

Introduction

The *Interagency Prescribed Fire Planning and Implementation Procedures Reference Guide* (IPFRG) requires prediction of fire behavior both inside and outside of unit boundaries. BehavePlus can be used in prescription development, documentation, and description. It can also be used to develop holding and contingency plans for these projects.

This is an introductory overview of the use of BehavePlus for prescribed fire. Later lessons will provide additional detail.

Objectives

1. Demonstrate the modeling capabilities of BehavePlus that can be applied to prescribed fire plans.
2. Acknowledge the role of models and of experience.
3. Recognize that the user is responsible for proper application of models with all of their limitations.
4. See examples of the table shading option of BehavePlus which can be used to examine tradeoffs that lead to acceptable fire conditions.

Where This Lesson Fits In

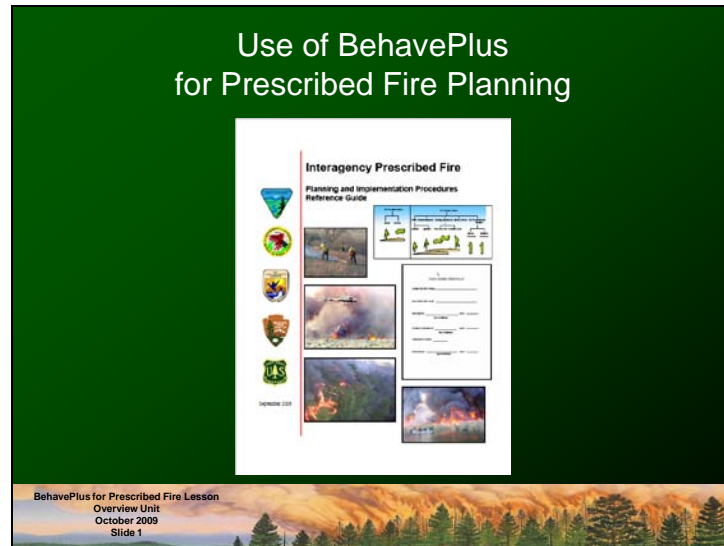
- This lesson is in the Overview Unit. It is a PowerPoint lesson. The BehavePlus program is not run.
- It introduces the topic of using BehavePlus to develop fire prescriptions.
- A lesson in the Operations unit gives instruction on how to use the table shading option of BehavePlus.

Lesson Changes: V4.0 to V5.0

Changes to the BehavePlus program require a minor change to this lesson. The overstory variables for SPOT changed. We updated the headers and footers, but did not redo many of the screen captures labeled BehavePlus 4.0.0.

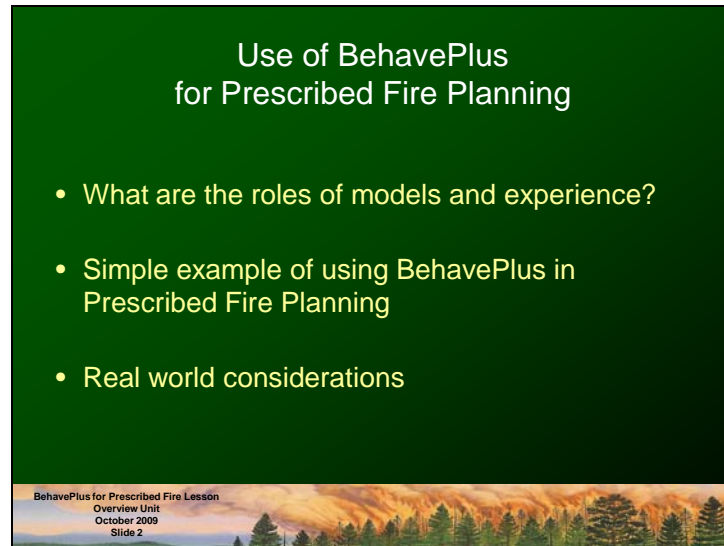
Following are the notes in a form that a presenter can use when showing the PowerPoint 'Slide Show'.

Slide 1



- An Interagency Prescribed Fire Guide is now in effect (http://www.nifc.gov/fire_policy/rx/rxfireguide.pdf).
- BehavePlus is one of the computer programs that you can use to aid in developing prescriptions and for modeling fire behavior.
- This lesson is an overview of the modeling capabilities that are applicable.

Slide 2



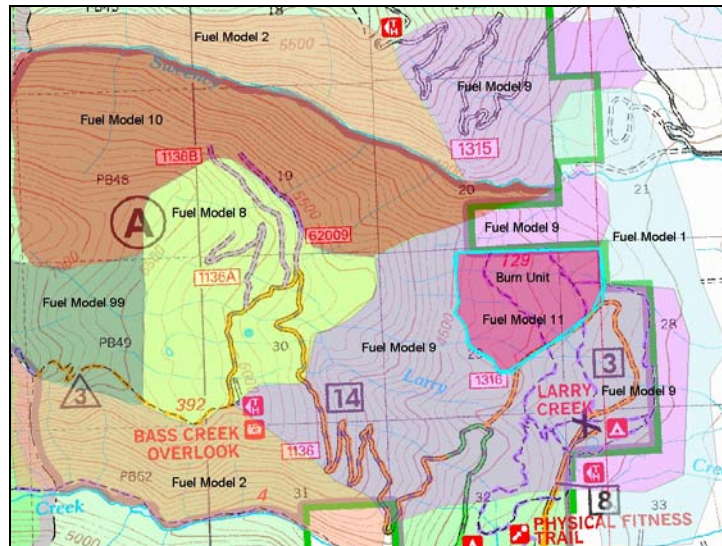
Use of BehavePlus
for Prescribed Fire Planning

- What are the roles of models and experience?
- Simple example of using BehavePlus in Prescribed Fire Planning
- Real world considerations

BehavePlus for Prescribed Fire Lesson
Overview Unit
October 2009
Slide 2

- Modeling is only part of the process of planning for prescribed fire.
- Experience also plays an important role.
- This lesson only describes a very simple example for surface fire spread.
- This lesson does not address the many real world considerations.

Slide 3



- There are many factors to consider in developing a fire prescription.
 - Fuel and terrain in the unit as well as outside.
 - Values at risk
 - Access
 - Conditions needed to achieve burn objectives and retain control.
- The real world is complicated...

Slide 4



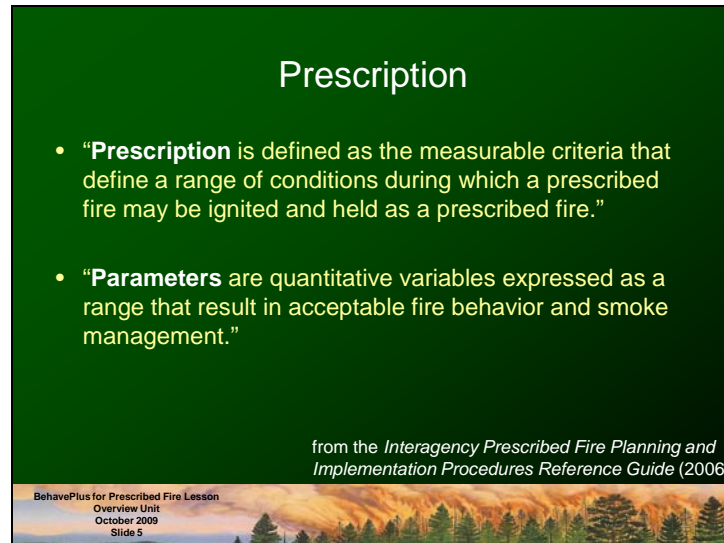
Use of BehavePlus for Prescribed Fire Planning

- Modules that can be used
- Site, environment, and containment variables
- Modeling for inside the prescribed fire area
- Modeling for outside the project boundary, contingency planning

BehavePlus for Prescribed Fire Lesson
Overview Unit
October 2009
Slide 4

- In this lesson we discuss the BehavePlus calculation modules that can be used for prescribed fire planning, including SURFACE, IGNITE, SPOT, SIZE, and CONTAIN.
- We will discuss relevant variables in the program that describe the
 - site (fuel, terrain, etc.),
 - the environment (wind, moisture, etc.), and
 - containment (line production rate, arrival time, etc.)
- We will talk about the modeling that you can do for inside the prescribed fire area,
- as well as the modeling necessary outside the project boundary for contingency planning.

Slide 5



Prescription

- “**Prescription** is defined as the measurable criteria that define a range of conditions during which a prescribed fire may be ignited and held as a prescribed fire.”
- “**Parameters** are quantitative variables expressed as a range that result in acceptable fire behavior and smoke management.”

from the *Interagency Prescribed Fire Planning and Implementation Procedures Reference Guide* (2006)

BehavePlus for Prescribed Fire Lesson
Overview Unit
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Slide 5

- These definitions come from the *Interagency Prescribed Fire Planning and Implementation Procedures Reference Guide* (2006).
- p. 21: “**Prescription** is defined as the **measurable criteria** that define a **range of conditions during which a prescribed fire may be ignited** and held as a prescribed fire.”
- p. 21: “**Parameters** are **quantitative variables** expressed as a **range that result in acceptable fire behavior** and smoke management.”

Slide 6

Modeling and Experience

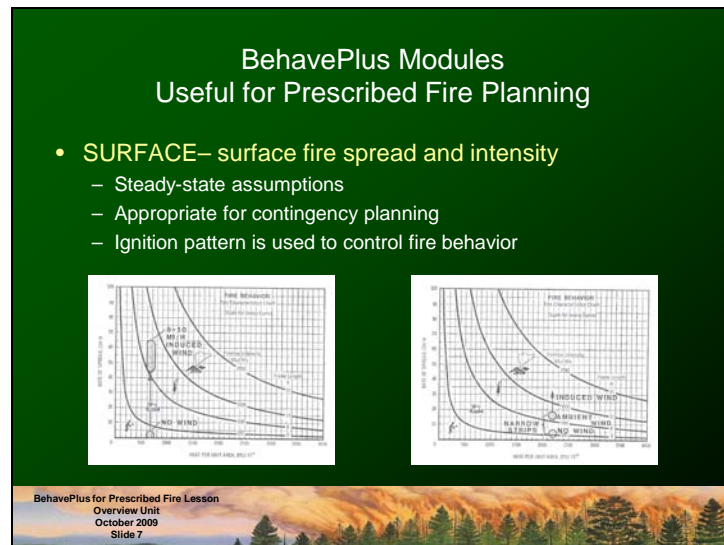
- **Models**
 - Quantitative, repeatable
 - Method for examining tradeoffs
 - Limitations and assumptions
- **Experience**
 - “Empirical evidence (historical evidence or researched data) and judgment may be utilized to identify or calibrate prescriptions. Weaknesses in modeling can be overridden, but must be justified with empirical evidence and/or verified actual fire behavior.”

from the *Interagency Prescribed Fire Planning and Implementation Procedures Reference Guide* (2006)

BehavePlus for Prescribed Fire Lesson
Overview Unit
October 2009
Slide 6

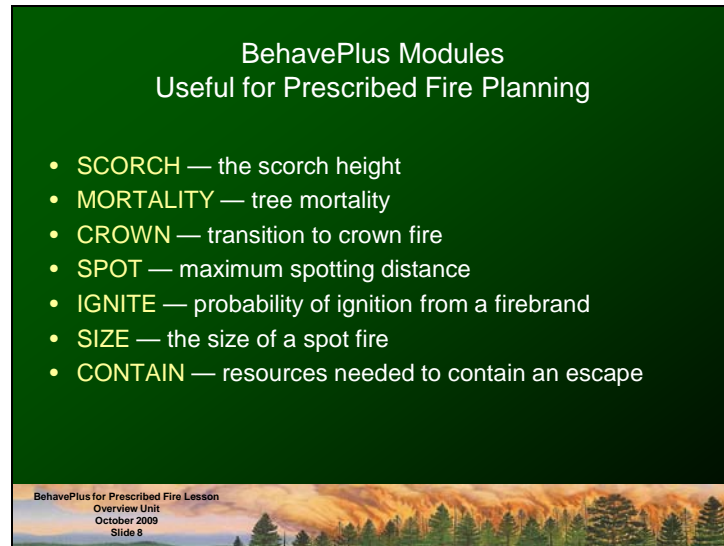
- Both modeling and experience play a role in prescribed fire planning.
- Models are both quantitative (produce numbers) and repeatable (given the same input, you get the same answers every time).
- Models can be used to examine tradeoffs (such as high wind and wet fuel vs. low wind and dry fuel).
- All models have limitations since they are based on simplifying assumptions (such as uniform fuel).
- The user is responsible for understanding the models and ensuring that they are properly applied.
- Recognizing the limitations of modeling, the *Interagency Prescribed Fire Planning and Implementation Procedures Reference Guide* (2006) specifically allows for the use of experience.
- However, that experience needs to be well-documented:
 - p. 21: “**Empirical evidence** (historical evidence or researched data) **and judgment may be utilized** to identify or calibrate prescriptions. Weaknesses in modeling can be overridden, but **must be justified with empirical evidence and/or verified actual fire behavior.**”

Slide 7



- We will go through the modules that are useful for prescribed fire planning.
- The SURFACE module is used to calculate surface fire spread and intensity.
 - A basic assumption of the Rothermel surface fire spread model is that the fire is spreading at steady-state.
 - This is appropriate for contingency planning in modeling escaped fire.
- Fire behavior inside the unit will often be controlled by the ignition pattern, which cannot be directly modeled.
- Fire behavior can either increase or decrease from the steady-state level.
- Steady-state calculations can be plotted on a fire characteristics chart with an indication of the increased or decreased fire behavior.

Slide 8

A presentation slide with a dark green background. The title "BehavePlus Modules Useful for Prescribed Fire Planning" is centered at the top in white text. Below the title is a bulleted list of seven modules in yellow text: SCORCH (scorch height), MORTALITY (tree mortality), CROWN (transition to crown fire), SPOT (maximum spotting distance), IGNITE (probability of ignition from a firebrand), SIZE (size of a spot fire), and CONTAIN (resources needed to contain an escape). At the bottom of the slide is a horizontal banner image showing a forest fire with orange and yellow flames rising from a line of green trees. Small white text in the bottom left corner of the banner reads: "BehavePlus for Prescribed Fire Lesson", "Overview Unit", "October 2009", and "Slide 8".

BehavePlus Modules
Useful for Prescribed Fire Planning

- SCORCH — the scorch height
- MORTALITY — tree mortality
- CROWN — transition to crown fire
- SPOT — maximum spotting distance
- IGNITE — probability of ignition from a firebrand
- SIZE — the size of a spot fire
- CONTAIN — resources needed to contain an escape


BehavePlus for Prescribed Fire Lesson
Overview Unit
October 2009
Slide 8

- In addition to the SURFACE module, all of the other modules can be used for prescribed fire planning.
- Each of the modules was briefly discussed in the initial BehavePlus overview lesson.
- Here, we will discuss the use of IGNITE, SPOT, SIZE, and CONTAIN specifically for prescribed fire.


Slide 9

BehavePlus
Site Description Variables

- Surface fuel model
- Overstory for...
 - Wind adjustment factor
 - Transition to crown
 - Scorch height and mortality
 - Spotting distance, source and in direction of wind
- Slope

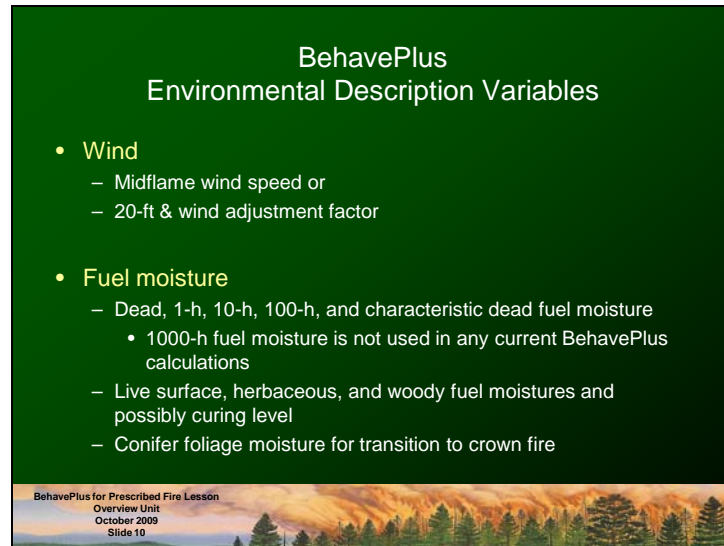


BehavePlus for Prescribed Fire Lesson
Overview Unit
October 2009
Slide 9



- Now we will go through the input values that can describe conditions for a prescribed fire.
- Surface fuel model inside the unit and for surrounding areas.
- Overstory description is used to calculate
 - Wind adjustment factor
 - Transition from surface to crown fire
 - Tree scorch height and tree mortality
 - Spotting distance (uses both the torching tree description and the overstory in the downwind direction)
- Slope steepness inside and outside the unit is used to calculate surface fire spread and intensity

Slide 10

A presentation slide with a dark green background and white text. The title is "BehavePlus Environmental Description Variables". Below the title are two main bullet points: "Wind" and "Fuel moisture". The "Wind" bullet point has two sub-points: "Midflame wind speed or" and "20-ft & wind adjustment factor". The "Fuel moisture" bullet point has three sub-points: "Dead, 1-h, 10-h, 100-h, and characteristic dead fuel moisture" (with a further sub-point "1000-h fuel moisture is not used in any current BehavePlus calculations"), "Live surface, herbaceous, and woody fuel moistures and possibly curing level", and "Conifer foliage moisture for transition to crown fire". At the bottom of the slide is a small landscape image of a forest with a fire in the background. Text at the bottom left of the slide reads: "BehavePlus for Prescribed Fire Lesson", "Overview Unit", "October 2009", "Slide 10".

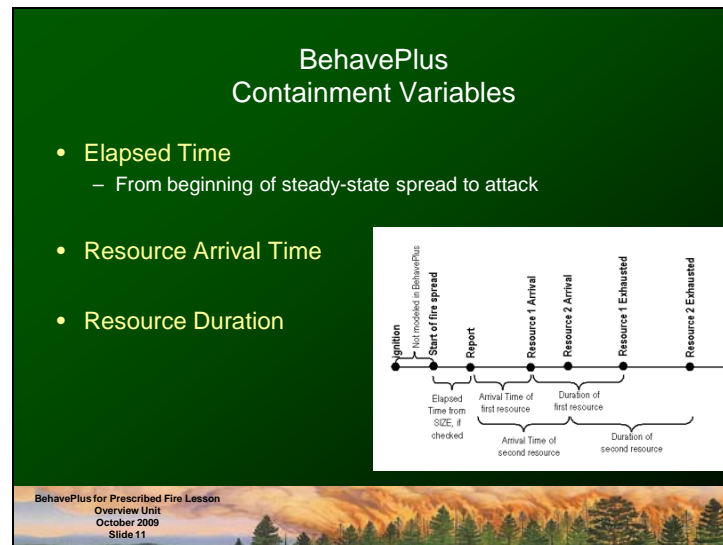
BehavePlus
Environmental Description Variables

- Wind
 - Midflame wind speed or
 - 20-ft & wind adjustment factor
- Fuel moisture
 - Dead, 1-h, 10-h, 100-h, and characteristic dead fuel moisture
 - 1000-h fuel moisture is not used in any current BehavePlus calculations
 - Live surface, herbaceous, and woody fuel moistures and possibly curing level
 - Conifer foliage moisture for transition to crown fire

BehavePlus for Prescribed Fire Lesson
Overview Unit
October 2009
Slide 10

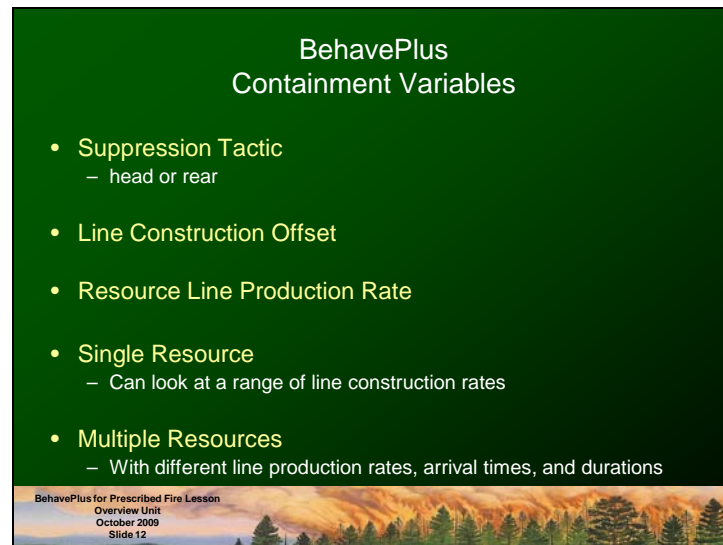
- Wind speed can be entered for the midflame height.
 - It might be better to use the 20-ft wind to be able to account for different wind adjustment factors inside and outside the unit depending on overstory and terrain.
- Fuel moisture for each of the dead fuel classes (1-h, 10-h, and 100-h) can be used.
- Characteristic dead fuel moisture is a combination of all of those and is useful in reducing the number of variables to consider in developing a prescription window.
- The moisture content of live surface, woody or herbaceous fuels.
 - Some of the new 40 fuel models are 'dynamic'. For those, live herbaceous fuel moisture has a very large effect.
- You now have the option in BehavePlus version 4, of entering curing level directly, rather than letting the program calculate it from live herbaceous moisture.
- The moisture content of conifer needles is called Foliar Moisture and is used to determine the transition from surface fire to crown fire.

Slide 11



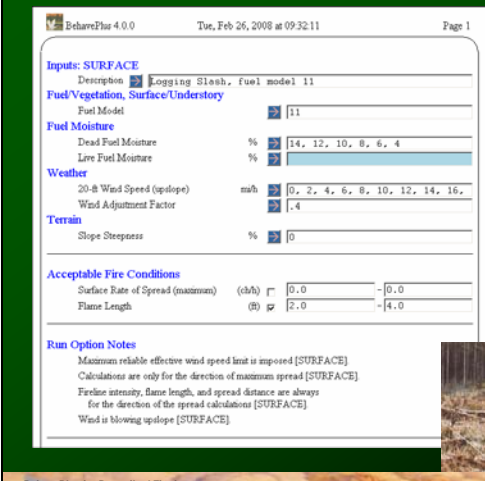
- Several time variables are used in modeling containment of an escaped fire.
- There is not a model to estimate the time from ignition to the start of steady state.
 - **Elapsed Time** is the time from the start of steady state to the time a spot fire is reported.
 - **Resource Arrival Time** is the length of time from report to arrival of suppression resources.
 - **Resource Duration** is the length of time a resource can work.
- Multiple resources (crews, equipment, etc.) can be specified to arrive and leave at different times.

Slide 12



- In addition to the Arrival Time and Resource Duration just described, other containment variables include—
 - Suppression Tactic as head or rear.
 - The fire would be contained at a much smaller size with head attack.
 - But the conservative, safe approach is rear attack.
- Line Construction Offset allows for the modeling of parallel attack.
 - Direct attack is adjacent to the fire, offset = 0
- Resource Line Production Rate is specified for each resource
 - The model splits the resource with half of the production rate on each side of the fire.
 - This is the case, even if the resource is a single piece of equipment.
 - This is a 'model', not reality.
- When only a single resource is specified, you can look at a range of line construction rates.
 - This is a good way to start modeling.
 - At a later stage in your modeling, you can specify the multiple resources that might be available.

Slide 13



Inputs: SURFACE
Description: Logging Slash, fuel model 11

Fuel/Vegetation, Surface/Understory
Fuel Model: 11

Fuel Moisture
Dead Fuel Moisture: 14, 12, 10, 8, 6, 4
Live Fuel Moisture: (blank)

Weather
20-ft Wind Speed (upslope): 0, 2, 4, 6, 8, 10, 12, 14, 16
Wind Adjustment Factor: 0.4

Terrain
Slope Steepness: 0

Acceptable Fire Conditions
Surface Rate of Spread (maximum): 0.0 - 0.0
Flame Length: 2.0 - 4.0

Run Option Notes
Maximum reliable effective wind speed limit is imposed [SURFACE]
Calculations are only for the direction of maximum spread [SURFACE]
Fireline intensity, flame length, and spread distance are always for the direction of the spread calculations [SURFACE]
Wind is blowing upslope [SURFACE]

SURFACE

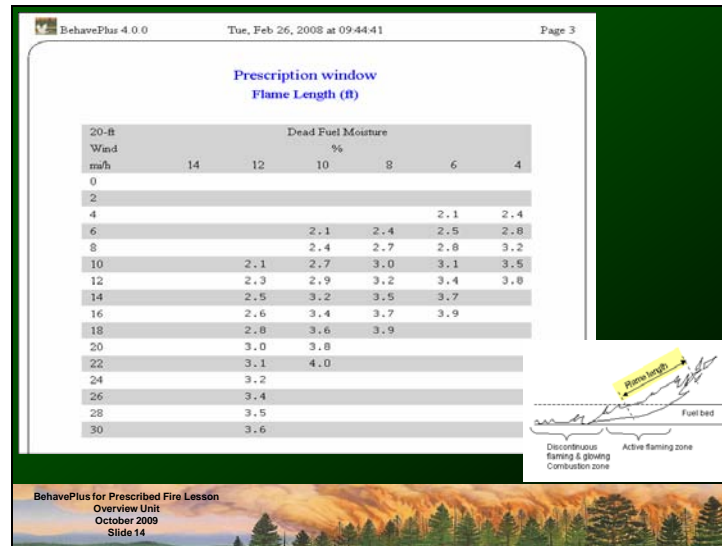
BehavePlus for Prescribed Fire Lesson
Overview Unit
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Slide 13

Let's look at a very simple run:

- Fuel Model 11, which represents light logging slash.
- We look at Dead Fuel Moisture ranging from 14 to 4%, from wet to dry conditions.
- There is no live fuel in fuel model 11, so the Live Fuel Moisture line is blank.
- We look at 20-ft winds ranging from 0 to 30 mi/h
- The Wind Adjustment Factor (WAF) is 0.4.
 - 20-ft wind speed times WAF is midflame wind speed.
- The ground is flat, so the Slope = 0.

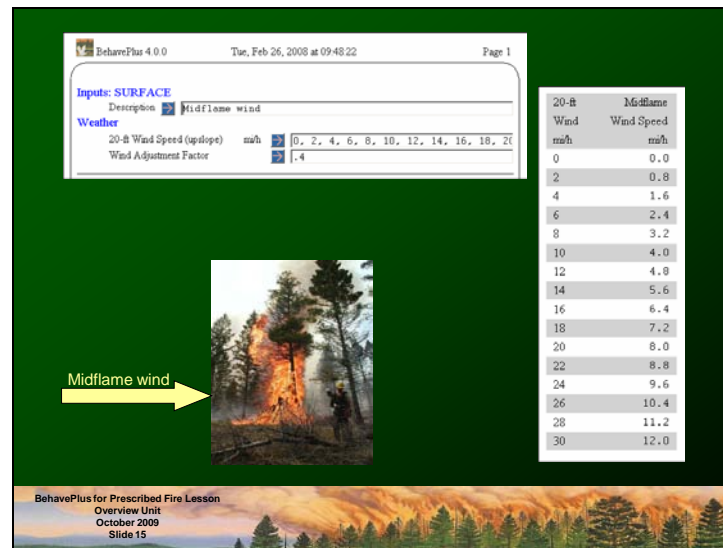
We specify under “Acceptable Fire Conditions” that flame lengths of 2 to 4 feet are ok. Calculating a run allows us to look at the tradeoffs between wind and moisture that give these acceptable fire conditions.

Slide 14



- The resulting table of calculated head fire Flame Lengths shows only the *acceptable* flame length values of 2 to 4 ft.

Slide 15



- You can produce a table of the Midflame Wind Speed values associated with the 20-ft Wind Speed values in the prescription window.

Slide 16

BehavePlus 4.0.0 Tue, Feb 26, 2008 at 09:53:46 Page 1

Inputs: SURFACE

Description: Fuel model 11, 100-h=5%

Fuel/Vegetation, Surface/Understory

Fuel Model: 11

Fuel Moisture

1-h Moisture %: 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2

10-h Moisture %: 14, 12, 10, 8, 6, 5, 4, 3, 2

100-h Moisture %: 5

Litter Herbaceous Moisture %: 5

Litter Woody Moisture %: 5

SURFACE

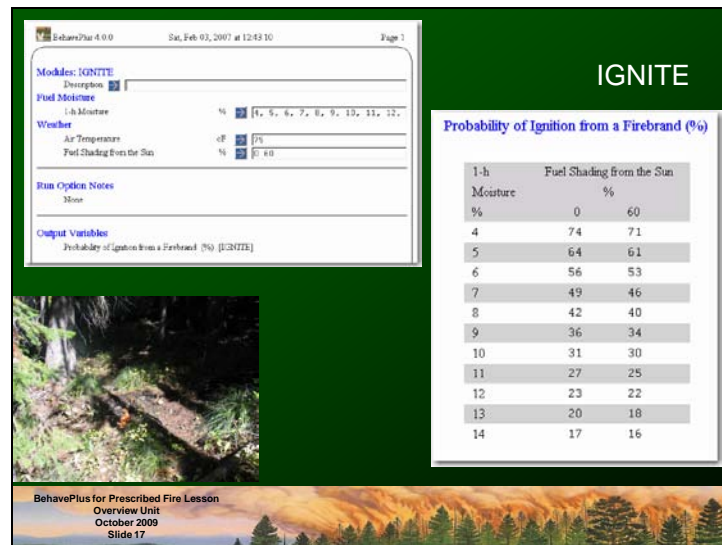
Fuel model 11, 100-h=5%
Characteristic Dead Fuel Moisture (%)

1-h Moisture %	14	13	12	11	10	9	8	7	6	5	4	3	2
14	13	13	13	13	12	12	12	12	12	12	12	11	11
13	13	12	12	12	12	12	11	11	11	11	11	11	11
12	12	12	12	11	11	11	11	11	10	10	10	10	10
11	11	11	11	10	10	10	10	10	9	9	9	9	9
10	10	10	10	10	10	9	9	9	9	9	8	8	8
9	10	9	9	9	9	9	8	8	8	8	8	8	8
8	9	9	9	8	8	8	7	7	7	7	7	7	7
7	8	8	8	7	7	7	7	7	6	6	6	6	6
6	7	7	7	7	6	6	6	6	6	6	5	5	5
5	7	6	6	6	6	6	5	5	5	5	4	4	4
4	6	5	5	5	5	5	4	4	4	4	4	4	4
3	5	5	4	4	4	4	4	4	3	3	3	3	3
2	4	4	4	4	3	3	3	3	3	3	2	2	2

BehavePlus for Prescribed Fire Lesson
Overview Unit
October 2009
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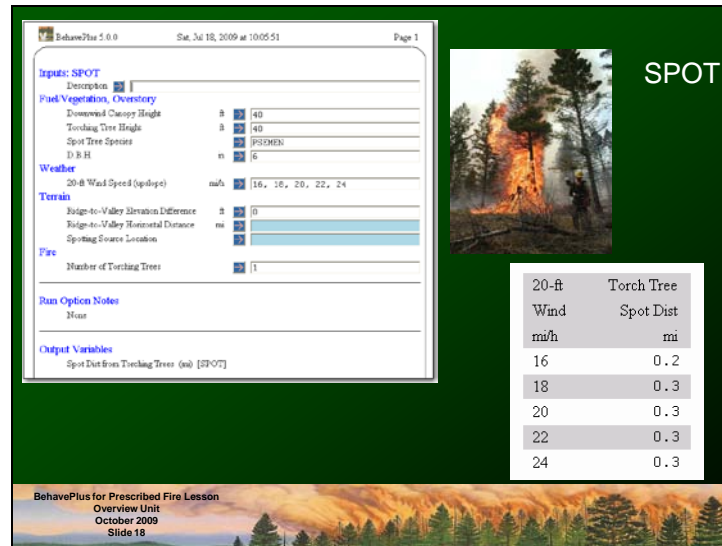
- You can also produce a table of 1-h and 10-h moisture values that correspond to the dead fuel moisture values in the prescription window.
- 100-h moisture has little effect on the results.
- In this example we set 100-h moisture as 5%.

Slide 17



- Using IGNITE, a prescription might include consideration of the Probability of Ignition from a Firebrand.
- This example shows calculated values for the range of 1-h moisture.
- Two levels of fuel shading from the sun (0 and 60%) are done to represent two locations that a firebrand might land.
 - In an area with no overstory (0%), and
 - In an area where overstory results in 60% shading.

Slide 18



The screenshot shows the BehavePlus 5.0.0 software interface. The main window displays the 'Inputs: SPOT' form. The form is divided into several sections: 'Fuel Vegetation, Overstory', 'Weather', 'Terrain', 'Fire', 'Run Option Notes', and 'Output Variables'. The 'Fuel Vegetation, Overstory' section includes fields for 'Downwind Canopy Height' (ft), 'Torching Tree Height' (ft), 'Spot Tree Species' (dropdown), and 'D.B.H.' (in). The 'Weather' section includes '20-ft Wind Speed (mph)'. The 'Terrain' section includes 'Ridge-to-Valley Elevation Difference' (ft), 'Ridge-to-Valley Horizontal Distance' (mi), and 'Spotting Source Location'. The 'Fire' section includes 'Number of Torching Trees'. The 'Run Option Notes' section includes a 'Name' field. The 'Output Variables' section includes 'Spot Dist from Torching Trees (mi) [SPOT]'. To the right of the form is a small image of a tree on fire, labeled 'SPOT'. Below the image is a table showing the results of the calculation.

20-ft Wind mi/h	Torch Tree Spot Dist mi
16	0.2
18	0.3
20	0.3
22	0.3
24	0.3

BehavePlus for Prescribed Fire Lesson
Overview Unit
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- Using SPOT, a prescription may include a calculation of the maximum spotting distance from a torching tree.
- In this example it is 0.2 or 0.3 miles under high wind speeds (16-24 mi/h) for *Pseudotsuga menziesii* (Douglas-fir).

Slide 19

BehavePlus 4.0.0 Sat, Feb 03, 2007 at 12:51:38 Page 1

Modules: SURFACE, SIZE, CONTAIN

Description []

Fuel/Vegetation, Surface/Understory

Fuel Model [11]

Fuel Moisture

Dead Fuel Moisture % [6]

Live Fuel Moisture % []

Weather

20-ft Wind Speed (upslope) mph [22]

Wind Adjustment Factor [0.3]

Terrain

Slope Steepness % [0]

Fire

Elapsed Time h [.3]

Suppression

Suppression Tactic [power]

Line Construction Offset ch [0]

Resource Line Production Rate ch/h [5.0, 10.0, 15.0, 20.0, 25.0, 30.0]

Resource Arrival Time h [0]

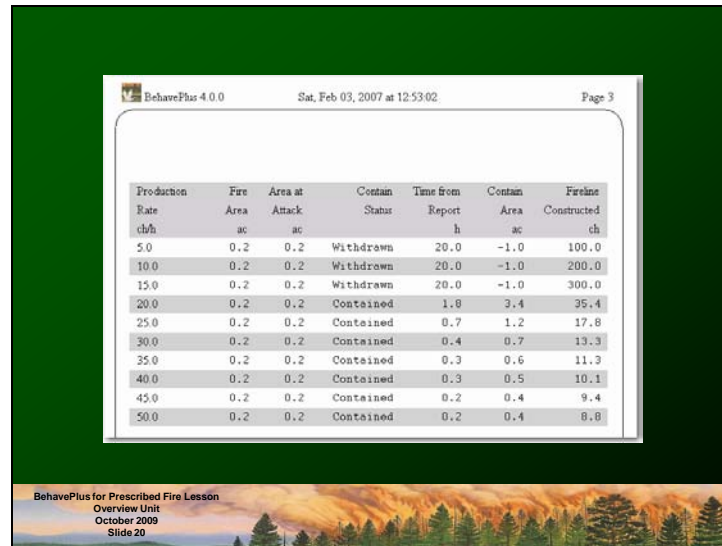
Resource Duration h [20]

CONTAIN

BehavePlus for Prescribed Fire Lesson
Overview Unit
October 2009
Slide 19

- The contingency portion of the prescription can include modeling of containment of a spot fire outside the unit.
- In this example, we look at a range of line production rates from 5 to 50 ch/h. This example uses three modules: SURFACE, SIZE, and CONTAIN.
- In this case, the Fuel Model is the same. However, we could just as easily use a different fuel model if the prescribed burn unit is surrounded by fuel of a different type.

Slide 20



BehavePlus 4.0.0 Sat, Feb 03, 2007 at 12:53:02 Page 3

Production Rate ch/h	Fire Area ac	Area at Attack ac	Contain Status	Time from Report h	Contain Area ac	Fireline Constructed ch
5.0	0.2	0.2	Withdrawn	20.0	-1.0	100.0
10.0	0.2	0.2	Withdrawn	20.0	-1.0	200.0
15.0	0.2	0.2	Withdrawn	20.0	-1.0	300.0
20.0	0.2	0.2	Contained	1.8	3.4	35.4
25.0	0.2	0.2	Contained	0.7	1.2	17.8
30.0	0.2	0.2	Contained	0.4	0.7	13.3
35.0	0.2	0.2	Contained	0.3	0.6	11.3
40.0	0.2	0.2	Contained	0.3	0.5	10.1
45.0	0.2	0.2	Contained	0.2	0.4	9.4
50.0	0.2	0.2	Contained	0.2	0.4	8.8

BehavePlus for Prescribed Fire Lesson
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- The fire is not contained unless the line production rate is 20 ch/h or higher.
 - For a line construction rate of 20 ch/h, 35.4 chains of fireline is constructed to contain the fire in 1.8 hours.
 - For a line construction rate of 50 ch/h, 8.8 chains of fireline is constructed to contain the fire in 0.2 hours.

Slide 21

BehavePlus 4.0.0 Sat, Feb 03, 2007 at 12:54:59 Page 1

Modules: SURFACE, SIZE, CONTAIN

Description: multiple resources

Fuel/Vegetation, Surface/Understory

Fuel Model: 11

Fuel Moisture

Dead Fuel Moisture: % 6

Live Fuel Moisture: % 2

Weather

20-ft Wind Speed (gust): mph 22

Wind Adjustment Factor: 0.3

Terrain

Slope Steepness: % 0

Fire

Elapsed Time: h 1.3

Suppression

Suppression Tactic: rear

Line Construction Offset: ch 0

Resource Name: 2-person 5-person

Resource Line Production Rate: ch/h 6 15

Resource Arrival Time: h 0 .5

Resource Duration: h 70 70

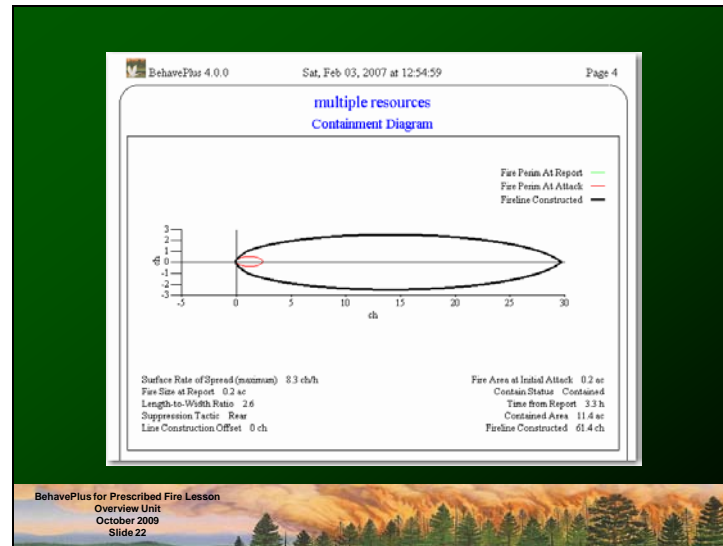
multiple resources

Area	0.2 ac
Fire Area at Initial Attack	0.2 ac
Contain Status	Contained
Time from Report	3.3 h
Contained Area	11.4 ac
Fireline Constructed	61.4 ch

BehavePlus for Prescribed Fire Lesson
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- This example demonstrates the use of multiple resources.
- First, we model a 2-person crew that can build line at 6 ch/h (396 ft/h) arriving at the time the spot fire is reported.
- Then, we add a 5-person crew that can build line at 15 ch/h (990 ft/h), arriving ½ hour after the spot fire is reported.
- With these resources, the fire is contained in 3.3 hours from the time of report at 11.4 acres.
- 61.4 chains (4,052.4 ft) of fireline are constructed.
 - We use chains in calculating Resource Line Production Rate because these are the units used in the *Fireline Handbook, Appendix A* (March 2004).

Slide 22





- You can view diagrams of the output to help you understand the CONTAIN modeling.
- In this example, the Fire Perimeter at Attack is noted in red. The Fire Size at Report is 0.2 acres.
- The total Fireline Constructed is in black. There were a total of 61.4 chains of Fireline Constructed, containing an area of 11.4 acres.

Slide 23

Including BehavePlus Results
in a Report or Prescribed Fire Plan

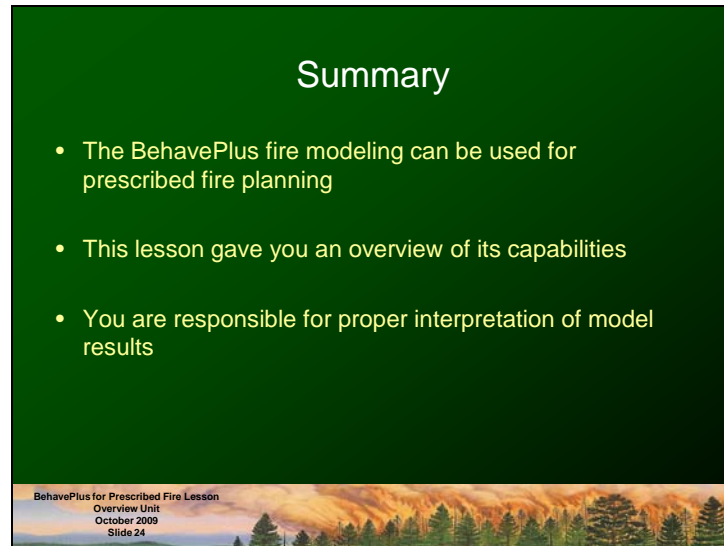
- See Handout and the lesson on “Results in Reports” in the Operation Unit.

BehavePlus for Prescribed Fire Lesson
Overview Unit
October 2009
Slide 23

- We have added a number of intermediate output variables to Version 4.
 - This is especially useful to someone who wants to better understand Rothermel's surface fire spread model.
- One of the intermediate values is characteristic dead fuel moisture, which is a weighted value of 1-h, 10-h, and 100-h moisture values.
 - It can be used to assess the relative influence of 1-h and 10-h moisture.
 - [A tip on this topic is available on www.firemodels.org]
- Tips on including BehavePlus outputs in reports is found in the relevant lesson of the Operation Unit.
- Image from: http://www.nifc.gov/fire_policy/rx/rxfireguide.pdf

Slide 24



The slide has a dark green background with the word "Summary" in white at the top center. Below it, there are three bullet points in yellow text. At the bottom of the slide, there is a horizontal banner with a landscape image of a forest and hills, and text on the left side.

Summary

- The BehavePlus fire modeling can be used for prescribed fire planning
- This lesson gave you an overview of its capabilities
- You are responsible for proper interpretation of model results

BehavePlus for Prescribed Fire Lesson
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- A lesson in the Operations Unit provides you with experience using the Table Shading option of BehavePlus.
- Remember, you are responsible for proper interpretation of model results. Models and Experience are both important in Prescribed Fire Planning.