REVIEW OF FSPRO ANALYSES COMPLETED IN 2010: COMMON ANALYTICAL ISSUES

Wildland Fire Management RD&A, May 2011

PROJECT DESCRIPTION

The Fire Spread Probability Simulator (FSPro) is a geospatial probabilistic model that predicts fire growth, and is designed to support long-term decision-making (more than 5 days). FSPro calculates two-dimensional fire growth and displays the probability that fire will visit each point (cell) on the landscape during the specified time; in the absence of suppression; and based on the current fire perimeter or ignition point.

The purpose of this white paper is to provide guidance regarding FSPro inputs and documentation. The guidance follows a review of recent FSPro inputs and outputs to identify common issues that could lead to inaccurate outputs and unintended use of FSPro analyses in decisions. We identified several common analytical practices that appear inconsistent with methods recommended by the developing scientists that are incorporated in S-495 Geospatial Fire Analysis, Interpretation, and Application. It is difficult to quantify the effect of some inputs on the predicted fire probability output; however, we hope by addressing some of these issues, analyses will be more robust and accurate. For instances of appropriate deviations from standard practices we recommend documentation of rationale. We strive to update this paper as new information is published that will provide guidance for future analyses.

We reviewed 46 FSPro analyses completed in 2010 to evaluate the robustness of each analysis using the spatial fire modeling guidelines taught in S-495, and the findings in Finney et al. (2010)[1]. At least five analyses per geographic area were represented if available. Sample analyses were based on these criteria:

- Analyses were selected with a status of "complete". It was assumed that by marking the analysis "complete", it was reviewed and was acceptable for use in decision-making.
- The first "complete" analysis was chosen for each of 46 incidents, when sorted alphabetically by analysis request date.

SUMMARY

Common Errors

1. Number of Fires—too few fires were used for the simulation
2. Live Herbaceous Fuel Moistures – calculated values were accepted but were inappropriate or too low
3. High Forecast to Analysis Length Ratio—too many forecast days were selected given the length of the analysis
4. Landscape Change Rules—use of landscapes with no adjustments to canopy characteristics or fuel models
5. Entering Notes—lack of documentation, especially where non-standard inputs were used
6. Burn Period – defaults were often used without considering the observed fire behavior

Factors that may contribute to poor results

1. Start and End Periods for ERC—season length is often too short
2. Wind Start and End Hours and Wind Type—defaults commonly accepted
3. Marking an Analysis as "Complete"—analyses are accepted that appear to be calibration runs

DETAILS - COMMON ERRORS

1. Number of fires

The number of fires used for analysis is an important consideration and should be based on the, purpose of the analysis, time requirements, fire size, and current fire activity. Using a low number of fires for the final run to develop a probability output will result in greater variability, lower reliability and may fail to adequately represent rare events. Finney et al (2010)[1] suggest that variability becomes increasingly stable and rare weather events were captured better when the number of simulated fires increased from 256 to 4000. Because the variability of the burn probabilities were reduced with an increase in the number of simulated fires, the reliability of the model to consistently represent rare events (events that occur with less than 20% probability) should increase.

For initial runs used for calibration and to develop a basic understanding of the variability of fire potential, using few simulations is appropriate. However, these analyses should remain in review status or be rejected; they should not be accepted and marked complete. While using a smaller number of fires is still suggested for calibration runs, using fewer than 1000 fires is not enough to produce repeatable quantitative estimates, and generally is inappropriate for strategic decisions.

In some cases, the number of fires simulated was reduced in order to reduce the processing time. There are numerous factors that relate to the processing time and there are several ways to reduce processing time. Factors that affect processing time and alternatives to reducing the number of simulations include:

- Landscape Resolution- Default landscape resolution for FSPro is 90 m. Using coarser resolution (larger pixel size) will decrease processing time. This is especially important to consider when modeling large fires. Coarsening could have an adverse effect on modeling results by over or under-emphasizing fuels or fire travel pathways relevant to fire spread. For example, if the landscape is resampled with non-burnable cells where burnable fuels actually reside, a possible fire pathway is eliminated in the model. This is more important when fuels are highly variable.
- Number of analyses being conducted –Analyses are processed in the order they are submitted. During periods of significant fire activity, analyses may sit in a queue waiting to be processed. Expect longer delays with increasing fire activity. Check the number of analyses and depth of the queue using the Queued and In Process filter. Try to schedule

[1] Finney, M.A., I.C. Grenfell, C.W. McHugh, R.C. Seli, D. Trethewey, R.D. Stratton, and S. Brittain. 2010. A Method for Ensemble Wildland Fire Simulation. Environ Model Assess. DOI 10.1007/s10666-010-9241-3.

your analyses during periods of lower activity, often early morning or later evening. WFDSS is working to increase processing capacity and thus deliver products quicker. As capacity increases, the need to make adjustments will reduce.

- Size of fire – Larger fires require more calculations and thus processing time. Make sure the ignition represents active fire and the previously burned area is unburnable. If appropriate, focus the analysis on a smaller area of concern rather than the entire fire

Table 1 displays a summary of the number of fires simulated in FSPRO for the 46 sampled analyses. 91% of the sampled analyses had 1000 fires or less, which is likely under predicting the lower probability zones (less than 20%).

Number of Fires per Simulation (N=46)		
Number of Fires	Count	Percent
256	9	19.6%
512	8	17.4%
1000	25	54.3%
1500	2	4.3%
2000	1	2.2%
5000	1	2.2%

Suggestions

- Although initial calibration and set-up runs can use fewer fires, the recommendation for final analyses used in decision-making is a **minimum** of 1000 fires. If time permits, and the queue is short, copy the analysis and rerun with 2000 fires or more.
- When there is a need to reduce processing time, consider using a coarser landscape, reducing the active perimeter, or breaking the analysis into smaller segments.

2. Live Fuel Moistures

The National Fire Danger Rating System (NFDRS) is the method applied in FSPro to compute dead and live fuel moistures using the selected ERC RAWS station. Live herbaceous and woody fuel moisture calculations are the weakest model in the NFDRS system. The live fuel moisture values should not be expected to exactly reflect specific species for the geographic area for which you are working. Further, live fuel moistures, especially live herbaceous fuel moisture in combination with the 40 fuel models (Scott and Burgan 2005), can strongly influence rate of spread and subsequent values of fireline intensity. Occasionally the calculated fuel moistures for the ERC bins are reasonable, but not often. The table below splits the 46 analyses by those where the default values for live herbaceous fuel moistures were applied, compared to those where values were adjusted.

Live Herbaceous Fuel Moisture Values (N=46)	
Item	**Total Count (Percent)**
Default Values Used from NFDRS	12 (26%)
Adjusted Values Entered	34 (74%)
Total	46 (100.0%)

Twenty-six percent of analysts used defaults, but whether or not this was a reasonable choice is difficult to ascertain. It is encouraging that 74% of analysts at least considered fuel moisture modifications, though again, there was no assessment as to whether the modifications were reasonable. The important take-home message is that live fuel moistures should always be assessed by the analyst, as defaults are often inappropriate.

Suggestions

- Usually live fuel moistures should be adjusted for local seasonal influences near the incident depending on the fuel models represented in the landscape file (lcp) and the length of the simulation.
- These observations and suggestions also apply to live woody fuel moistures.
- If field measurements are not available, guide selection of values based on 1) curing (see Table 2 in Scott and Burgan 2005); 2) the national live fuel database (http://72.32.186.224/nfmd/public/index.php); 3)rough estimates of live fuel moisture based on plant phenology from Rothermel (1983); 4) departure from relative and average greenness maps (available on many geographic area coordination center websites); or 5)experimental live shrub moisture maps (http://www.wfas.net/index.php/live-fuel-moisture-experimental-products-42).

Table 2—Level of curing versus live herbaceous moisture content.

Level of curing		Live herbaceous moisture content
Uncured	0 percent	120 percent or more
One-quarter	25	98
One-third	33	90
One-half	50	75
Two-thirds	66	60
Three-quarters	75	53
Fully cured	100	30 or less

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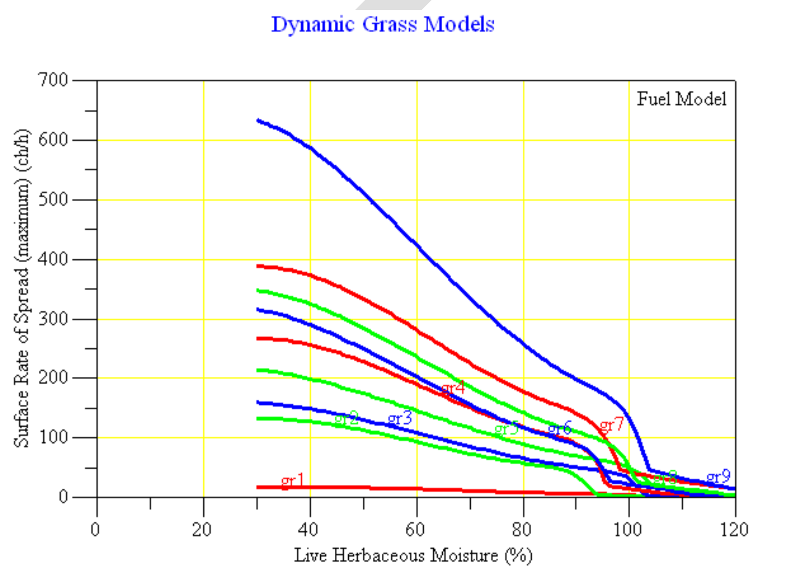
- The live fuel moisture values are affected by some settings in the station catalog, such as vegetation type and climate class, greenup and freeze dates, as well as the quality of the selected station data. Remember to review these settings in WFDSS once a RAWS station has been selected.
- When copying an FSPro analysis, the live fuel moisture values used during early summer may need to be changed later on in the fires life-cycle (late-summer, early fall), reflecting seasonal changes in vegetation.
- Use Behave Plus to evaluate how ROS changes with live herbaceous moisture especially for the dynamic fuel models (GR 1 – GR9; GS1-GS4; SH1 & SH9, TU1 & TU3).



Example output from Behave Plus. Surface Rate of Spread (chains per hour) by Live Herbaceous Fuel Moisture (percent) for each of the Dynamic Grass fuel models (GS 1- GS9). Inputs (6, 7, 8%, dead 1-hr, 10-hr, 100-hr fm; 10 mph wind; 10% slope).

3. High Forecast to Analysis Length Ratio

FSPro is designed to apply a wide range of time-series generated climatology information (an ensemble) of ERCs and fuel moistures that could occur for an incident including rare weather events (high winds and low ERCs, for example). The user has the option to include forecasted ERC and wind information to fine tune the time series to known incident conditions, but it is not always needed. When forecast confidence is high, using forecasts is a practical option, but a general rule of thumb is to use no more than 33% of the analysis period as "forecast".

For instance, 3 days of forecasted data locks-in the ERC (and subsequent fuel moistures, burn period and spotting) and wind speed for the first 3 days of the simulation. If 1000 fires are modeled for 7 days with 3 days of forecast, the first 3 days of every 7-day simulation (for 1000 simulations) will show little FSPro output variability for fires that do not exhibit crown fire and spotting. This leaves 4 out of 7 days for FSPro to utilize probabilistic wind and weather inputs.

For 46 analyses, we computed the forecast to analysis length ratio (number of forecast days/number of simulated days). In 46 analyses, 9% had a HIGH forecast to analysis length ratio greater than 0.714 or greater. For these samples, 5 to 6 days of forecasts were used for 7 day analyses. Additionally, 33% of the sampled analyses had a moderate forecast to analysis length ratio of 0.429. For many of these analyses, 7 –day fires were modeled using 3 days of forecast data.

ERC Stream (N=46)					
Number of Simulated Days	Number of Forecast Days	Forecast to Analysis Length Ratio	Count	Moderate Ratio	High Ratio
5	0	0.000	1		
7	0	0.000	5		
7	1	0.143	1		
7	2	0.286	5		
7	3	0.429	12	12	
7	5	0.714	2		2
7	6	0.857	2		2
14	0	0.000	3		
14	1	0.071	1		
14	2	0.143	2		
14	3	0.214	7		
14	5	0.357	2		
14	6	0.429	3	3	
Sum			46	15	4
Percent				33%	9%

Suggestions

- FARSITE or Near-Term (NTFB) may be the most appropriate tool if the weather forecast is highly reliable, or there is a specific fire spread scenario being modeled.
- Allow FSPro to statistically select wind and ERC for the majority of the simulation period to create a probability map with variability.

4. Landscape Change Rules

The landscapes (LCPs) available in WFDSS are regional to national scale data sets. Subsequently, it is unlikely the fuels and canopy characteristics will truly reflect the area for a particular incident. Applying landscape editor rules allows an analyst to modify a landscape to better model fire behavior.

There are a number of reasons why modifying a landscapes may be advantageous for fire behavior modeling. First, fuels and canopy data are derived from plot and remote sensing information generating values used best with the Scott and Reinhardt crown fire method. While the Scott and Reinhardt crown fire method is available with short-term fire behavior (STFB) and near-term fire behavior (NTFB), FSPro only uses the Finney Crown Fire Method. Compared to the Scott and Reinhardt crown fire method, the Finney crown fire method requires a more extreme fire environment to sustain active crowning and predicts a lower spread rate when it does predict active or passive crowning. Subsequently, it may be necessary to modify input data when using the Finney crown fire method, such as increasing canopy bulk density, decreasing canopy base height, and increasing wind speed, in order to simulate observed or expected crown fire behavior (one exception is Landfire Rapid Refresh v1.0.1, which is calibrated to the Finney crown fire method). Second, many WFDSS-generated LCPs do not reflect the most up-to-date disturbance, which could markedly affect fire modeling simulation results. See WFDSS help for more information about specific landscape data sets.

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Landscape Modifications (N=46)				
Data source	Count	Fuel Model Modifications	Canopy Modifications	Was This Data Source Calibrated for Finney Crown Fire Method?
Alaska Landfire	4	0	0	No
Alaska 2009	1	2	1	No
Landfire National v1.0.0	21	9	7	No
CA Landscape 082710	11	0	0	No

Landfire Rapid Refresh v1.0.1	9	6	0	Yes
SUM	46	17	8	
PERCENT		37%	17%	

The number of analyses with fuel modifications is quite low—37% for fuel model changes, and 17% for canopy changes. While most analyses should have modified canopy fuels when using a landscape that is not calibrated to the Finney Crown Fire Method, only 31% of analyses showed such modifications.

Suggestions

- The Landscape Critique is a helpful report to evaluate a landscape. Go to Analyses – Landscape and click "Generate LCP Critique". After about a minute, refresh this page (by clicking on the bolded word, "Landscape" in the left hand menu), and that same button will change to "Download LCP Critique". A PDF report is created that displays the range of values for elevation, slope, aspect, fuels, etc. This report also describes ranges of these landscape inputs by fuel model. An analyst can quickly view the range of canopy base height and canopy bulk density for any fuel model to know if it has potential for surface, passive or active crown fire.
- For testing assumptions about surface, passive and active crown fire, use Short-term fire behavior with your chosen landscape first. While STFB will only predict weather and wind for one moment in time (i.e. the current wind and weather for the current ERC), it can be a good tool to better understand the potential of your landscape to produce passive or active crown fire. After running STFB, view your results by going to Analysis – Menu- Results on the left hand menu. Then, in the Layers menu, go to Analysis - Short-term results - Basic Output - Crown Fire Activity.
- Use the historical fire perimeter data overlaid on your chosen lcp to observe if the lcp reflects that disturbance. Once an lcp has been created, go to View Landscape in the left hand menu. The fuel model map will show automatically. Expand the left hand menu to show Fire Related – Fires Since 01/01/2010 and Historical Fires 2001-2009.
- Use the Landscape Editor tools to modify the landscape. Go to Analyses – Landscape Editor. Click Add and input parameters to make a modification to the landscape. Create and critique the new landscape. See Help documentation for further instructions.
- Use WFDSS and Landfire help to understand the assumptions of the various landscapes. Since 2010, both the California and Landfire lcps have changed and been updated. WFDSS now has Landfire Rapid Refresh 2008 v1.1.0, reflecting all disturbances through 2008; California Landscape reflects fires and other disturbance up to 2010.
- Obtain intelligence from local personnel about disturbance. Use the polygon tool to create a mask representing this disturbance. Use that mask with the Landscape Editor tool to modify surface and canopy fuels accordingly.

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- In most cases, observations of fire behavior and fuel complexes are important to incorporate into the FSPro analysis rather than accepting default landscapes.

5. Entering Notes

Fire Behavior Specialists' notes are important. They provide a decision trail for current and future analysts to follow. They document an analyst's reasoning and inform individuals of the assumptions made at the time of the analysis. Take time and enter notes throughout the FSPro analysis process; they become critical if the inputs vary from standard protocols.

Notes can be typed into several different FSPro input screens and existing notes can be edited. Analysts can submit an analysis to process and then type in notes while the simulation is running, but once an analysis is 'accepted' or 'rejected', the analysis cannot be edited nor have notes added or deleted.

In the 46 FSPro runs, 48% of them showed notes to document the analysis, but 52% did not use notes. In many cases, the notes did not explain the irregularities (e.g. no notes explaining why 2 percent live herbaceous fuel moisture was used).

Suggestion

- Once an analysis is accepted, and the status is changed to "complete", that analysis becomes viewable to any viewer with a WFDSS logon. The assumption behind a completed analysis is that the output was applied to manage a wildfire. Notes from an analyst are essential to document the thought process. See WFDSS Help to understand how to use Notes.

6. Burn Period

Burn period should be realistic based on what is being observed for the current ERC. FSPro produces reasonable fire spread estimations for each successive fire simulation when burn periods are realistic. The default burn period values (in minutes) are a good starting point, particularly for a moderate fire season. An effective way to validate burn period is to monitor the actual fire and conservatively estimate the number of minutes the fire actively spreads given that day's ERC.

Although 22% of the analyses had adjusted burn periods, either to lengthen (8 analyses) or to shorten (2 analyses) the burn period, 78% of the analyses accepted the default burn period.

For example, if the ERC was 65 and the time the fire was actively burning was 7 hours a day, start with the 89th percentile bin, (because 65 falls between a Min ERC value of 59 and Max ERC value of 68)and change the burn period to 7 hours * 60 minutes = 420. From that starting point, increase the 97th percentile by one hour, and decrease the lower percentiles by one hour (see figure).

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%ile	Min ERC	Max ERC	1 Hour FM	10 Hour FM	100 Hour FM	Herb FM	Woody FM	Burn Period	Spot Prob	Delay
97	68	81	3.0	3.7	6.5	30	80	480	0.15	0
89	59	68	4.1	4.9	8.2	60	100	420	0.10	0
80	52	59	4.6	5.6	9.7	75	110	360	0.05	0
70	48	52	5.5	6.6	10.7	90	130	300	0.01	0
60	44	48	6.0	7.1	11.7	120	150	240	0.00	0

Add Row | Delete Row | Delete All Rows | Recalculate Fuel Moistures

Suggestion

- Analysts should consider changing the ERC bin representing the current ERC to reflect the observed burn period. Starting with that value, increase the Burn Period for higher ERC bins, and decrease the Burn Period for lower bins (usually in 60 minute increments). Increasing the burn period will likely predict larger fire size; conversely, decreasing the burn period will likely predict smaller fire sizes for each successive fire simulation.

DETAILS - FACTORS THAT MAY CONTRIBUTE TO POOR RESULTS

1. Start and End period for ERC

The start and end dates defined in the Date Filter for the ERC Classes should be defined to represent seasonal variability around the Analysis Start date. The date filter is important because it defines the Min and Max ERC values for the various ERC bins which determines overall fire growth. It also determines the Min ERC value for the last bin, which is equal to or below the 60th percentile, when fires will no longer spread.

Three out of 46 analyses had date filters that may have not captured the seasonal variability for their fire simulation. All three had the End Date filter set within 5 days of the end of their analysis period, without a mention of this selection in the notes. The rest of the analyses (43 out of 46) encompassed a wide range of dates around the Analysis Start date.

Suggestions

- We recommend always providing a buffer of approximately a couple months prior to the start date and a month to the season end to account for seasonal variability.
- ERC Dates have to encompass a larger time frame than your analysis dates.
- The default ERC dates in WFDSS are set to the general fire season for the geographic area where the ignition occurs. This is a good starting point for the ERC Class date filter. You can change those dates and select “Generate ERC Classes”, to evaluate how different date filters will impact the values in the ERC bins.

2. Winds: Start and End Dates/Hours & Wind Type

The combination of wind speed and direction is influential on prospective fire growth for each of the successive fire simulations in FSPro. The Time Filter on the FSPro Winds menu option is the filter which contributes to how the Weighted Wind bins are populated. The default in WFDSS is 2 weeks before the Analysis Start Date for the Start Month/Day. The End Month/Day is set to one

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month after the Analysis Start Date. Default time is set between 1000 and 2000 hours. The objective is to select the time periods that will capture the winds of concern that are most influential for the fire, modeling objectives and scenario. You may find that you need to extend these dates to adequately capture the winds that are pertinent to the incident. Ideally, the time filter should reflect the hours of the day when active burning occurs for that incident.

Of the 46 completed analyses, 74% used the default dates and 57% used the default times. It's unclear if analysts consciously chose the defaults because that time and date period optimally represented a range of wind speed and directions that would likely occur on their incident. One analyst set the time filter to represent 4 hours, although he/she accepted the default burn periods of 5 to 6 hours for the higher ERC bins. Although there may be a valid reason to set up the analysis this way, notes were not written to explain the reasoning.

Wind type also has a marked effect on prospective fire growth. The wind type on the FSPro Winds menu option defaults to 10-min average winds used from the selected RAWS station. However, the analyst may choose "both" or "gusts" to increase the selected wind speeds used for the simulations. "Both" uses a combination of the 10-min average and gusts wind speeds. Gust information is the peak recorded wind speed and its associated direction within the observation hour and it samples higher wind speeds.

Of the 46 completed analyses, 37% used 10-min average; 61% used both; and 2% used gusts. When selecting wind type, it is also important to pay attention to the Calm Weight, because typically it is not advantageous to have a RAWS station with a high Calm Weight (> 10%) that did not capture wind speeds very well. Five out 46 analyses had calm weights that exceeded 10 percent.

Suggestions

- Use the Wind Rose option to graphically display if the winds adequately sample the dominant wind speed and direction expected or observed on the incident.
- Make changes to the Time Filter and use the Wind Rose to observe if those changes better represent observed or expected wind speed and direction.
- Use "10-min average" winds, when the area you are in is experiencing an average fire season or is just below the average.
- Use "both" wind types (includes 10-min average and gusts) to model extreme conditions or a severe fire season; or if you need to include the probability of encountering higher wind speeds during a simulation.
- Use "gusts" sparingly, as you are submitting the modeled fire to the potential for higher winds throughout the entire simulation period. The gusts only option may be appropriate for short simulation durations such as 7 days as long as there are high forecasted winds affecting fire behavior.
- If you need to use "gusts" wind speeds to get adequate fire spread, this may be an indication that fuel models or fuel moisture settings, etc. may not be adequately representing the fire behavior.

- Always evaluate the selected wind types given your observations of the current fire environment, observed fire behavior, and the expected and forecasted weather for the area which you are working.

3. Marking an Analysis as "Complete"

Statistics were not compiled for this FSPro analysis topic because only "complete" analyses were sampled in this initial assessment. When an analysis is "Accepted" by an analyst, the status changes from "Review" to "Complete". This implies that it is ready to be viewed by others and used in decision-making. However, a casual assessment indicates that analysts accept FSPro outputs clearly meant as drafts. For example, three "complete" runs may be listed, with the first titled, "Calibration" using 256 fires, the second titled, "Calibration2" with 500 fires, and the third titled, "Final" with 1000 fires. Clearly, the first two were not meant as final products to be used in decision-making. It is understood, however, that sometimes run names do not describe the run—if an analyst later decides to accept what was a "calibration", the name cannot be changed after the fact (this is where the use of Notes can come in handy). Completed analyses will be archived as permanent fire records (per Forest Service CIO).

Analysts reported that they completed an analysis in order for other people to review it or "see" it in WFDSS. However, viewing privileges for analyses in "Review" status can be granted without the analyst having to mark a draft or calibration analysis as "Complete". Other WFDSS users can be granted privileges to view an analysis from the "Analysis Privileges" tab on the left side menu and finding the username in the Address Book.

Suggestions

- Viewing privileges can be granted for a non-complete analysis
- Be very judicious in marking analyses "complete"
- If an analysis is accepted as "complete" but is not intended for decision making, there should be notes that clearly state the use of the analysis

Conclusion

We identified some common FSPro issues and presented some suggestions for improvement, but the geospatial fire modeling interface and the field of fire behavior modeling will continue to change. WFDSS is constantly being updated with new and revised Help menu items, webinars, and white papers. Additionally, in an effort to make the most up-to-date information available to all analysts, the material for S-495, Geospatial Fire Analysis, Interpretation, and Application online units 1-8 are available on the FRAMES website as free downloads (FRAMES.Subject Areas>Fire Behavior>S495 at http://frames.nbii.gov/portal/server.pt?open=512&objID=212&&PageID=2840&mode=2&in_hi_userid=2&cached=true). The Wildland Fire Management RD&A welcomes your feedback.

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