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# Do you BEHAVE? – Application of the BehavePlus fire modeling system

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**Abstract**
The BehavePlus fire modeling system is the successor to BEHAVE, which was first used in the field in 1984. It is public domain software, available for free use on personal computers. Information on user communities and fire management applications can be useful in designing next generation systems. Several sources of information about BehavePlus are summarized to indicate the number of users, level of use relative to other systems, and fire and fuel management applications that BehavePlus supports.

**Additional keywords:** Fire behavior, decision support, fire suppression, prescribed fire

## Introduction

The BehavePlus fire modeling system is a desktop application that produces tables, graphs, and simple diagrams of modeled fire behavior, fire effects, and fire environment. BehavePlus is used to model surface and crown fire spread rate and intensity, transition from surface to crown fire, fire size and effect of containment efforts, tree scorch height and mortality, fuel moisture, wind adjustment factor, spotting distance, and more. BehavePlus is not limited to a specific application, but is designed to be used for any fire management application for which fire model results are useful. BehavePlus is used for a range of applications including wildfire prediction, prescribed fire planning, and fuel hazard assessment, as well as communication, education, and training.

BehavePlus has been available since 2001. It is the successor to the BEHAVE fire behavior prediction and fuel modeling system, which was first available at Rocky Mountain Research Station's Missoula Fire Sciences Laboratory in 1977 and was offered for field application in 1984. The update from BEHAVE to BehavePlus version 1.0 was funded by the Joint Fire Science Program (JFSP). Updates through version 5.0 have been supported by the U.S. Forest Service Fire and Aviation Management (sponsor) and the Rocky Mountain Research Station (developer). Background of BehavePlus including its relationship to the spatial systems FARSITE, FlamMap, and FSPro is provided by Andrews (2007).

This paper was written for a conference with the theme 'Beyond Fire Behavior and Fuels: Learning from the Past to Help Guide Us in the Future.' Examination of application of a system that has been in place from the early years of the use of computers in fire management to the present can contribute to a discussion of future systems.

Several sources of information on application of BehavePlus are summarized in this paper. As an indication of how many people use the system, we report on responses to the license agreement and visits to BehavePlus web pages. The use of BehavePlus in comparison to other systems is shown in the results of four separate surveys. User responses to inquiries about application of BehavePlus are summarized, and examples of formal use of BehavePlus by U.S. Agencies are described.

While summaries about application of BehavePlus are given here without interpretation, the information can be used in formulating an analysis of user communities and their fire modeling needs. While BehavePlus is a relatively simple system with broad application and many users, other systems are necessarily more complex with a specific application and a limited user group. Relationships among systems, modeling capabilities, and applications can indicate areas for potential consolidation in the development of the next generation of systems that support fire and fuel management.

**How many people use BehavePlus**

There is no way to determine exactly how many people use BehavePlus. A program that is available for unrestricted distribution is not designed to be tracked. We summarize responses we have received from the 'postcardware' license agreement and visits to the BehavePlus web pages as an indication that there are a large number of users.

*Postcardware license agreement*

BehavePlus is public domain software and available for free download from www.firemodels.org. It was developed by the Rocky Mountain Research Station on contract with Systems for Environmental Management (SEM). The installation window describes the license agreement (Fig. 1): 'By installing and using BehavePlus5 you agree to mail a picture postcard depicting your local area…'

According to Wikipedia, 'Postcardware, also called cardware, is a style of software distribution similar to shareware, distributed by the author on the condition that users send the author a postcard. … Postcardware, like other 'novelty' software terms, is often not strictly enforced.'

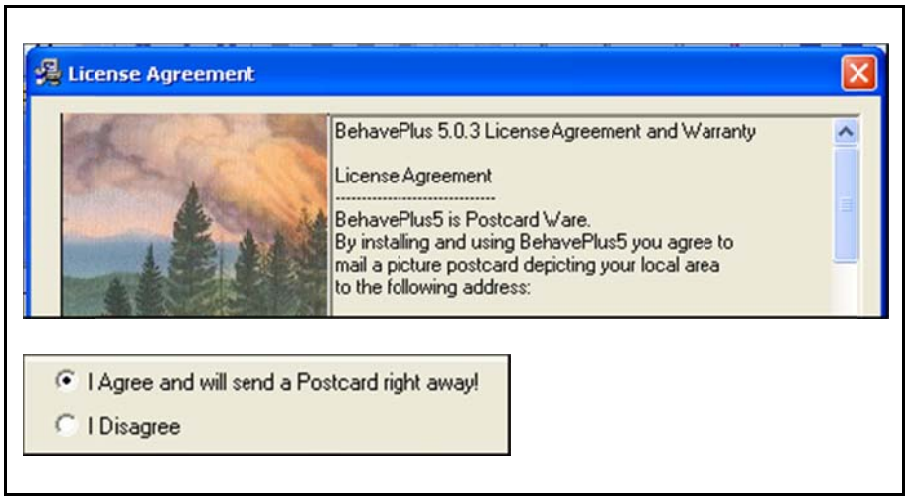


**Fig. 1.** Installation of BehavePlus program displays a license agreement, by which a person has to agree to send a post card depicting his or her local area.

We have received 571 postcards, cards, and letters, which we greatly appreciate. Responses came from 46 U.S. States and 16 other countries: Australia, Botswana, Brazil, Canada, Finland,

France, Gabon, Germany, Italy, Mexico, New Zealand, Philippines, South Africa, Spain, Sweden, and Uruguay. We also received a cap from Saskatchewan, Canada, and a fire prevention air fresher from Valencia, Spain.

We did get some excellent photos of local fuel and fire. Other postcards were vacation spots or jokes. We received formal letters apologizing for not having a postcard to send and asking if the letter would suffice. Several admitted they had downloaded several versions and hadn't sent a card, but were finally sending one. The Stewardship Coordinator for the Aldo Leopold Foundation in Wisconsin sent a CD of their fuel types. Participants in a Prescribed Fire Planning and Implementation course in Tallahassee, Florida, sent a package of postcards representing their home bases. The University of North Texas Wildland Fire Ecology and Management Class sent class photos labeled 'Behaving Ourselves.'

Others (don't worry…we don't know who you are) didn't send a card, which is fine, even if you checked 'I agree…' As noted in Wikipedia, the agreement is not strictly enforced. We do know that far more people have downloaded BehavePlus than have sent a postcard.

While the 'postcard' information isn't in a form suited for generating a summary of application of BehavePlus, we did learn that many people are using it for a range of applications. The postcards provide an interesting personal perspective.

*Webpage visits and download count*

The BehavePlus program and supporting material is on www.firemodels.org. Google Analytics showed that for the year prior to October 1, 2010, there were 163,313 pageviews on FireModels.org by 21,340 absolute unique visitors. The BehavePlus Introduction page was viewed 12,833 times (9,833 unique page views) (Fig. 2). The BehavePlus Downloads page was viewed 8,205 times (6,191 unique views) in that year.

Because of changes in the server and software support for www.firemodels.org in the last year, we have not been able to specifically count downloads of the BehavePlus version 5.0. There were, however, 4,586 downloads of BehavePlus version 4.0 from September 2008 through June 2009.


**Fig. 2.** The BehavePlus Introduction page was viewed 12,833 times (9,833 unique page views) in the year prior to Oct. 1, 2010.

**Use of BehavePlus Relative to Other Systems**

Results of four surveys indicate that BehavePlus is the most widely used computerized fire system in the U.S. Two surveys gave responders a list of systems from which to select. The other two asked open-ended questions. The following discussions of survey results are restricted to BehavePlus.

*Exploring Information Needs for Wildland Fire and Fuels Management, 2004*

Miller and Landres (2004) reported the results of a questionnaire and workshop that sought to gain a better and deeper understanding of the information needs of wildland fire and fuel managers. They listed 50 types of information and tools in nine categories and asked respondents to indicate which ones were used to support fire and fuel management decisions in their management areas. Fig. 3 shows the percentage of users that selected each of the 27 computerized tools in three categories: fire spread/behavior models, fire danger/fire weather models, and fire effects models. BEHAVE was used by 95% of the 143 responders.

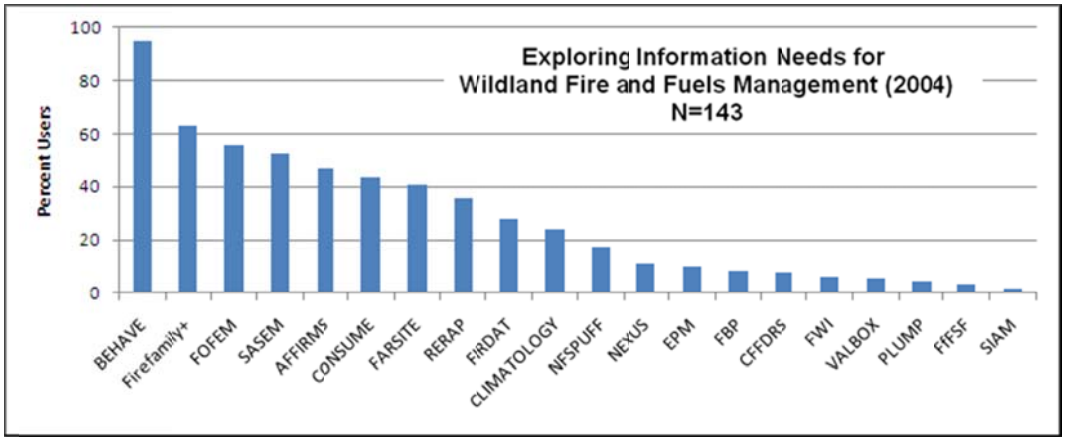


**Fig. 3.** BEHAVE was used by 95% of responders to a survey by Miller and Landers (2004). The plot shows the results for 27 computerized tools in the categories of fire spread/behavior, fire danger/fire weather, and fire effects models.

*NAFRI RX-510 and FML course survey, 2006*

In gathering information about which fire and fuel analysis tools are used, Tim Swedberg, JFSP Communications Director, conducted surveys during two courses (RX-510 and FML) at the National Advanced Fire & Resource Institute (NAFRI) in Tucson, Arizona, in 2006. The survey form was titled 'Which Models Do You Use?' and asked each person to 'Please make a checkmark next to the programs you now use!' A table of 40 applications was taken from a review draft of Peterson *et al*. (2007). (FEIS was only on the RX-510 list and FIREMON was only on the FML list.)

The target group of the RX-510 course, Applied Fire Effects, was 'natural resource managers involved in planning and implementing the use of wildland fire from the project level to the landscape scale.' The Fire Management Leadership course (FML) was directed to Forest Service Forest Supervisors/Deputy Forest Supervisor levels and their equivalent in other

agencies. The course was 'a comprehensive look at the Agency Administrator's leadership role within the Fire Management Program….'

The trainees in the two courses were quite different (operations and management), but the responses were surprisingly similar. The percentage of trainees who use the top 16 systems is shown in Fig. 4. The other 24 systems were used by fewer than 6% of the responders. Fourteen systems had either one or no checkmarks indicating use. All but one person in each of the courses indicated that they use BehavePlus: 51 of 52 FML trainees and 24 of 25 RX-510 trainees.

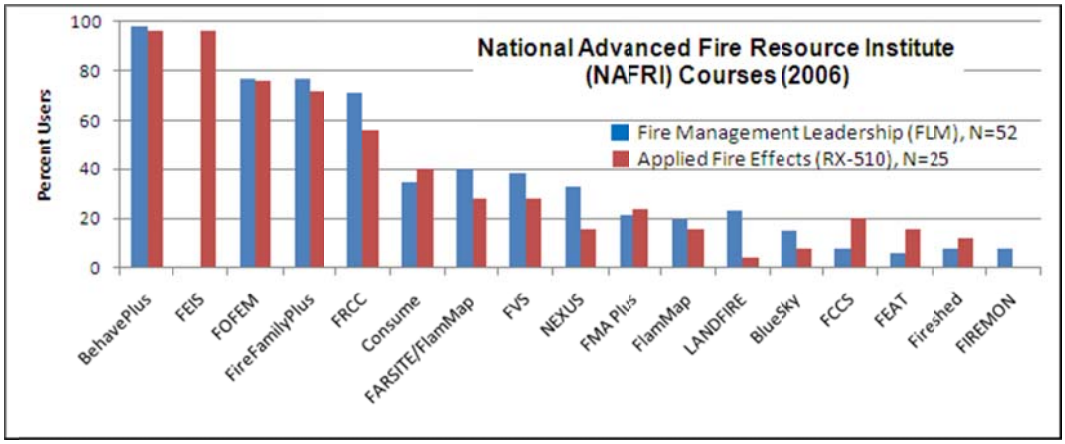


**Fig. 4.** BehavePlus was used by 76 of 78 trainees (97%) in the 2006 NAFRI courses, FML and RX-510. The top 16 of 40 listed systems are shown on the plot. Twenty-four other systems were selected by fewer than 6% of responders.

*Fire and Fuels Specialists Software Tools Survey, 2008*

A summary of Fire and Fuels Specialists Software Tools Survey conducted by the Joint Fire Science Program and National Interagency Fuels Working Group was reported by H. Michael Rauscher (2009). 'As part of a comprehensive study of the issues related to software systems in the fire and fuels subject area, it was desirable to understand what software tools were actually in use nationwide for fuels treatment analysis and planning. The survey asked each respondent the following questions: What software program(s) are you using to perform fuels treatment planning work? ... the point of the survey was not to produce a statistically valid result but rather to obtain an impression of what software tools fuels specialists used most frequently and conversely, which ones they did not use.'

Forty-six software tools were listed in the 44 responses. Thirty-nine (89%) listed BehavePlus (or BEHAVE) (Fig. 5). The next highest was listed by 19 (43%). Six of the 46 tools were listed by more than 25 percent of the responders, and twenty-five tools were listed only once.

The report stated: 'Behave, with all its variants, is one software tool that is almost universally used (89% of respondents) on a routine basis. It is by far the single most widely used software tool.'

*Technical and Social Influences on the Success of Fire Science Delivery, 2007-2008*
Data for a study titled 'Technical and Social Influences on the Success of Fire Science Delivery' were collected in 2007 and 2008 during fire and fuels preseason meetings, workshops, and training courses (Wright 2010). While an assessment of software tools was not a primary purpose of the study, the following survey question was included: 'In your current job, how often do you run fire behavior or vegetation prediction models? Please list which ones?'

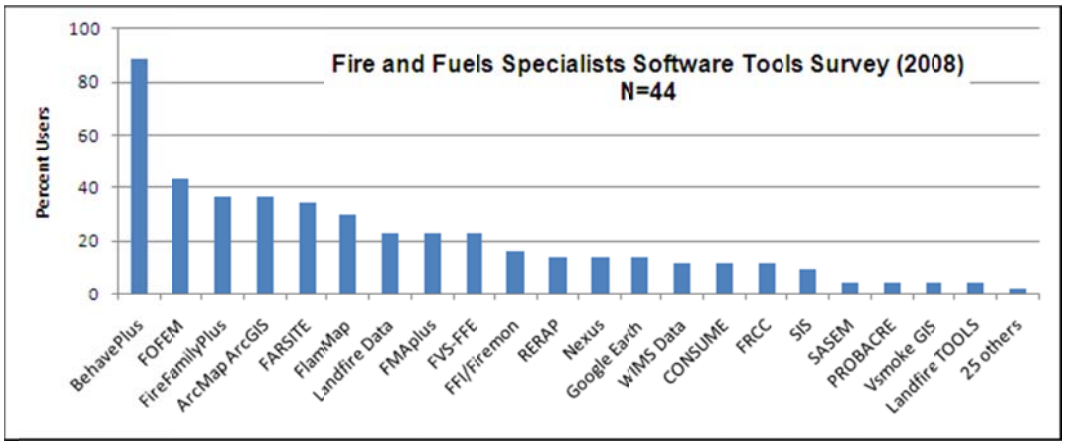


**Fig. 5.** BehavePlus was listed by 89% (39 of 44) responders to the question 'What software program(s) are you using to perform fuels treatment planning work?' (In addition to the tools on the plot, 25 others were listed once.)

Fig. 6 shows the seventeen systems that were listed by more than 1% of respondents. Of the 385 respondents who listed specific tools, 331 (86%) listed BehavePlus; the next highest listed system was 26%. Thirty-four tools were listed by three or fewer respondents. Thirty percent (116 of 385) listed only BehavePlus.

Results were also categorized by Agency, region, position, and fire assignment (Table 1; unpublished data). BehavePlus had the highest use in all subcategories; the next highest is listed for reference. It is not surprising that BehavePlus is used by a large percentage of people in the Fire Assignment categories or by those with the positions of Fire Management Officer; Fuels, Fire Use, Prescribed Fire Specialist; and Fire Planner. It is more notable that Fire Ecologists also listed BehavePlus more than any other system. BehavePlus, however, includes fire effects models, and fire behavior is important in the study of fire ecology.

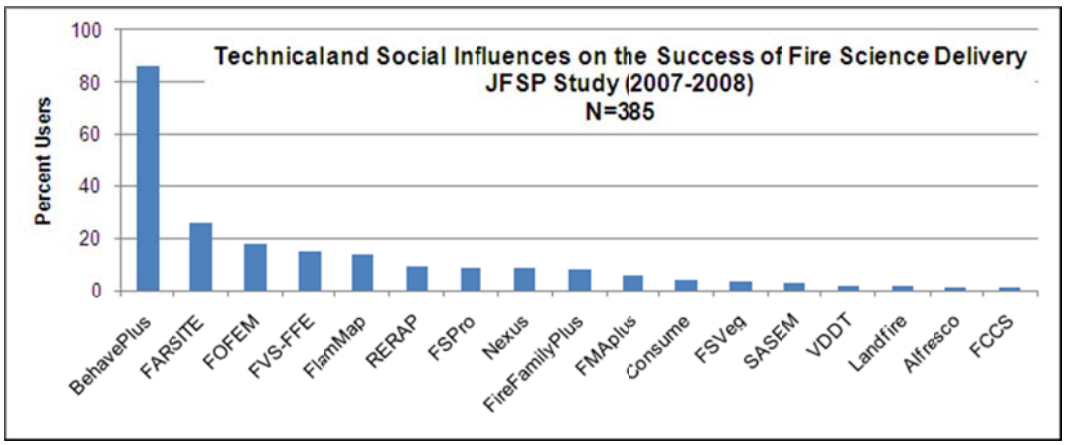


**Fig. 6.** Results of a survey conducted as part of a JFSP study. In addition to the 17 systems shown, 34 others were listed by three or fewer respondents.

**Table 1. Number and percentage of responders in each category that use BehavePlus, compared to the percentage of the next highest listed system. (unpublished data)**

| Category | | Number in category | Percentage that use BehavePlus | Percentage of next highest listed system |
|---|---|---|---|---|
| Agency | USFS | 216 | 85% | 29% |
| | NPS | 83 | 82% | 31% |
| | BLM | 59 | 93% | 14% |
| | USFWS | 13 | 93% | 31% |
| | BIA (6), States (7), TNC (1) | 14 | 86% | 29% |
| Position | Fire Management Officer or AFMO | 111 | 88% | 21% |
| | Fuels, Fire Use, Prescribed Fire Spec., Fire Planner | 109 | 93% | 31% |
| | Fire Ecologist | 24 | 58% | 42% |
| | Line Officer, Deputy LO, Staff Officer | 30 | 60% | 23% |
| Fire assignment L | ong Term Fire Analyst (LTAN) | 41 | 83% | 63% |
| | Fire Behavior Analyst (FBAN) | 28 | 86% | 43% |
| | Prescribed Fire Burn Boss | 152 | 90% | 22% |
| | Prescribed Fire Manager | 30 | 93% | 23% |
| | Fire Use Manager | 63 | 94% | 19% |
| | Incident Commander | 23 | 100% | 22% |

**How is BehavePlus used**

BehavePlus is not designed for a specific fire management application. It is suited to any application that uses fire behavior or fire effects models. Following are summaries of two informal questions on application of BehavePlus (and BEHAVE), from 1983 and from 2009, providing some documentation on how BehavePlus is used.

*BEHAVE pilot test, 1983*

While the fire behavior prediction portion of the BEHAVE system was available at the Missoula Fire Sciences Lab in 1977, it was not immediately available for field application because of computer limitations (Andrews 2007). BEHAVE was used for fire management applications as soon as it was available.

The initial development test was conducted in 1982. Testers used the program via telephone lines to the Missoula Fire Lab computer. One line was available during working hours, and people had to sign up for time. Six lines were available without reservation at other times. The initial letter to testers included a list of evaluation questions. The thank you letter included the following: 'When we designed the review form, we didn't anticipate that some users would incorporate BEHAVE into their regular fire management duties during the test period.' Following is from the pilot test report, December 1983.

For what fire management activities did you actually use BEHAVE during the pilot test?

- Slash burns
- Writing and analyzing fire prescriptions
- Estimating behavior of escaped fires
- Fuel treatment evaluation
- Wilderness fire planning
- Comparison with observed fire behavior
- Building site-specific fuel models
- Gaming of various fire situations
- Timber sale fuel assessments
- Define economic parameters for the activity fuel appraisal process
- Prescribed underburning project
- Developing burning windows for burn bosses
- Preattack planning
- Teaching fire behavior
- Designing a system to classify fire hazard
- Contingency planning
- Dispatching
- Assess wildlife proposal to leave small mammal habitat. Determined what effect that would have on spotting potential.

*'Do You BEHAVE?' e-mail question, 2009*

Under the subject line 'Do You BEHAVE?' an informal request for feedback was sent by the author in January 2009 to people who were registered for News on BehavePlus on FireModels.org. The e-mail was also forwarded to those on the International Association of Wildland Fire (IAWF) FireNet e-mail list, and it was posted to www.MyFireCommunity.net.

'I'm doing an informal canvas to find out how people are using the BehavePlus fire modeling system (or the old BEHAVE). Please tell me by e-mail …. Do you use it for fire prescriptions, wildfire, research, training, fuel hazard analysis, etc.? …'

We received 54 replies:

- 25 U.S. Federal agencies (19 FS, 4 BLM, 1 FWS, 1 BIA)
- 9 U.S. State agencies (2 CA, CO, KS, MN, MT, OH, WA, WI)
- 7 Private, contractors, consultants
- 2 Universities
- 1 TNC (The Nature Conservancy)
- 2 Research
- 2 City of Santa Barbara
- 2 Canadian provinces (NB, ON)
- 4 Other international (New Zealand, Scotland, South Africa, Spain)

Following are selected excerpts from the replies without reference to an individual, position, location, or employer.

While most responses provided more detailed description of their use of BehavePlus, one gave the brief answer:

> '*I use it for fire behavior predictions, just as intended.'*

Many use it for a range of applications:

> *'I use BehavePlus for prescribed fire prescriptions, research, fuels hazard analysis and training.'*
>
> '*I use BEHAVE for Rx fire planning and review, training, wildfire behavior prediction.'*
>
> *'I use both BehavePlus and the old BEHAVE for fire prescriptions when developing prescribed burn plans, fire behavior forecasts when working as an FBAN on wildfire assignments, development of pre-suppression fire behavior forecasts on days of high fire potential, fuel hazard analysis, and during large fire reviews.'*

Twenty-three of the responses specifically mentioned use for wildfire prediction, many in their role as a Fire Behavior Analyst (FBAN). Thirty-three cited use for prescribed fire. Following are quotes related to those categories and others.

Wildfire.

> *'… for writing firing plans to evaluate firing methods.'*
>
> *'As an FBAN trainee I have used BehavePlus to predict and verify the fire behavior while on an incident.'*
>
> *'When we are under severity conditions I use it to model potential fire behavior and then discuss suppression options with my crew.'*

*'In any fire situation from prognostications at the regional level to those for specific slopes on specific fires I will use what I call benchmark BEHAVE runs. These are generally runs that are already completed, many of which I store on my own website, and I only use them for documentation and reference purposes.'*

*'Actually as an FBAN I only use BEHAVE to get the down and dirty worst case scenario and then do field verification and modification of my predictions (many times I've only done one run per fire, unless there's a significant wx [weather] or fuel type change), …'*

*'Use BehavePlus mostly on wildfire as a FBAN. . . .mostly as a CYA because the limitations of the model prevent any real representational forecasting of the extreme fire behavior I'm observing.'*

*'I generally use BehavePlus for the electronic files for fire records and I still use the BEHAVE Appendix B for general initial attack on fires and when working on fires as an FBAN since I can have the line personnel refer to the Appendix B while out on the fire line.'*

Prescribed fire.

'*For us with the Fire Crew at the university any potential prescribed burn must be scouted and modeled in BehavePlus before we can commit to or initiate a prescribed burn.'*

*'I also use Behave to illustrate adequacy of holding or contingency resources on burns, but I have zero faith in the outputs.… But it's about all you have to come up with some rationale for the number and kind of resources needed for a particular burn.'*

*'For RX prescriptions I can see how it does help; since one had a much wider span of fuel loadings to choose from – it eliminates some of the old 'professional' judgment and is much cleaner in the burn plan.'*

*'I utilize BehavePlus to model fire behavior for fire prescriptions and to justify contingency resources.'*

*'We include Behave modeling in every one of our Prescribed Burn Plans to develop and support the burn prescription.'*

*'BehavePlus is the primary modeling tool the Forest uses for Burn Plan development, to identify resources needed to manage the fire at the highest potential of the burn window. Tables are printed and included in the Burn Plan appendix.'*

Training.

*'Students use the software to learn how fuels, weather, and topography affect fire spread and intensity, and they also use it to compose a burn prescription/burn plan for a real site as their final project.'*

*'I also give my students Behave to 'fool around with' – most of them have no idea of fire, being Easterners, and behave allows them to investigate the various aspects of weather, fuels and topography without leaving the lab…'*

*'As a training tool for my fire fighters, expanding their knowledge.'*

Analysis.

*'...sensitivity analysis.'*

*'I used, in part, models including CONTAIN in BehavePlus to demonstrate that the guideline is false. No publications or reports, but this will change our training materials and heuristic thinking a bit.'*

Communication.

*' ... we used behave effectively in community based fire education programs designed to promote coordinated, community-wide hazard mitigation on private lands ... the results and maps were used in meetings with community leaders and later at community meetings to show the wildfire threat to neighborhoods. ... we were able to demonstrate the benefits of doing coordinated fuel modifications…'*

*'Using in conjunction with FlamMap/FARSITE to illustrate the changes in fuel hazard. ... show this to local fire cooperators and occasional public meetings.'*

Planning.

*'Enclosed is a link to a wildland fire plan that I used behave on for the initial hazard assessment.'*

*'Pre fire planning, gaming fires for community wildfire protective planning'*

*'As a matter of fact, I am using it today on a project for a major land owner who needs to know fire ROS for a proposed subdivision. It works well for this application.'*

*'I have used behave to look at ROS, FL, and intensities during the NEPA process to identify areas to create or extend fuel breaks. Working with the silviculturist on proposed treatments to verify the effectiveness of the treatment.'*

Hazard analysis and fuel treatment.

*'I periodically use BehavePlus in my consulting work to demonstrate the potential of wildfires in treated and untreated fuel profiles.'*

*'...for supporting recommendations for post-harvest fuels reduction treatments in commercial and pre-commercial timber sales and projects. I often would print the output tables as appendices to the planning document.'*

*'I do use it somewhat for hazard analysis, (Is the area in question flammable? And if so what would a fire there look like?)'*

*'We use BehavePlus in fuel hazard analysis. We use it in the drafting of fuelbreaks networks…'*

*'I still use Behave infrequently for fuel management project evaluations.'*

Post-fire analysis.

> *'I helped with the fire behavior calculations for the NFPA publication to help verify the actual values observed that day …'*
>
> *'I use it to estimate initial spread of a fire I am investigating and prove/disprove my theory on that fire start. It becomes part of my fire investigation report.'*

Relationship to other systems.

> *'Even though we use the Canadian System, I have found it useful for comparative purposes and also some of the other features and capabilities …'*
>
> *'While not as temporal or reflective of terrain variability like FARSITE it gives a good quick indication of conditions for initial discussions with my colleagues.'*
>
> *'I use Behave … to get a feel for the difference between what models using the same algorithms as Behave are going to say a fire is going to do. I think it helps to get more complex models fine tuned quicker to fiddle with changes in Behave, then take what you learn and apply it to other models.'*
>
> *'As I don't know how to use Farsite or the other geospatial fire behavior prediction tools, due to my lack of GIS skills and access to GIS software, I use BehavePlus or the old BEHAVE for all of my fire behavior modeling work. Behave is a very important program to me. I hope that it continues to be supported.'*
>
> *'I tend to distrust the products that do fire progressions on a landscape basis. There are just too many variables that change too fast, but they make really nice maps that people just love to look at and so request the products without having a clue on the model limitations.'*
>
> *'Now that there are dozens of complex fire behavior modeling programs out there of different sorts with different end products, I am ever more appreciative that your program has withstood the test of time. When I am out on a fire many of the inputs for these other models are often unavailable, or there is a long delay in obtaining them, and it takes several days to calibrate the models to current fire behavior. But with BehavePlus, some field observations and a weather forecast, I am always able to produce a satisfactory product in a timely manner to respond to the many and varied questions of fie managers. I am so thankful to have Behave as the 'old reliable' in my hip pocket, and that it is still the basis of all the other fire models out there.'*

**U.S. interagency applications**

BehavePlus is formally mentioned in various U.S. Interagency documents including training, guides, and ICS task books. BEHAVE was originally developed to automate fire behavior modeling taught in the 1976 S-590 course. Courses and application of BehavePlus have changed and expanded since then.

*NWCG training courses*
BehavePlus is a prerequisite for, is used in, or results are shown in at least the following courses (NWCG 2010):

- S-390, Introduction to Wildland Fire Behavior Calculations
- S-490, Advanced Fire Behavior Calculations
- S-495, Geospatial Fire Analysis, Interpretation, and Application
- S-590, Advanced Fire Behavior Interpretation
- RX-301, Prescribed Fire Implementation
- RX-341, Prescribed Fire Plan Preparation

*ICS positions*
The National Interagency Incident Management System Wildland Fire Qualification System Guide, PMS 310-1, establishes 'minimum requirements for training, experience, physical fitness level, and currency standards for wildland fire positions which all participating agencies have agreed to meet *for national mobilization*' (NWCG 2009).

The Task Book for Fire Behavior Analyst (FBAN) and Long Term Fire Analyst (LTAN) describes position performance. Use of BehavePlus (and other systems) is specifically mentioned in several evaluation tasks. There is also a position designated as Behave Technical Specialist (BHAV) with S-490 as the required training (NWCG Chair 2005). Prescribed Fire Burn Boss Type 1 (RXB1) and Prescribed Fire Manager Type 1 (RXM1) require S-490.

The S-590 course is a requirement for FBAN/LTAN qualification. In order to assure an adequate supply of highly qualified FBAN and LTAN candidates for future incident management teams, a mentoring program for S-590 candidates was established. While an S-590 candidate cannot serve as an FBAN or LTAN trainee, they can be assigned to an incident as a Behave Technical Specialist (BHAV). This provides experience in the use of the fire behavior tools prior to attending the S-590 course.

*Prescribed Fire Guide*
The Interagency Prescribed Fire Planning and Implementation Procedures Guide (USDA/USDOI 2008) describes the required elements of a Prescribed Fire Plan (a legal document). The prescription includes a range of fire behavior (flame length, rate of spread, spotting distance, etc.) required to meet the burn objectives while meeting control objectives. 'These predictions must be modeled using fire behavior model runs or empirical evidence …' 'When used, fire behavior calculations must be developed using an appropriate fire behavior modeling program.' BEHAVE is specifically mentioned as an option in determining minimum holding resources.

**Appropriate application**
Models should be used in conjunction with human judgment based on experience and education. There has always been an appropriate concern about people putting too much faith in models. Consider the following two quotes, the first from the 1983 BEHAVE Pilot Test and the second from the 2009 'Do You BEHAVE?' e-mail question. The young people referred to in the first quote are probably now the experienced people who are worried about young people.

*'We are starting to get people who are taking the outputs generated by many of our computer programs and fire management as pure fact—especially our young people who are less trained and experienced.' (1983)*

*'What is more important in any prognostication of fire behavior is what is between the ears. I have seen too many young folks taken down the wrong road of believing that what comes out of BEHAVE and other modeling tools is what the fire is going to do.' (2009)*

The proper use of models can, however, play an important role in wildland fire management. It is not possible to have the full range of experience as noted by Gisborne (1948).

*'If you have fought forest fires in every different fuel type, under all possible different kinds of weather, and if you have remembered exactly what happened in each of these combinations your experienced judgment is probably pretty good. But if you have not fought all sizes of fires in all kinds of fuel types under all kinds of weather then your experience does not include knowledge of all the conditions.'*

Wildland fire personnel should seek a balance in using models while developing experience, always keeping in mind the limitations of both models and experience. Use of BehavePlus and other modeling systems for predicting wildfire behavior is suited to judgment and adjustment of model results. On the other hand, fire modeling is applied differently in planning applications. A relative change (e.g., higher or lower intensity) might be a useful result, without as much concern for specific values. And planners might not have and might not be gaining on-the-ground fire experience. Care should always be taken in interpreting model results in the context of the fire and fuel management decision they support.

When the BEHAVE pilot test was conducted, computers were a new tool for fire managers. One of the evaluation questions was 'Do you want to get anything off of your chest concerning use of computers in fire management?' The 1983 Evaluation report stated 'Very few answered 'NO' in response to this question. … Responses indicate that BEHAVE pilot test participants feel that computers have a definite place in fire management activities.' Following is an insightful comment by one of the pilot test users (Dr. Stew Pickford, professor, University of Washington):

*'Computers and fire management—they are unavoidable. As such, they will be used as crutches, excuses, and scapegoats. They will be misused, overused, and unused. They will bemuse, confuse, diffuse, intimidate and irritate, but Management must realize that computers are not the problem—only a tool of the problem*.'

It seems that in 2010, computers do in fact have an established place in fire management activities. The rate of change in computer technology is overwhelming, and the workload of fire and land managers is expanding. Fire models will always have limitations, and it will continue to take time for users to feel comfortable with a computer software tool. Fire modeling systems, however, can and do effectively support wildland fire management.

**Summary**

It is apparent from the summaries of various sources of information on application of the BehavePlus fire modeling system (and its predecessor) that people do in fact 'BEHAVE.' The user community includes fire behavior analysts, prescribed fire planners, students, professors,

researchers, fire ecologists, line managers, and incident commanders. They work for U.S. government agencies at all levels: federal, state, county, city. Contractors, consultants, and private organizations use BehavePlus. And there are a significant number of users outside of the U.S.

A reason that BehavePlus is used by so many is that it is not designed for a specific application such as wildfire prediction or fuels management. It is used for those applications and also to give people a basic understanding of wildland fire, to communicate fire management alternatives to the public, to gain an understanding of the mathematical fire models, to develop fire prescriptions, to support research analyses, to do post-fire investigations, and more.

The broad, diverse base of users with various backgrounds as well as the wide range of applications indicates that there is a need to assess available and needed training for BehavePlus (and its successor). BehavePlus has an extensive context-sensitive help system that includes description of variables and relationships; and a series of self-study lessons are available for download from www.firemodels.org. Some aspects of BehavePlus are incorporated into established NWCG courses or pre-work; and various groups have developed training as needed. A comprehensive training package would include not only program operation, but model understanding and application. It should address basic model limitations, assumptions, and sensitivity of results to input values. Additional instruction is needed for specific applications such as prescribed fire planning. A consideration in developing training material is the audience. Some users might not have the background to be able to recognize problems in input or output values that require additional examination and analysis. A Fire Behavior Analyst (FBAN) will have both background training and extensive fire experience. But many BehavePlus users have neither the fire experience nor access to the S-courses. Although we might like to do so, it is not possible to say that people should not use BehavePlus unless they've had a specified level of coursework and fire experience.

Another reason that BehavePlus is widely applied is that it is relatively simple to use and freely available to run on a personal computer. The user enters input values without the need to develop or access data files. This allows incorporation of user experience, judgment, and adjustment of values. The user has significant control over the form of the output and also has the option of exporting results for further analysis using other software.

Many fire management applications do not require the detailed information provided by spatial systems, but are in fact better satisfied by simple tables and graphs. When the products generated by spatial systems are needed, BehavePlus can serve a supporting role. While the spatial systems FARSITE (Finney 1998) and FlamMap (Finney 2006) are based on essentially the same mathematical models as is BehavePlus, there remains a need for a point-based system. It is difficult to see specific cause and effect relationships in a landscape of thousands of model calculations. BehavePlus overcomes the necessary black-box aspects of spatial systems. A user can and should use BehavePlus to examine, for example, the effect of fuel model, live fuel moisture, or canopy cover on modeled fire behavior.

Similarly BehavePlus can support the fire behavior modeling that is being incorporated into Internet-based systems including the Wildland Fire Decision Support System (WFDSS) (Seli *et al.* 2010) and the Interagency Fuel Treatment Decision Support System (IFT-DSS) (JFSP 2009). Those systems are designed for specific applications and user groups and will not include all of the modeling capabilities and features of BehavePlus.

While it is not possible to know exactly why responders to the four surveys use BehavePlus (or BEHAVE) more than other systems, there are likely reasons in addition to those described

above. BEHAVE was one of the first systems available to fire managers and became an established tool. It has had the continued support of the developers and sponsor, and design and fire modeling capabilities have been updated and expanded over time.

It is hard to draw general conclusions from these surveys. Some widely used systems didn't show up because of the way that the question was asked. And the reason that only a few users selected or listed a system might be a function of the group that was surveyed or of a narrow focus of the system application. While these surveys give some guidance on development of next generation systems, another approach might be to examine details of applications and the information needed to support decisions. An assessment of which systems provide that information can identify gaps and overlaps in the large selection of systems available for fire and fuel management (Andrews 2006).

Although BehavePlus is an established tool for many fire and fuels management applications, it is in need of update. Much of the BehavePlus design was determined in 1998 (Andrews and Bevins 1998). While the program has many good features, there are recognized weaknesses (Heinsch and Andrews 2010). Similar to the major update from BEHAVE to BehavePlus, it is time for another major update (BehavePlusPlus?). The approach, however, should not be merely an update to the BehavePlus program, but rather a broader update that facilitates integration of fire behavior, fire effects, and fire danger rating systems and of point and spatial systems. A step in moving forward is to start with a sound foundation of the basic building blocks in the form of a library of mathematical fire model code. This will facilitate resolving internal differences among existing systems, will provide an improved means of incorporating new research results, and will aid development of both web and desktop applications.

Fire and fuels managers would undoubtedly welcome systems that are developed to meet their needs in the form of complementary components with a consistent modeling foundation, user interface, look and feel, and graph and report generators. This examination of application of BehavePlus can be taken into consideration in the planning of the next generation of systems.

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