ATTACHMENT 1

FLORIDA WILDLAND FIRE RISK ASSESSMENT APPLICATION UPDATE

FLORIDA FIRE RISK ASSESSMENT

FINAL PROJECT REPORT

TABLE OF CONTENTS

LIST OF TABLES

TABLE | TITLE | PAGE

LIST OF FIGURES

FIGURE | TITLE | PAGE

SECTION 1.0 INTRODUCTION

This section provides an overview of the State of Florida Fire Risk Assessment project.

Section 1.1 Background

Florida possesses a unique set of characteristics that make much of the state highly susceptible to wildland fire:

- First, the state is blessed with an abundance of wildlands. Unfortunately, the state has also experienced an explosion of new residents into these wildlands, creating an urban/wildland interface in a large portion of the state.
- Second, Florida's weather is conducive to starting and spreading numerous, and sometimes, large wildland fires. Florida's rate of lighting strikes is unequaled in the nation. Lightning, coupled with extended periods of drought, set the stage for catastrophic fire episodes. While lightning accounts for a large proportion of wildland fire ignitions, human-caused fires are ever increasing as the population rises.
- Third, Florida's wildland vegetation evolved in a fire dependent ecosystem. The vegetation is adapted to burn periodically. Fine fuels, which are easily ignited and spread fire rapidly, are abundant throughout Florida. The lack of fuel treatment in much of the wildlands has promoted an accumulation of these fuels that will burn with such intensity as to hamper suppression efforts.

To reduce the effects due to wildland fire, communities and fire management organizations desire to actively manage fire risk. However, managing fire risk is difficult since wildland fuels constantly change across the landscape and through time. Fire behavior is effected by fuel loading, weather conditions, and topography of which only fuel loading can be effected by humans. In addition, many social, technical and institutional barriers exist to proactive fire risk management and planning.

The purpose of the Fire Risk Assessment is to identify the potential for wildland fires within the State of Florida and prioritize areas where tactical analysis and treatment may be desired. It will also be used to locate areas within the state where interagency planning may be desired to efficiently manage fire risk. The results can be used to complete a more detailed analysis at the local level and communicate wildland fire management concerns to the Florida's public.

The results of the risk assessment can be used to:

- Identify areas that may require additional tactical planning;
- Allow agencies to work together and better define priorities and improve emergency response;
- Develop a refined analysis of a complex landscape and fire situations using GIS;
- Increase communication with local residents to address community priorities and needs; and
- Plan for resource needs.

Section 1.2 Project Activities

Section 1.2.A Fuels and Tree Canopy Mapping

Fuels and tree canopy maps were generated from multi-temporal Landsat Thematic TM imagery using advanced automated classification techniques. A total of 28 Landsat TM scenes were used which provided information for both leaf-on and leaf-off conditions. Derivative bands, such as ratios and vegetation indices were also generated for use in the classification. The final classes used in the fuels map were based on the Fire Behavior Predication System's 13 fuel models. Fire behavior specialists and local fire and fuels management experts determined the final tree canopy cover classes.

Contractor worked with the DOF district personnel to collect data from approximately 3,000 field sites across the state of Florida. A portion of these sites were set aside for use in the accuracy assessment the remaining sites were used to establish relationships between the imagery and features on the ground. Data on every fuel model and tree canopy class was collected and used to correlate the variability in the imagery with the variability on the ground. Draft maps were generated and reviewed by district staff. The final fuel map was developed using the comments from the draft review. The tree canopy map was generated using information from the final fuels map and ancillary data sources.

Section 1.2.B GIS Data Integration and Fire Risk Assessment

The Fire Risk Assessment System (FRAS) combines indices of Wildland Fire Susceptibility and Fire Effects to generate a "Levels of Concern" map, which identifies areas within the State at risk to wildland fires. The Fire Response Accessibility Index categorizes areas within the state by accessibility from initial dispatch locations. Existing data was acquired and new data derived to create the statewide Fire Risk Assessment. The inputs for each index and a brief description of how they were developed are provided below.

WILDLAND FIRE SUSCEPTIBILITY INDEX

- Non-burnable areas – derived from the fuel classification using Landsat TM data
- Slope - derived from 1:250,000 Digital Elevation Model Data (DEM)
- Aspect - derived from 1:250,000 Digital Elevation Model Data (DEM)
- Elevation - derived from 1:250,000 Digital Elevation Model Data (DEM)
- Fuels – from classification of Landsat TM data
- Crown Closure – from classification of Landsat TM data

Potential weather – derived from NOAA and National Fire Danger Rating System (NFDRS) weather data per weather influence zone

FIRE EFFECTS

Environmental Effects Index:

- Critical Facilities – derived from Florida's burn authorization plan, school locations, and highways and interstates

- Plantations- derived from Water Management District land use/land cover maps
- Utility Corridors – compiled from Florida Power and Light provided coverages
- Urban Interface – compiled from Bureau of Census data, Landsat TM imagery and National Interagency Fire Center definitions

Suppression Costs:

- Muck – derived from SURGO soils data
- Fuel Type - derived from the fuel classification using Landsat TM data
- Levels of Concern Index

FIRE RESPONSE ACCESSIBILITY

- Roads–from GDT Dynamap 1000 road data
- Resource Locations –GPS point locations of all resources provided by DoF and USFS, and a point coverage from FDEM

Following their acquisition, all GIS layers were assembled into statewide coverages and each layer was reviewed for quality. All layers were then co-registered to one another using Florida's customized Albers projection in the HPGN datum. The layers were re-sampled to a common minimum mapping unit (30 meters) and partitioned into Florida Division of Forestry Districts.

Section 1.2.C Fire Risk Assessment System Development

The Fire Risk Assessment System (FRAS) tool was developed to allow users to perform scenario based planning for wildland fire risk and Levels of Concern. The tool allows users to apply models developed by fire specialists to update fuel models, fuel types, and fire occurrence areas to recalculate wildland fire susceptibility index. The FRAS tool then combines wildland fire susceptibility index with environmental effects and suppression costs to determine an overall Levels of Concern. Users have the ability to weight the different layers that comprise environmental effects and suppression costs based on their local knowledge of the area. The FRAS tool also allows users to update the fire response accessibility layer by updating roads and resource locations.

SECTION 2.0 FUELS AND TREE CANOPY MAPPING

Section 2.1 Data Acquisition

Twenty-eight individual otho-rectified Landsat TM images were acquired for the mapping process. Multi-temporal imagery (imagery from Landsat 5 and imagery from Landsat 7) was used to represent leaf-on and leaf-off vegetation conditions. The imagery was mosaiced into three separate regions: north, middle and south. The fuels classification was performed separately on each region to minimize regional vegetation differences.

Table 1. Acquisition Dates for Landsat Imagery

Path/Row	Leaf-on Date	Leaf-off Date
P17 R39	3/28/99	12/1/99
P14 R40	3/28/99	12/1/99
P17 R41	3/25/98	12/1/99
P18 R39	4/22/00	12/24/99
P19 R39	5/15/00	11/29/99
P20 R39	6/8/00	1/7/00
P15 R41	5/14/98	2/5/00
P15 R42	5/14/98	2/5/00
P15 R43	5/14/98	2/5/00
P16 R39	4/8/00	12/26/99
P16 R40	3/5/99	12/26/99
P16 R41	3/5/99	12/26/99
P16 R42	3/5/99	12/26/99
P16 R43	3/5/99	12/26/99

Section 2.2 Image Pre-Processing

Upon receipt of the imagery, a basic quality control review was performed to ensure that the two dates of imagery were co-registered to the pixel and to check for missing data, haze, and clouds.

The imagery was selected to minimize the total cloud cover in all TM scenes. Unfortunately, when working with a statewide dataset it is nearly impossible to acquire completely cloud free imagery. In order to minimize their impacts, the clouds were removed prior to any image interpretation. Areas with clouds in one date of the imagery (for example leaf-on) were classified using the leaf-off imagery and vice versa. In addition, non-burnable areas such as water, sand, and urban areas were masked out of the imagery using information from ancillary data.

Two ratio bands, bands 4/3 leaf-on and bands 5/4 leaf-off were generated. The leaf-on bands 3, 4, 5, and 6, leaf-off bands 3, 4, 5, and 6, the 4/3 ratio, and the 5/4 ratio were stacked into one image. This was the final image stack used in the classification process.

An unsupervised classification was then performed and any additional non-burnable clusters were identified and masked out of the imagery

Section 2.3 Sample Features of Interest

FINALIZE CLASSIFICATION SYSTEM

Contractor worked closely with fuels experts including Don Carlton (Fire Program Solutions), Butch Neal (PBS&J), James Brenner, and Sam LaNeave to develop a draft and final fuels classification system (Appendix 8.1) and tree canopy cover classes. The classification schemes were used to assign fuel labels during the field data collection and to assign canopy closure categories to each field site.

FIELD DATA COLLECTION

Prior to field data collection, unsupervised clusters were created using the final stacked imagery. ERDAS ISODATA algorithm was run on the imagery to create 80 clusters. The purpose of the unsupervised classification was to generally characterize the spectral variation of the area to guide in the selection of the field sites. Field sample sites were delineated using the individual clusters as a guide. The minimum size of the field sites was 3 by 3 pixels or 90 by 90 meters.

Field data for the fuels and tree canopy classification was collected by DOF Staff (see Section 7. for a full listing). Contractor developed field data collection manuals and field forms based on the rule set developed for the fuel classification system. A weeklong workshop was held to provide the state personnel with in-depth training on the field procedures and data collection methods

As part of the training, Contractor provided the DOF and each member of the field crew with a field manual containing the following information:

- An overview of the project;
- General field collection procedures;

- Tools that will be used to collect field information;
- Step by step instructions of how to fill out the field forms;
- Land Cover Classification Key;
- Fuels Classification Key;
- Field Forms; and,
- GPS Procedures.

Image maps, location maps, and UTM coordinates were also provided to the DoF for use in collecting field data. The Image Maps covered USGS 7 ½ minute quadrangle areas, and were printed at a 1:24,000 scale with roads, streams, and field sample locations identified. They were printed as color infrared composites to emphasize differences in vegetation. Smaller scale location maps of each district showed the location of the individual Image Maps. UTM coordinates for the center point of each field site were provided to assist in navigation to each site and to help identify the correct location.

The field sampling methodology was designed to simultaneously collect samples for both map development and accuracy assessment. It was also developed such that the sites were accessible and all fuel and canopy classes were adequately sampled. The USGS Land Use/Land Cover map was used to stratify and focus the sample design. All sites were overlaid on the Landsat TM imagery and visited in the field to ID the fuels and crown closure classes.

District	Assigned Sites	New Sites	Total
Blackwater	113	80	193
Chipola River	184	80	264
Tallahassee	116	80	196
Perry	103	80	183
Suwanee	75	80	155
Jacksonville	59	80	139
Bunnell	102	80	182
Withlacoochee	97	80	177
Waccassa	164	80	244
Orlando	157	80	237
Lakeland	66	80	146
Myakka River	129	80	209
Ockeechobee	273	80	353
Caloosahatchee	198	80	278
Everglades	310	80	390
Total	**2146**	**1200**	**3346**

Each district was assigned a specific number of sites. In addition to the assigned sites delineated on the maps, the districts were also asked to collect 80 new sites. The new sites were collected in order to capture any variability or fuels found in the field that was underrepresented in the assigned sites. The table above summarizes the assigned, new and total sites visited by each district.

QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

In order to ensure that the field data collected were complete, consistent and accurate, several QC tasks were implemented. First, field forms were reviewed as they were received and second, a sample of field sites were visited a second time so an evaluation could be made on the consistency of the data collection and to identify where confusion was occurring in the field.

FIELD FORM REVIEW

As the field forms were being completed and sent back to Contractor they were reviewed for completeness and consistency. If forms were incomplete or data was missing Contractor contacted the appropriate district leader to a) determine if copies of the missing forms were available at the district office or from the observer or b) to discuss actions necessary to ensure that the observer correctly complete the field forms.

FIELD DATA EVALUATION

Field checks were performed on a district-by-district basis using a sample of 10% of the 3500 field sites checked for quality. The 350 QC sites were divided equally between the 15 districts. Twenty sites were randomly selected for each district. A master list of all QC sites was compiled in order to assess the progress and results of each district.

A Contractor team member or a DOF district leader completed a QA/QC form (Appendix XX) for each QC site. Each site was visited and information on the vegetation class, fuel model and crown closure were be collected. The information was then compared to the original site field forms submitted by the DoF. An acceptable or unacceptable label was assigned to each site and a master list including the site number, region, and date of visit was prepared.

At the time of the original data collection, field personnel had the option of selecting a second fuel model if they were unsure of the correct fuel model for the site. Only the primary fuel model label from the original site visit was used in the field data evaluation.

ASSEMBLE FIELD DATABASE

Field data was entered into a GIS database as it was received. During this time sites were flagged if there were inconsistencies on the field form such as the fuel model label not matching the fire carrier label or if a sites had significantly changed since the image acquisition. Sites were also flagged if they were marked as not observable or viewed from a distance. All of the flagged field sites were reviewed individually. Sites that were questionable were forwarded along with the site photos to Don Carlton for review. Sites that remained questionable were removed from the database and excluded from the classification or accuracy assessment.

Using the final field database, a random number generator was run to extract a stratified random sample of sites for use in accuracy assessment. During this process it was determined that there were not enough field sites available for the quantitative accuracy assessment for fuel models 1, 5, 6, 10, 11 and 12. Fifty sites were extracted from the database for fuel models 2, 3, 4, 7, 8, and 9 for use in the accuracy assessment. The remaining sites were used in the creation of the fuels and tree canopy maps.

Each field site was assigned a canopy closure class:

- 1 to 20 % canopy closure
- 21 to 50% canopy closure
- 51 to 80% canopy closure
- 81 to 100% canopy closure

- 0% (or no data gathered)

Section 2.4 Image Classification

DRAFT FUELS CLASSIFICATION

Each region was independently classified and modeled. An initial unsupervised classification was implemented on the burnable only imagery. This imagery had all of the non burnable areas (water, urban, bare ground, and sand) masked out in the image preprocessing phase and included data and ratio bands from both Landsat 5 & Landsat 7. Using an iterative process these initial 50 clusters were used to mask the imagery and create additional clusters. Models were developed that split clusters into their appropriate fuel classes using the field data, imagery, and ancillary data. The modeling consisted of two phases statistical association of spectral classes with fuel model-types and ecological modeling based on ancillary information. Spectral association was based on statistical relationships between field data and spectral information.

Next, the model results were compared against the TM imagery. Each cluster was reviewed across all regions and refinements were made to the models. Any confused clusters were identified and further modeled. As "confused" clusters were labeled into appropriate consistent fuel classes, they were removed from further modeling efforts to focus on clusters that required additional modeling. The final models were redesigned and rerun in an iterative manner until consistent fuel classes were developed for all modeled clusters.

DRAFT FUELS MAP REVIEW

The draft fuels maps were compared to the TM cluster base and imagery to check for consistency and accuracy. The draft maps and a copy of the digital data were also provided to the State of Florida and individual Districts for review. Contractor staff facilitated two 1-day workshops to outline the review process with the districts. The district staff then spent several weeks assessing the maps in the field. During this review period, Contractor analysts also reviewed the draft maps in the field. In addition, all available ancillary GIS and plot data were used in the evaluation process

The hardcopy draft maps were returned to Contractor with comments and editorial notes. To complete the draft map review, Contractor and DOF visited with each of the district teams to gather additional information and discuss their findings.

FUELS MAP EDITING

Final edits were made using the information collected during the draft map review. Edits were made to each district and region (north, middle and south)

The edits focused on specific clusters and associated fuel classes that were difficult to model during the initial modeling process. In areas where obvious non-systematic errors were found, manual editing using a heads up digitizing approach was performed to correct localized errors.

FINAL FUELS MAP PRODUCTION

A final review was done on each region by an analyst other than the one assigned to map and edit the region. This process ensured that all comments were incorporated into the final classification. The final maps were created and a final QC was performed.

TREE CANOPY CLASSIFICATION AND FINAL MAP PRODUCTION

The same imagery that was used to create the fuels map was used to create the tree canopy map. A forest only mask was created by using information from the final fuels map, water management district maps, and gap analysis map. The imagery was masked using the forest only mask. The resulting image was of forested areas only. A 75 class unsupervised classification was ran on each region and initial models were developed. Again the modeling process consisted of a statistical association of spectral classes with the tree canopy classes. The spectral association was based on statistical relationships between field data and spectral information.

Section 2.5 Accuracy Assessment

The final fuel classification map was assessed using two different approaches, a qualitative and a quantitative approach. The quantitative assessment used accuracy assessment sites that were collected at same time the original field data were collected. The qualitative assessment involved random**ly** field checking various areas throughout the state and evaluating the agreement with the final map.

When evaluating the final fuels map it was also important to consider the accuracy of the field data that were used in the creation of the map. For this reason an additional accuracy assessment was created from the actual field data using the information gathered during the field QC/QA phase. This information was also used to derive the fuzzy logic rules for the quantitative assessment.

FIELD DATA REVIEW

Field site QC data were collected to assess the overall quality of the field data. A total of 23 sites were assigned to each district (23 sites x 15 districts = 345 sites), only 268 were actually visited. Sites were marked as correct or incorrect based on the fuel model, vegetation, and tree canopy closure labels.

A confusion matrix was used to summarize the field verification results. The table below shows the first visit fuel model call on the y-axis and the second or QA/QC fuel model call on the x-axis (Table 2).

Table 2. QA/QC Confusion Matrix

Second Visit

First Visit	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM11	FM12	Ag	Urban	Water
FM2	**45**	4	1	3	2	7	2	0	0	0	0	3	0	0
FM3	2	**20**	0	1	0	0	0	1	0	0	0	0	0	0
FM4	1	0	**13**	0	1	1	0	0	1	0	0	0	0	0
FM5	0	0	0	**2**	0	1	0	1	0	0	0	0	0	0
FM6	0	0	1	1	**1**	0	0	0	1	0	0	0	0	0
FM7	0	0	3	0	0	**13**	1	0	0	0	0	0	0	0
FM8	2	0	3	1	1	0	**45**	9	0	0	0	0	0	0
FM9	2	0	2	3	0	6	10	**21**	0	1	0	0	0	0
FM10	0	0	0	0	2	1	0	1	**1**	0	0	0	0	0
FM11	0	0	0	0	0	0	0	0	0	**5**	0	0	0	0
FM12	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0
Ag	2	0	0	0	0	0	0	0	0	0	0	**14**	0	0
Urban	1	0	0	0	0	0	0	0	0	0	0	0	**0**	0
Water	1	0	0	0	0	0	0	0	0	0	0	0	0	**0**

The overall accuracy when comparing the first field visit to the QC visit is 67.5%.

When a site was revisited in the field by a different data collector, 181 of 268 sites were assigned the same label. The matrix shows that there was a high degree of confusion in the shrub and tree litter categories. For example fuel models 8 and 9 are easily confused. On the first visit 61 sites were identified as fuel model 8, and 45 sites were identified as fuel model 9. When these sites were revisited 45 sites were identified as fuel model 8, and 21 sites were identified as fuel model 9. The call for fuel model 8 and 9 agreed 74% and 47% of the time.

Most of the confusion occurring between fuel model types was caused by trying to classify non-discrete conditions such as shrub height, grass height, and the % of grass, shrub, and tree litter into specific discrete classes. This analysis showed that a more flexible analysis was needed to evaluate the overall accuracy of the final map. Because the determination of the fuel model was sometimes not obvious in the field the resulting maps needed a more comprehensive analysis of accuracy.

QUALITATIVE ASSESSMENT

Contractor and Mark Brennan (Contractor), Donald Carlton (Fire Program Solutions), James Brenner and DOF (Florida DOF), spent November 16 through November 21, 2001 field checking the final fuels maps. Specifically, Chipola River, Suwannee, Perry, Jacksonville, Bunnell, Okeechobee and the Orlando districts were visited. A fuel model call was determined in the field and compared to the fuel model identified on the final map. Based on 104 sites that were visited, 85 sites or 81.7% agreed with the map. Through this process, areas requiring minor edits were recorded and the final maps were modified.

QUANTITATIVE ASSESSMENT

The final fuels map was assessed quantitatively by using error matrices. Both traditional (deterministic) and fuzzy error matrices were utilized. The error matrix is a square array of numbers set out in rows and columns which express the number of pixels assigned to a particular category in one classification relative to the number of pixels assigned to a particular category in another classification. The columns usually represent this reference data while the rows indicate the classification generated from the remotely sensed data (Congalton and Green 1999). The error matrix is an effective way to represent accuracy in that the individual accuracies of each category are plainly described along with both the errors of inclusion (commission errors) and errors of exclusion (omission errors) present in the classification. A commission error occurs when an area is included into a category when it doesn't belong. An omission error is excluding that area from the category in which it does belong. Every error is an omission from the correct category and a commission to a wrong category. In addition to showing errors of omission and commission, the error matrix can be used to compute other accuracy measures, such as overall accuracy, producer's accuracy and user's accuracy.

The deterministic matrix used a total of 391 sites, 47 – 50 sites per fuel model. Because there were very few samples of fuel models 1, 5, 6, 10, 11, and 12 they were not included in the quantitative accuracy assessment. The deterministic error matrix identifies sites as correct and incorrect only (Table 3).

Table 3. Deterministic Error Matrix

		MAP							
		FM 2	**FM 3**	**FM 4**	**FM 7**	**FM 8**	**FM 9**	**Ag**	**Water**
	FM 2	**36**	2	0	2	0	0	8	0
F	**FM 3**	7	**37**	0	4	1	0	1	0
I	**FM 4**	3	1	**18**	12	6	5	1	1
E	**FM 7**	3	0	0	**30**	4	11	0	0
L	**FM 8**	4	1	1	4	**35**	4	0	1
D	**FM 9**	4	1	2	8	7	**26**	2	0
	Ag	9	0	0	0	0	0	**39**	1
	Water	0	2	0	1	4	0	0	**42**

The overall accuracy when comparing the field data to the map data is 67.3%.

There were 263 total correctly classified sample units out of 391 total samples; therefore the overall accuracy is 263/391 or 67.3%. Overall accuracy is simply the sum of the major diagonal (i.e., the correctly classified sample units) divided by the total number of sample units in the entire error matrix**.**

The Kappa analysis is a discrete multivariate technique used in accuracy assessment for statistically determining if one error matrix is significantly different than another (Bishop et al. 1975, Congalton and Green 1999). The result of performing a Kappa analysis is a KHAT statistic, which is another measure of agreement or accuracy (Cohen 1960). This measure of agreement is based on the difference between the actual agreement in the error matrix (i.e., the agreement between the remotely sensed classification and the reference data as indicated by the major diagonal) and the chance agreement, which is indicated by the row and column totals (i.e., marginals). In this way the KHAT statistic is similar to the more familiar Chi square analysis. The Kappa coefficient for this assessment is 63.7%.

Two additional accuracy measures include producer's and user's accuracy (Story and Congalton 1986). Producer's accuracy is a measure of omission error, which is the total number of correct samples dived by the total number of samples as derived from the reference data. User's accuracy is a measure of commission error, which is the total number of correct samples divided by the total number of samples that were classified in that category. The results are presented below:

3Producers Accuracy

Fuel Model 2 = 36/66 = 54.5%
Fuel Model 3 = 37/44 = 84.1%
Fuel Model 4 = 18/21 = 85.7%
Fuel Model 7 = 30/61 = 49.12%
Fuel Model 8 = 35/57 = 61.4%
Fuel Model 9 = 26/46 = 56.5%
Agriculture = 39/51 = 76.5%
Water = 42/45 = 93.3%

Users Accuracy

Fuel Model 2 = 36/48 = 78.0%
Fuel Model 3 = 37/50 = 74.0%
Fuel Model 4 = 18/47 = 38.0%
Fuel Model 7 = 30/48 = 63.0%
Fuel Model 8 = 35/50 = 70.0%
Fuel Model 9 = 26/50 = 52.0%
Agriculture = 39/49 = 80.0%
Water = 42/49 = 86%

One of the assumptions of the traditional or deterministic error matrix is that an accuracy assessment sample site can have only one label. However, classification scheme rules often impose discrete boundaries on continuous conditions in nature, such as fuel type in this case. For this project, both deterministic and fuzzy error matrices will be compiled. Fuzzy error matrices take into account areas that although they are not absolutely correct, are acceptable based on the fuzzy rules. For example areas mapped as fuel model 9 may be acceptable if they were mapped as a fuel model 7 as confusing between fuel model 9 and 7 can occur when the percentage of shrub and timber litter under the canopy both approach 50%.

As part of this process, rules were developed using the existing classification scheme, experience from the field, input from the DOF staff on their field data forms and results from the QA/QC analysis to determine which classification errors are acceptable and unacceptable.

The following are the proposed fuzzy logic rules for the map classes As stated above, these rules were developed based on the classification scheme, experience in the field during the draft and final map review, information provided by the DOF field staff on the field forms and results from the QA/QC of the field data.

Table 4. Fuzzy Rules

FUEL MODEL 2
FUEL MODEL 3 IS ACCEPTABLE. THIS IS BASED ON THE CONFUSION IN THE FIELD BETWEEN FUEL MODELS 3 AND 2 BASED ON GRASS HEIGHT. FUEL MODEL 97 IS ACCEPTABLE. THIS IS BASED ON PASTURE BEING CLASSIFIED AS AGRICULTURE VS. GRASS.
FUEL MODEL 3
FUEL MODEL 2 IS ACCEPTABLE. THIS IS BASED ON THE CONFUSION IN THE FIELD BETWEEN FUEL MODELS 3 AND 2 BASED ON GRASS HEIGHT.
FUEL MODEL 4
FUEL MODEL 7 IS ACCEPTABLE. THE DIFFERENCE BETWEEN THE TWO FUEL MODELS IS BASED ON SHRUB HEIGHT (6 FEET BEING THE CUT-OFF). FUEL MODEL 9 IS ACCEPTABLE. THE LINE BETWEEN THESE TWO FUEL MODELS IS % TIMBER LITTER VS. SHRUB.
FUEL MODEL 7
FUEL MODEL 4 IS ACCEPTABLE. THE DIFFERENCE BETWEEN THE TWO FUEL MODELS IS BASED ON SHRUB HEIGHT (6 FEET BEING THE CUT-OFF). FUEL MODEL 9 IS ACCEPTABLE. THERE IS CONFUSION BETWEEN THESE TWO CLASSES AS SHRUB COVERAGE DECREASES.
FUEL MODEL 8
FUEL MODEL 9 IS ACCEPTABLE. FOR MIXED FOREST AREAS THERE IS CONFUSION BETWEEN THESE TIMBER LITTER MODELS DEPENDING ON THE FOREST/LITTER COMPOSITION %.
FUEL MODEL 9
FUEL MODEL 8 IS ACCEPTABLE. FOR MIXED FOREST AREAS THERE IS CONFUSION BETWEEN THESE TIMBER LITTER MODELS DEPENDING ON THE FOREST/LITTER COMPOSITION %. FUEL MODEL 7 IS ACCEPTABLE. THERE IS CONFUSION BETWEEN THESE TWO CLASSES AS SHRUB COVERAGE DECREASES.
FUEL MODEL 97
FUEL MODEL 2 IS ACCEPTABLE. THIS IS BASED ON PASTURE BEING CLASSIFIED AS AGRICULTURE VS. GRASS.

Table 5. Error Matrix with Fuzzy Classes

		MAP							
		FM 2	FM 3	FM 4	FM 7	FM 8	FM 9	Ag	Water
R	FM 2	36	2/0	0/0	0/2	0/0	0/0	8/0	0/0
E	FM 3	7/0	37	0/0	0/4	0/1	0/0	0/1	0/0
F	FM 4	0/3	0/1	18	12/0	0/6	5/0	0/1	0/1
E	FM 7	0/3	0/0	0/0	30	0/4	11/0	0/0	0/0
N	FM 8	0/4	0/1	0/1	0/4	35	4/0	0/0	0/1
C	FM 9	0/4	0/1	0/2	8/0	7/0	26	0/2	0/0
	Ag	9/0	0/0	0/0	0/0	0/0	0/0	39	0/1
	Water	0/0	0/2	0/0	0/1	0/4	0/0	0/0	42

Total overall accuracy when including the fuzzy rules is 84.0%

The off diagonal elements in the fuzzy error matrix contain two separate values (Table 5). The first value represents those that, although not absolutely correct, are acceptable within the fuzzy rules. The second value indicates those that are still unacceptable. Therefore, in order to compute accuracies (overall, producer's and user's), the values along the major diagonal and those deemed acceptable (i.e., those in the first value) in the off diagonal elements are combined. This combination of absolutely correct and acceptable answers totals 336 out of 400 total samples results in an overall accuracy of 84.0%. This overall accuracy is significantly higher than the original (deterministic) error matrix.

The producer's and user's accuracy results are presented below:

Producers Accuracy

Fuel Model 2 = 52/66 = 78.8%
Fuel Model 3 = 39/44 = 88.6%
Fuel Model 4 = 18/21 = 85.7%
Fuel Model 7 = 50/61 = 82.0%
Fuel Model 8 = 42/57 = 73.7%
Fuel Model 9 = 46/46 = 100%
Agriculture = 47/51 = 92.2%
Water = 42/45 = 93.3%

Users Accuracy

Fuel Model 2 = 46/50 = 92.0%
Fuel Model 3 = 44/50 = 88.0%
Fuel Model 4 = 35/50 = 70.0%
Fuel Model 7 = 41/50 = 82.0%
Fuel Model 8 = 39/50 = 78.0%
Fuel Model 9 = 41/50 = 82.0%
Agriculture = 48/50 = 78.0%
Water = 42/50 = 84%

Section 2.6 Change Detection Pilot Study

PURPOSE

The purpose of the pilot change detection project was developing methods for identifying and mapping fuel model changes in the state of Florida. This methodology will be used to periodically to update the Fire Behavior Prediction System (FBPS) Fuel Model map of the state. The study area, which included the Landsat path 17, row 39 scene, focused on the Suwannee District. The results of the pilot project and the methodology will used repeatedly for updating the statewide fuels map.

DATA ACQUISITION

Terrain corrected Landsat TM imagery was acquired for the project area. The updated Landsat 7 imagery was acquired on 3/28/2002. The original Landsat 5 scene used for the fuels mapping was acquired on 3/28/1999.

IMAGE PRE-PROCESSING

The first step in pre-processing was to ensure that the two Landsat scenes were properly co-registered. Improper registration can cause errors in the change detection by labeling edge areas as change when there are not. The best way to verify the co-registration is to follow linear and point features that are not subject to change during the time between the two dates of imagery. Features such as roads, intersections, parking lot corners and other relatively permanent features work very well. Features such as agricultural fields and waterlines should be avoided as crop rotations and weather influences may change these types of features. Registration between imagery should be less than one pixel RMS (Root Mean Square), preferably less than 0.5 pixels.

Following verification of the registration, the pixel edges of the most recent imagery were aligned with the edges of the original imagery. The 2002 Landsat 7 imagery was shifted 15 meters north and 20 meters west to align the pixel edges with our base 1999 Landsat 5 imagery.

Once the imagery was aligned it was stacked into a single multi-date composite image file. This stack was the input to the multi-temporal change classification but it can also be used to visually identify changed when used with a multi-temporal band combination such as:

Red = NIR 2002, Green = NIR 1999, Blue = NIR 1999

For this band combination, changes will be displayed in red or cyan depending on the direction of change in the pixel values. Pixels that have a higher value in 2002 will be red and pixels with a lower value in 2002 will be cyan. More brilliant colors indicate a higher magnitude of change. Gray areas in the imager indicate areas of relatively little or no change.

The first step when stacking the two dates of imagery was to set the analysis window in the ERDAS Imagine Spatial Modeler. The window was set to the extent of the Landsat 5 scene used in the original fuels classification (3/28/1999). Using the original imagery eliminates any need to shift the final classification at the end of the project to match the original fuels map. The inputs to the modeler are the two Landsat scenes, which are layered using the Layer Stack function and output to a new file.

The multi-temporal stacked image was the input to an unsupervised classification to generate a signature file. The signature file was used as an input to a Maximum Likelihood classifier, which in turn generates the cluster layer and statistics needed for the change detection. The unsupervised classification parameters to generate the signature file are as follows:

Number of Classes: 255
Maximum Iterations: 40
Convergence Threshold: 0.97
Initialize from Statistics
Initializing Options
  Initialize means along principal axis
  Automatic Scaling
Color Scheme Options: NIR 2002 (R) NIR 1999 (G) NIR 1999 (B)

Two hundred fifty five classes were used to allow the clusters freedom to group into as many clusters as an 8-bit image will allow. In most cases several clusters will contain no pixels in the output layer and suggests that fewer clusters were needed to capture the spectral variability.

Maximum Iterations and convergence threshold values are related. The Maximum Iterations needs to be set high enough to allow 97% of the pixels to remain in their respective cluster in the last iteration. To clarify, the initial iterations in the bins in which the pixels are grouped are separated in equal divisions. In subsequent iterations pixels migrate to bins where the statistics are more similar. Eventually 97% of the pixels will stay in their bin and the classification will finish.

Statistics were initialized using the Principal Axis. This is the vector that all layers in the imagery have most in common with. The Principal Axis or first Principal Component is generally related to image brightness. The Color Scheme Option is not necessary, however it provides visual cues to where the change is occurring.

FIELD DATA COLLECTION

Contractor delineated 948 potential field sample sites and provided the Florida Division of Forestry staff with maps and field forms to collect additional field sites. Contractor spent a day in Lake City with DOF staff to review the field data collection methodology. Data were collected for 932 of the 948 total sites. Of these, 694 sites were visited, 93 were viewed from a distance, 137 were not observable and 8 sites did not have a level of observation indicated. Of the total sites, 159 were determined to be questionable due to inconsistencies on the data form, of these sites, a fuel model was assigned to 48. The field data will be reviewed and entered into a GIS coverage and provided to the Division of Forestry. During the field training it was decided that all clear-cut areas with large slash piles were to be classified as fuel model 11, therefore areas classified as fuel model 10 that were clear cuts were recoded to fuel model 11.

IMAGE CLASSIFICATION

CHANGE CLASSIFICATION

The output cluster layer contains up to 256 values reflecting the 256 classes input in the unsupervised classification step. The attributes contain mean value columns for each of the

256 clusters in each of the spectral bands in the multi-temporal image stack. In order to perform change detection, several new attribute columns must be calculated.

The first attribute that needs to be calculated is a difference column. Because the goal was to detect vegetation changes, the near infrared signature means were used in this calculation (specifically layers 4 and 10 in the image stack). The order of the subtraction is not important as long as it is documented. In this project the NIR 1999 signature mean (layer 4) was subtracted from the 2002 signature mean (layer 10). This operation resulted in positive differences for higher NIR values in 2002 and negative values where NIR values are lower in 2002.

Once the difference column was calculated, mean and standard deviation statistics were calculated for the column. All clusters except 0 (unclassified) and clusters with no pixels (histogram = 0) were selected when calculating the statistics. The mean of the difference column should be near zero, if it is not the calculations should be redone. In this case the mean was a difference of 5.3. The reason the mean is not zero is that differences in weather characteristics, atmospheric effects, phonological stage, and moisture content can impact the pixel values from year to year. Also, the number of pixels in the clusters is not distributed evenly. These factors do not influence the change detection because each direction of change threshold is determined independently.

The final calculation is a standard deviation interval. This is calculated as follows:

(NIR Difference – NIR difference mean) / NIR Difference Standard Deviation

The standard deviation is helpful when determining thresholds quickly. Generally, clusters with a standard deviation that has an absolute value of greater than 3 are most likely change and can be labeled quickly.

Thresholding is a technique used to systematically determine the value where change is separated from no-change. To make this process easier the attribute should be sorted by standard deviation interval. Starting with the positive tail of the standard deviation intervals, clusters were highlighted that had the largest whole number value. Fore example, if the largest value was 6.3 standard deviations, the standard deviation interval values greater than or equal to 6 are highlighted. Comparing the two dates of imagery as well as any other data helped to confirm that change had occurred to the highlighted clusters. If the area highlighted was determined to be change, the opacity to those clusters was turned off and the next lower whole number standard deviation interval was highlighted (Highlight intervals greater than or equal to 5 and less than 6). The process was repeated until there were areas highlighted that did not appear as change. Within that interval, each cluster was checked individually until the value and cluster where change is separate from no change was found and the interval value closest to the mean where change occurs was noted. The entire process was repeated for the negative standard deviation tail starting with the most negative interval. If there was a question as to whether a cluster near the threshold was change or no-change a decision was made to over-classify change rather than exclude areas that may be change.

CHANGE MASK CREATION

Once the thresholds were determined, a change mask was created by recoding the cluster layer. The clusters determined to be change clusters were those in the positive standard deviation tail to a value of 1 and those change clusters in the negative tail to 2, both were recoded. The no-change clusters were all coded to 0. The output mask then identified change and the direction of change. The next step was to eliminate areas too small to evaluate. To be considered as significant change the area needed to contain a minimum of 25 contiguous pixels otherwise the change pixels were eliminated. This was accomplished through the clump and sieve utility in ERDAS Imagine.

MASKING IMAGERY TO CHANGE AREAS

In order to classify fuels in change areas, the most recent image (2002 in this case) was masked using the change mask. To ensure the data was snapped to the original classification, this task was performed using the Spatial Modeler with the original (1999) imagery coordinates to set the window. In the model, areas in the 2002 imagery were written in areas where the mask was greater than 0. The output image was used in the fuels classification.

ASSIGNING FUEL LABELS TO AREAS OF CHANGE

The signature file (developed from the field sites) and stacked multi-temporal image were the inputs used in the supervised classification. The supervised classification was run in order to assign labels to the areas identified as change. Using the Supervised Classification tool in ERDAS Imagine, the following items were specified:

Input Raster: Image stack (Landsat 7 bands 1-5 and 7)
Input Signature: Signature file created from the field sites
Distance File: None
Fuzzy Classification: Unchecked
Non-parametric Rule: None
Parametric Rule: Maximum Likelihood
Classify zeros: Unchecked
Use Probabilities: Unchecked

DRAFT MAP REVIEW

Contractor's Remote Sensing Analyst, spent four days in the field reviewing the draft maps for accuracy. The fuels classification for the areas of change was overlaid onto the Landsat imagery to create field maps. As sites were visited, notes were made on the fuels directly on the map and systematic errors were identified. The total area visited in the field equaled eight, 1:24,000 quads throughout the study area.

EDITING AND FINAL MAP PRODUCTION

Following the draft map review, final edits were made to the draft fuels classification based on field notes and pictures. Final maps were produced and distributed to the Division of Forestry for internal review and assessment.

ACCURACY ASSESSMENT

A qualitative assessment of the final fuels change map was performed during a field trip the week of October 7 through October 9. Contractor, Jim Brenner and DOF met with Lee Barnwell from the Suwannee district and John Fish from the Perry District. During this the change detection maps were reviewed and areas that had been misclassified were noted as such. Following the map review, we made edits to the areas that had been identified in the field and created a new fuels map. Because several issues were identified in the Mallory Swamp area we crated a second draft map of the area and received final comments from the Perry District and incorporated those edits into the final map.

SECTION 3.0 GIS DATA INTEGRATION

Contractor worked directly with the Florida Division of Forestry to define the GIS layers that were critical to the Fire Risk Assessment. Once the required model inputs were defined and acquired, Contractor performed quality control, co-registered the data sets to Florida's customized Albers projection in the HPGN datum, aligned all grids to each other, and partitioned layers into established management units as listed in Table 1. Abbreviations used per established management unit, DoF district, in the naming convention of the files.

Table 6. DOF Districts

District	Abbreviation
Blackwater	BLA
Bunnell	BUN
Caloosahatchee	CAL
Chipola River	CHI
Everglades	EVE
Jacksonville	JAC
Lakeland	LAK
Myakka River	MYA
Okeechobee	OKE
Orlando	ORL
Perry	PER
Suwannee	SUW
Tallahassee	TAL
Waccasassa	WAC
Withlacoochee	WIT

Table 7. Index of GIS Data Stack

Layer Name	Description and Methodology
Aspect	Slope and aspect affect the way a fire behaves. This layer will be used to model fire behavior. Pensacola Quad was processed differently than the rest of the state. Therefore, SIS filtered the Pensacola Quad in order to limit the effect of the smearing and pixelization from the original dataset. Slope and Aspect were calculated independently for the Pensacola Quad and then later joined with the Slope and Aspect for the rest of the state. This was to limit the edge elevation differences that would adversely effect the slope and aspect calculations.
Census Data	The Redistricting Census 2000 TIGER/Line files were downloaded as shapefiles from http://www.geographynetwork.com/data/tiger2000 per county. They were unzipped, converted from ArcView shapefiles to ArcInfo, joined together, and projected to the Alber's projection. The census data files from USGS became available on March 27, 2001 and were downloaded. They were later updated on 9/28/2001. The files were imported into Access for easier manipulation. Key fields from the database that were joined to the spatial coverage were: total population, households, housing units, land area and water area. Population density, household density, and housing unit density were calculated.
Critical Facilities	This layer is made up of the information contained within the burn authorization plan. Buffers shall be set at 1000m for airport and heliports and 500m from any other feature contained in the critical facilities layer. This layer represents areas that are sensitive to smoke.
Cultural Resources	The following datasets were used to generate this cultural resource coverage: non-sensitive historical structures, greenways project cultural and historic features, bridges, cemeteries, national register of historic places, standing structures, and archaeological sites. A 90m buffer was placed around each of the points, lines or polygons contained in the above datasets. These buffered coverages were then joined into one cultural resources coverage.
Dead End Roads	Dynamap/1000 is a vector based, digital, geographic database in which streets and features are represented as line segments, polygons or points. Each side of a street or feature has associated data such as Census codes and Federal Information Processing Standards (FIPS) codes. Street segments have street name information, address ranges, and ZIP Codes. For more information regarding the dynamap databases, see the GDT User's Guide.
Delayed Access,	Accessibility was derived from buffers being placed around GDT

Inaccessible Areas	roads. The access codes are as follows: accessible - < ½ mile from nearest road, delayed accessibility - ½ mile to 1 mile from nearest road, inaccessible - > 1 mile from nearest road,
District Boundaries	District Boundaries for the Division of Forestry. The district boundaries were clipped to the 1:24,000 seashore to remove water. Liberty County was clipped out of the 1:24,000 county coverage and joined with Tallahassee district and removed from Chipola River district.
Drainage Ditches	Ditches pose a threat to fire fighting activities in that personnel may not be able to safely reach a fire due to blockage by canal. Ditches have been extracted from the USGS hydrological coverage. The USGS defined 'DITCH OR CANAL' as any manmade, flowing water feature used to irrigation, drainage or transportation.
Elevation	DEM data records elevation in meters above mean sea level. Roughly 85% of public domain DEM's have level 2 and below processing, meaning that they have received some post processing by USGS. Common post processing methods include filling of sinks and low level filtering to remove "noise" that can occur in flat areas. SIS will not be providing any post processing to DEM's for input into the system. 1:250,000 Scale 90m DEM's will make up the data layer. All DEM data will be mosaiced to provide the basis for a number of system layers, namely slope and aspect. Pensacola Quad was processed differently than the rest of the state. Therefore, SIS filtered the Pensacola Quad in order to limit the effect of the smearing and pixelization from the original dataset.
Fuels	Fuel map of the state of Florida based on the Anderson classification scheme (Anderson, Hal E. 1982. Aids to determining fuel models for estimating fire behavior. USDA For. Serv. Gen. Tech. Rep. INT-122, 22p. Intermt. For. And Range Exp. Stn., Ogden, Utah 84401).
Hazardous Waste Sites	Superfund, storage tanks and contaminated tanks derived from the Department of Environmental Protection data. Only active or open status sites were selected to remain in the hazardous waste site data layer.
Historical Fire Locations	This layer was derived from the State of Florida's database on past fire occurrence combined with Federal Fire Occurrence data from the Forest Service, Department of Interior and the Department of Defense. The data has been collected and reviewed for data quality and merged. Redundant points were removed based on land ownership, if the fire in the database fell outside of the jurisdiction for that agency then it was removed.
Land Management	Land management boundaries derived from the managed_areas

	coverage from the DOF, the Eglin Air Force Base from Eglin and BIA lands from the Bureau of Indian Affairs.
Non-Burnable Areas	This layer is derived from the fuels map using the water management district land use / land cover as ancillary data. The following is the list of land cover types from the water management district LULC coverage developed to represent non-burnable lands: Residential High Density, Commercial and Services, Industrial, Lakes, Reservoirs, Oceans Seas and Gulfs, Beaches Other than Swimming, Sand Other than Swimming, Bare Ground, and agriculture.
Potential Weather	Weather data was collected from the National Fire Danger Rating System's (NFDRS) weather stations and the National Weather Service *Summary of the Day* data available from the National Climatic Data Center. The weather data was amalgamated per Weather Influence Zones, or areas of relatively homogenous weather patterns. The National Weather Service Forecast Zones were used to define the weather influence zones. Weather percentiles per zone are determined to model the effects normal to extreme weather has on fire behavior. These percentiles were calculated using the software program FireFamilyPlus.
Resource Locations	Locations of DOF's, USFS, and local fire department fire fighting personnel and resources. This coverage is used to determine the accessibility to fire locations.
Road Density	Dynamap/1000 is a vector based, digital, geographic database in which streets and features are represented as line segments, polygons or points. Each side of a street or feature has associated data such as Census codes and Federal Information Processing Standards (FIPS) codes. Street segments have street name information, address ranges, and ZIP Codes. For more information regarding the dynamap databases, see the GDT User's Guide. The GDT road database was used to generate a road density coverage where the units are meter length of road per square meter of area.
Roads	Dynamap/1000 is a vector based, digital, geographic database in which streets and features are represented as line segments, polygons or points. Each side of a street or feature has associated data such as Census codes and Federal Information Processing Standards (FIPS) codes. Street segments have street name information, address ranges, and ZIP Codes. For more information regarding the dynamap databases, see the GDT User's Guide.
Slope	Slope and aspect affect the way a fire behaves. This layer will be used to model fire behavior. Pensacola Quad was processed differently than the rest of the state. Therefore, SIS filtered the Pensacola Quad in order to limit the effect of the smearing and pixelization from the original dataset. Slope and Aspect were calculated independently for the Pensacola Quad and then later joined with the

	Slope and Aspect for the rest of the state. This was to limit the edge elevation differences that would adversely effect the slope and aspect calculations.
SURGO Muck Soils	Muck soils were extracted from SURGO data by the DOF. Muck soils constitute areas of concern for fire fighting efforts, as fires within these areas tend to be expensive and difficult to extinguish. Two classes were determined: Class 1: "Organic Soils" (histosols) are true organic soils with greater than 16" of peat or muck. These soils will present the greatest problem to fire suppression efforts. Class 2: Soils that can have a veneer of organic soil typically less that 16". These are important to identify because they may pose some difficulty.
Threatened and Endangered Species Negatively Impacted by Fire	Occurrence-based potential habitat for rare species that are negatively impacted by fire. The habitat data was created by selecting suitable land cover types within the vicinity of known occurrences of the species. This is different from other potential habitat methods that are more predictive--that is they model any habitat that might be suitable for the species regardless of whether known occurrences exist.
Tree Canopy Cover	Tree canopy cover was classified into 4 groups: 1 – 0 to 20% tree canopy cover 2 – 21 to 50% tree canopy cover 3 – 51 to 80% tree canopy cover 4 – 80 to 100% tree canopy cover
Urban Interface	The urban interface will be derived from a combination of the urban areas delineated on the fuels map and the Census Bureau data. This layer will highlight key areas for fire prevention based on the human element. The urban interface areas are buffered by 990m to sufficiently represent areas of concern. Two grids were created to represent the buffers around the two types of potential interfaces that exist within the state of Florida. These grids were defined according to the NIFC (defn: the urban wildland interface community exists where humans and their development meet or intermix with wildland fuel): Category 1. Interface Community – exists where structures directly abut wildland fuels. There is a clear line of demarcation between residential, business and public structures and wildland fuels. Wildland fuels do not generally continue into the developed area. The development density for an interface community is usually 3 or more structures per acre, with shared municipal services. Fire protection is generally provided by a local government fire department with the responsibility to protect the structure from both an interior

	fire and an advancing wildland fire. An alternative definition of the interface community emphasizes a population density of 250 or more people per square mile. Category 2. Intermix Community – The Intermix Community exists where structures are scattered throughout a wildland area. There is no clear line of demarcation; wildland fuels are continuous outside of and within the developed area. The development density of the intermix ranges from structures very close together to one structure per 40 acres. Fire protection districts funded by various taxing authorities normally provide life and property fire protection and may also have wildland fire protection responsibilities. An alternative definition of intermix community emphasizes a population density of between 28-250 people per square mile.
Utility Corridors	Buffered transmission and gas lines – inside the buffer represents areas where smoke and fire can become dangerous for utility companies.

These data layers, in part, were used to develop the inputs into the final GIS data. The layers in the final stack include all the modeled layers from the Fire Risk Assessment. Figure 1 shows the relationship between the model inputs.

Figure 1. Relationship Between GIS Layers in Data Stack

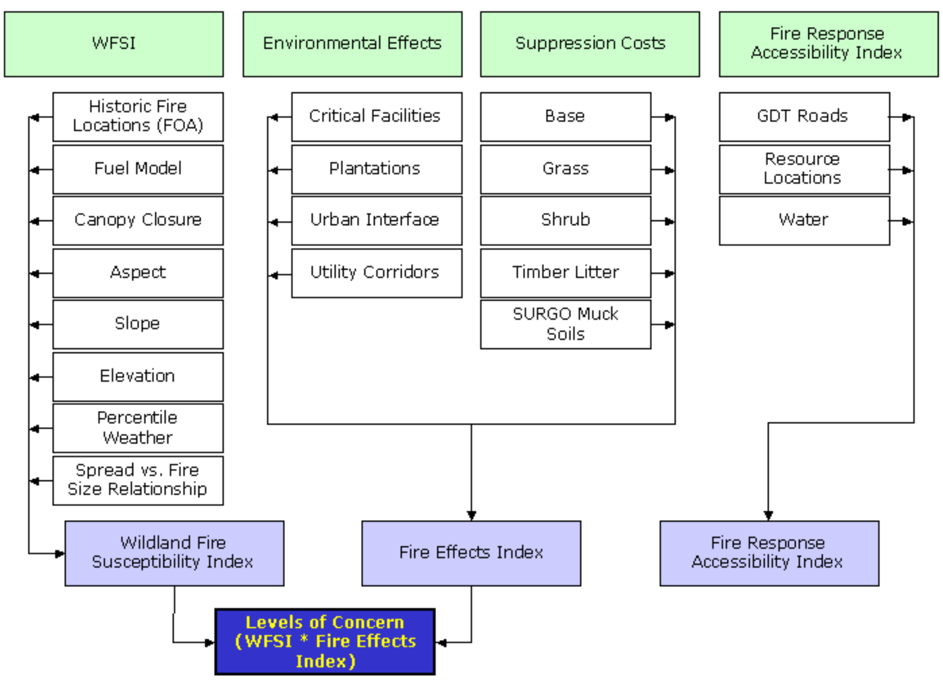
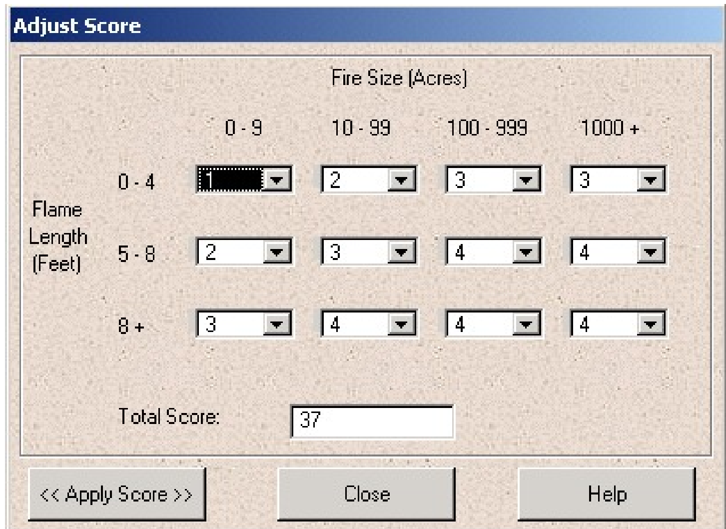


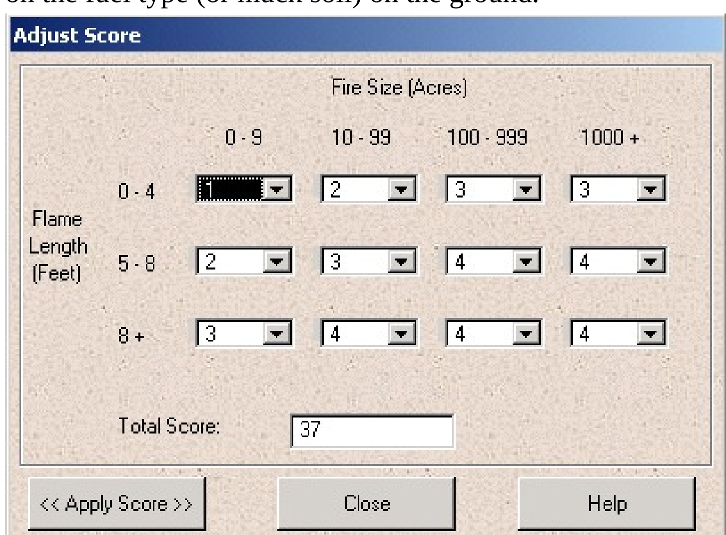
Table 8 GIS Data Layers Included in the Final GIS Data Stack.

Layer Name	Description and Methodology
Aspect	Slope and aspect affect the way a fire behaves. This layer will be used to model fire behavior. Pensacola Quad was processed differently than the rest of the state. Therefore, SIS filtered the Pensacola Quad in order to limit the effect of the smearing and pixelization from the original dataset. Slope and Aspect were calculated independently for the Pensacola Quad and then later joined with the Slope and Aspect for the rest of the state. This was to limit the edge elevation differences that would adversely effect the slope and aspect calculations.
Base File for Non-Spatial Analyst Users	This coverage was created to reduce processing time for modeling for the non-spatial analyst users. The following coverages were unioned together to produce the locbase shapefile: Critical facilities Plantation Urban Interface Utility Corridors SURGO Muck Soils Fire Carrier Fire Response Accessibility Index
Critical Facilities	This layer is made up of the information contained within the burn authorization plan. Buffers shall be set at 1000m for airport and heliports and 500m from any other feature contained in the critical facilities layer. This layer represents areas that are sensitive to smoke.
District Boundaries	District Boundaries for the DoF. The district boundaries were clipped to the 1:24,000 seashore to remove water. Liberty County was clipped out of the 1:24,000 county coverage and joined with Tallahassee district and removed from Chipola River. The boundaries were then converted to GRID for spatial modeling.
Elevation (Digital Elevation Model)	DEM data records elevation in meters above mean sea level. Roughly 85% of public domain DEM's have level 2 and below processing, meaning that they have received some post processing by USGS. Common post processing methods include filling of sinks and low level filtering to remove "noise" that can occur in flat areas. SIS will not be providing any post processing to DEM's for input into the system. 1:250,000 Scale 90m DEM's will make up the data layer. All DEM data will be mosaiced to provide the basis for a number of system layers, namely slope and aspect. Pensacola Quad was processed differently than the rest of the state. Therefore, SIS filtered the Pensacola Quad in order to limit the effect of the smearing and pixelization from the original dataset.
Environmental Effects	This layer was derived through the FRAS (Fire Risk Assessment System) to determine the levels of environmental effects. The environmental ef-

	fects that are included in this analysis are critical facilities (from DoF burn authorization plan and include schools, hospitals, airports, interstates and highways, etc.), plantations (natural and planted), urban interface, and utility corridors (transmission lines). Each environmental input was assigned an effects score by DoF fire managers using the matrix below:  To arrive at a final environmental effects score, the individual total scores for the inputs; critical facilities, urban interface, plantations and utility corridors were each divided by 192 (highest potential score is 48 with 4 inputs = 4*48=192). These numbers were then summed to provide the total environmental effects. The equation used for the published results was: Environmental Effects = [((33/192)*cfac)+((31/192)*plnt)+ ((37/192)*urbn)+((27/192)*util)]*100
Fire Carrier	Fuels are classified into four groups: grass, brush, timber litter and slash. According to Anderson (1982. Aids to Determining Fuel Models For Estimating Fire Behavior USDA For. Serv. Gen. Tech. Rep INT-122, 22p. Intermt. For. And Range Exp. Stn., Ogden, Utah 84401), the differences in fire behavior among these groups are related to the fuel load and size class. A grass fire carrier is further split into Fuel Models 1, 2, and 3; Brush fire carrier is split into Fuel Models 4, 5, 6, and 7; Timber Litter fire carrier is split into Fuel Models 8, 9, and 10; Slash fire carrier is split into Fuel Models 11, 12, and 13. Due to the nature of slash fuel models and the speed in which they change to another type of fire carrier, slash was not extracted into this fire carrier grid. Instead, slash was combined with non-burnable lands into an ‘Other’ category.
Fire Effects	The purpose of the index is to identify those areas that have environmental values at risk to wildfire and/or are costly to suppress. The fire effects index was calculated by combining the final environmental effects

	and suppression costs grids using the following equation: Fire Effects = (0.80 * Environmental Effects) + (0.20 * Suppression Costs) The final fire effects values range from 0 – 100.
Fire Occurrence Areas	The Fire Occurrence Area is based on historic fire ignition data from the Division Forestry, the USDI-Department of the Interior (DOI) and the Department of Defense (DOD). Fire occurrence data for the DOI agencies included the National Park Service, the Fish and Wildlife Service and the Bureau of Indian Affairs. Fire occurrence data for the DOD agencies included US Air Force's Eglin Air Force Base. Fire occurrence data was gathered for 20 years. The years 1981-2000 are used for the base period. For some agencies, fire occurrence data was not available for this entire time period and for these agencies, fire occurrence was annualized based on the number of years available. A surface grid was generated from the point locations using Inverse Distance Weighting (IDW) modeling techniques.
Fire Response Accessibility Index	The fire response accessibility index is calculated based on distance from fire fighting resource locations. The speed traveled on roads was estimated at 40 miles per hour with travel on roads being projected as eight times faster than travel off road. Water was coded as 'NO DATA', meaning that travel across water could not be done unless there was a road crossing. A cost distance analysis was run using ArcView to assign an approximate time to reach each cell.
Fuels	Fuel map of the state of Florida based on the Anderson classification scheme (Anderson, Hal E. 1982. Aids to determining fuel models for estimating fire behavior. USDA For. Serv. Gen. Tech. Rep. INT-122, 22p. Intermt. For. And Range Exp. Stn., Ogden, Utah 84401).
Levels of Concern	The Levels of Concern value was assigned by multiplying the wildland fire susceptibility index by the fire effects index. The LOC output can be used to prioritize areas for further analysis.
Non-Burnable Areas	This layer is derived from the fuels map using the water management district land use / land cover as ancillary data. The following is the list of land cover types from the water management district LULC coverage developed to represent non-burnable lands: Residential High Density, Commercial and Services, Industrial, Lakes, Reservoirs, Oceans Seas and Gulfs, Beaches Other than Swimming, Sand Other than Swimming, Bare Ground, and agriculture.
Plantations	Actively managed and natural plantations.
Resource Locations	Locations of DOF's, USFS, and local fire department fire fighting personnel and resources. This coverage is used to determine the accessibility to fire locations. The local fire department dataset contains a point coverage of fire stations, EMS, and volunteer fire department locations. Ten of these point

<table>
<tr><td></td><td>locations fell outside of the shoreline boundary and were therefore removed from the database.</td></tr>
<tr><td>Roads</td><td>Dynamap/1000 is a vector based, digital, geographic database in which streets and features are represented as line segments, polygons or points. Each side of a street or feature has associated data such as Census codes and Federal Information Processing Standards (FIPS) codes. Street segments have street name information, address ranges, and ZIP Codes. For more information regarding the dynamap databases, see the GDT User's Guide.</td></tr>
<tr><td>Slope</td><td>Slope and aspect affect the way a fire behaves. This layer will be used to model fire behavior. Pensacola Quad was processed differently than the rest of the state. Therefore, SIS filtered the Pensacola Quad in order to limit the effect of the smearing and pixelization from the original dataset. Slope and Aspect were calculated independently for the Pensacola Quad and then later joined with the Slope and Aspect for the rest of the state. This was to limit the edge elevation differences that would adversely effect the slope and aspect calculations.</td></tr>
<tr><td>Suppression Costs</td><td>The suppression costs are evaluated by fire carrier. Each cell in the state has been assigned a base, grass, shrub, timber litter or muck suppression score. DoF fire managers used the matrix shown below to assign the base and muck scores. The grass, shrub and timber litter scores were based on suppression billing information provided by the DoF districts for the past five years. The final suppression value for each cell was assigned based on the fuel type (or muck soil) on the ground.



The following code was used to generate Suppression Costs:
IF (Muck exists) then (60/72)
Else if (grass exists) then (9/72)
Else if (shrub exists) then (33/72)</td></tr>
</table>

	Else if (timber litter exists) then (40/72) Else (32/72) End IF
SURGO Muck Soils	Muck soils were extracted from SURGO data by the DOF. Muck soils constitute areas of concern for fire fighting efforts, as fires within these areas tend to be expensive and difficult to extinguish.
Towns and Municipal Boundaries	Town and Municipal Boundaries for the state of Florida GDT extracted the data included in these boundary files from the 1990 Census Version TIGER/Line files (CD-ROM edition). For more information regarding the Towns and Municipal Boundary layer, please refer to the Place Boundary files in the GDT Data Users Guide.
Tree canopy cover	Tree canopy cover. The values in the dataset have the following meanings: 0 – background 10 – 0 to 20% tree canopy cover 30 – 21 to 50% tree canopy cover 60 – 51 to 80% tree canopy cover 75 – 80 to 100% tree canopy cover
Urban Interface	The urban interface was derived from a combination of the urban areas delineated on the fuels map and the Census Bureau data. This layer highlights key areas for fire prevention based on the human element. The urban interface areas are buffered by 990m to sufficiently represent areas of concern. Urban Interface was created to represent the buffers around the two types of potential interfaces that exist within the state of Florida. These grids were defined according to the NIFC (defn: the urban wildland interface community exists where humans and their development meet or intermix with wildland fuel): URBN1: Category 1. Interface Community – exists where structures directly abut wildland fuels. There is a clear line of demarcation between residential, business and public structures and wildland fuels. Wildland fuels do not generally continue into the developed area. The development density for an interface community is usually 3 or more structures per acre, with shared municipal services. Fire protection is generally provided by a local government fire department with the responsibility to protect the structure from both an interior fire and an advancing wildland fire. An alternative definition of the interface community emphasizes a population density of 250 or more people per square mile. URBN2: Category 2. Intermix Community – The Intermix Community exists where structures are scattered throughout a wildland area. There is no clear line of demarcation; wildland fuels are continuous outside of and within the developed area. The development density of the intermix ranges from structures very close together to one structure per 40 acres.

	Fire protection districts funded by various taxing authorities normally provide life and property fire protection and may also have wildland fire protection responsibilities. An alternative definition of intermix community emphasizes a population density of between 28-250 people per square mile.
Utility Corridors	Buffered transmission lines – inside the buffer represents areas where smoke and fire can become dangerous for utility companies.
Water	Areas of water extracted from the Fuels classification grid.
Weather Influence Zone (Low, Moderate, High and Extreme) Weather Category	Potential fire behavior was evaluated using the program FlamMap. FlamMap is a GIS-based analytic tool. It uses topographic information, fuel characteristics, and weather to calculate rate-of-spread, flame length, fire type, and other characteristics of fire behavior. The purpose of using FlamMap is to generate fire behavior data that are comparable across the landscape for a given set of weather, fuels and fuel moisture data inputs. FlamMap is based on the GIS data themes and algorithms used in FARSITE (Fire Area Simulator) as described by Finney (1998). GIS data are required for 5 data themes and optional for 3 themes as follows: The fire behavior variable calculated by FlamMap for the FRAS is fire rate of spread. This variable was developed because it can be used to estimate a fire's expected fire size. Additional fire behavior outputs such as fire intensities and flame length are available outputs of the FlamMap program. FlamMap calculates the behavior of a fire occurring in each 30x30 meter cell under defined weather conditions. Fire behavior is described independently for each individual cell. FlamMap does not account for contagious processes that may affect fire behavior in an adjacent cell. For each WIZ, one weather data set was developed with a weather observation for each day from January 1, 1981 through December 31, 2000. This data was checked for errors and then imported into the USDA-Forest Service's *FireFamilyPlus* program. The National Fire Danger Rating System (NFDRS) index Spread Component (SC) was calculated for each day. The fire season was assumed to be from October 1 through May 31. The SC was calculated using a NDFRS fuel model G. Though little fuel model G exists within Florida, fuel model G contains fuel loading in all of the dead (1-h, 10-h and 100-h) and live (herbaceous and woody) fuel categories. This allows for the influence in the SC calculation the fuel moisture values in all of the fuel categories. In addition, climate class 3 (sub-humid / humid) and slope class 1 (0-25%) were used. The Spread Component was then divided into four commutative percentile categories Low (0-15%), Moderate (16-90%), High (91-97%) and Extreme (98-100%). The median SC was determined for each category. The environmental values for 1-h, 10-h, 100-h timelag fuel moisture, live herbaceous fuel moisture, live woody fuel moisture and the 20 foot 10

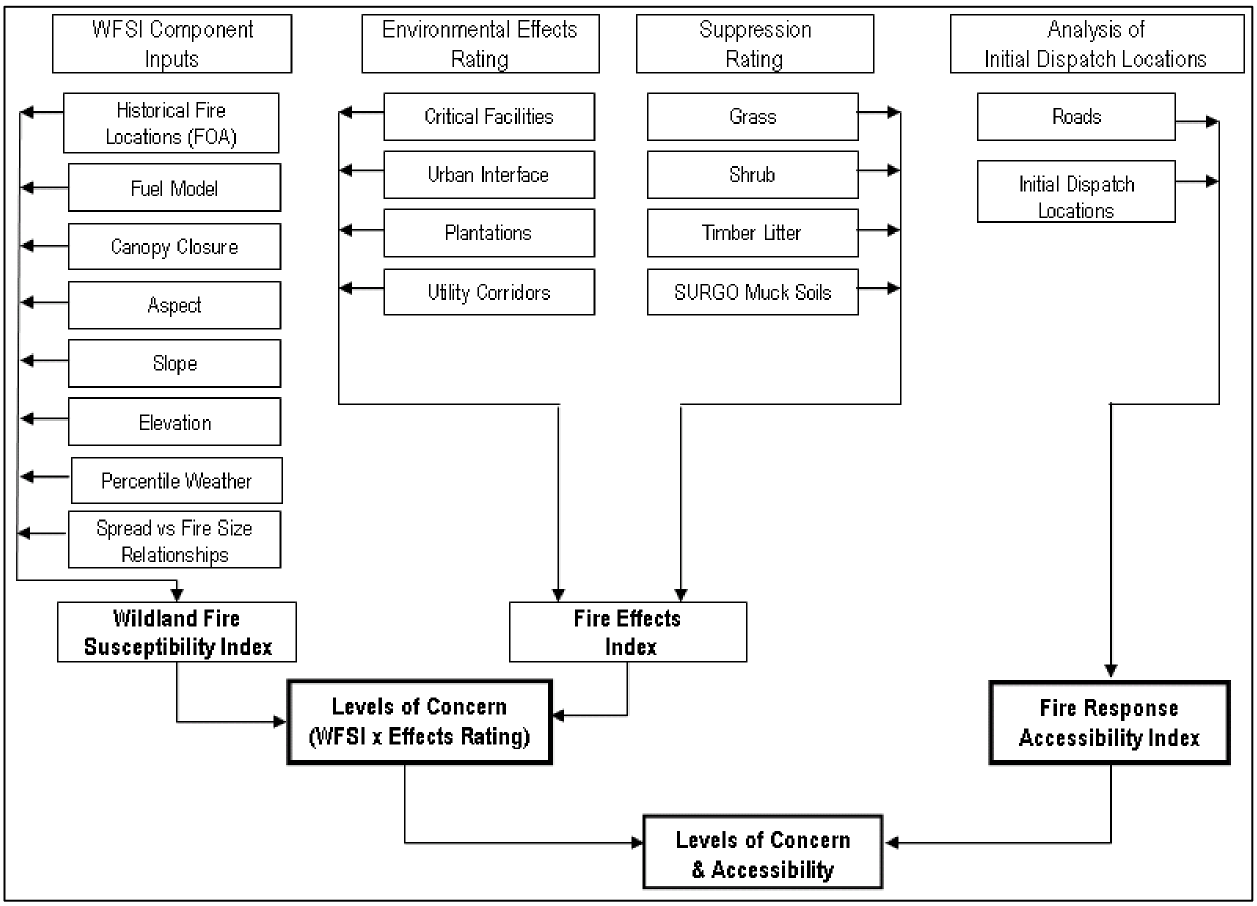
	minute average wind speed were determined as the average of the respective values on days when the SC was equal to the median SC. This allowed for the determination of four percentile weather categories with the percent of occurrence of each category and with environmental values to define the weather conditions within each category. For each day from January 1, 1981 through December 31, 2000, the NFDRS Spread Component was calculated using the *FireFamilyPlus* program. Each fire within the fire occurrence database for all agencies within a Weather Influence Zone has a fire start date. Each historic fire was assigned a Spread Component. The four percentile weather categories were also developed using the same assumptions for SC and the four categories have SC ranges. Hence, a correlation could be made assigning each historic fire to one of the four percentile weather categories. From these assignments, the proportion of fires that occurred in each percentile weather category was determined. A relationship between the rate of spread and final fire size was developed using the fire report data from the Division of Forestry for the period 1981-2000 for each Weather Influence Zone. Several fire size classes were used to estimate the amount of time from fire start to fire containment. For all Weather Influence Zones, the time from fire start to fire containment for the benchmark fire sizes of 0.5, 2, 10, 50, 100, 500 and 1000 acres was determined. Additional fire sizes greater than 1000 acres were used when fires of these sizes occurred historically within a WIZ. The average fire rate of spread for each benchmark fire size was estimated by using the double ellipse area model developed by Fons (1946) as documented by Anderson (1983). The model calculates fire size (Area) as: Area = $K * D^2$ where K is a constant dependent solely on mid-flame wind speed and D is the distance the fire has traveled from its point of origin (D = rate of spread times containment time). Mid-flame wind speed was set at 1, 2, 3, 5, 7, 9, and 12 mph for each of the benchmark sizes of 0.5, 2, 10, 50, 100, 500 and 1000-acre fires. The mid-flame wind speed was set at a value of 12 mph or larger for fires with final fire sizes greater than 1000 acres. A relationship between the fire size and average rate of spread values for the benchmark fire sizes was developed using multi-variable regression. A fourth order polynomial was determined to be the best equation form to use $Y = A + B*X+C*X^2 + D*X^3+ E*X^4$ where X = rate of spread, Y is the expected fire size and A-E are the regression coefficients. In some cases, A was changed so that a 0.5-acre fire was expected when the rate of spread was 1 chain per hour (1.1 feet per minute). A maximum expected fire size was set for all Weather Influence Zones to account for physical conditions that would limit fire spread.
Wildland Fire Susceptibility Index	A Wildland Fire Susceptibility Index (WFSI) was developed based on the calculation of the probability of an acre burning. This WFSI integrates the probability of an acre igniting and the expected final fire size based on

	the rate of spread in the four weather percentile categories into a single measure of wildland fire susceptibility. Based on necessary assumptions, the WFSI is not the probability of an acre burning but a relative comparison of index values between areas in the State. It provides a measure for comparison and ordination. The wildland fire susceptibility analysis integrates the probability of an acre igniting and wildland fire behavior. It combines the data from the Fire Occurrence Areas with fire behavior data developed by FlamMap. A WFSI was computed for each 30x30 meter cell of burnable vegetation within the State.

SECTION 4.0 FIRE RISK ASSESSMENT

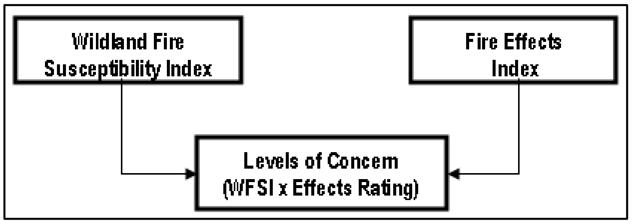
The Fire Risk Assessment includes two primary indices assigned to each 30 meter x 30 meter cell in the State are the Levels of Concern (LOC) and the Fire Response Accessibility Index (FRAI).

Figure 2. Fire Risk Assessment Process Flow

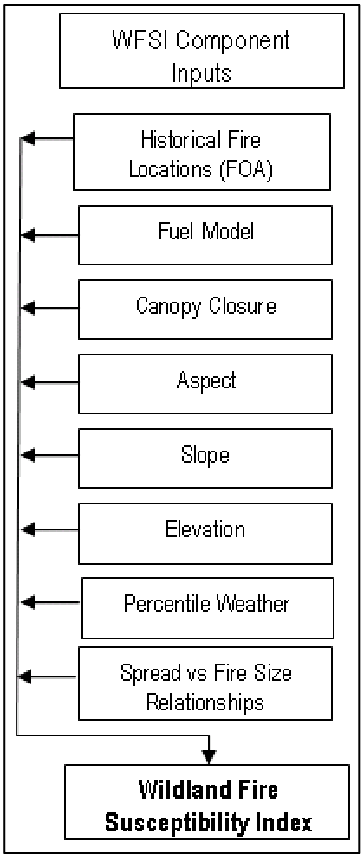


Section 4.1 Levels of Concern

The Levels of Concern is calculated as the Wildland Fire Susceptibility Index (WFSI) times the Fire Effects Index (FEI).



Section 4.1.A Wildland Fire Susceptibility Index



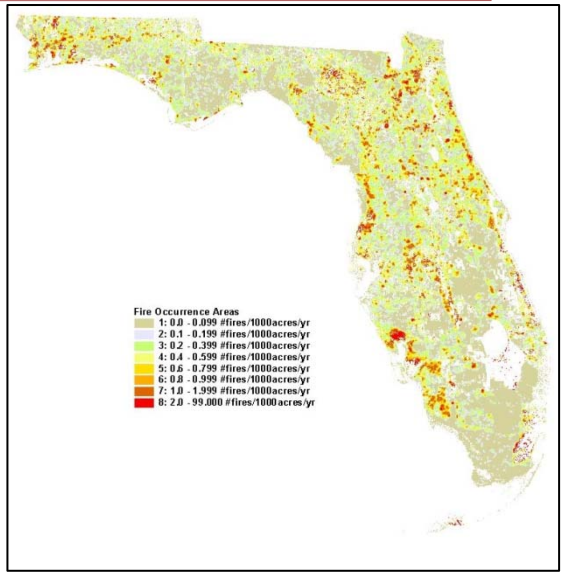
The Wildland Fire Susceptibility Index (WFSI) is a value between 0 and 1. It was developed consistent with the mathematical calculation process for determining the probability of an acre burning. The WFSI integrates the probability of an acre igniting and the expected final fire size based on the rate of spread in four weather percentile categories into a single measure of wildland fire susceptibility. Due to some necessary assumptions, mainly fuel homogeneity, it is not the true probability. But since all areas of the State have this value determined consistently, it allows for comparison and ordination of areas of the state as to the likelihood of an acre burning.

FIRE OCCURRENCE (FIRE OCCURRENCE AREAS)

A Fire Occurrence Area (FOA) is an area where the probability of each area igniting is the same. The historical fire locations from the past 20 years were used with a few exceptions. Pictorially, if one were to locate the point location for historic ignitions on a map of an FOA, the points would appear to be equally spaced.

FIRE OCCURRENCE DATA USED

The potential for wildland fire occurrence is based on historic fire ignition data from the Florida Division of Forestry, the USDA-Forest Service, the US Department of the Interior (DOI) and the Department of Defense (DOD). Fire occurrence data for the DOI agencies included the National Park Service, the Fish and Wildlife Service and the Bureau of Indian Affairs. Fire occurrence data for the DOD agencies included US Air Force's Eglin Air Force Base. Fire occurrence data was gathered for 20 years. The years 1981-2000 are used for the base period. For some agencies, fire occurrence data was not available for this entire time period and for these agencies, fire occurrence was annualized based on the number of years available.



OVERVIEW OF FOA DEVELOPMENT PROCESS

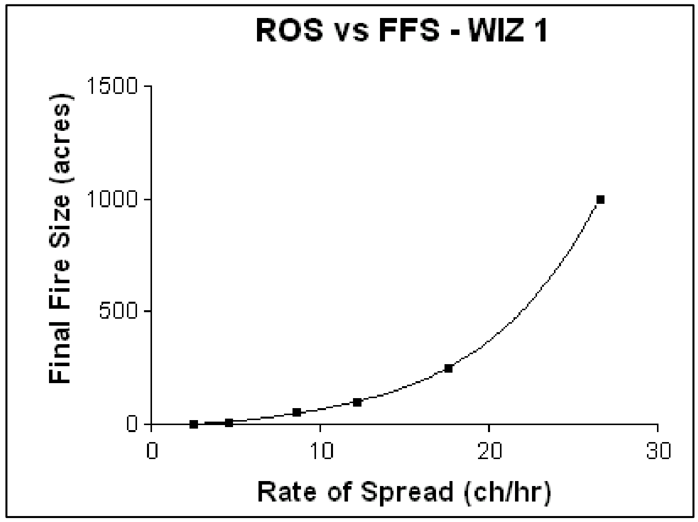
A grid illustrating the probability of a wildfire igniting was developed using ARC/INFO GRID by analyzing the location of historic ignitions. Fire occurrence rates in Fire Occurrence Areas (FOA) were described as the number of fires ignited per 1,000 acres per year. A surface grid with fires per 1,000 acres per year was generated using the density calculation available in ArcInfo GRID. FOAs were developed to identify areas were the probability of a fire igniting was similar. Hence, within an FOA, the probability of each acre igniting is the same.

FOA CLASSIFICATIONS AND MAP

Eight FOA categories were defined. The table below defines the FOA rate in each FOA as well as statewide acreages and average. The figure at the right shows the FOAs for the State.

FOA Acres	FOA Rate From	FOA Rate To	Avg FOA Rate (Fires/1000 acres/yr)	Percent of Acres	Cum Percent of Acres
10,567,243	0.000	0.099	0.0352237	36.5%	36.5%
5,106,232	0.100	0.199	0.1457859	17.6%	54.1%
5,874,037	0.200	0.399	0.2877662	20.3%	74.4%
2,978,297	0.400	0.599	0.4893515	10.3%	84.7%
1,647,387	0.600	0.799	0.690712	5.7%	90.3%
983,224	0.800	0.999	0.8915045	3.4%	93.7%
1,433,696	1.000	1.999	1.3260515	4.9%	98.7%
381,831	2.000	99.000	3.5963585	1.3%	100.0%
28,971,947			0.15000	100.0%	

EXPECTED FINAL FIRE SIZE



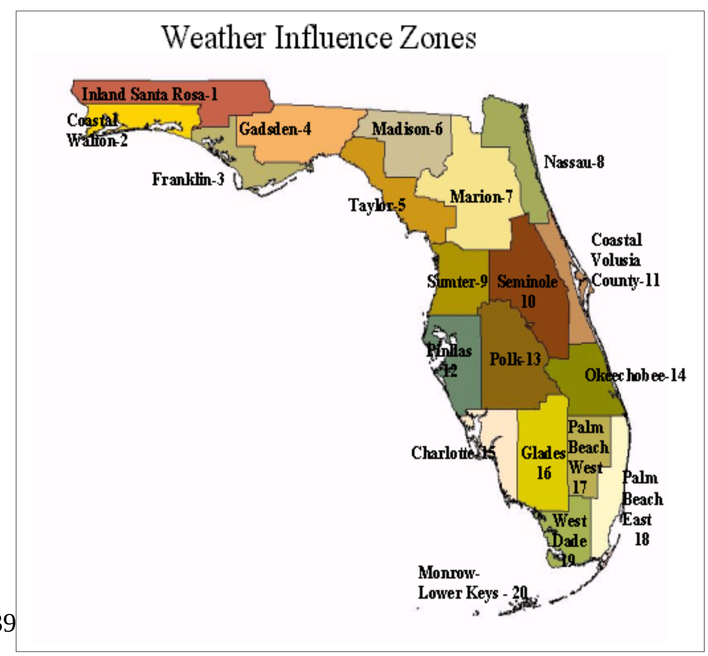
For a cell, the FOA provides an estimate of the cell igniting. To calculate the WFSI, the expected size of a fire needs to be determined to facilitate estimating the probability of an acre burning. To do this, it was necessary to develop relationships between fire spread rates and the expected final fire size. The inputs to this relationship are the expected fire behavior, which depends, are fuels, weather and topography and a measure of suppression effectiveness of fire protection forces.

For each Weather Influence Zone, a relationship between the rate of spread and final fire size was developed using the fire report data from the Division of Forestry for the period 1981-2000. Details of how this relationship was developed are contained in the section titled *Rate of Spread vs. Final Fire Size Relationships* that follows.

The process used to develop the fire rate of spread follows. Fire behavior prediction requires definition of the weather, fuels and topography.

WEATHER

Weather in the state of Florida varies geographically therefore Weather Influence Zones (WIZ) were developed by the Division of Forestry State Meteorologist. Twenty Weather Influence Zones were developed for the State.

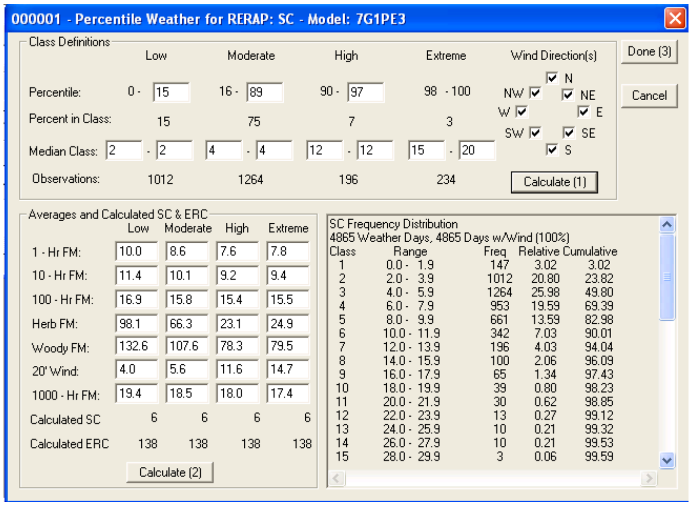


WEATHER INFLUENCE ZONES

Within each WIZ, daily weather data was gathered from 1981 - 2000 from land management agency maintained weather stations and from National Oceanographic and Atmospheric Administration (NOAA) maintained weather stations. A computer program was developed by the Division of Forestry's State Meteorologist to geo-reference the weather observations from the weather stations within a WIZ to the geographic center of the WIZ. Hence, one weather data set was developed with a weather observation for each day from January 1, 1981 through December 31, 2000 for each WIZ. From this weather data set, percentile weather was developed for each WIZ.

DEVELOPMENT OF PERCENTILE WEATHER VALUES

For each WIZ, one weather data set was developed with a weather observation for each day from January 1, 1981 through December 31, 2000. This data was checked for errors and then imported into the USDA-Forest Service's *FireFamilyPlus* program. The National Fire Danger Rating System (NFDRS) index Spread Component (SC) was calculated for each day. The fire season was assumed to be from October 1 through May 31. The SC was calculated using a NDFRS fuel model G. Though little fuel model G exists within Florida, fuel model G contains fuel loading in all of the dead (1-h, 10-h and 100-h) and live (herbaceous and woody) fuel categories. This allows for the influence in the SC calculation the fuel moistures values in all of the fuel categories. In addition, climate class 3 (sub-humid / humid) and slope class 1 (0-25%) were used.



The Spread Component was then divided into four commutative percentile categories Low (0-15%), Moderate (16-90%), High (91-97%) and Extreme (98-100%). The median SC was determined for each category. The environmental values for 1-h, 10-h, 100-h timelag fuel moisture, live herbaceous fuel moisture, live woody fuel moisture and the 20 foot 10 minute average wind speed were determined as the average of the respective values on days when the SC was equal to the median SC. This allowed for the determination of four percentile weather categories with the percent of occurrence of each category and with environmental values to define the weather conditions within each category. Below is an example printout of percentile weather values from FireFamilyPlus for WIZ 1.

```
Station: 000001: Inland Santa Rosa       Variable: SC
 Model: 7G1PE3
         Data Years: 1981 - 2000
         Date Range: October 1 - May 31
Wind Directions: N, NE, E, SE, S, SW, W, NW

Percentiles, Probabilities, and Mid-Points
    Variable/Component Range        Low        Mod        High       Ext
            Percentile Range      0 - 15     16 - 89    90 - 97    98 - 100
       Climatol. Probability        15         75          7          3
```

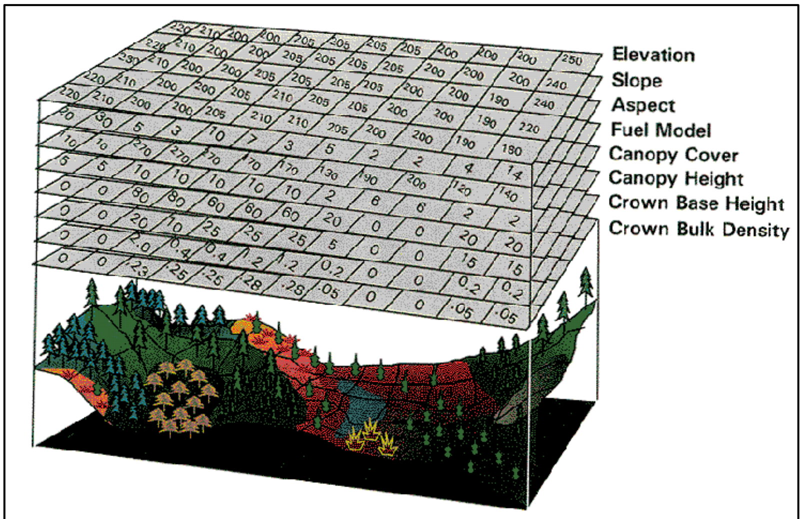
Mid-Point SC	2 - 2	4 - 4	12 - 12	15 - 20
Num Observations	1012	1264	196	234
Calculated Spread Comp.	3	4	12	16
Calculated ERC	23	28	31	32
Fuel Moistures				
1 Hour Fuel Moisture	10.00	8.60	7.60	7.80
10 Hour Fuel Moisture	11.40	10.10	9.20	9.40
100 Hour Fuel Moisture	16.90	15.80	15.40	15.50
Herbaceous Fuel Moisture	98.10	66.30	23.10	24.90
Woody Fuel Moisture	132.60	107.60	78.30	79.50
20' Wind Speed	4.00	5.60	11.60	14.70
1000 Hour Fuel Moisture	19.40	18.50	18.00	17.40

PROPORTION (PERCENT) OF FIRES THAT OCCUR WITHIN EACH PERCENTILE WEATHER CATEGORY

If 15 percent of the days during the fire season are in the Low Percentile Weather Category, one cannot assume that 15 percent of the fires during the fire season will occur on the days in this Category. For each day from January 1, 1981 through December 31, 2000, the NFDRS Spread Component was calculated using the *FireFamilyPlus* program. Each fire within the fire occurrence database for all agencies within a Weather Influence Zone has a fire start date. Each historic fire was assigned a Spread Component based on the fire's start date. The four percentile weather categories were also developed using the same assumptions for SC and the four categories have SC ranges. Hence, a correlation could be made assigning each historic fire to one of the four percentile weather categories. From these assignments, the proportion of fires that occurred in each percentile weather category by WIZ was determined.

FIRE BEHAVIOR PREDICTION

Potential fire behavior was evaluated using the program FlamMap. FlamMap is a GIS-based analytic tool. It uses topographic information, fuel characteristics, and weather to calculate rate-of-spread, flame length, fire type, and other characteristics of fire behavior.



FLAMMAP

The purpose of using FlamMap is to generate fire behavior data that are comparable across the landscape for a given set of weather, fuels and fuel moisture data inputs. FlamMap is based on the GIS data themes and algorithms used in *Farsite* (Fire Area Simulator) as described by Finney (1998). GIS data are required for 5 data themes and optional for 3 data themes as follows:

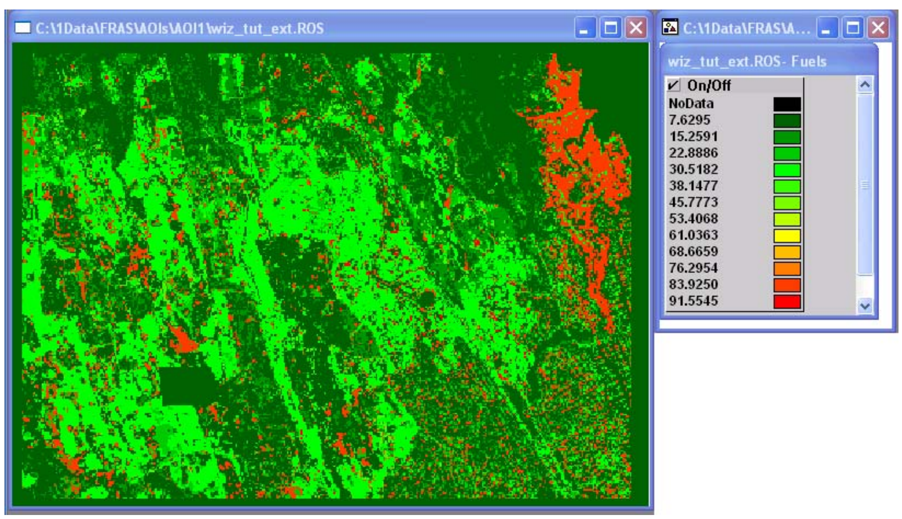
Required Themes

- Elevation
- Slope
- Aspect
- Surface fuel model
- Canopy Cover

Optional Themes

- Stand Height
- Canopy Base Height
- Canopy Bulk Density

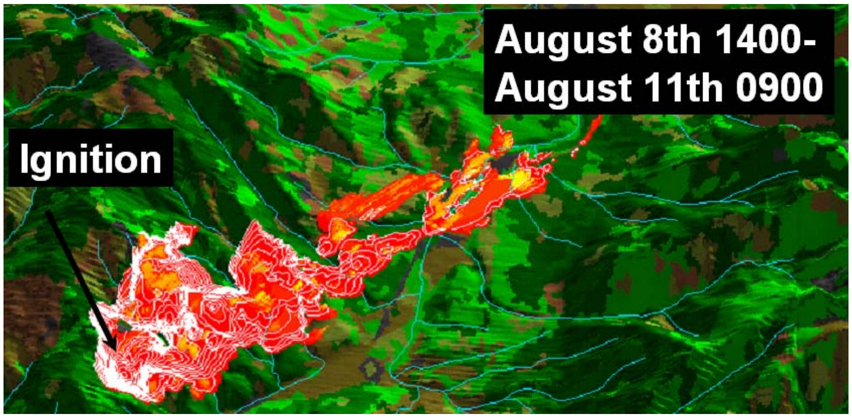
For the FRA, only the required themes were used due to data availability.



The fire behavior variable calculated by FlamMap for the FRAS is fire spread rate. This variable was developed since it can be used to estimate a fire's expected fire size. Additional fire behavior outputs such as fire intensities and flame length are available outputs of the FlamMap program.

FlamMap calculates the behavior of a fire occurring in each 30x30 meter cell under defined weather conditions. Fire behavior is described independently for each individual cell. FlamMap does not account for contagious processes that may affect fire behavior in an adjacent cell. An example using the Extreme Percentile Weather data appears in the figure above. The scale is in meters per minute.

FARSITE



The Farsite (Fire Area Simulator) program is a two-dimensional fire behavior prediction. It predicts the fire behavior based on GIS data layers. In the FRAS, Farsite was not used but the data layers needed to use Farsite are the same as those needed for FlamMap. Use of Farsite to predict fire behavior and fire growth is facilitated by the data layers developed in the FRA.

Table 9. Comparison of Farsite and FlamMap

FARSITE	FLAMMAP
DYNAMIC – SPACE AND TIME SPECIFIC • Needs an ignition point • Needs a simulation start time and stop time • Produces fire behavior only inside the fire perimeter	**STATIC – TIME AND CONDITION SPECIFIC** • No ignition point or location • No simulation start time and stop time • Generates fire behavior everywhere

Table 10. Comparison of Uses for Farsite and FlamMap

USES	FARSITE	FLAMMAP
MODEL THE GROWTH OF FIRES	**YES**	**NO**
Support Assessments of Risk	No	Yes
Different Fuel/Weather Scenarios	Yes	Yes
Active Fire Behavior Prediction	Yes	No

Table 11. Comparison of Farsite and FlamMap Inputs

INPUTS	FARSITE	FLAMMAP
GIS Layers for Fuels and Topography	YES	YES
Initial Fuel Moisture Values	Yes	Yes
Uses Custom Fuel Models	Yes	Yes
Uses Weather and Wind Files	Yes	No
Fire Start time and Stop Time	Yes	No
Fire Ignition Location	Yes	No
Desired Spread Direction	No	Yes
Constant Wind Speed and Direction	No	Yes

Table 12. Comparison of Farsite and FlamMap Outputs

OUTPUTS	FARSITE	FLAMMAP
Fire Arrival Time at a Location	YES	NO
Spread Rate	Yes	Yes
Flame Length	Yes	Yes
Fireline Intensity	Yes	Yes
Heat per Unit Area	Yes	Yes
Crown Fire Type	Yes	Yes
Fire Spread Direction	Yes	No
Midflame Windspeed	No	Yes
Solar Irradiance	No	Yes
1-hr Timelag Fuel Moisture	No	Yes
10-hr Timelag Fuel Moisture	No	Yes

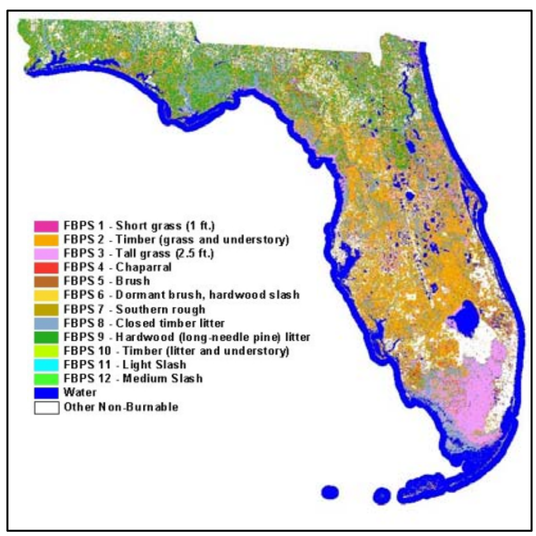
FUEL - SURFACE FUEL MODELS

An FRA design requirement was to classify each acre of burnable land in Florida using the fuel models in the Fire Behavior Prediction System (FBPS). The fuel models are in the table at the right.

FBPS Fuel Model	Description
1	Short grass (1 ft.) - FBPS
2	Timber (grass and understory) - FBPS
3	Tall grass (2.5 ft.) - FBPS
4	Chaparral -FBPS
5	Brush - FBPS
6	Dormant brush, hardwood slash - FBPS
7	Southern rough - FBPS
8	Closed timber litter - FBPS
9	Hardwood (long-needle pine) litter - FBPS
10	Timber (litter and understory) - FBPS
11	Light slash - FBPS-M-Avg Depth
12	Medium slash - FBPS-M-Avg Depth
13	Heavy slash - FBPS-M-Avg Depth

To facilitate classification of the State, a Florida Fuel Model Dichotomous Key was developed. Fifty DOF employees were trained in its use. These employees sampled over 3,000 plots assigning a FBPS fuel model to each. Correlations were made between the spectral reflectance value of the plots and the fuel model allowing for a uniform assignment of fuel models through the state.

The figure at the right shows the final fuel model map for the state.



To analyze fuel management mitigation measures, custom FBPS derivative fuel models were developed to complement the existing 13 fuel models. A custom FBPS derivative fuel model is a custom fuel model that minimizes, reduces, or increases fuel loading and fuel bed depth for each of the original FBPS fuel models. By altering the fuel loading and fuel bed depth of the existing fuel models in a consistent manner, the characteristic surface area to volume ratio and the relative packing ratio are preserved with the parent FBPS fuel model. Minor modification were made to fuel bed depth also within these constrains extending the concept to model unusually “fluffy” or “compact” fuel beds.

The table below defines the attributes of the FBPS derivative fuel models. The standard 13 FBPS fuel models have an identifier 1-13. The custom derivative fuel models were developed to allow for assignment of a fuel model to post-treatment fuel beds and to also provide fuel models to assign to fuel beds as they change over time following treatment.

Table 13. Attributes of FBPS Derivative Fuel Models

Name	1h T/A	10h T/A	100h T/A	Herb T/A	Woody T/A	1h SA/V	Herb SA/V	Woody SA/V	Depth (Feet)	Mx Ex
1 Short grass (1 ft.) - High	0.74	0.00	0.00	0.00	0.00	3500	0	0	1.00	12
2 Timber (grass and understory) - FBPS	2.00	1.00	0.50	0.50	0.00	3000	1500	0	1.00	15
3 Tall grass (2.5 ft.) - FBPS	3.01	0.00	0.00	0.00	0.00	1500	0	0	2.50	25
4 Chaparral -FBPS	5.01	4.01	2.00	0.00	5.01	2000	0	1500	6.00	20
5 Brush - FBPS	1.00	0.50	0.00	0.00	2.00	2000	0	1500	2.00	20
6 Dormant brush, hardwood slash - FBPS	1.50	2.50	2.00	0.00	0.00	1750	0	0	2.50	25
7 Southern rough - FBPS	1.13	1.87	1.50	0.00	0.37	1750	0	1550	2.50	40
8 Closed timber litter - FBPS	1.50	1.00	2.50	0.00	0.00	2000	0	0	0.20	30
9 Hardwood (long-needle pine) litter - FBPS	2.92	0.41	0.15	0.00	0.00	2500	0	0	0.20	25
10 Timber (litter and understory) - FBPS	3.01	2.00	5.01	0.00	2.00	2000	0	1500	1.00	25
11 Light slash - FBPS	1.50	4.51	5.51	0.00	0.00	1500	0	0	1.00	15
12 Medium slash - FBPS	4.01	14.03	16.53	0.00	0.00	1500	0	0	2.30	20
1A Short grass (1 ft.) - Low	0.52	0.00	0.00	0.00	0.00	3500	0	0	0.70	12
1N Short grass (1 ft.) - Low Spread	0.10	0.00	0.00	0.00	0.00	3500	0	0	0.12	12
1Z Short grass (1 ft.) - High	0.96	0.00	0.00	0.00	0.00	3500	0	0	1.30	12
2A Timber (grass and understory) - Low	1.40	0.70	0.35	0.35	0.00	3000	1500	0	0.70	15
2N Timber (grass and understory) - Low Spread	0.14	0.07	0.04	0.04	0.00	3000	1500	0	0.07	15
2Z Timber (grass and understory) - High	2.60	1.30	0.65	0.65	0.00	3000	1500	0	1.30	15
3A Tall grass (2.5 ft.) - Low	2.10	0.00	0.00	0.00	0.00	1500	0	0	1.75	25
3N Tall grass (2.5 ft.) - Low Spread	0.12	0.00	0.00	0.00	0.00	1500	0	0	0.10	25
3Z Tall grass (2.5 ft.) - High	3.91	0.00	0.00	0.00	0.00	1500	0	0	3.25	25
4A Chaparral - Low	3.51	2.81	1.40	0.00	3.51	2000	0	1500	4.20	20
4N Chaparral - Low Spread	0.15	0.12	0.06	0.00	0.15	2000	0	1500	0.18	20
4Z Chaparral - High	6.51	5.21	2.60	0.00	6.51	2000	0	1500	7.80	20
5A Brush - Low	0.70	0.35	0.00	0.00	1.40	2000	0	1500	1.40	20
5N Brush - Low Spread	0.09	0.05	0.00	0.00	0.18	2000	0	1500	0.18	20
5Z Brush - High	1.30	0.65	0.00	0.00	2.60	2000	0	1500	2.60	20
6A Dormant brush, hardwood slash - Low	1.05	1.75	1.40	0.00	0.00	1750	0	0	1.75	25
6N Dormant brush, hardwood slash - Low Spread	0.14	0.23	0.18	0.00	0.00	1750	0	0	0.23	25
6Z Dormant brush, hardwood slash - High	1.95	3.26	2.60	0.00	0.00	1750	0	0	3.25	25
7A Southern rough - Low	0.79	1.31	1.05	0.00	0.26	1750	0	1550	1.75	40
7N Southern rough - Low Spread	0.10	0.17	0.14	0.00	0.03	1750	0	1550	0.23	40
7Z Southern rough - High	1.47	2.44	1.95	0.00	0.48	1750	0	1550	3.25	40
8A Closed timber litter - Low	1.05	0.70	1.75	0.00	0.00	2000	0	0	0.14	30
8N Closed timber litter - Low Spread	0.75	0.50	1.25	0.00	0.00	2000	0	0	0.10	30
8Z Closed timber litter - High	1.95	1.30	3.26	0.00	0.00	2000	0	0	0.26	30
9A Hardwood (long-needle pine) litter - Low	2.04	0.29	0.11	0.00	0.00	2500	0	0	0.14	25
9N Hardwood (long-needle pine) litter - Low Spread	0.47	0.07	0.02	0.00	0.00	2500	0	0	0.05	25
9Z Hardwood (long-needle pine) litter - High	3.79	0.54	0.20	0.00	0.00	2500	0	0	0.26	25
10A Timber (litter and understory) - Low	2.10	1.40	3.51	0.00	1.40	2000	0	1500	0.70	25
10N Timber (litter and understory) - Low Spread	0.30	0.20	0.50	0.00	0.20	2000	0	1500	0.10	25
10C Timber (litter and understory) - High	3.91	2.60	6.51	0.00	2.60	2000	0	1500	1.30	25
11A Light slash - Low	0.85	2.54	3.11	0.00	0.00	1500	0	0	0.56	15
11N Light slash - Low Spread	0.29	0.86	1.05	0.00	0.00	1500	0	0	0.19	15
11Z Light slash - High	2.22	6.65	8.13	0.00	0.00	1500	0	0	1.48	15
12A Medium slash - Low	3.01	10.55	12.43	0.00	0.00	1500	0	0	1.73	20
12N Medium slash - Low Spread	0.28	0.98	1.16	0.00	0.00	1500	0	0	0.16	20
12Z Medium slash - High	4.64	16.23	19.13	0.00	0.00	1500	0	0	2.66	20

A description of the custom FBPS derivative fuel models follows.

Low Derivatives of the FBPS Fuel Models 1-12

For each FBPS fuel model, a low version was developed by reducing the fuel loading in each category by 30% and by reducing the fuel bed bulk depth by 30%. The consistent reduction in depth and loading maintains the fuel bed bulk density and characteristic (average) surface area to volume ratio for the fuel bed. The low derivative fuel models are designated with the letter A following the standard fuel model number. For example, a 1A is the low loading version of a FBPS fuel model 1.

High Derivatives of the FBPS Fuel Models 1-12

For each FBPS fuel model, a high version was developed by increasing the fuel loading in each category by 30% and by increasing the fuel bed bulk depth by 30%. The high derivative fuel models are designated with the letter Z following the standard fuel model number. For example, a 1Z is the high loading version of a FBPS fuel model 1.

Low Spread Derivatives of the FBPS Fuel Models 1-12

For each FBPS fuel model a low spread version was developed by reducing to a low level the fuel loading and fuel bed depth in each standard fuel model. The rate of spread in these models is approximately 1 ch/hr using the Extreme Percentile weather conditions. It is meant to simulate the expected fire behavior in some fuel bed immediately post-treatment. The low spread fuel models are designated with the letter N following the standard fuel model number. For example, a 1N is the low spread version of a FBPS fuel model 1.

WEATHER

Percentile weather values were used within each Weather Influence Zone.

TOPOGRAPHY - SLOPE, ASPECT AND ELEVATION

Within FlamMap, data layers for the State were developed for slope, aspect and elevation for USGS Digital Elevation Model (DEM) information.

PERCENT CANOPY COVER

A data layer defining the percent canopy cover was developed using satellite imagery and information gathered at the 3,000 sample plots.

CANOPY FUELS (Canopy Ceiling Height, Canopy Base Height and Canopy Bulk Density)

Due to lack of funding to process the data to develop these three canopy data layers, they were not developed for the Risk Assessment, although the model has been built to accommodate these layers once they become available.

RATE OF SPREAD VS FINAL FIRE SIZE RELATIONSHIPS

For each Weather Influence Zone, a relationship between the rate of spread and final fire size was developed using the fire report data from the Division of Forestry for the period 1981-2000. Several fire size classes were used to estimate the amount of time from fire start to fire containment. For all Weather Influence Zones, the time from fire start to fire containment for the benchmark fire sizes of 0.5, 2, 10, 50, 100, 500 and 1,000 acres was determined. Additional fire sizes greater than 1,000 acres were used when fires of these sizes occurred historically within a WIZ.

A			2.0000000
B			-2.9950000
C			1.5890000
D			-0.0975100
E			0.0036050
Max Size			2000
Largest Fire			1080
WIZ-->			1
ROS	Avg	Std Dev	Acres
1	0.5	0.2	0.5
2	1.3	0.4	1.6
3	3.1	1.3	5.0
4	6.6	2.8	10.1
5	12.1	5.0	16.8
6	20.0	8.0	24.8
7	30.8	12.0	34.1
8	45.0	17.2	44.6
9	62.9	24.0	56.3
10	85.1	32.6	69.5
15	276.8	112.3	168.0
20	649.2	278.8	374.4
25	1269.0	569.3	804.9
30	2207.6	1027.5	1629.5
35	3427.5	1770.2	2000.0
40	5003.6	2879.1	2000.0
45	6991.7	4425.4	2000.0
50	9492.6	6459.7	2000.0
55	12570.3	9058.9	2000.0
60	16290.5	12310.7	2000.0
65	19212.3	14298.3	2000.0
70	21849.3	16655.9	2000.0
75	24442.1	19915.0	2000.0
80	27347.0	24205.3	2000.0
85	29947.6	29126.7	2000.0
90	32620.6	34923.8	2000.0
100	36124.3	38901.0	2000.0
120	40031.6	42376.1	2000.0

The average fire rate of spread for each benchmark fire size was estimated by using the double ellipse area model developed by Fons (1946) as documented by Anderson (1983). The model calculates fire size (Area) as: Area = K * D^2 where K is a constant dependent solely on mid-flame wind speed and D is the distance the fire has traveled from its point of origin (D = rate of spread times containment time). Mid-flame windspeed was set at 1, 2, 3, 5, 7, 9, and 12 mph for each of the benchmark sizes of 0.5, 2, 10, 50, 100, 500 and 1,000-acre fires. The mid-flame windspeed was set at a value of 12 mph or larger for fires with final fire sizes greater than 1,000 acres.

A relationship between the fire size and average rate of spread values for the benchmark fire sizes was developed using multi-variable regression. For all fuel models except fuel model 3, a fourth order polynomial was determined to be the best equation form to use. The form is $Y = A + B*X+C*X^2 + D*X^3 + E*X^4$ where X = rate of spread, Y is the expected fire size and A-E are the regression coefficients. In some cases, A was changed so that a 0.5-acre fire was expected when the rate of spread was 1 chain per hour

(1.1 feet per minute). For fuel model 3, a power function was used. The form is $Y = A + B*X^C + D*X^E$ where X is the rate of spread.

A maximum expected fire size was set for all Weather Influence Zones to account for physical conditions that would limit fire spread. These values were based on historic fire sizes.

The table provides an example using WIZ 1. The equation developed was:

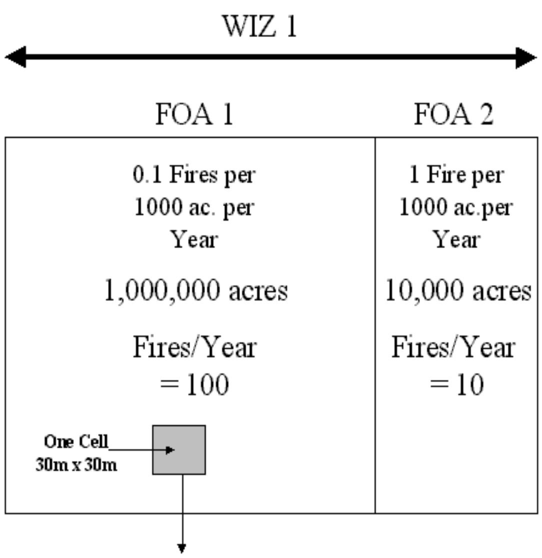
$$FFS = 2.0 - 2.995*X + 1.589*X^2 - 0.09751*X^3 + 0.003605*X^4$$

with a maximum fire size of 2,000 acres. Note that for spread rates greater than 35 ch/hr, the final fire size remains at 2,000 acres.

Columns in the table on the previous page are also provided for the State-wide average for a given rate of spread as well as the standard deviation based on the 20 WIZs in the State.

EXAMPLE OF THE CALCULATION OF WFSI

The WFSI is calculated for each percentile weather category for each 30 meter x 30-meter cell on burnable area within the State. The four values from the four Percentile weather Categories are summed to obtain the WFSI for a cell. The calculation is done for cells within a FOA and WIZ intersection. When the calculation is done for a cell, it is assumed that all cells in the FOA and WIZ intersection have the attributes of the cell. In essence, one is asking, "What would be the expected probability of an acre burning if all cells in the FOA and WIZ intersection were the same at the selected cell?"

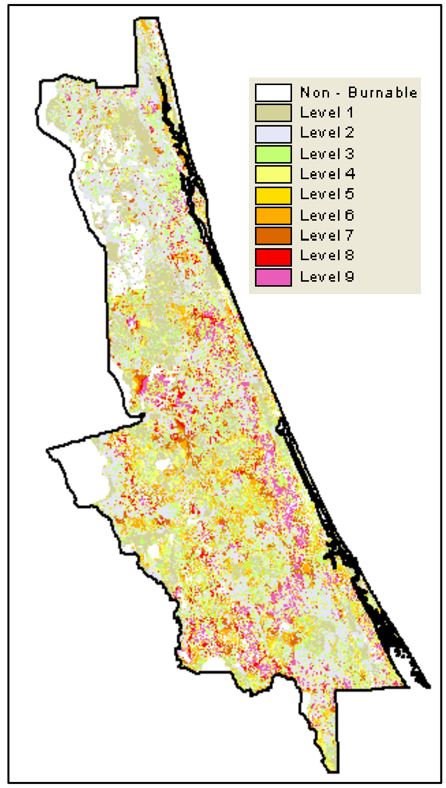


To assist in the understanding of the calculation, an example is presented. Assume that the calculation is being done for a cell in FOA 1, WIZ 1. The data flow is shown via the example in Table below. For the example, assume that the fire occurrence rate in FOA 1 is 0.1 fires / 1000 acres / year and assume there are 1,000,000 acres in the FOA 1, WIZ 1 intersection.

Table 14. Example Calculation of WFSI

Row	Item	Percentile Weather				Total
		Low	Moderate	High	Extreme	
1	Percent of Fires	10%	80%	8%	2%	100%
2	Number of Fires	10	80	8	2	100
3	Rate of Spread (ch.hr)	2	5	12	24	N/A
4	Final Fire Size (acres)	1	6	98	900	N/A
5	Annual Acres Burned	10	480	784	1800	3074
6	WFSI	0.0001	0.0048	0.0074	0.0180	0.0374

The figure on the previous page shows that within FOA 1 and WIZ 1, there are 100 fires per year. Row 1 gives the Percent of Fires that have historically occurred within each of the Percentile Weather Categories.

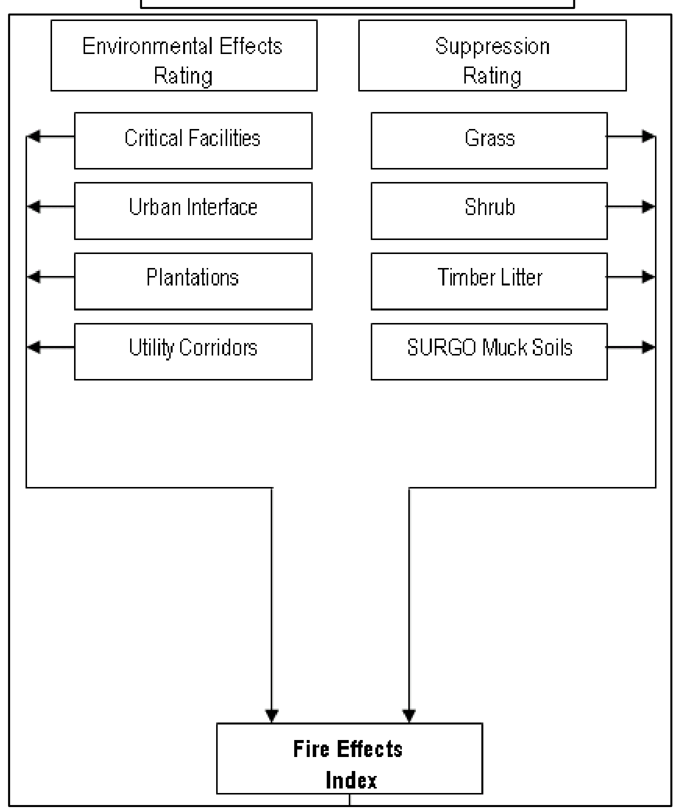


Multiplying the Proportion of Fires in each Percentile Weather Category by the total number of fires in the FOA 1 / WIZ 1 intersection (100 fires) allows for determination of the Number of Fires in each Percentile Weather Category, Row 2.

The FlamMap program has calculated a Rate of Spread for each Percentile Weather Category (Row 3) and a Rate of Spread versus expected Final Fire Size Relationship (Row 4) has been determined. This allows for the determination of the expected Final Fire Size within each Percentile Weather Category.

Multiplying the Number of Fires per year in each Percentile Weather Category by the expected Final Fire Size yields the Annual Expected Acres Burned for each Percentile Weather Category (Row 5).

Dividing the Annual Expected Acres Burned for each Percentile Weather Category by the total acres within the FOA1, WIZ 1 intersection (1,000,000 acres) yields the WFSI within each Percentile Weather Category Row 6). The WFSI for the cell is the sum of the four Percentile Weather Category WFSI values. An example of the WFSI map for the Bunnell District is in the figure above.



Section 4.1.B Fire Effects

The Fire Effects index is comprised of two inputs:

⇒ Environmental Effects

⇒ Suppression Costs

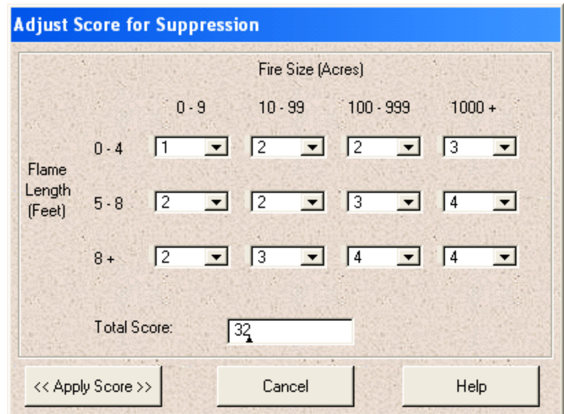
The purpose of the index is to identify those areas that have environmental values at risk to wildland fire and/or are costly to suppress. The environmental effects that are included in this analysis are:

⇒ Urban Interface

⇒ Utility Corridors

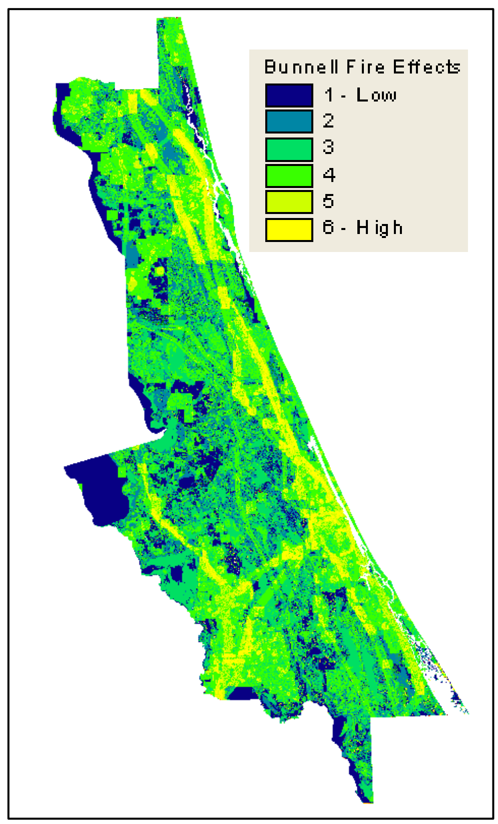
⇒ Plantations (natural and planted)

⇒ Critical Facilities (from DOF burn authorization plan)



Each environmental input was assigned an effects score by DOF fire managers using the matrix (See figure at right). To arrive at a final environmental effects score (rating), the individual scores for the inputs; critical facilities, urban interface, plantations and utility corridors were summed.

The suppression costs are evaluated by fuel type. Each cell in the state has been assigned either a grass, shrub, timber litter or muck suppression score. DOF fire managers used the matrix shown to the right to assign the fire suppression and muck scores. The grass, shrub and timber litter scores were based on suppression billing information provided by the DOF districts for the past five years. The final suppression value for each cell was assigned based on the fuel type (or muck soil) on the ground.



The Fire Effects Index was then calculated by combining the final environmental effects and suppression costs scores using the following equation:

Fire Effects = (0.80 * Environmental Effects)

+ (0.20 * Suppression Costs)

The final Fire Effects Values can range from 0 – 100.

An example of the Fire Effects Score map for the Bunnell District is in the figure at the right. A description of how the Environmental Effects Score and the Suppression Costs Score were developed follows.

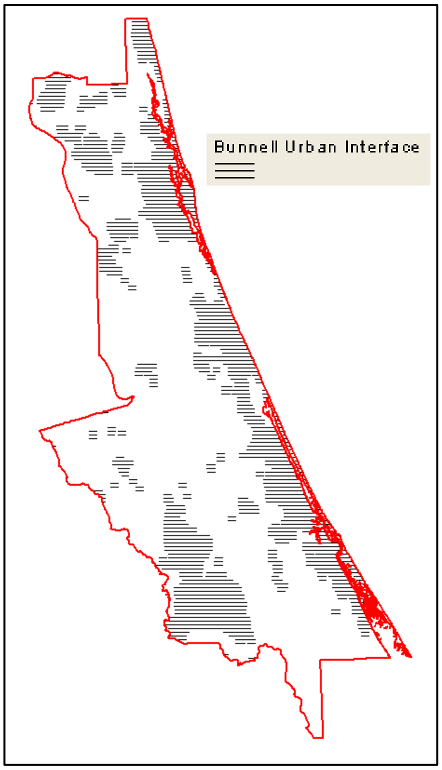
ENVIRONMENTAL EFFECTS ELEMENTS

The following are the environmental effects elements: Urban Interface, Utility Corridors, Plantations (natural and planted) and Critical Facilities (from DOF burn authorization plan)

URBAN INTERFACE

The urban interface was derived from a combination of the urban areas delineated on the fuels map and the Census Bureau data. This layer highlights key areas for fire prevention based on the human element. The urban interface areas were buffered

(990 meters) to sufficiently represent areas of concern (See figure at right).



Urban Interface was created to represent the buffers around the two types of potential interfaces that exist within the state of Florida.

URBN1: Category 1. Interface Community – exists where structures directly abut wildland fuels. This category was defined as having a population density of 250 or more people per square mile.

URBN2: Category 2. Intermix Community – The Intermix Community exists where structures are scattered throughout a wildland area. There is no clear line of demarcation; wildland fuels are continuous outside of and within the developed area. This category was defined as having a population density of between 28-250 people per square mile.

UTILITY CORRIDORS

Generating a buffer around transmission lines developed the Utility Corridors layer. Inside the buffer represents areas where smoke and fire can become dangerous.

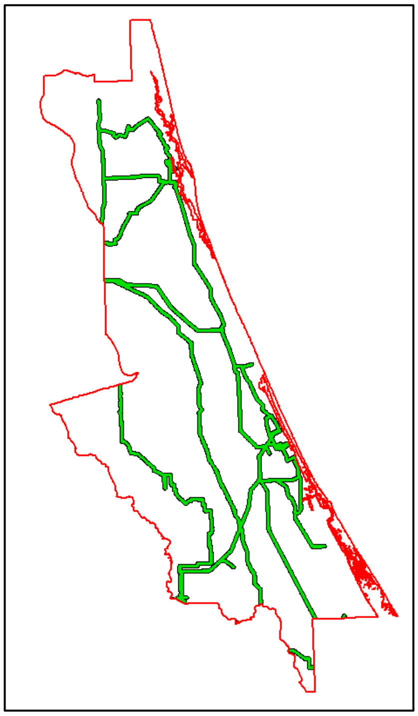
PLANTATIONS

Plantations were derived from the Florida Water Management Districts Land Use and Land Cover database and includes the following classes; forest regeneration, mesic flatwoods, pine plantations, longleaf pine, pine flatwoods, sand pine and upland coniferous forest.

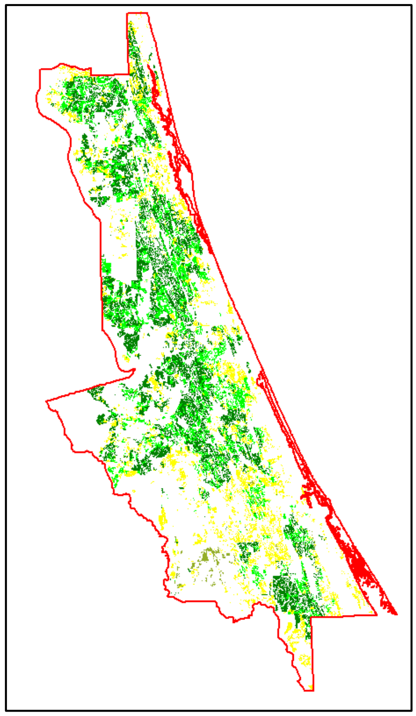
CRITICAL FACILITIES

Critical facilities information was derived from the DOF burn authorization plan. Buffers were set at 1,000 meters for airport and heliports and 500 meters from any other feature in the critical facilities layer including schools, hospitals, airports, interstates and highways. This layer represents areas that are sensitive to smoke.

Utility Corridors



Plantations



Critical Facilities

EXPECTED SUPPRESSION COSTS ELEMENTS

FUEL TYPE

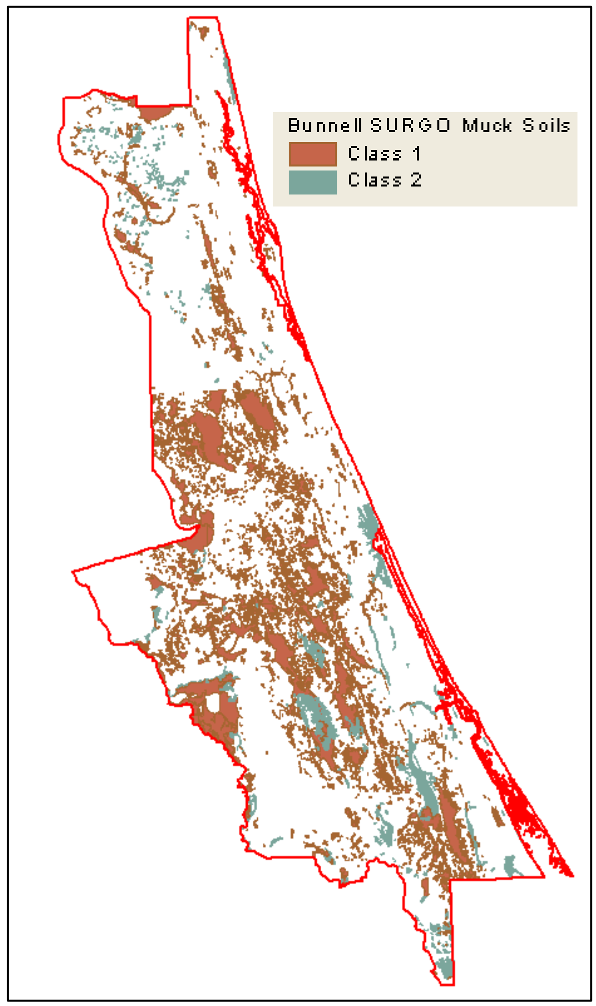
The fuels layer was used to assign each cell in the State a fuel type of grass, shrub, timber litter or base (other).

MUCK SOILS

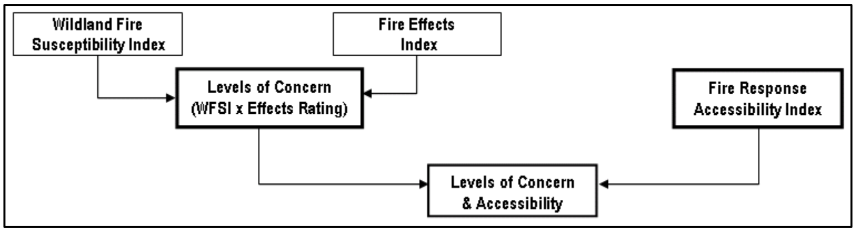
Muck soils were extracted from SURGO data by the DOF. Muck soils constitute areas of concern for fire fighting efforts, as fires within these areas tend to be expensive and difficult to extinguish. The muck soils were classified into two groups but combined into one for the analysis.

CL1 - "Organic Soils" (histosols) are true organic soils with greater than 16" of peat or muck. These soils will present the greatest problem to fire suppression efforts.

CL2 - Soils that can have a veneer of organic soil typically less that 16". These are important to identify because they may pose some difficulty.



Section 4.1.C Calculating Levels of Concern

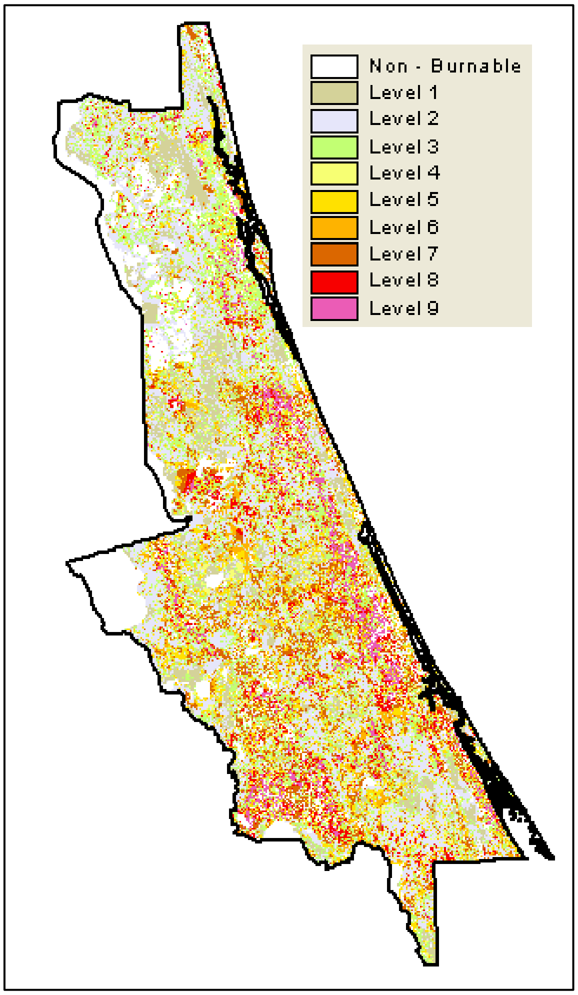


Levels of Concern is calculated as the Wildland Fire Susceptibility Index (WFSI) times the Fire Effects Index (FEI). How is it Calculated?

Level of Concern = WFSI * Fire Effects Index

The WFSI is a value between 0 and 1. The Fire Effects Index is a value between 0 and 100. Hence the LOC is a value between 0 and 100.

Classifications and Map



The output values were assigned to nine LOC categories ranging from low concern to high concern. The LOC output can be used to prioritize areas for further analysis. The FRAS allows the capability to modify the fuels, fire occurrence data (modifying WFSI) and Fire Effects Scores to generate new results and compare them to the published data. An example of the Levels of Concern map for the Bunnell District is in the figure at the right.

The LOC results can be used to complete a more detailed analysis at the local level and communicate wildland fire management concerns.

The LOC results can be used to:

⇒ Identify areas where mitigation options may be of value,

⇒ Allow agencies to work together and better define priorities,

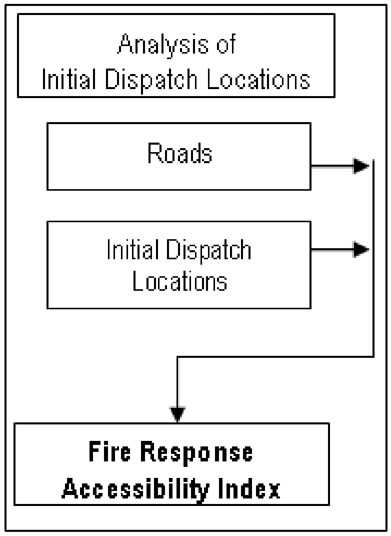
⇒ Develop a refined analysis of a complex landscape and fire situations using GIS, and

⇒ Increase communication with local residents to address community priorities and needs.

Section 4.2 Fire Response Associability Index

The Fire Response Accessibility Index (FRAI) is a relative measure of how long it would take initial attack resources to drive from their initial dispatch location (fire station or other fire fighting resources) to the cell.

Section 4.2.A Overview of Process



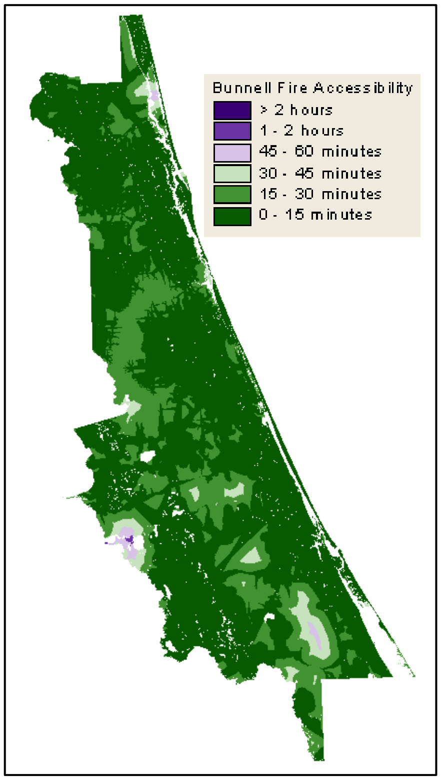
The Fire Response Accessibility Index (FRAI) is calculated based on the distance from Resource locations. The speed traveled on roads was estimated at 40 miles per hour. Travel on roads was assumed to be eight times faster than travel off road. Water was coded as 'NO DATA', meaning that travel across water could not be done unless there was a road crossing. A cost distance analysis was run allowing Arc/Info to assign an approximate time to reach each cell.

The Fire Response Accessibility Index allows users to identify areas of low accessibility from their resources. Coupled with the Levels of Concern data, this information will highlight areas where accessibility is low and the level of concern is high, providing valuable information for anyone concerned with the impacts of wildland fire.

Section 4.2.B Classifications and Map

The FRAI is divided into six categories as follows:

FRAI Class	Estimated Travel Time from Initial Dispatch Location to Cell
1	> 120 minutes
2	60-120 minutes
3	45 – 59 Minutes
4	30 – 44 Minutes
5	15- 29 Minutes
6	0 – 14 Minutes



SECTION 5.0 FIRE RISK ASSESSMENT SYSTEM (FRAS)

Section 5.1 Goals and Purpose

The primary purpose of FRAS is to provide an automated tool for DoF staff, as well as other Florida fire specialists, to access and use the officially published data results of the Florida Fire Risk Assessment project. A series of spatial map data has been compiled and derived as the key part of the project to support operational staff in the future assessment and management of wildland fire risk across the state. This data has been derived by a team of fire experts and reflects the latest and most accurate data describing the wildland fire risk situation within Florida. Tools are provided in FRAS that support the printing of maps and reports using the Published Results.

It is also anticipated that a key use of FRAS and the results will be to communicate the existing fire risk situation within the state to managers, officials and legislators, not only operational staff. The data has been developed to facilitate comparison of areas across the state in this regard.

In addition, FRAS provides modeling capabilities that facilitate DoF staff in modifying key inputs, such as fuel models and fire occurrence, to analyze the effect of mitigation options on the Wildland Fire Susceptibility Index (WFSI) and Levels of Concern (LOC). Areas where the FOA, WFSI or LOC are high are candidates for mitigation options. This allows District staff to leverage local knowledge and expertise while taking advantage of the data derived from the assessment process.

FRAS was developed with the capabilities to:

Review and print maps and reports of the official FRA project Published Results data.

Allow the user to define a custom Area of Interest to support modeling of custom outputs, such as ROS, WFSI, LOC, and FRAI as well as reporting and mapping.

Change key inputs including resource locations, modifying fire occurrence classes, or modifying fuel models to reflect mitigation options in a defined AOI.

The overall purpose of FRAS is to provide unrestricted access to the data derived from the Fire Risk Assessment project in support of operational staff analyzing mitigation options.

Section 5.2 Application Design

FRAS was developed as a standalone application that operates on the ArcView 3.x GIS software.[1] FRAS was designed to utilize the FlamMap program in a standalone mode to support the calculation of fire behavior outputs including the seamless conversion of data between the two programs. The integration approach also supports future planned development of the FlamMap program that will continue to occur independently by Dr. Mark Finney.

[1] FRAS was specifically designed to operate on the 3.2 version of ArcView GIS. The application will not operate on the ArcGIS platform.

FRAS was also designed to leverage the capabilities found in the ArcView GIS platform. The standard ArcView interface has been used as the framework for the FRAS interface. FRAS is accessed via a series of custom pull-down menu options within ArcView 3.x that provides custom functionality and manages data in the standard ArcView *View-Theme* data organization. All other ArcView functions are available while the FRAS options are available. In several instances, custom tools have been developed to facilitate analysis and review of data. However, none of the core capabilities found within ArcView have been removed. The ArcView GIS platform provides a robust and extensive framework for growth of FRAS and further analysis by operational staff.

The data model employed with FRAS utilizes a predefined directory structure that uses ArcView shapefiles, ArcInfo GRID coverages, and standalone Dbase files (.dbf) as the key data elements.

To speed processing time, the non-spatial analyst modeling approach is based on the original pre-defined data layers provided in the GIS data stack. The approach uses attribute modeling of the XXXlocbase.shp shapefile where XXX represents the three-letter abbreviation for the district. This coverage was created to reduce processing time for modeling for the non-spatial analyst users and is not meant to be updated. The following coverages were unioned together to produce the locbase shapefile:

- Critical facilities
- Plantation
- Urban Interface
- Utility Corridors
- SURGO Muck Soils
- Fire Carrier
- Fire Response Accessibility Index
- Wildland Fire Susceptibility Index

Due to limitations within the ArcView and ArcInfo software packages, and to speed processing time for users without Spatial Analyst, data values used to generate the polygons were rounded. As a result, there may be minor discrepancies between the grid and polygon published results. For specific information on how the datasets were rounded please refer to the respective metadata files.

If significant changes have been made to any of these data layers, they will not be represented in the locbase shapefile and therefore will not be reflected in any modeling performed using FRAS to recalculate Levels of Concern.

SECTION 6.0 PROJECT PARTICIPANTS

The FRAS project team is comprised of staff from State of Florida Division of Forestry, Contractor and independent consultants. This team includes fire behavior and planning specialists, as well as remote sensing and GIS specialists. In addition to the project team, a number of additional fire management experts were involved in numerous workshops undertaken throughout the project. Primary team members include:

STATE OF FLORIDA DIVISION OF FORESTRY

- Jim Brenner, Fire Management Administrator (Project Manager)
- Sue McLellan, GIS Analyst
- Scott Goodrick , State Meteorologist

PROJECT CONSULTANTS

- Donald Carlton, Fire Program Solutions – Fire Protection Planning Specialist
- Butch Neal, PBS&J – Fuels and Fire Behavior Specialist
- Geoff Babb, The Nature Conservancy – Fuels and Fire Behavior Specialist

PROJECT TEAM MEMBERS

This section provides a detailed list of project team members who provided critical information during FRAS workshops, the Field Data collection and draft map review.

WORKSHOP MEMBERS – EFFECTS RANKINGS

A two-day workshop was held to assign risk scores and rankings to Environmental Effects and suppression costs to produce the published fire effects results. These scores are being used as defaults to derive Levels of Concern in FRAS. The following DOF staff were involved in assigning the final scores and rankings:

John Kern, Ralph Crawford, Tim Elder, James Brenner, Mike Long, Ray Geiger, Mark Hebb, Jim Karels, Mike Kuypers, Ed Flowers, Bruce Hill, Brian McKee, Joe Anderson

WORKSHOP MEMBERS – FUEL PROFILES

A two-day workshop was held to develop fuel profiles (years 0 through 10) following different fuel treatments to develop the **FRAS Fuels Modification Tool**. We would like to recognize the following DoF staff for their participation at the Workshop.

Mark Clere, Keith Mousel, John Kern, Tim Elder, Fred Adrian, Duane Weis, Dave Fogler, George Custerer, James Brenner

FIELD DATA COLLECTION

The DOF District staff spent countless hours in the field collecting the field data and reviewing draft maps. We would like to acknowledge those that collected data for each District.

Blackwater – Ed Ferguson, Wes Jones, Allen Qualls

Bunnell- Ray Durham, Will Raulerson, Phillip Yoeman, Rick Davis, Brad Lane, Leonard King, Gary Carpenter, Rabun Jarriel, Jim Hostetter, Donnie Trice, Stephen Lloyd, Charles Cassels

Caloosahatchee – Mark Ferguson, Nate Jenkins, Marc Rogers, Roy, Mike Sawyer

Chipola River – Brian Archer, Roger Avriett, Tom Beitzel, Joey Brady, Frank Brogdon, Dan Childs (Tindall Air Force Base Forester), Geoff Cummings, Rochelle Ferrera, Annie Jones, Kristi Kaple, Gery McIntyre, LeaAnna Melton, Chester Rushing, David Stull, Steve Tullar, Shane Wells, Cory Wilson, Roger Yarbrough, Daniel Young, Richard Gilmore (Consulting Forester assist)

Everglades – Alex de la Paz, Papayorgis, Skip Russell, Sean Sinclair, Robert Trincado, Chris Wasil, Malcolm Francis

Jacksonville – Annaleasa Winter, Johnnie Addison, Steve Gaul, Larry Stombock, Henry Hobbs, J.L. Anderson, Tim Keener, Brad Mizeras, Thelton Goff, Beth Smith, Stanley Brown, Bob Ray, Bill Chandler, Jerry Clevenger, Jody Farley, Tim Stiltner

Lakeland – Pat Dwyer, Dennis Herndon, Terry Jones, Pat Keogh, John Knowles, Ned Waters, Robin Whitaker, Windeeaters

Myakka River – Ed Flowers, Duane Weis, Ed Ferguson (Blackwater), Doug Robicheaux (Blackwater), Jeremy Keller, Steve Wilson

Okeechobee – Brighton, Hammock, Randy Gregory (Tallahassee), Travis Bentley (Tallahassee), Robert Trincado (Everglades), Vincent Hill (Tallahassee), Chris Wasic (Everglades), Frank Gibbs (SFR), Mike Lightsey (SFR), Dale Armstrong, Charlie Collier, Giovanni Cueto, Tim Elder, Ken Fucci, Mike Good, Tim Hawks, Shannon Hyattt, Tim Rain, Mike Sawyer, Jim Swingle, Keith Yeates

Orlando – Brad Blackman, Dan Bogenrief, Joe Burroughs, Charlie, Kase Coggins, Mike Coker, Tom Donohoe, John Koehler, Dana Sussmann, Travis Bentley (Tallahassee), Ron Weis

Perry – Robin Marquette, Shane Wells, Carlor Gutierrez, Howard Holland, Jimmy LaValle, John Fish, Rufus McMullen, Ralph Crawford

Suwannee – Lee Barnwell, Jon Handrick, Stan Shepard, Bryan Thrasher, Jay Tucker, Neal White, Tim Wilkinson

Tallahassee – Herbert Franklin, Travis Bentley, Vincent Hill, Phil Czechorowski, Randy Gregory, Milton Shuler, Shane Wells

Waccasassa – Ralph Crawford, Sarah Culhane, Jarc, Jeffrey Watson, Shane Locke, Rufus McMullen, Meadows, Matt Johnson

Withlacoochee – Terry Claflin, Pat Dwyer (Lakeland District), David Fogler, Dennis Herndon (Lakeland District), Michael Josey, John Kern, Alan Kirby, Shane Locke (Waccasassa), Ray Lovett, Tonya Miller, Gary Schreiber, Jason Thompson, Derik Vogt, Vince Morris, Colleen Werner

SECTION 7.0 LITERATURE CITED

Anderson, Hal E. 1982. Aids to determining fuel models for estimating fire behavior. USDA For. Serv. Gen. Tech. Rep. INT-122, 20 p.

Anderson, Hal E. Predicting wind-driven wild land fire size and shape. 1983. Research Paper INT-305. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 26 p.

Andrews, Patricia L. 1986. BEHAVE: fire behavior prediction and fuel modeling system-BURN subsystem, Part 1. USDA For. Serv. Gen. Tech. Rep. INT-194. 130 p.

Andrews, Patricia L. 1989. BEHAVE: fire behavior prediction and fuel modeling system-BURN subsystem, Part 2. USDA For. Serv. Gen. Tech. Rep. INT-260. 93 p.

Bishop, Y., S. Fienberg, and P. Holland. 1975. Discrete Multivariate Analysis: Theory and Practice. MIT Press, Cambridge, MA.

Burgan, Robert E. and Richard C. Rothermel. 1984. BEHAVE: fire behavior prediction and fuel modeling system-FUEL subsystem. USDA For. Serv. Gen. Tech. Rep. INT-167. 126 p.

Cohen, J. 1968. Weighted kappa: Nominal scale agreement with provision for scaled disagreement or partial credit. Psychological Bulletin. Vol. 70, NO. 4, pp., 213-220.

Congalton, R. and K. Green. 1999. Assessing the accuracy of Remotely Sensed Data: Principles and Practices. CRC/Lewis Press, Boca Raton, FL. 137 p.

Environmental Systems Research Institute. 1996. Avenue, Customization and Application Development for ArcView GIS. Redlands: Environmental Systems Research Institute.

Environmental Systems Research Institute. 1996. ArcView GIS, The Geographic Information System for Everyone. Redlands: Environmental Systems Research Institute.

Finney, Mark A. 1998. FARSITE: Fire Area Simulator -- model development and evaluation. USDA Forest Service, Research Paper RMRS-4, Rocky Mountain Research Station, Ft. Collins, CO. 45p.

Fons, Wallace T. 1946. Analysis of fire spread in light forest fuels. J. Agri. Res. 72(3): 93-121.

Kennedy, Heather. 2001. The Dictionary of GIS Terminology. Redlands: Environmental Systems Research Institute.

Story, M., and R. Congalton.. 1986. Accuracy assessments; A users's perspective. Photgrammetremetric Engineering and Remote Sensing. Vol. 52, No. 3, pp. 397-399.

SECTION 8.0 TECHNICAL APPENDICES

Section 8.1 Final Fuels Classification Scheme

I. Non-Flammable Areas

A. **Water**

Fuel Model 0

B. **Rock**

Fuel Model 99

C. **Urban, Non-Wildland**
This includes all areas classified as urban.

Fuel Model 98

II. Transitional Vegetation
Areas where vegetation cover is less than 25% and is presumed to be dynamically changing from one land cover type to another, often because of land use activities. Examples include transition phase between forest and agricultural land, and temporary clearing of woody or herbaceous vegetation. Includes areas changed due to natural causes (e.g. fire, flood, etc.)

A. Fresh Slash is present (0-3 years or so) with no live fuel present

SLASH FUEL MODELS

B. Dead/down material is present and aged and overgrown with live fuel.

1. Slash is from trees. Leaves have fallen and cured. Considerable vegetation (tall weeds) has grown in amid the slash and has cured or dried out (Canopy closure has little or no effect on the rate of spread, but may require sustained moderate winds to support the rate of spread; under certain conditions juvenile stands of Chinese tallow may also fit in this fuel model)

   Fuel Model 6

2. Slash is from trees. Needles and leaves have fallen and considerable vegetation (tall weeds and some shrubs) has overgrown the slash. Fire spreads in surface fuels consisting of litter and/or dead and down stemwood occasionally produced by weather (tornado or hurricane) or other biological impacts such as insect defoliation and mortality. Dry ladder fuels resulting from herbicide application to vine laden treed communities and light slash associated with incompletely harvested timber operations may also contribute to this fuel type.

   Fuel Model 10

III. Planted/Cultivated Vegetation

Areas dominated by typical green vegetation with cover ranging from 25-100% at peak times of growing season. Vegetation has been planted in its current location, and/or is treated with annual tillage, a modified conservation tillage, or other intensive management or manipulation.

A. Planted/Cultivated Woody - Vegetation Occupies Greater than 25% Cover of Area

Of vegetation present, 25-100% of the cover is woody; includes orchards, vineyards, and tree plantations planted for the production of fruit, nuts, fiber (wood), or ornamental:

1. If orchard…………………………………………………………….**Fuel Model 97**
2. If > 60% of surface cover is grass .... **Natural/Semi-natural Grassland**
3. If > 60% of surface cover is shrub .... **Natural/Semi-natural Shrubland**
4. If > 60% of surface cover is trees ....**Natural/Semi-natural Forest**
5. If > 60% of surface cover is dead/down material... **Transitional**

A. Pasture/Hay

Of vegetation present, 75-100% of the cover is herbaceous. The majority of the vegetation in these areas is planted and/or maintained for the production of food, feed, fiber, or seed. The areas of herbaceous vegetation planted by humans in developed settings or for livestock grazing or the production of seed or hay crops or planted for wildlife use and areas of grasses, legumes, or grass-legume mixtures planted or intensely managed for livestock grazing or the production of seed or hay crops.

GRASS FUEL MODELS

B. Cropland

Areas of herbaceous vegetation planted characterized by regular (e.g. annual, semi-annual, biennial) tillage.

Fuel Model 97

IV. Native/Natural and Exotic Vegetation

Areas dominated by typical green vegetation with cover ranging from 25-100% at peak times of growing season. Vegetation is native or naturalized that has not been cultivated or treated with any annual management regime.

A. Wetlands

Areas dominated by natural vegetation in which the soil or substrate is periodically saturated with or covered with water.

1. **Non-woody Wetlands**

Of the vegetation present, 75-100% of the vegetated surface cover is herbaceous. Examples include freshwater marshes and wet prairies. Disturbed sites may include torpedo grass, Japanese climbing fern, and sesbania.

GRASS FUEL MODELS

2. **Woody Wetlands**

Of the vegetation present, woody vegetation (either tree or shrub species) makes up 25-100% surface cover. Examples include Ti-ti stands, mangrove swamp, hpericum marshes, cypress swamp, bay swamp, gum swamp, pond pine forest. Disturbed sites may include Brazilian pepper stands, primrose willow stands, Japanese ligustrum stands.

a. Ti-ti stands/thickets > 70 % of cover

1. Greater than or equal to 3 inch DBH

Fuel Model 8

2. Less than 3 inch DBH

Fuel Model 5

b. Canopy 25 to 60%

1. Greater than 60% of surface cover Herbaceous

GRASS FUEL MODELS

2. Greater Than 60% of surface cover Shrubs

SHRUB FUEL MODELS

c. Canopy > 60%

1. Melaleuca

Fuel Model 4

2. Not Melaleuca

Timber Litter Fuel Models

B. Uplands – Flatwoods and Sandhills
Areas dominated by vegetation in which the soil or substrate is not periodically saturated with or covered with water.

1. **Natural/Semi-Natural Grasslands**
Of the vegetation present, natural upland herbaceous vegetative cover ranges from 75-100%. Most of these areas are dominated by graminoids, and are extensively utilized by grazing animals. Examples include areas dominated by wiregrass and broomsedge. Disturbed sites may be dominated by cogongrass, air-potato, kudzu and castorbean.

GRASS FUEL MODELS

2. **Natural/Semi-Natural Forest – Plantation – Shrubland – Young Forest**

b. Primary carrier of fire is dead/down material resulting from management or a significant natural event.

1. No live fuel present

SLASH FUEL MODELS

2. Live fuel is present

Fuel Model 10

B.) Shrub cover > or = 60%

A. Hardwood Canopy (Trees and Shrubs) > or = 75%

TIMBER LITTER MODELS

B. Hardwood Canopy (Tree and Shrubs) < 75%, Pine overstory or no overstory

SHRUB FUEL MODELS

C.) Shrub cover < 60%

1.) Surface cover is > or 60% timber litter

TIMBER LITTER FUEL MODELS

2.) Surface cover is > 60% grass

GRASS FUEL MODELS

GRASS FUEL MODELS

PRIMARY CARRIER OF THE FIRE IS GRASS

A. Fire spreads in perennial grassy fuels (1 foot or less) where live fuel is a part of the system. The density of the overstory or canopy may contribute to a reduced rate of spread and reduce the intensity.

Fuel Model 2

B. Fire spreads in grassy fuels without canopy or where a limited canopy has little effect on the rate of spread. Fire spreads in annual grasses or periphyton moss (south Florida only) and the fuel bed is < or = 1 foot tall.

Fuel Model 1

C. Fire spreads in grassy fuels without canopy or where a limited canopy has little effect on the rate or intensity, the fuel bed is > 1 foot tall or is cogongrass

Fuel Model 3

SHRUB FUEL MODELS

PRIMARY CARRIER OF THE FIRE IS BRUSH OR LITTER BENEATH BRUSH.

A. Live fuels are not present

Fire spreads through patchy shrubs *(3-6 feet in height)* with little or no logging slash and where canopy closure has little or no effect on the rate of spread, but may require sustained moderate winds to support the rate of spread; an example would be areas dominated by Rosemary Scrub.
Fuel Model 6

B. Live fuels present

1. Fires spreads in *shrubs < or = 4 feet in height.* Palmetto/gallberry association with pine canopy. Managed pine flatwoods may be represented.

Fuel Model 7

2. Fire spreads in *shrubs > 4 feet in height* and/or melaleuca or cogongrass is present and are likely to contribute to the overall intensity of the shrub ignition, which may and often does lead to canopy involvement. (Scrubby flatwoods, Pine Flatwoods, coastal palmetto, and tall palmetto, Ti Ti, Pine Plantations and Oak scrub.

Fuel Model 4

3. Fire spreads in light, green shrubby herbaceous vegetation often with substantial overstory. However, shrubby flamelength rarely lead to or contribute to the ignition of the overstory; wild grape, kudzu, or other vines may be present, but do not provide sufficient age and biomass to contribute as ladder fuels which would lead to canopy involvement. (young scub, 1-2 year old plantations, scrubby ftatwoods)
Fuel Model 5

<u>TIMBER LITTER FUEL MODELS</u>
PRIMARY CARRIER OF THE FIRE IS LITTER BENEATH A TIMBER STAND

A. Dead foliage is tightly compacted, short needle (2 inches or less) conifer litter or hardwood litter. (Include aged stands of Brazilian Pepper and Australian pine).

Fuel Model 8

B. Fire spreads in the surface litter of leafy or fine, blowy fuels. A canopy of long needle pine or deciduous hardwoods contribute to the seasonal accumulation of litter without logging slash. Some closed canopy pine plantations and Turkey Oak fit in this class.

Fuel Model 9

C. Fire spreads in surface fuels consisting of litter and/or dead and down stemwood occasionally produced by weather (tornado or hurricane) or other biological impacts such as insect defoliation and mortality. Dry ladder fuels resulting from herbicide application to vine laden treed communities and light slash associated with incompletely harvested timber operations may also contribute to this fuel type.

Fuel Model 10

SLASH FUEL MODELS
PRIMARY CARRIER OF THE FIRE IS LOGGING SLASH

A. Slash is not continuous. Needle litter or small amounts of grass or shrubs must be present to help carry the fire, but primary carrier is still slash. Live fuels are absent or do not play a significant role in fire behavior. The slash depth is about 1 foot.

Fuel Model 11

B. Slash generally covers the ground (heavier loadings than Model 11), though there may be some bare spots or areas Of light coverage. Average slash depth is about 2 f t. Slash is not excessively compacted. Approximately one-half of the needles may still be on the branches but are not red. Live fuels are absent or are not expected to affect fire behavior.

Fuel Model 12

C. Slash is continuous or nearly so (heavier loadings than Model 12). Slash is not excessively compacted and has an average depth of 3 ft. Approximately one-half of the needles are still on the branches and are red. OR all the needles are on the branches but they are green. Live fuels are not expected to influence fire behavior.

Fuel Model 13

D. Same as C, EXCEPT all the needles are attached and are red.

Fuel Model 4

Section 8.2 Florida Fire Risk Assessment Field Sample Site Form

4.1 **Obs**: ______________________________ 4.2 **Date**: ________/________/________
Day *Month* *Year*

4.3 **New Site**: Y / N

4.4 **Site ID**: __________/_____________________/_________
Site# *Quad Name* *Region*

4.5 **GPS Location**: Easting (m) ________ Northing (m) ________ 4.6 UTM Zone: ____

4.7 **Level of Observation**: Plots measured Viewed from distance Not observable

4.8 **Number of Fuel Models**: 1 fuel model More than 1 fuel model

4.9 **Land Cover Class:**

Non-Veg | Transitional | Planted/Cult. | Non-Woody Wetland | Woody Wetland | Natural/Semi. Grasslands | Deciduous Forest | Evergreen Forest | Mixed Forest | Natural/Semi-l Natural Shrub or Young Forest

Planted/Cult.: Planted/Cult. Woody | Pasture/ Hay | Cropland

4.10 Are you in a Pine or Melaleuca Stand? Y / N

4.11 Prevalent Tree Species:
Species 1 ____________________________
Species 2 ____________________________
Species 3 ____________________________

4.12 What is the primary fire carrier (circle one):

Grass (GR) Shrub (SH) Timber Litter (TL) Slash (SL) None (N)

4.13 Photos:
Roll#_______ Frame# _________ (if film camera)
File Name (if digital camera)

4.14 **Is the area actively managed?** Y / N
4.15 **Management Activities** ____________________

4.16 Change since 1998? Y / N
Cause of Change _________________________

4.17 First Choice FBPS fuel model ___________

4.18 **Second Choice FBPS fuel model** __________
(use only if uncertain between two fuel models)

4.19 Grass cover 100% Y / N
Shrub cover 100% Y / N

4.20 **Site Description**
(*This should include fire and management history from 1998 to present, age of fuels, and any other information relevant to the site.)*

____

____

Field Sample Site – Fuel Model Assessment

Once all of the Site and Plot data have been collected on the forms an assessment of the “fit” of all 13 fuel models at that site must be done. Check the “Good” column for the fuel model that is the most accurate representation of the site. Check the “Acceptable” column when the fuel model could be considered as call for the site. Check the “Unacceptable “ box for the fuel models that would not be used to describe the site.

Fuel Model	Good	Acceptable	Unacceptable
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			

Section 8.3 Florida Risk Assessment – Field Sample Site Plot Form

8.1 Obs. ______________________________________ 8.2 Date: ____/_______/_____
Day Month Year

8.3 Site ID _________/___________________/________ 8.4 Plot # _______
Site t# Quad Name Region

8.5 **GRASS/HERBACEOUS**
8.5.a Percent Cover ______%
8.5.b Average Grass Height _________ in.
8.5.c Dominant Species (optional) ____________________

8.6 SHRUBS

	8.6.a Distance to Shrub (ft)	8.6.b Width of Shrub (ft.)	8.6.c Length of Shrub (ft.)	8.6.d Height of Shrub (ft.)
Quad 1				
Quad 2				
Quad 3				
Quad 4				

Plot Layout

8.6.e. Dominant Species (optional) _____________________________

	Quad 1	Quad 2	Quad 3	Quad 4
Distance (ft.)				

8.7 Pine Re-generation

8.8 Tree Canopy Cover: _________

8.9 TREES

	8.9.a **Distance to tree (ft.)**	8.9.b **DBH (in.)**	8.9.c **Tree Height (ft.)**	8.9.d **Live Limb Height (ft.)**
Tree 1				
Quad 1				
Quad 2				
Quad 3				
Quad 4				
Tree 2				
Quad 1				
Quad 2				
Quad 3				
Quad 4				
Tree 3				
Quad 1				
Quad 2				
Quad 3				
Quad 4				