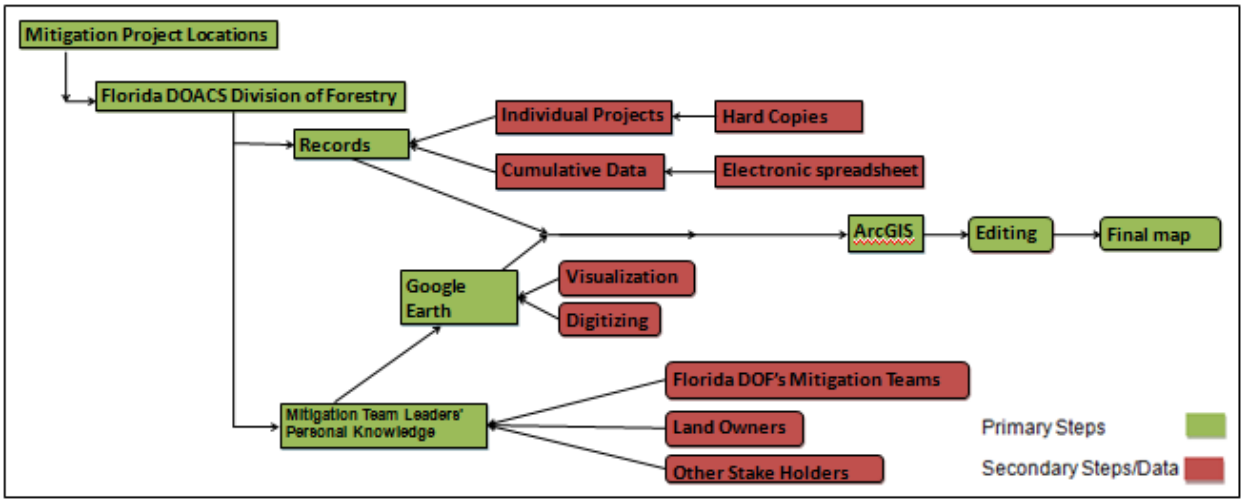


Figure 2-3. The process for developing maps.

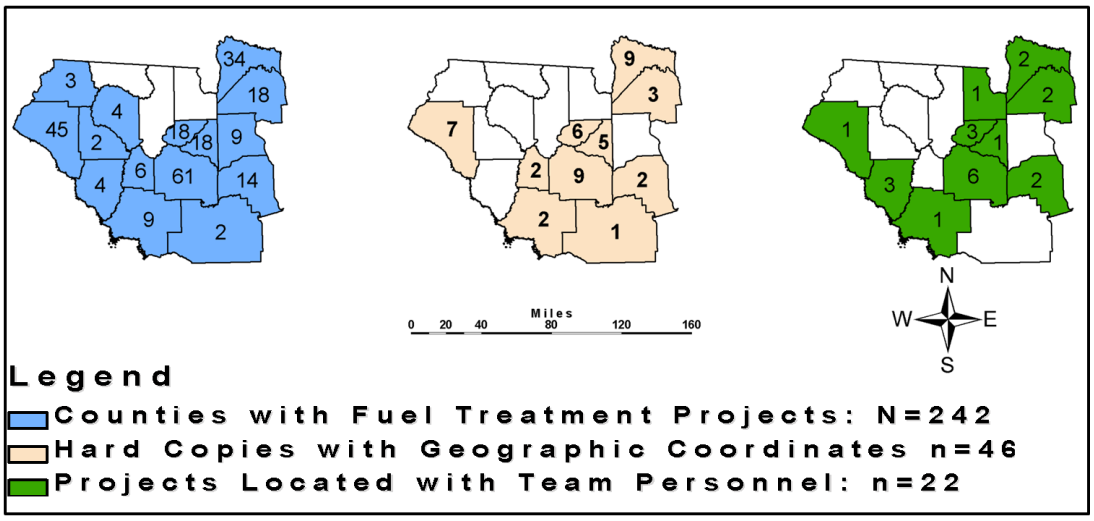


Figure 2-4. A distribution of existing records and located project sites respective to Florida DACS Division of Forestry Region 2. Numbers in each county show number of projects located per data source.

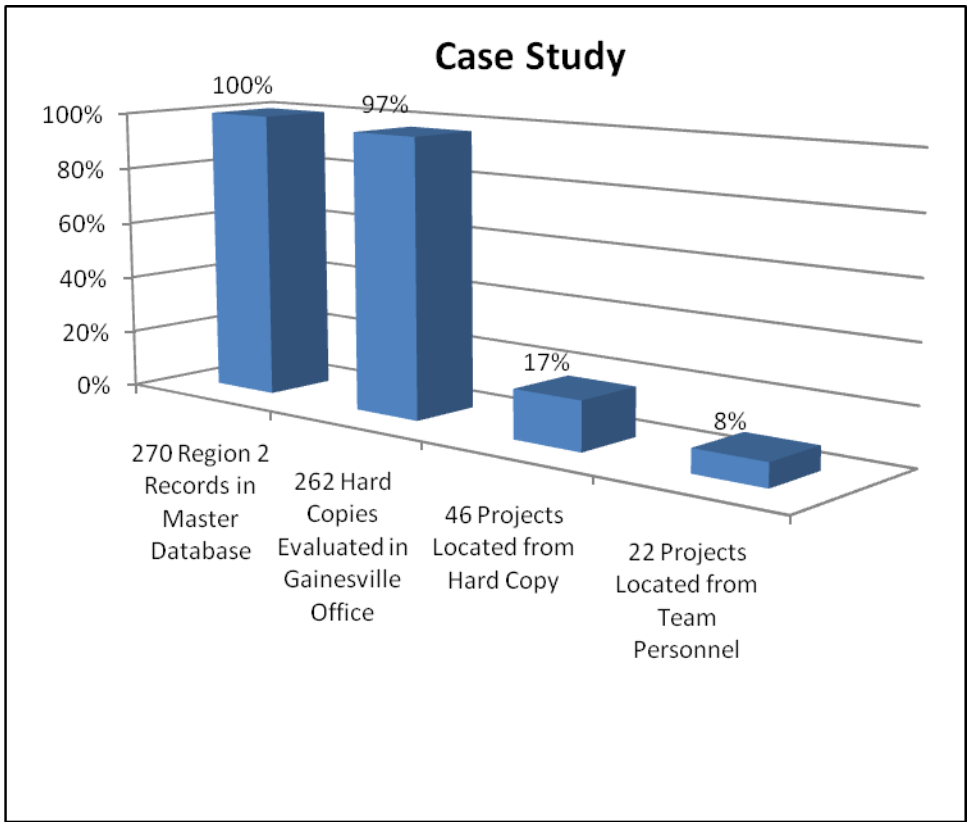


Figure 2-5. Total projects completed in FDACS DOF Region 2 during 2004- 2007. Note, only a small portion were mapped from existing data and personnel's firsthand knowledge.

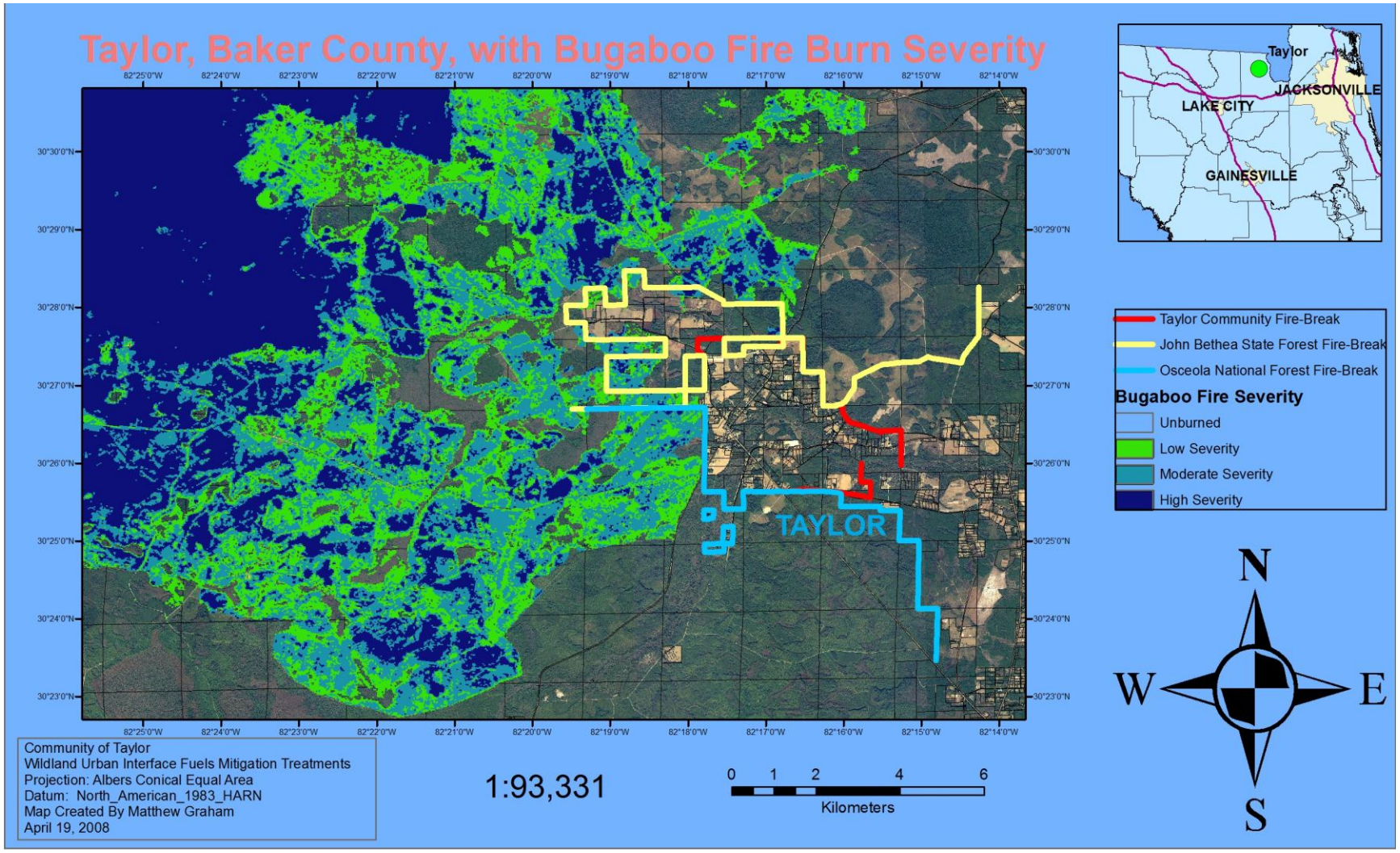


Figure 2-6. The Bugaboo Fire burned up to the firebreaks surrounding the community of Taylor and these firebreaks greatly aided the suppression crew's successful defense of all resident's homes.

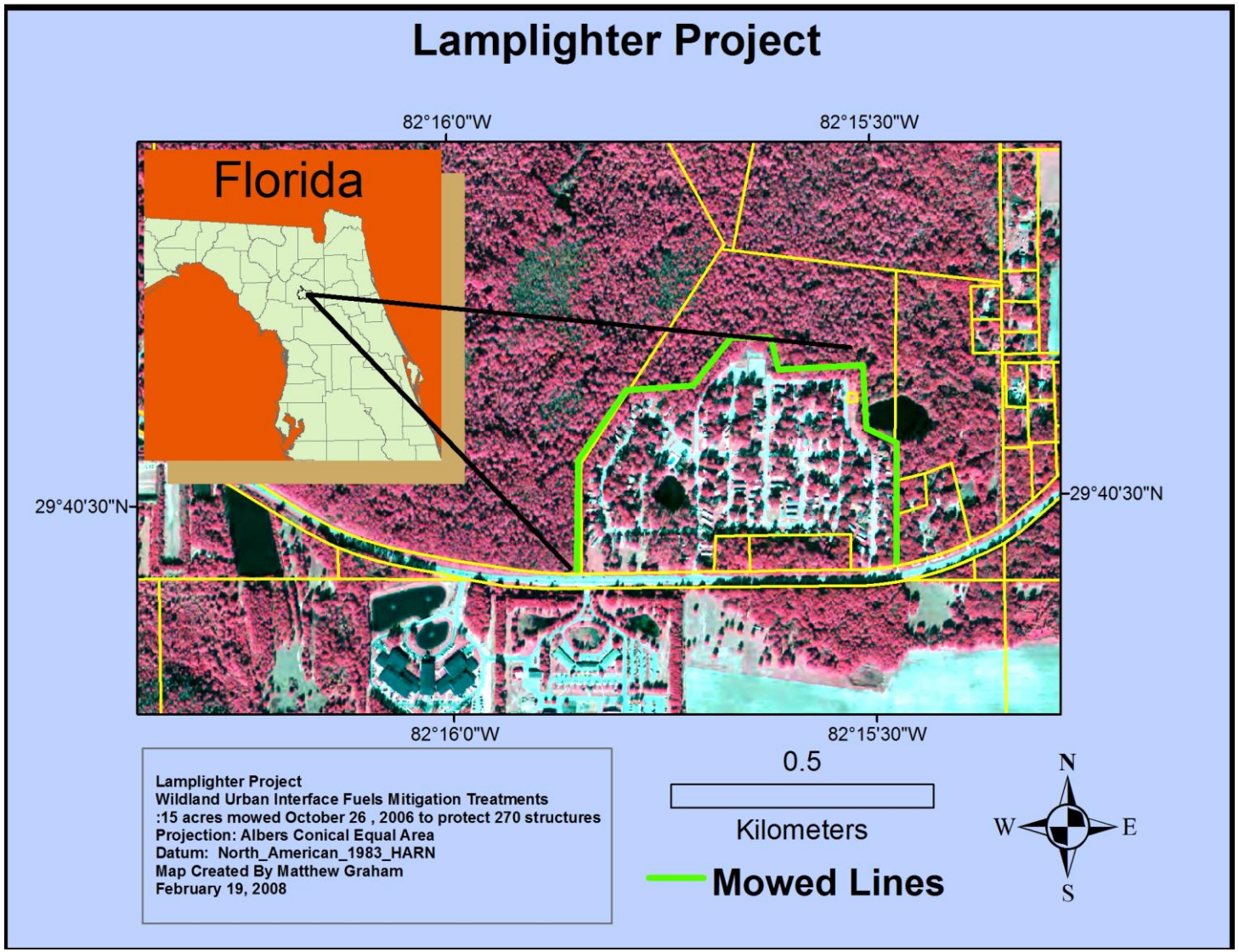


Figure 2-7. The Lamplighter Estates Mitigation Project. The mowed buffer protected the community from a wildfire. Although the fire is not located on the map, it impacted the fire line and did not cross.

APPENDIX A
MAPS OF WUI FUELS MITITGATION TRETATMENTS

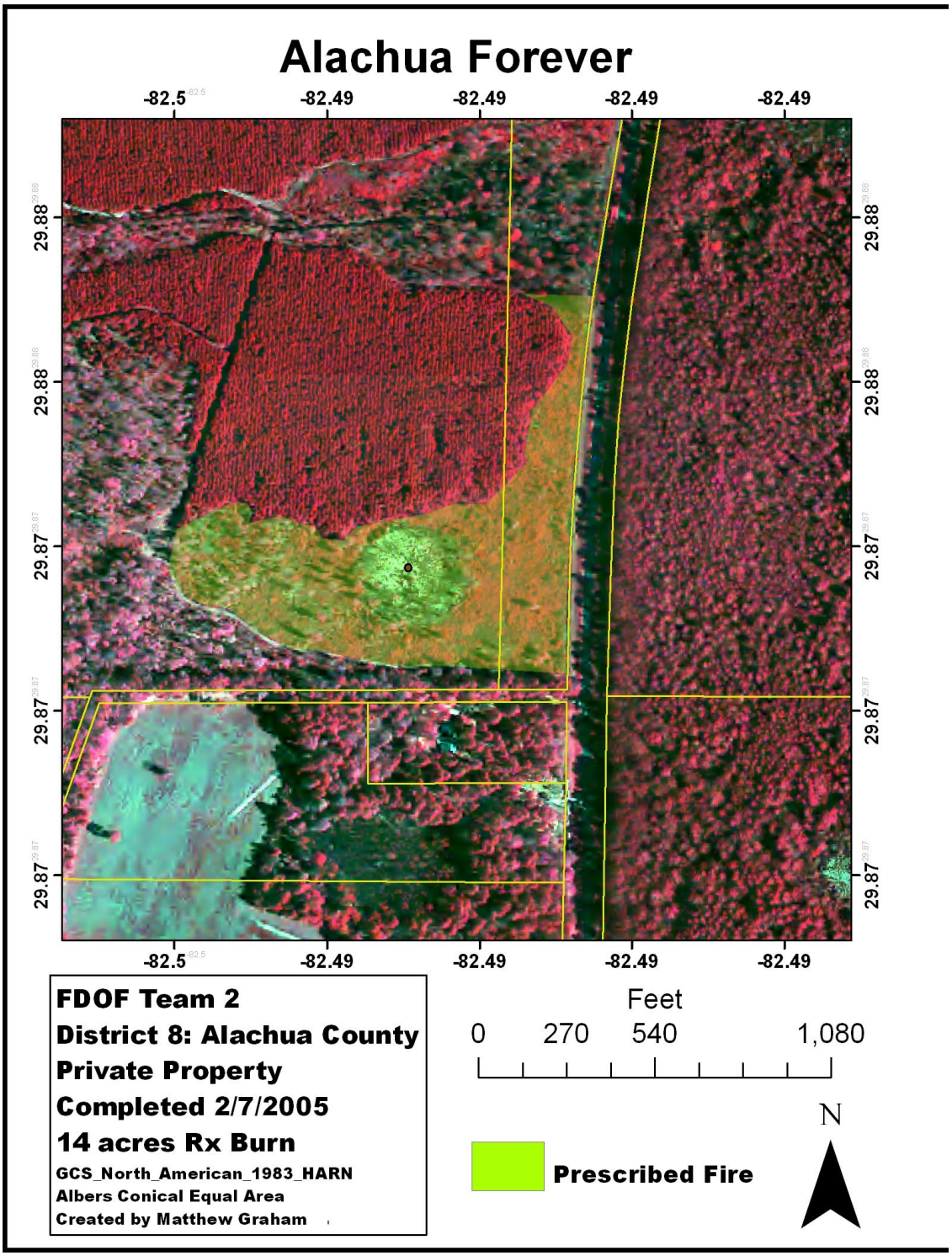


Figure A-1. Alachua Forever

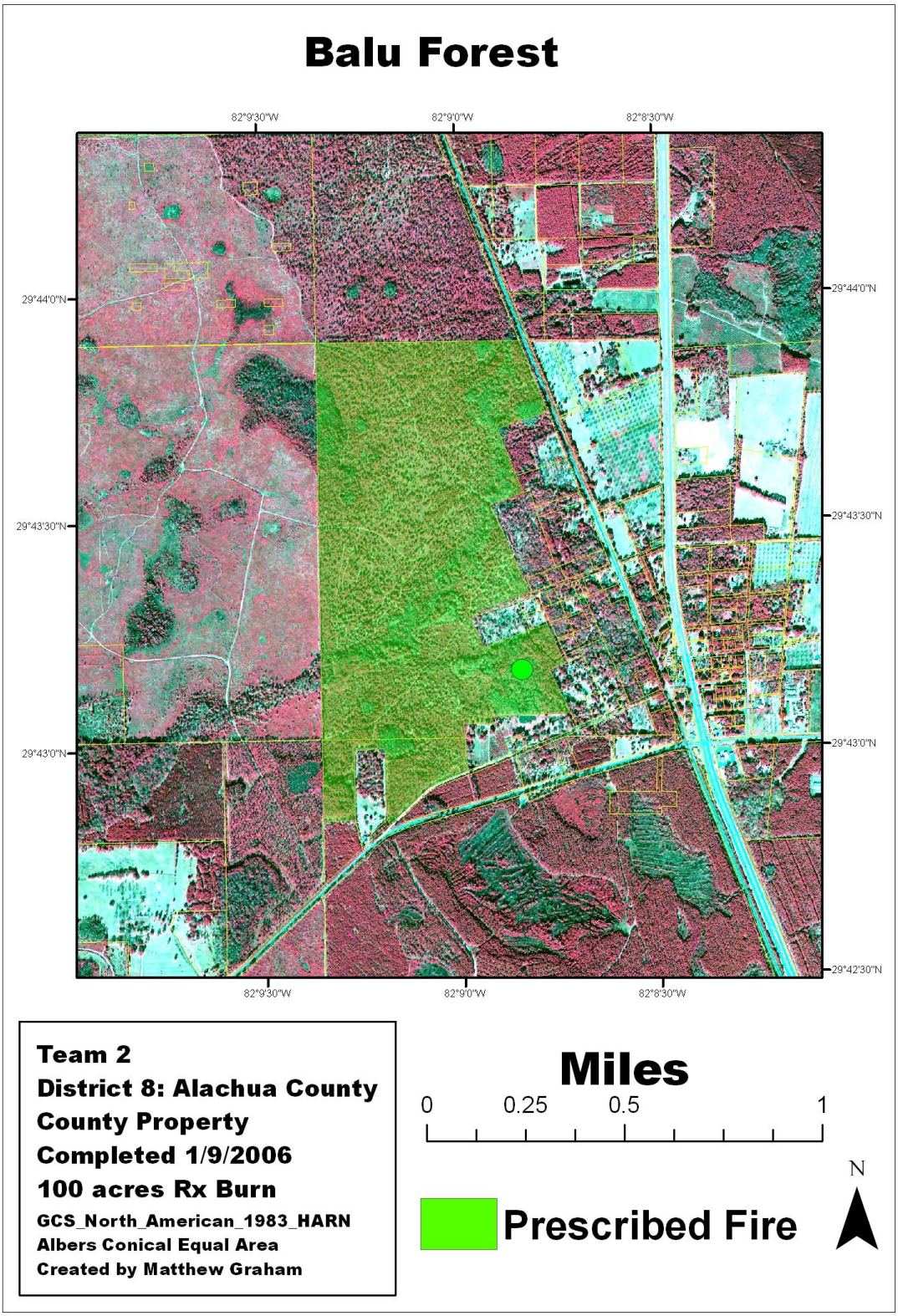


Figure A-2. Balu Forest.

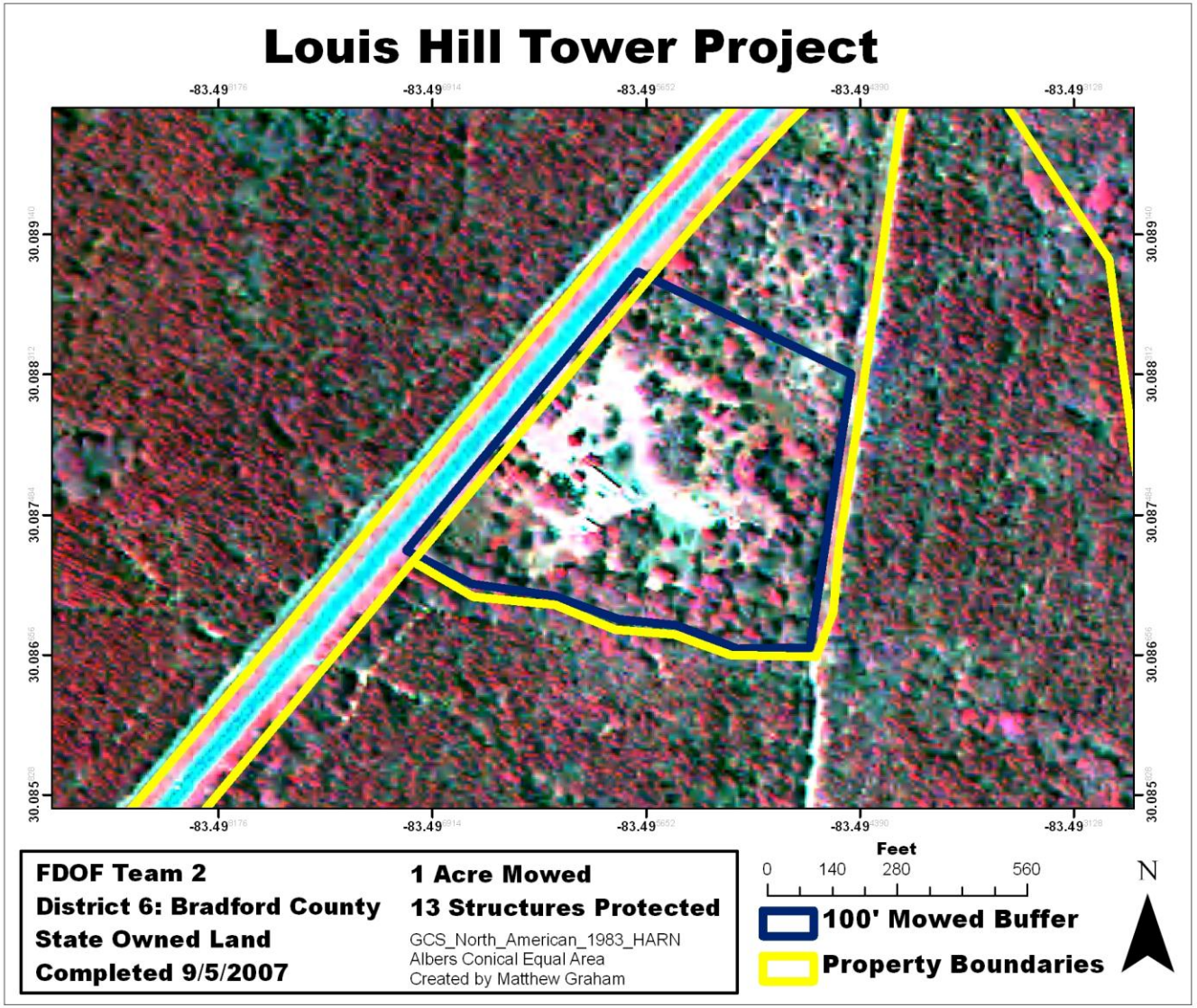


Figure A-3. Louis Hill Tower Project

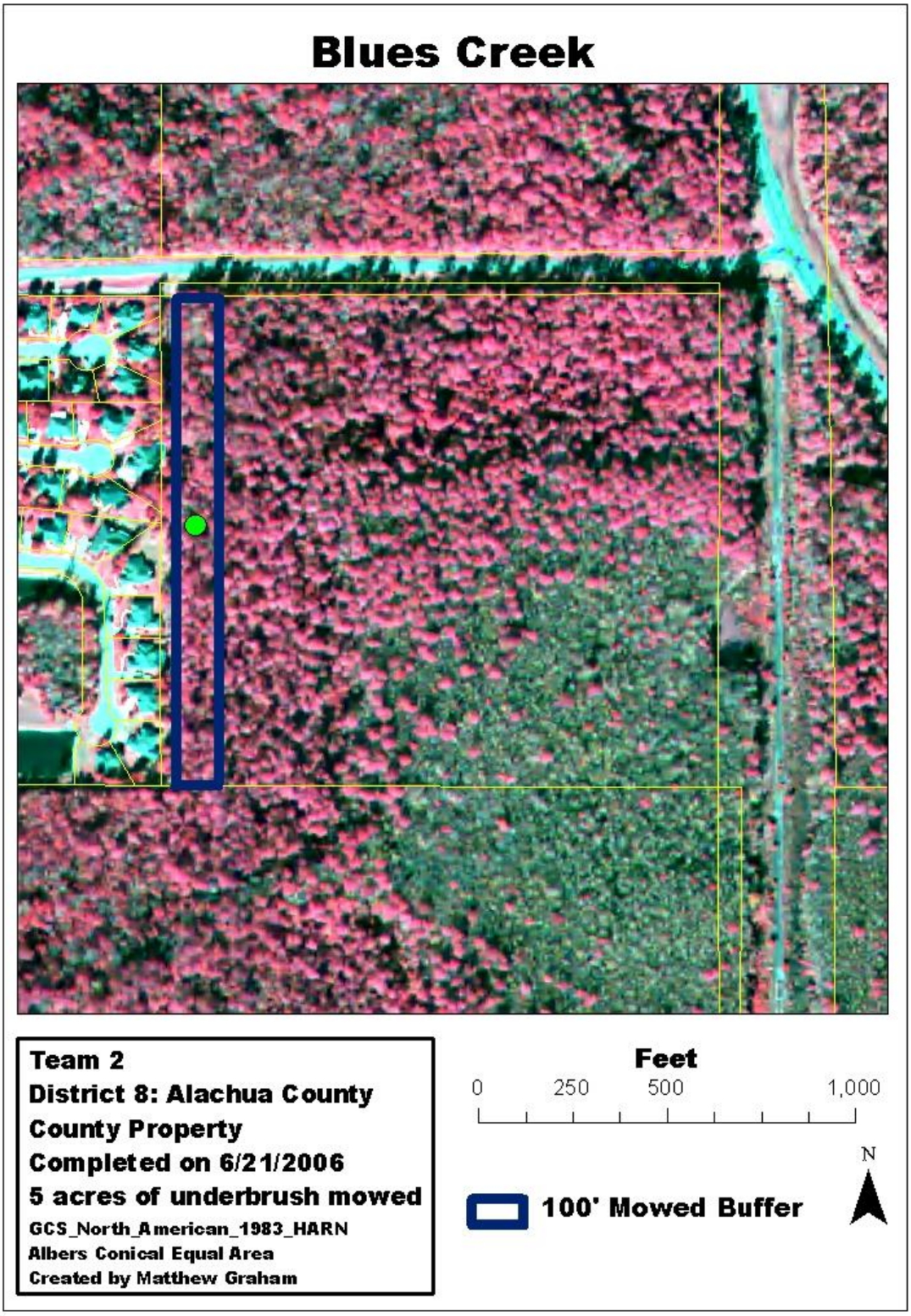


Figure A-4. Blues Creek.

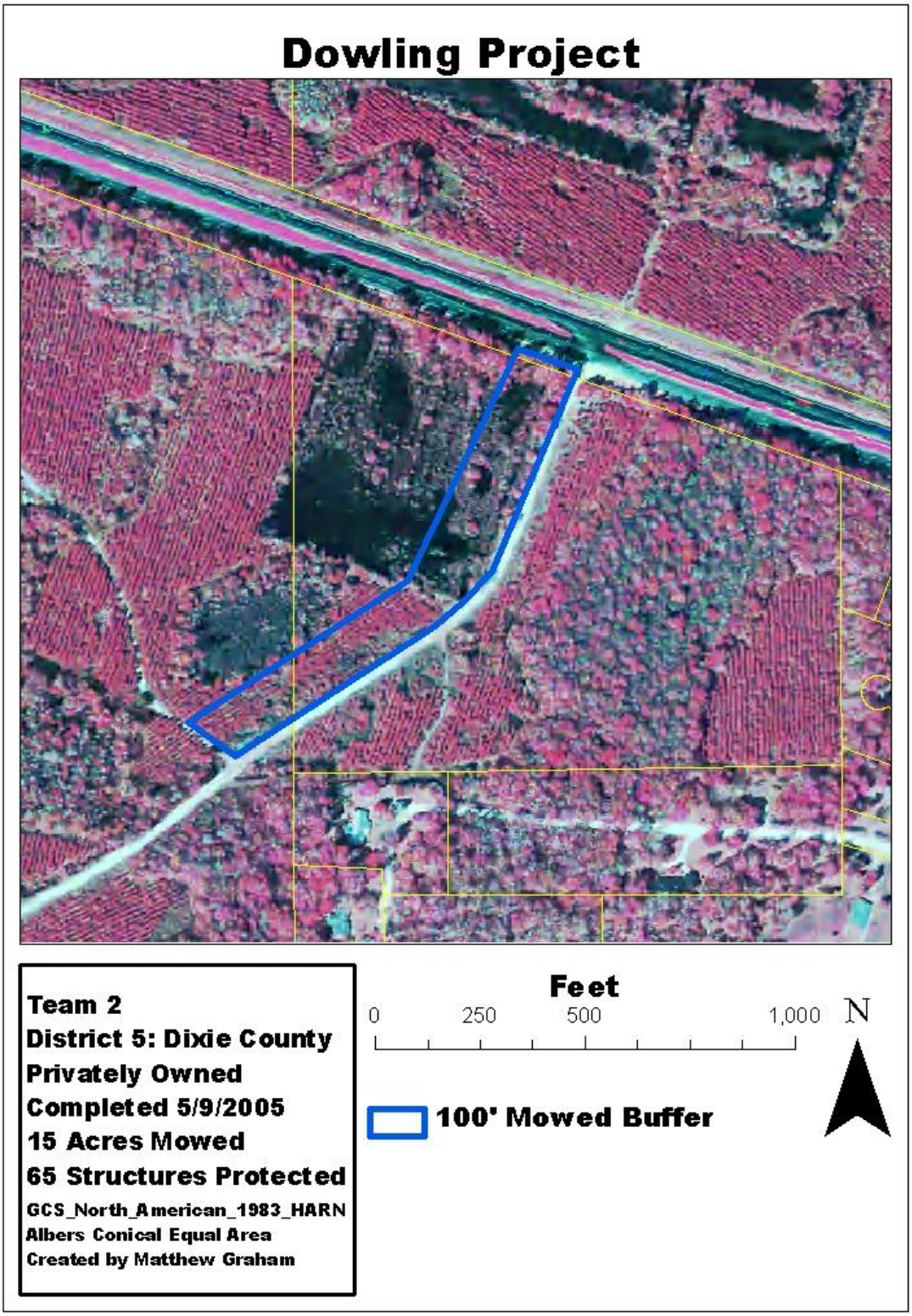


Figure A-5. Dowling Project.

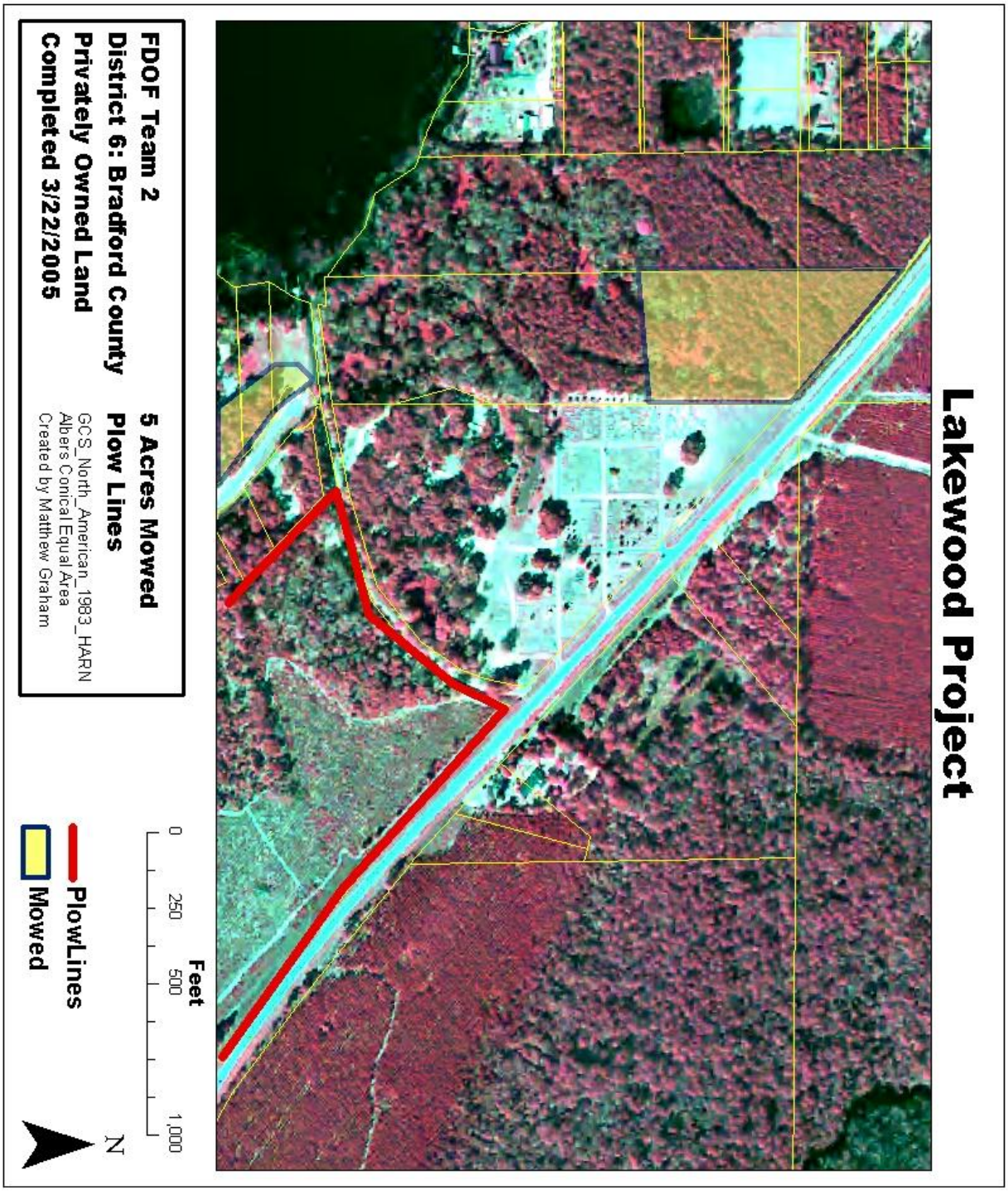


Figure A-6. Lakewood Project

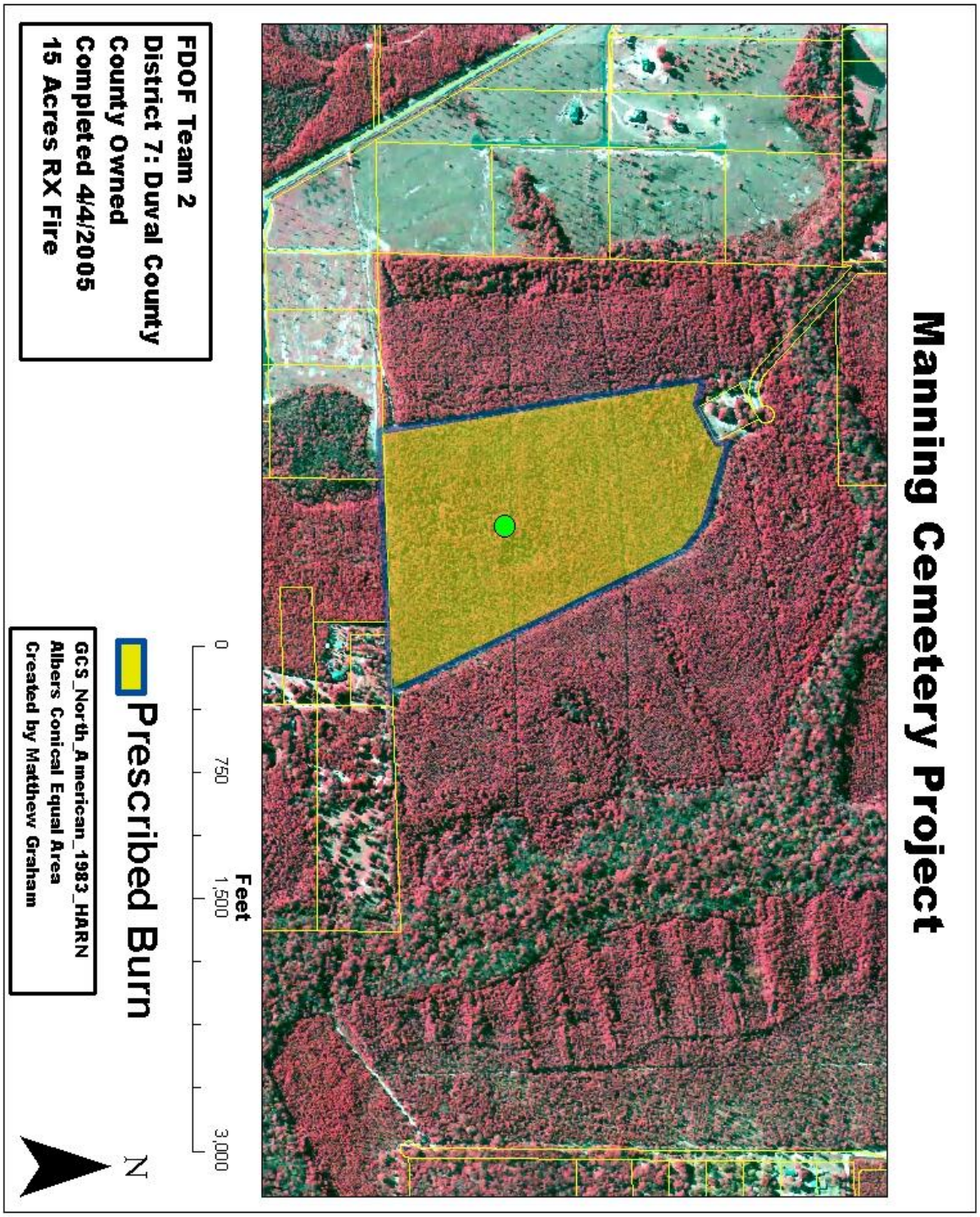


Figure A-7. Manning Cemetery Project

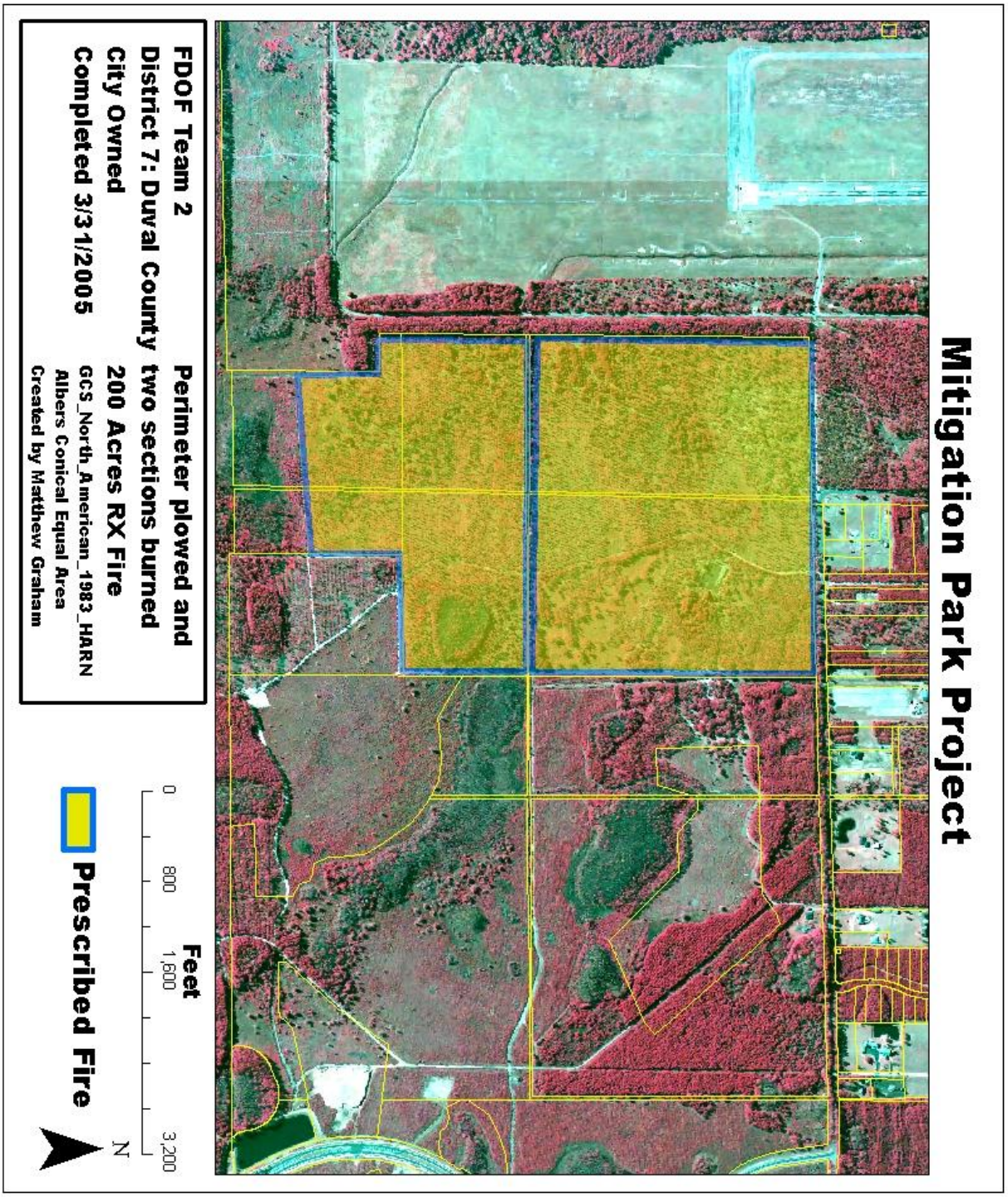


Figure A-8. Mitigation Park Project.

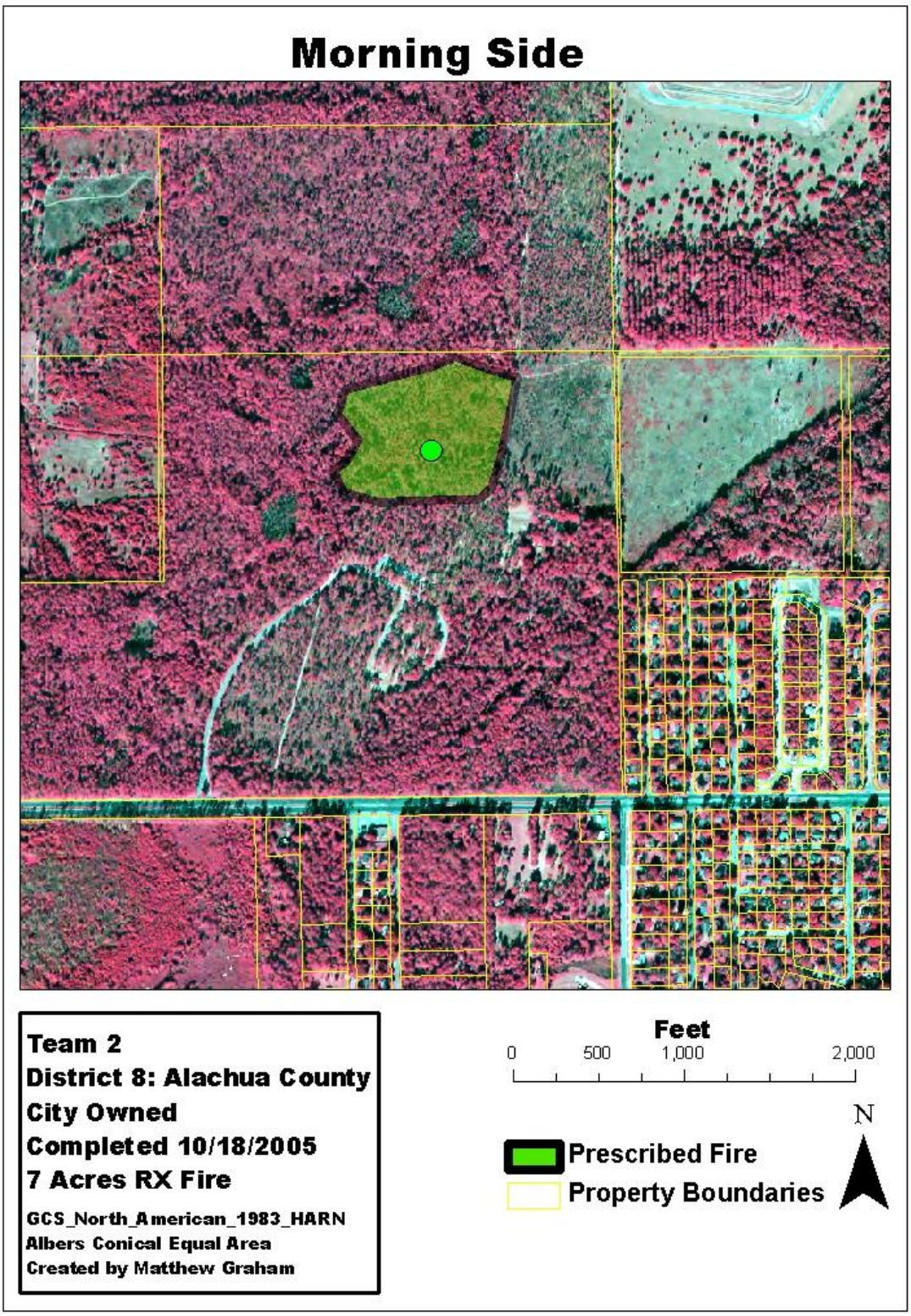


Figure A-9. Morning Side Project.

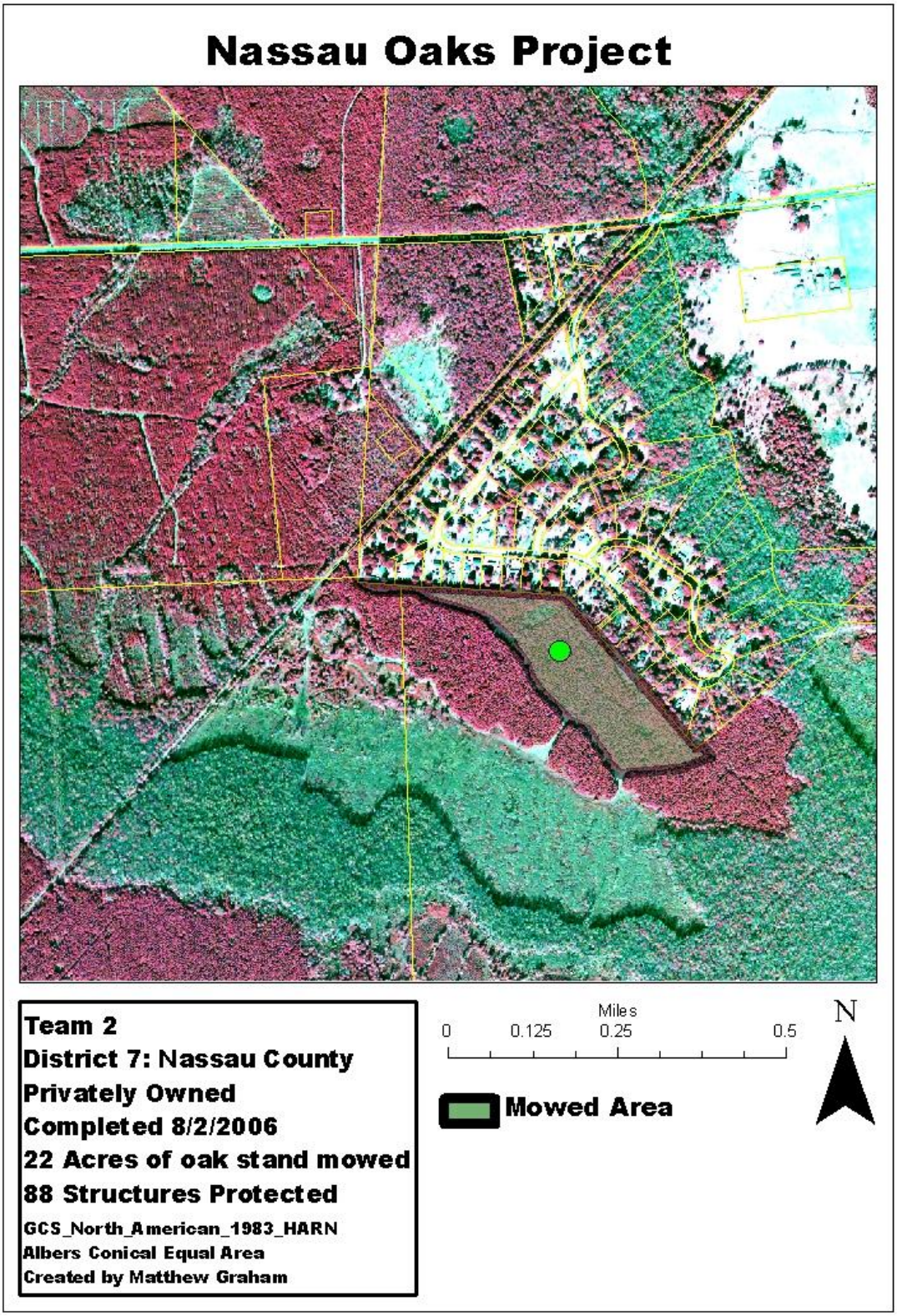


Figure A-10. Nassau Oaks Project.

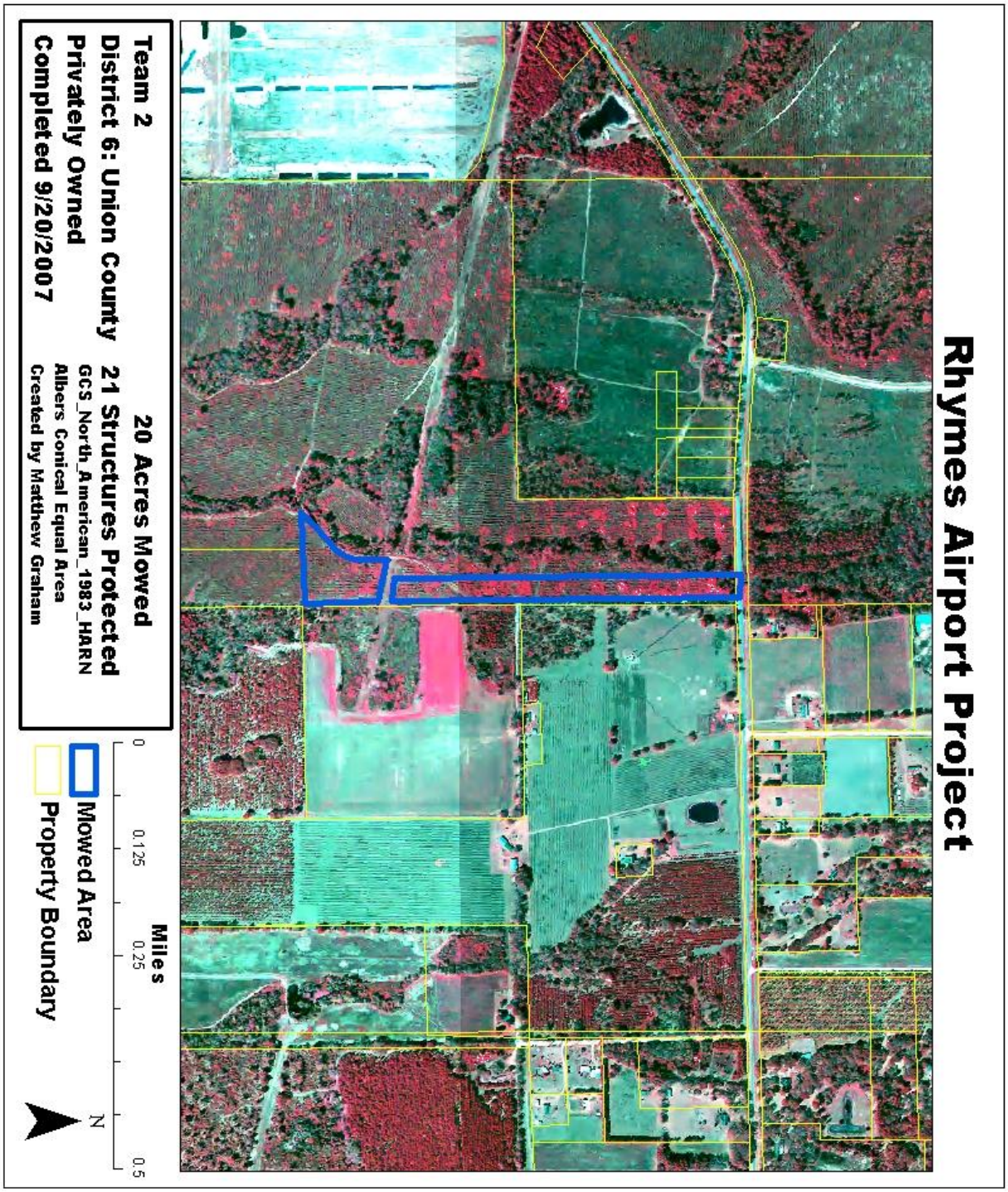


Figure A-11. Rhymes Airport Project.

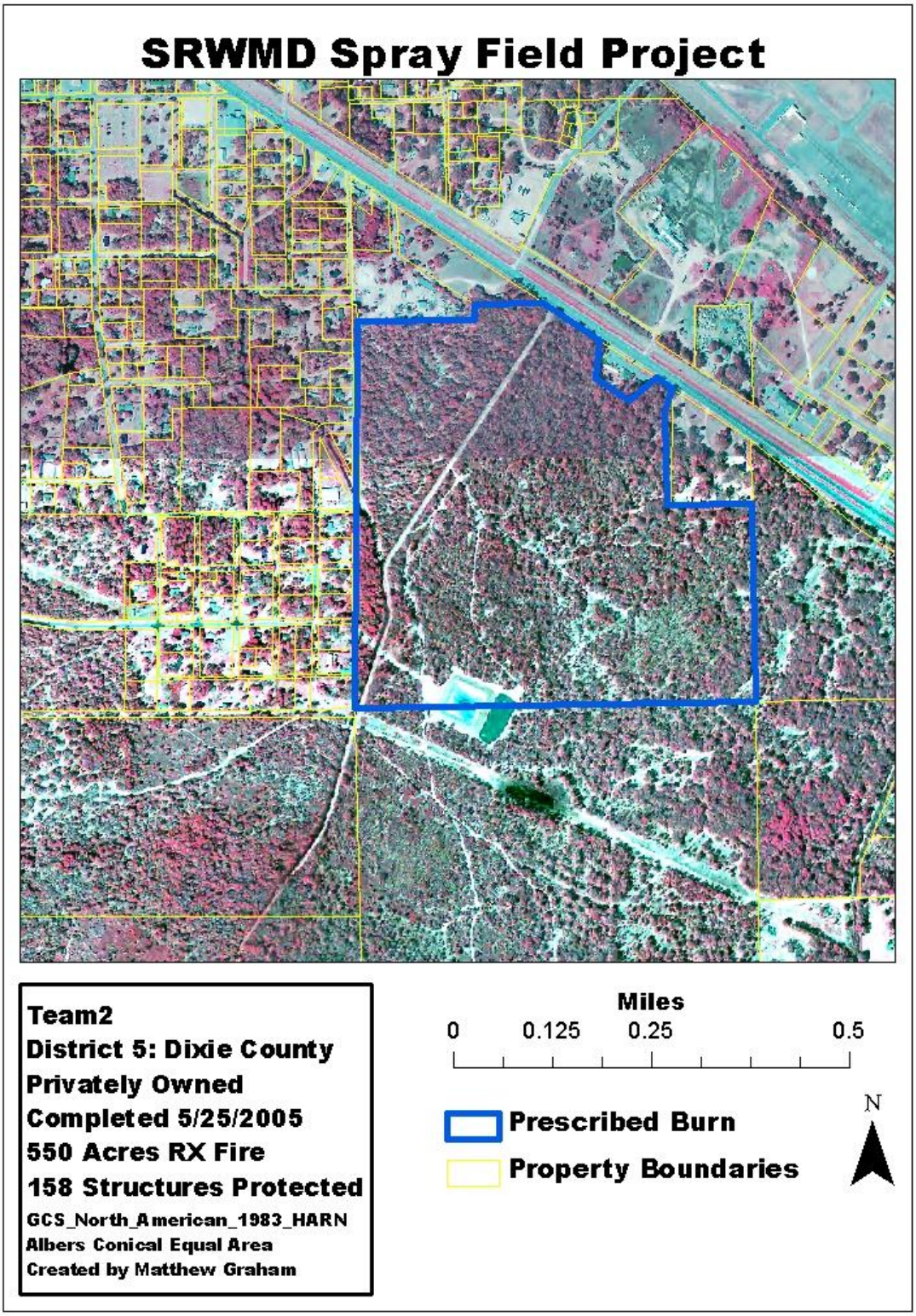


Figure A-12. SRWMD Spray Field Project.

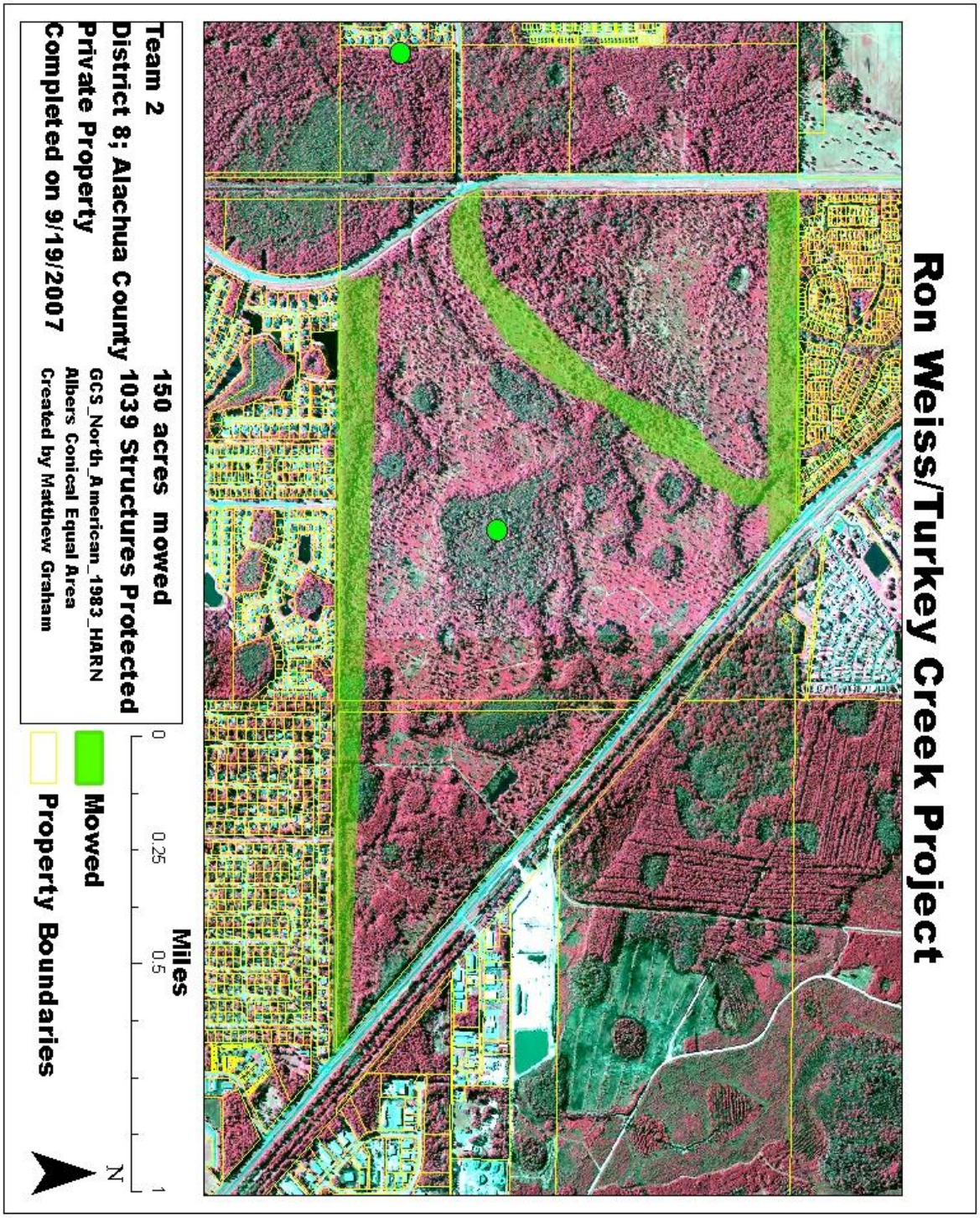


Figure A-13. Ron Weiss/Turkey Creek Project.

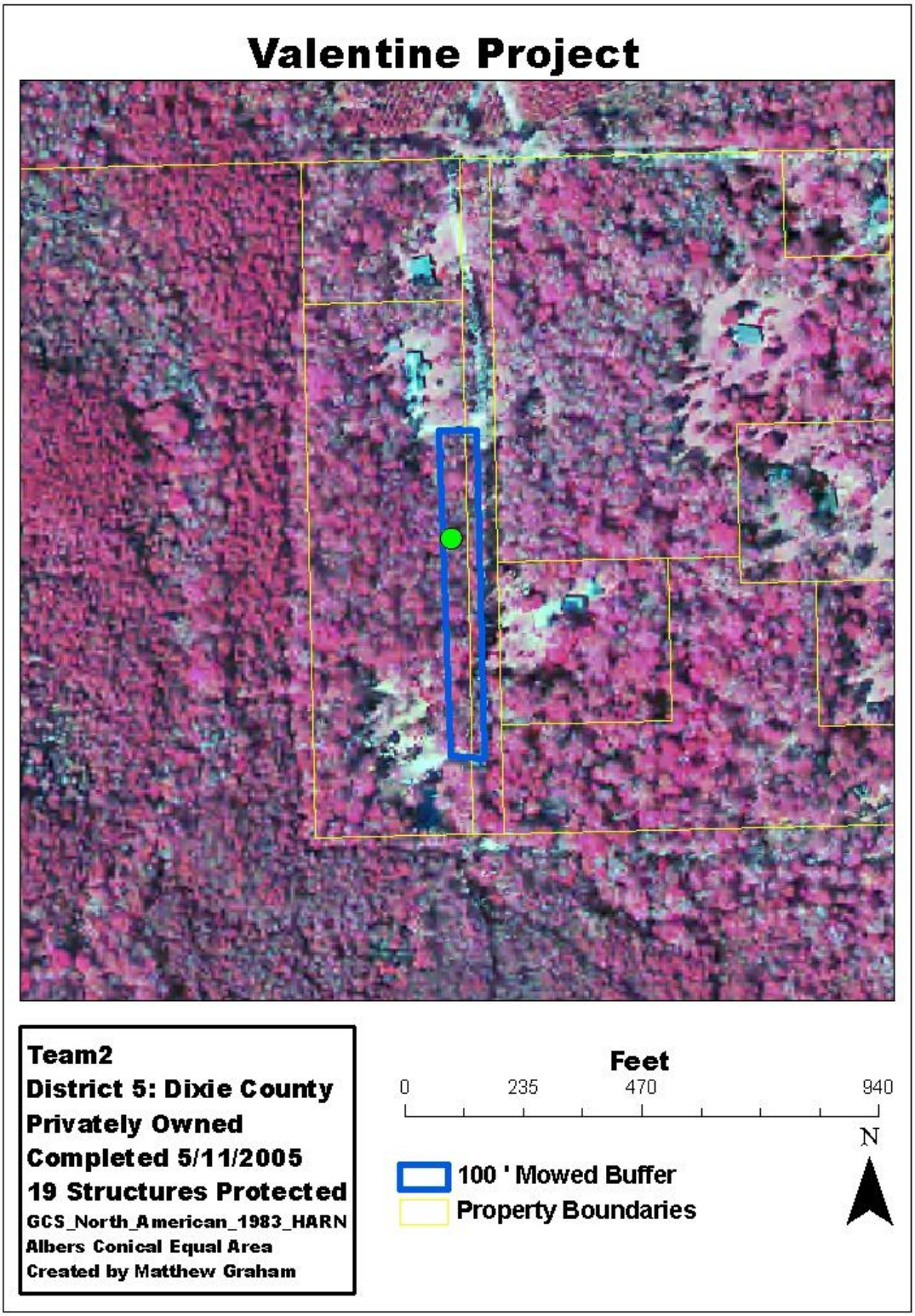


Figure A-14. Valentine Project.

APPENDIX B
MAPS OF WUI FUELS MITITGATION TRETATMENTS II

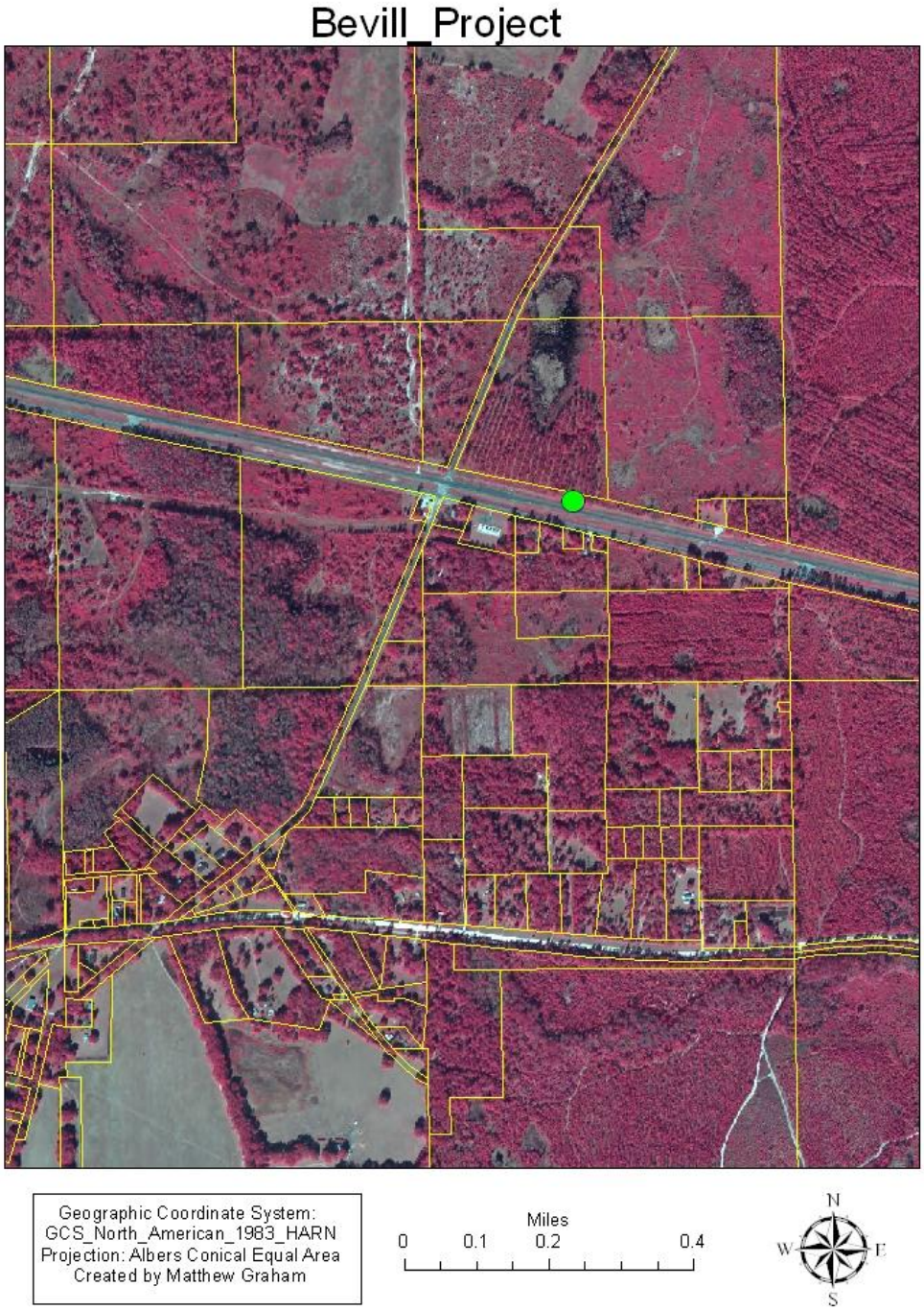


Figure B-1. Bevill Project.

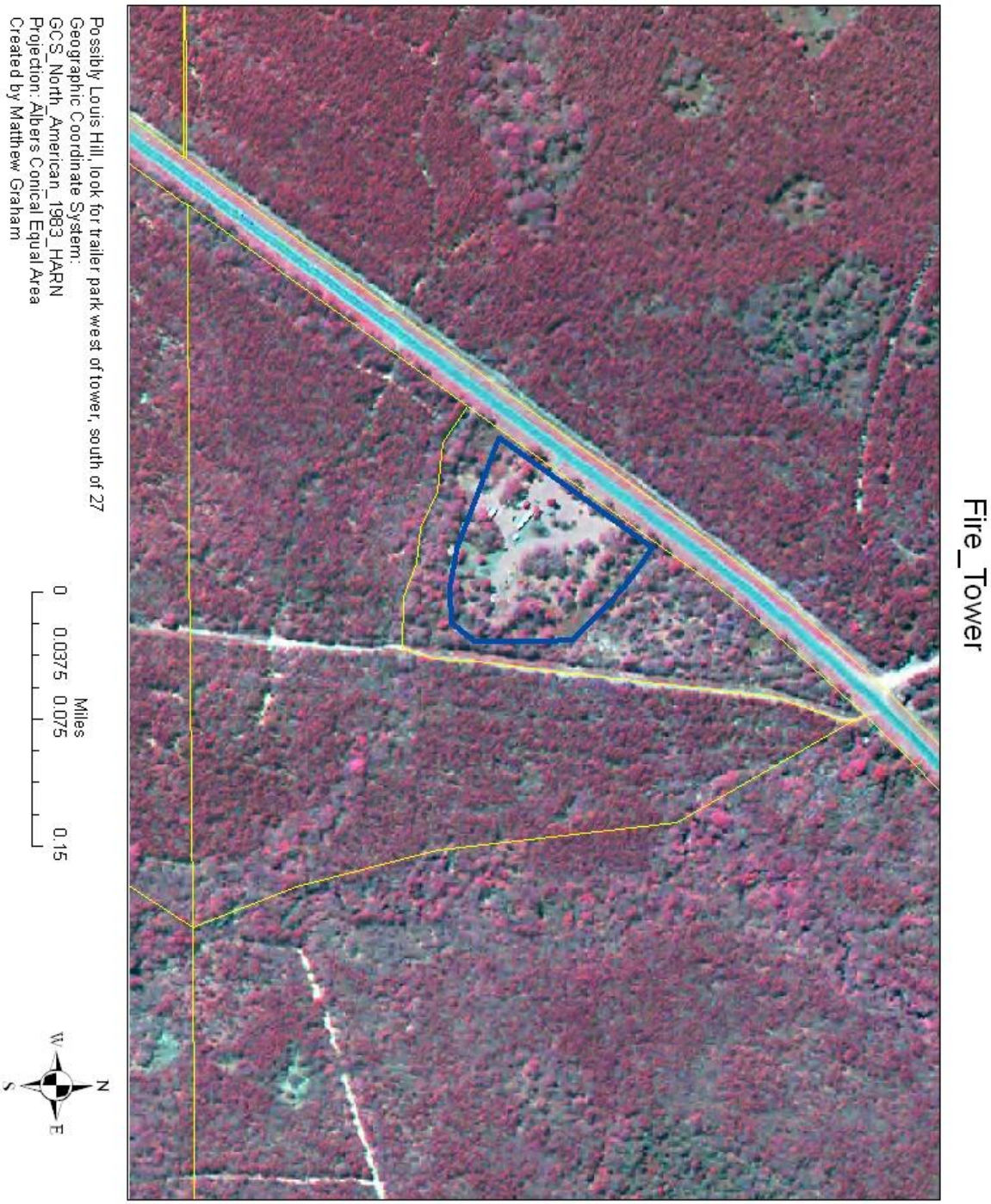


Figure B-2. Fire Tower Project.

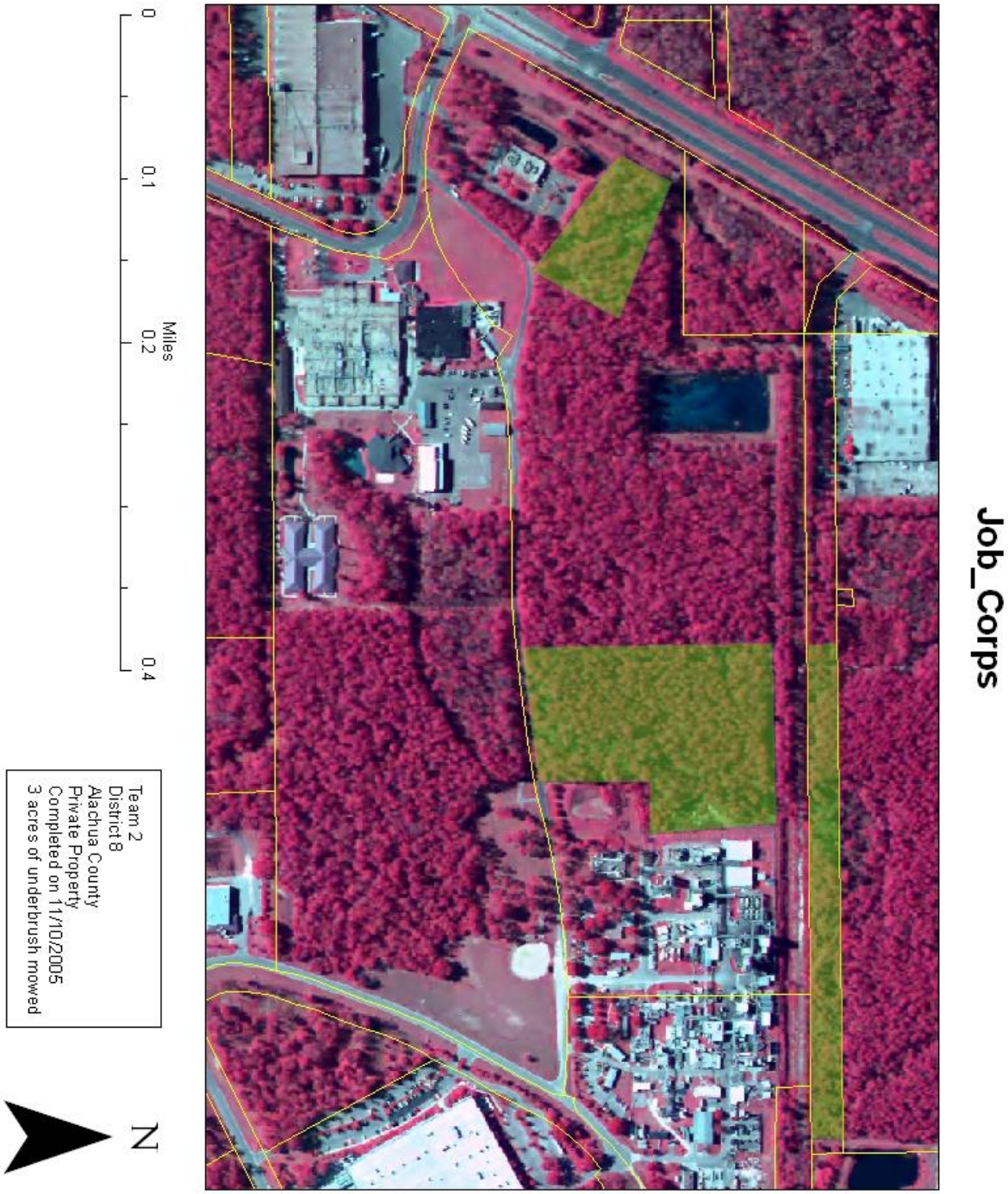


Figure B-3. Job Corps Project.

Figure B-4. JR Davis Project.

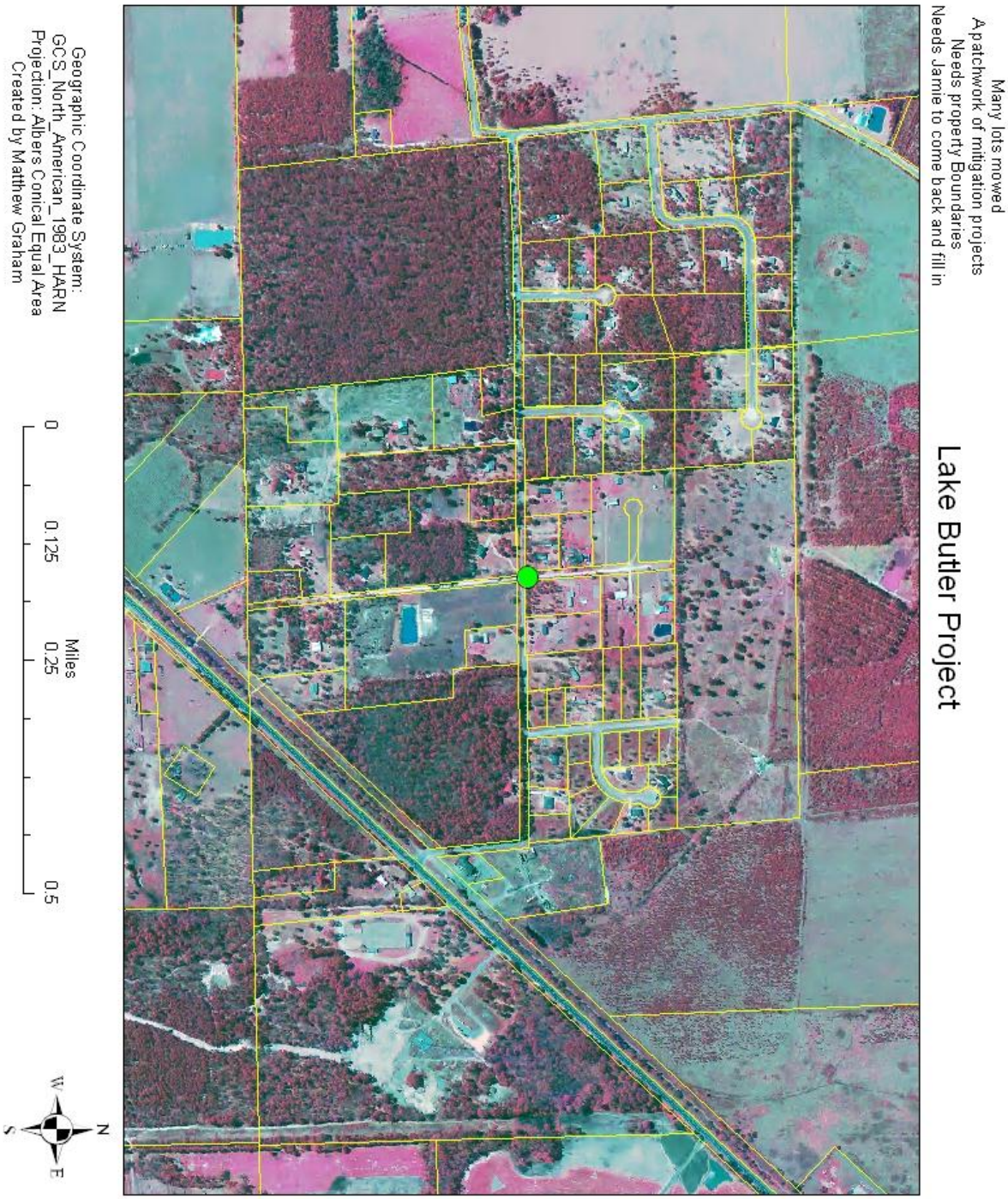


Figure B-5. Lake Butler Project.

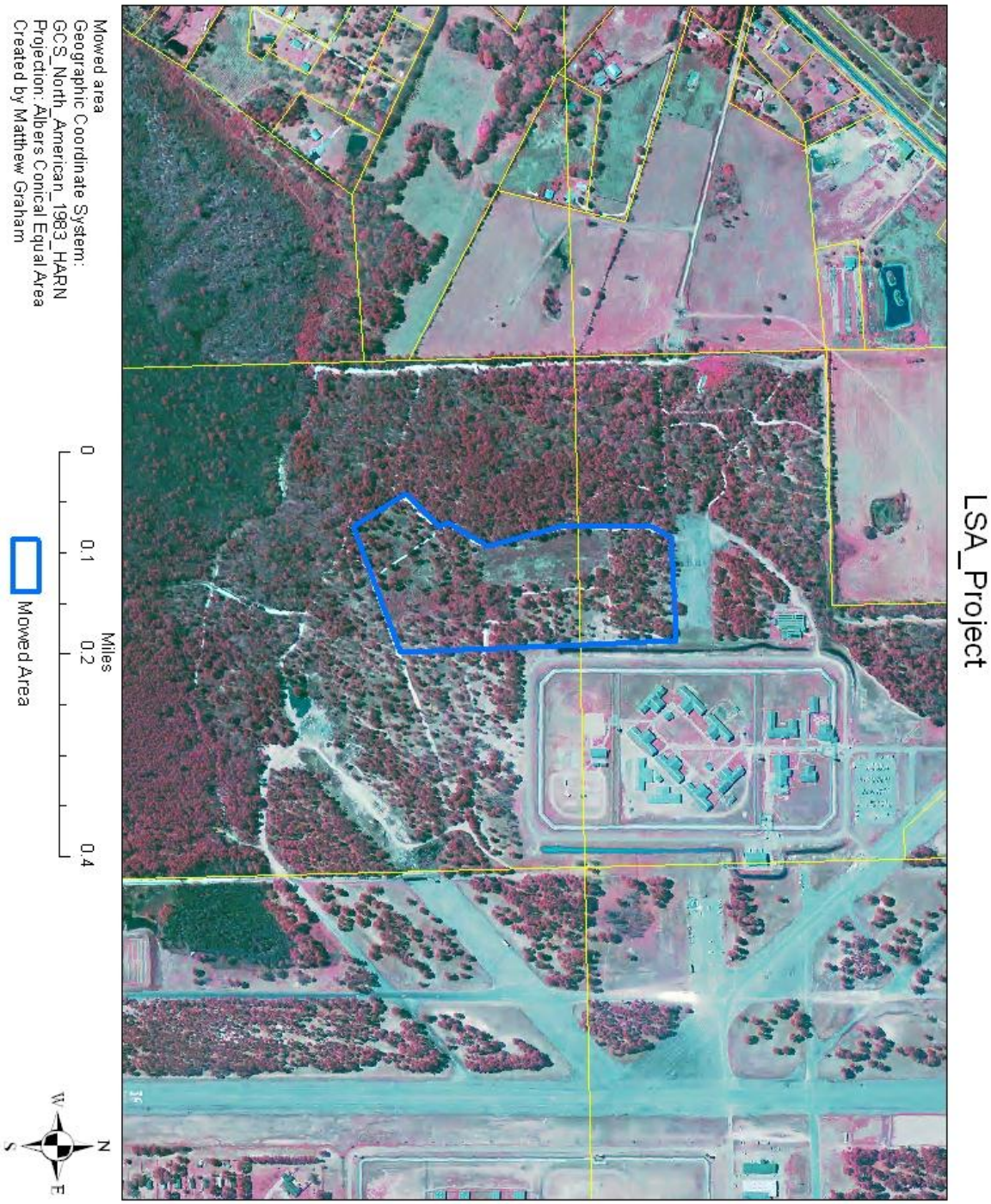


Figure B-6. LSA Project.

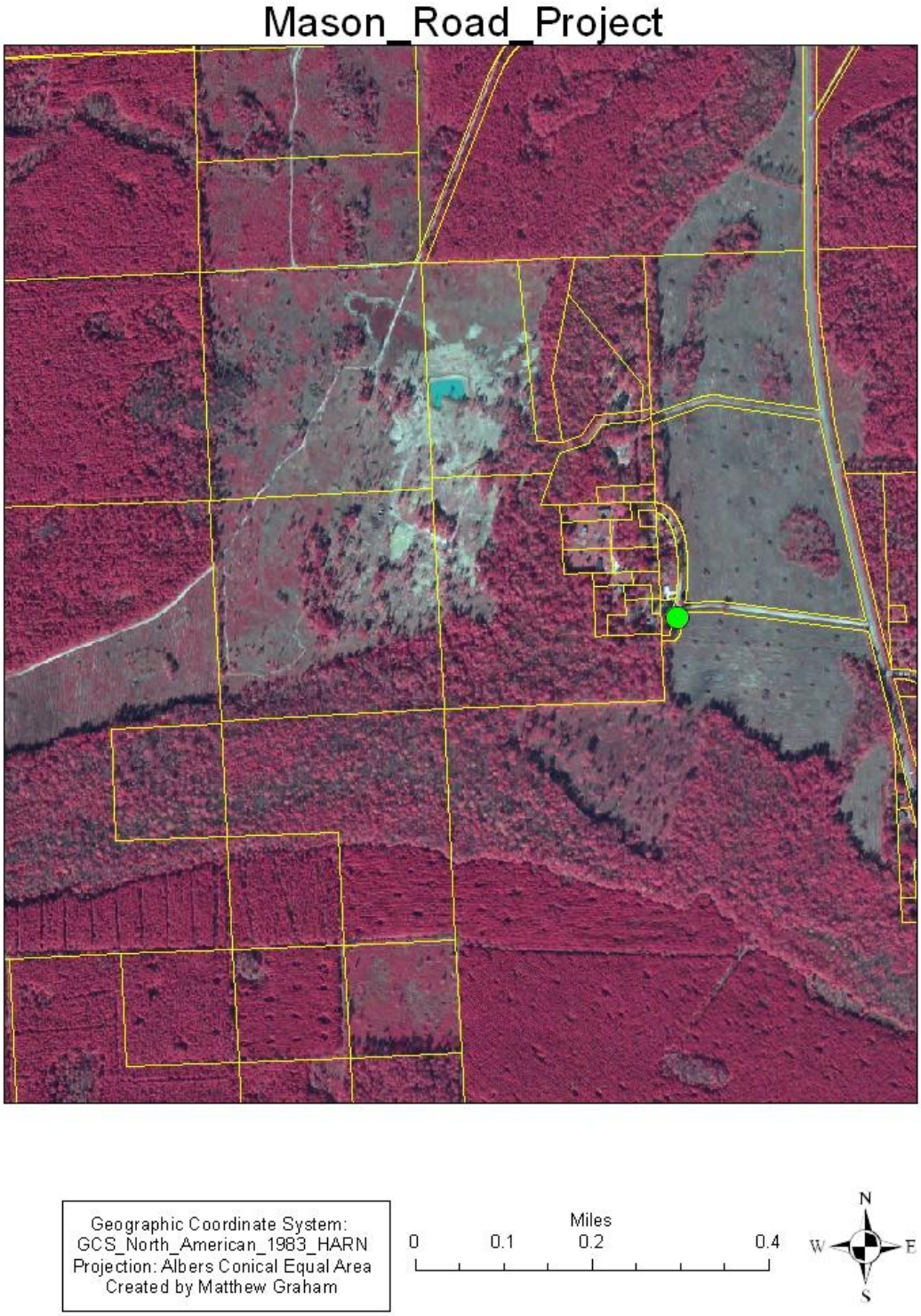


Figure B-7. Mason Road Project.

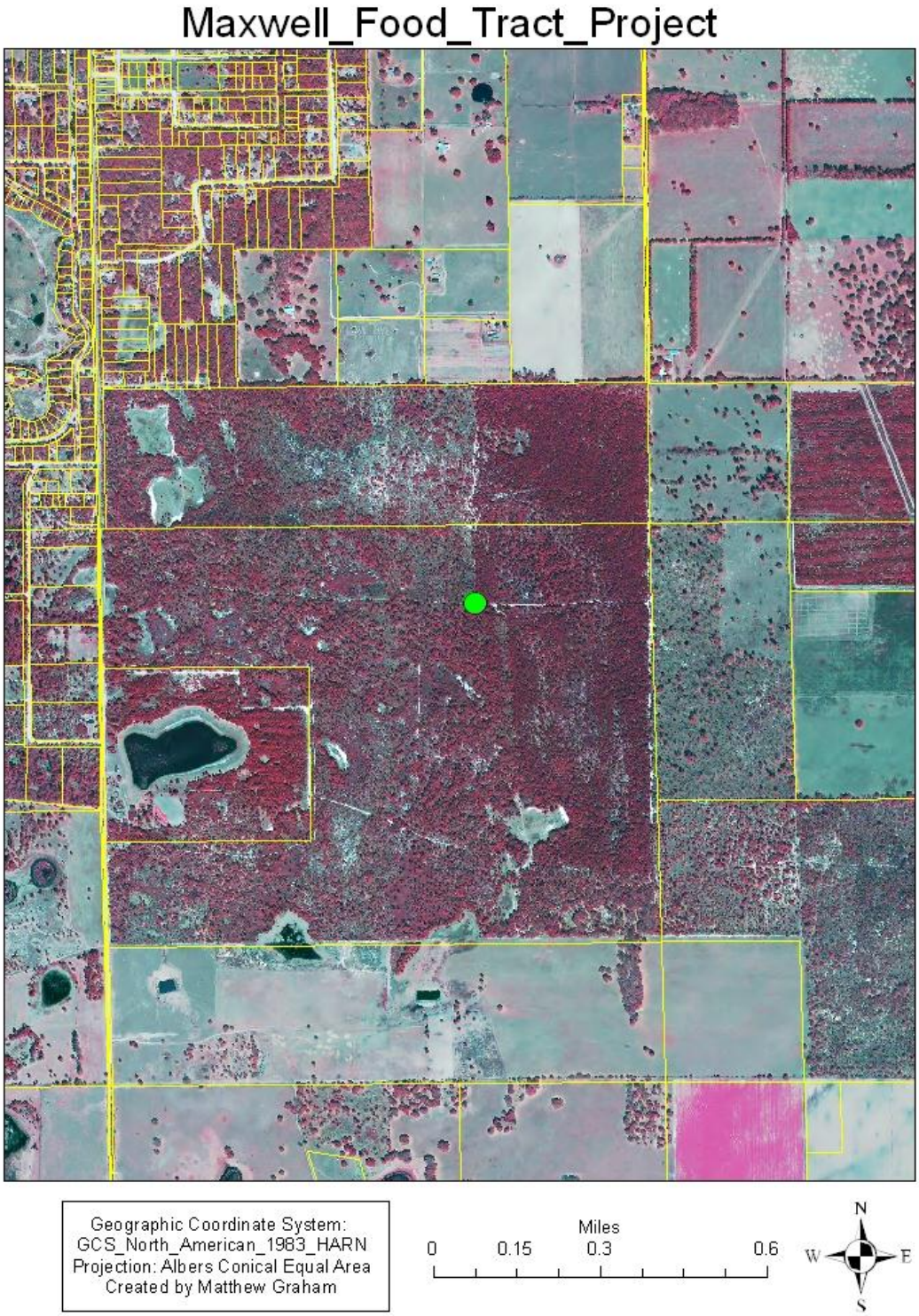


Figure B-8. Maxwell Food Tract Project.

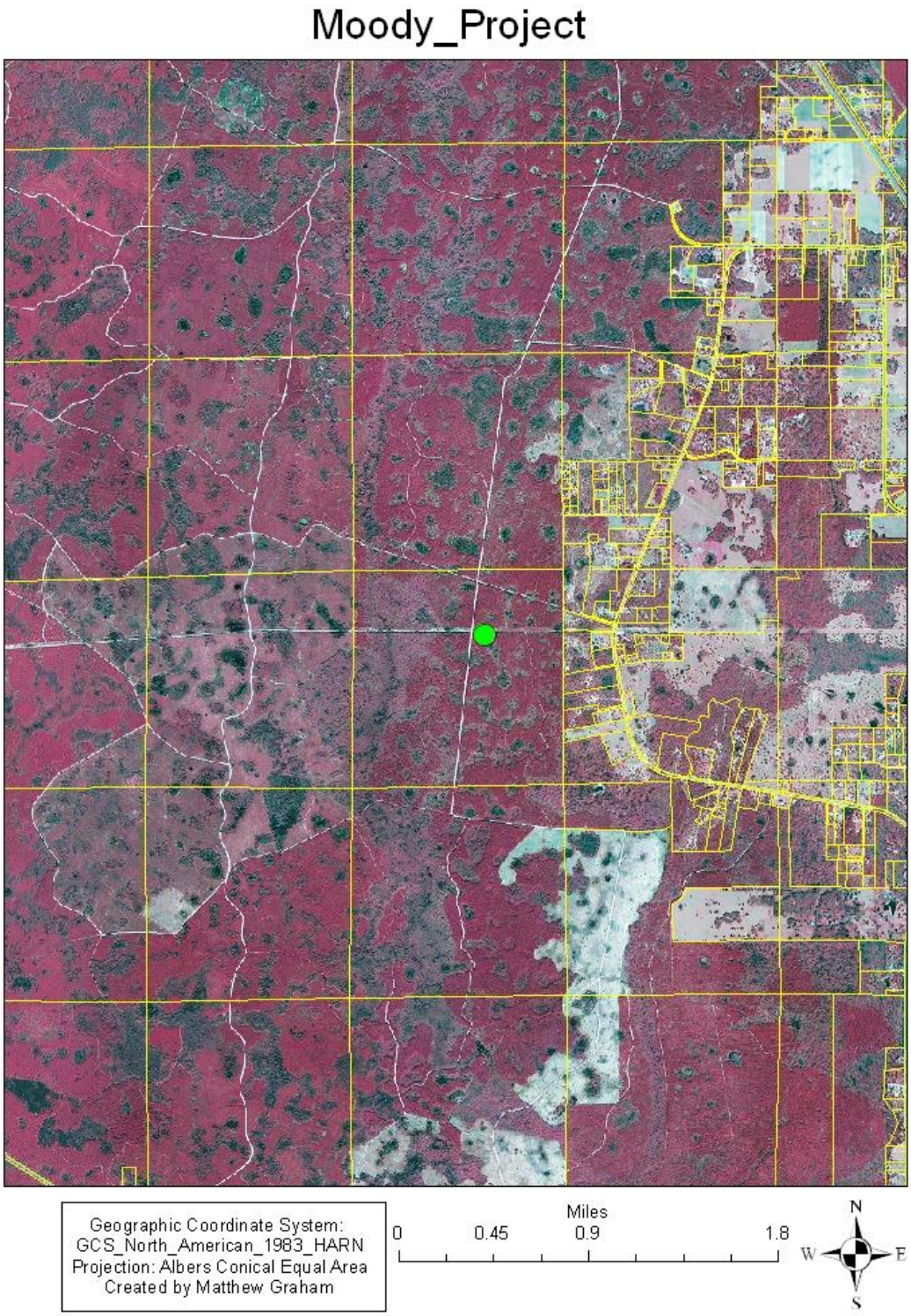


Figure B-9. Moody Project.

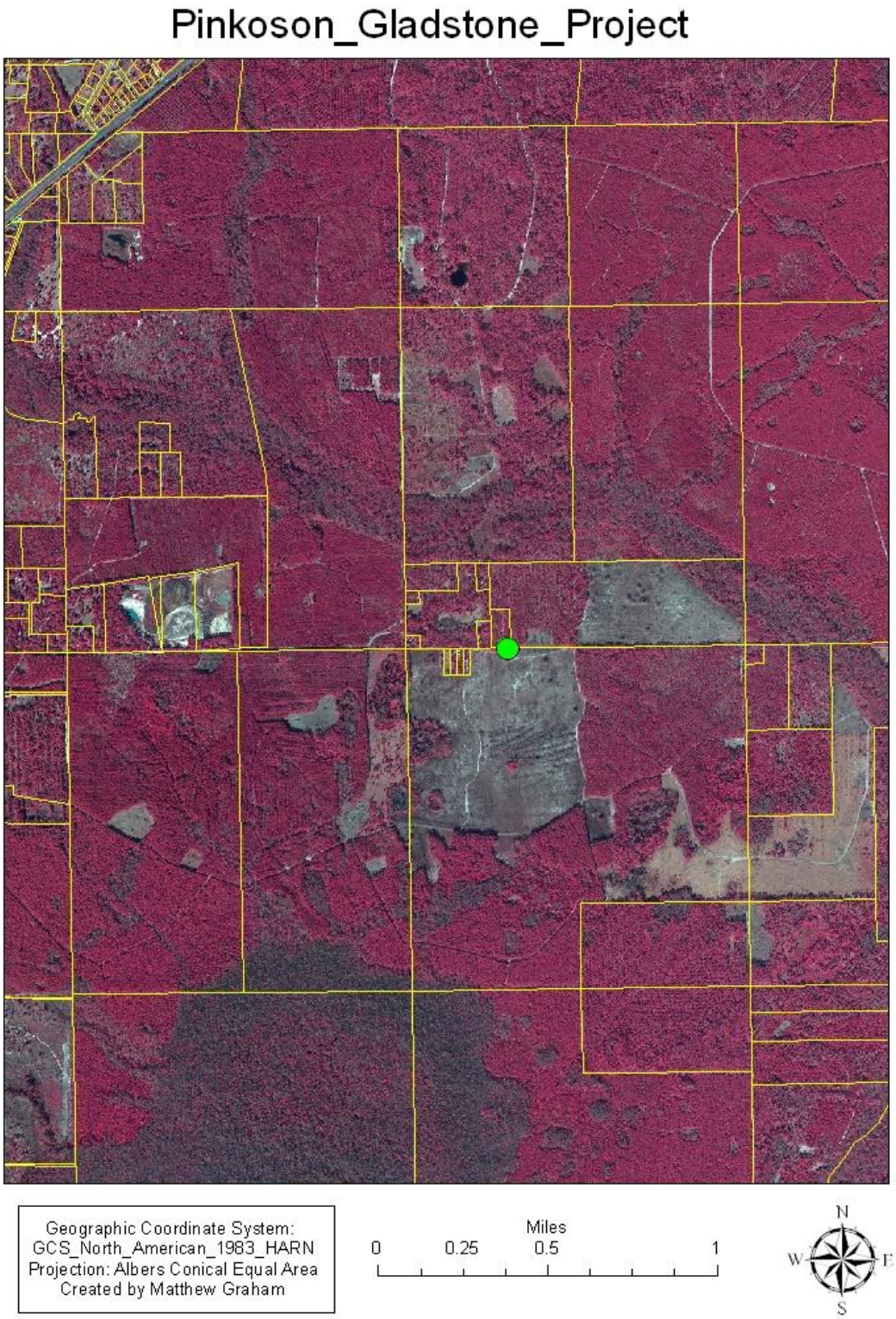


Figure B-10. Pinkoson Gladstone Project.

Figure B-11. Putnam EOC Project.

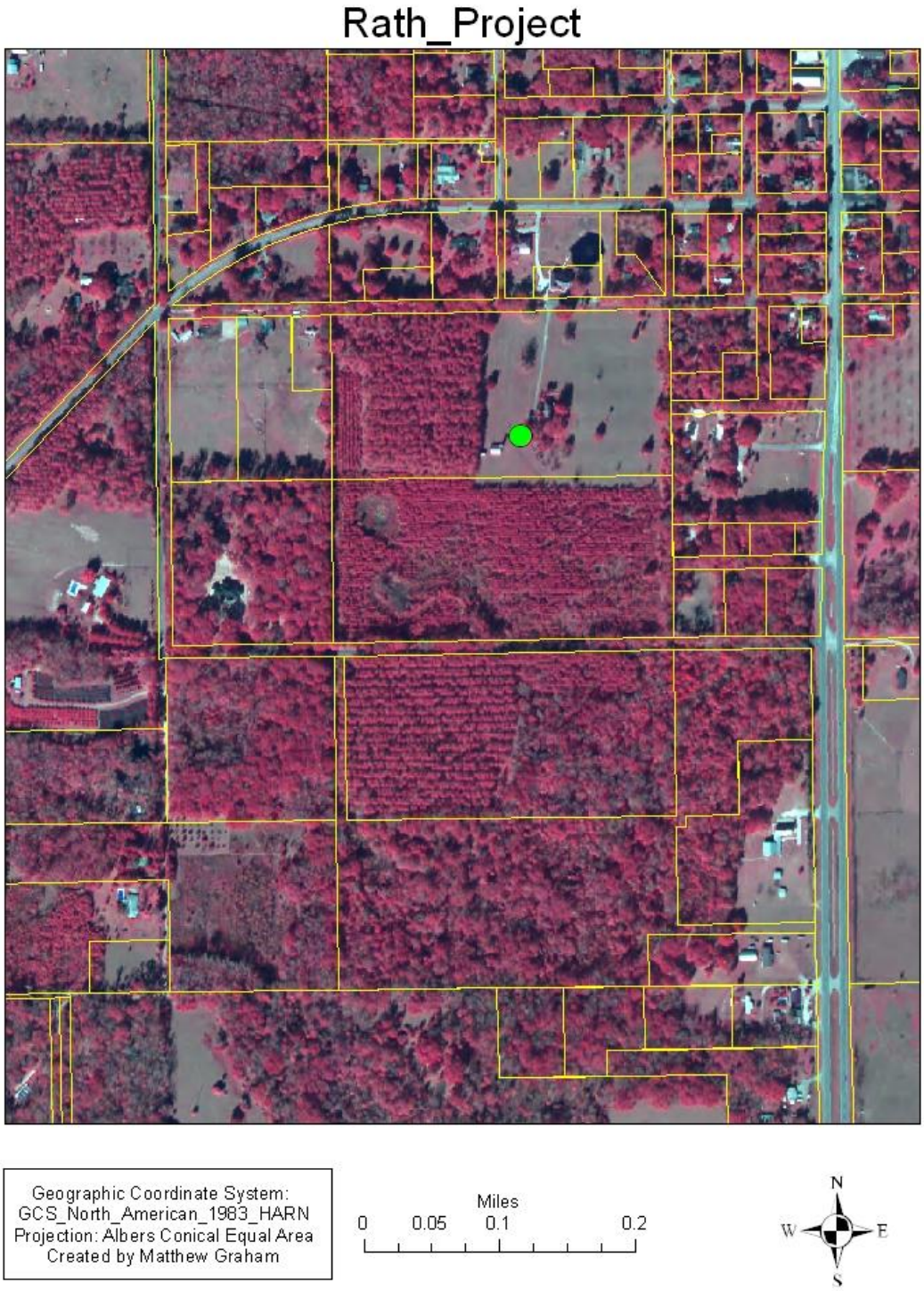
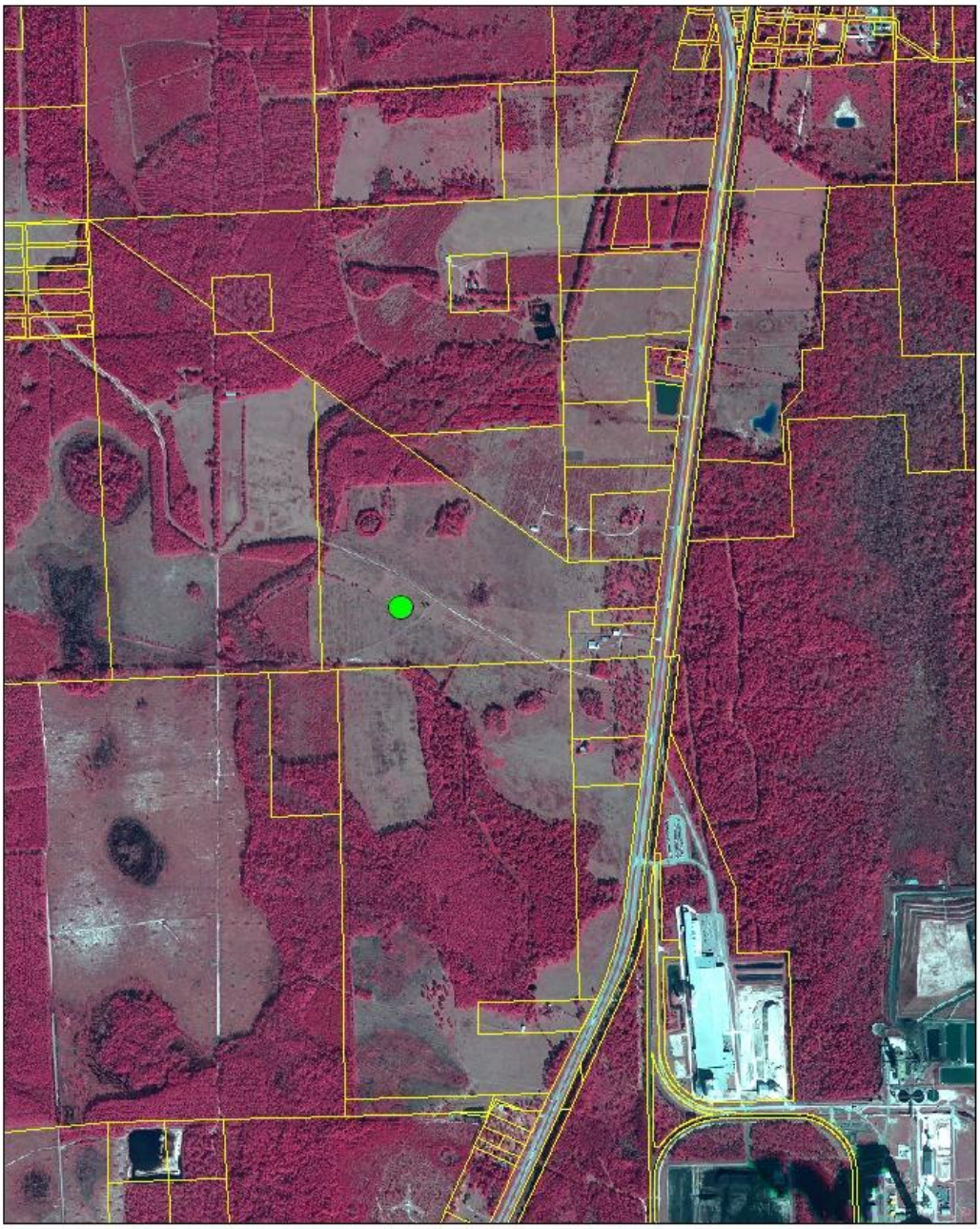


Figure B-12. Rath Project.

p-burn
need property boundary
get back to Jamie

seminole electric



Geographic Coordinate System:
GCS_North_American_1983_HARN
Projection: Albers Conical Equal Area
Created by Matthew Graham

Miles
0 0.2 0.4 0.8

N
W E
S

Figure B-13. Seminole Electric Project.

Figure B-14. Whisham Seal Lane Project.

mowing, many private lots
Plowing perimeters
Needs property boundaries
Needs Jamie to look at again
A community of high fire occurence

Whispering Pines

Geographic Coordinate System:
GCS_North_American_1983_HARN
Projection: Albers Conical Equal Area
Created by Matthew Graham

Miles
0 0.25 0.5 1

N
W E
S

Figure B-15. Whispering Pines Project.

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BIOGRAPHICAL SKETCH

Matthew Graham received his Bachelors in Environmental Studies and Anthropology, Cum Laude, from Florida State University in 2001. He worked professionally as an Instrument Man for a number of engineering and surveying companies using the money to travel prior to enrolling in the Department of Geography at the University of Florida in 2005. During his time at UF, he has worked as a Teaching Assistant for the Department of Geography at UF, a Prescribed Fire Technician for The Nature Conservancy, and as a Geospatial Analyst for the Kobziar Fire Science Lab of UF's School of Forest Resources and Conservation. He leaves UF employed as a Land Surveyor in Mine Planning for Dupont Titanium Technologies primarily working on projects involving mining, storm water systems, and topographic reclamation. He is a native Floridian who hopes to see continued and improved conservation and sustainability initiatives implemented by the government on behalf of citizens yet unborn.