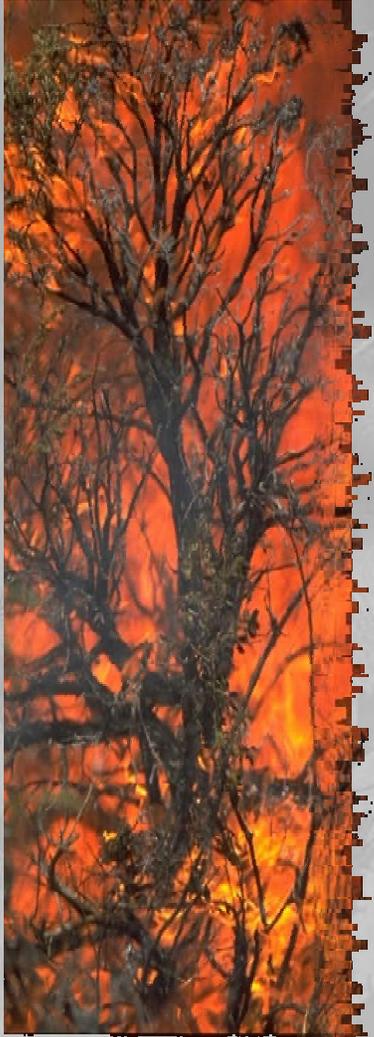


A new set of standard fire behavior fuel models for use with Rothermel's spread model

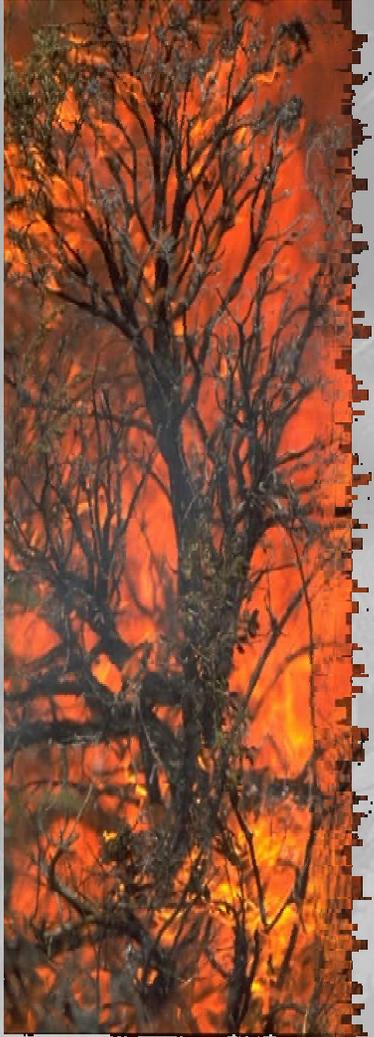
Joe H. Scott

Missoula, MT



# Abstract

- In this session we
  - present a new set of standard fire behavior fuel models
  - describe their characteristics and relationship to the original 13 models
  - present tools for learning the new set



# Introduction

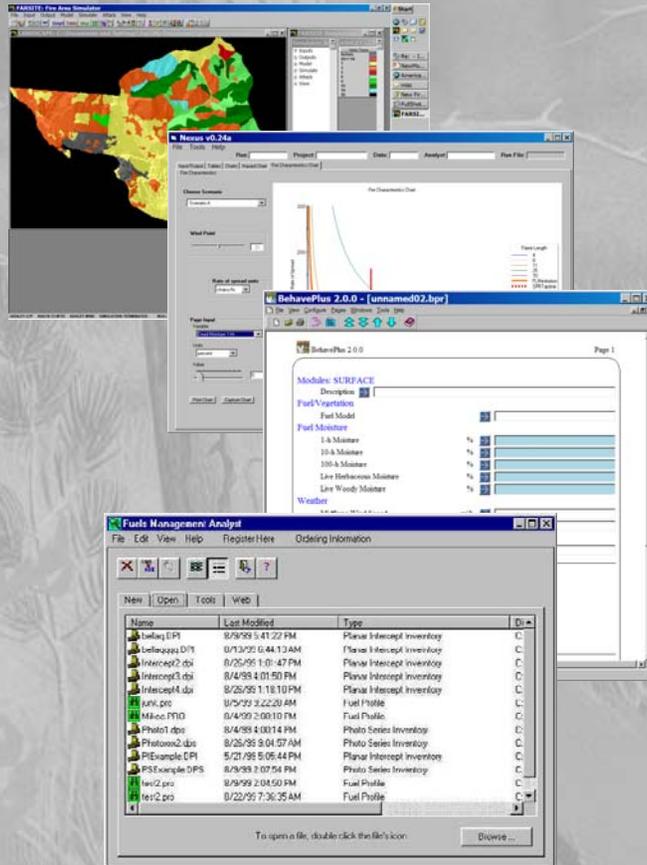
- Predicting fire behavior is an essential fire management task
- Fire behavior prediction models are driven by a large set of fuel inputs
- For convenience, fuel inputs have been arranged into fuel models



# What is a fuel model?

- Set of fuel inputs needed by a fire model
  - Fire behavior fuel models: drive Rothermel's fire spread model; currently a set of 13 standard models
  - NFDRS fuel models: used to calculate fire danger indices; currently a set of 20 models
  - Fuel Loading Models: will drive Albini's Burnup model (fuel consumption)
- We address fire behavior fuel models only

# Systems



- FFE-FVS
- FMAplus
- NEXUS
- BehavePlus
- FARSITE
- FlamMap
- Behave by Remsoft



# History

- Rothermel (1972) – 11 fuel models; extinction moisture constant for whole set
- Albini (1976) – added two models to create the original 13; listed separate extinction moistures
- Anderson (1982) – described each fuel model; included selection aids



# History

- Many fuel inputs have never varied among fuel models; we did not consider varying them in this new set
  - 10-h and 100-h dead fuel SAV ratio
  - Total and effective mineral fraction
  - Owendry fuel particle density

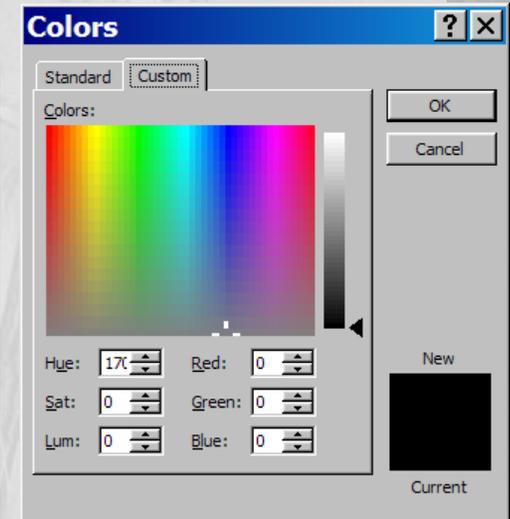
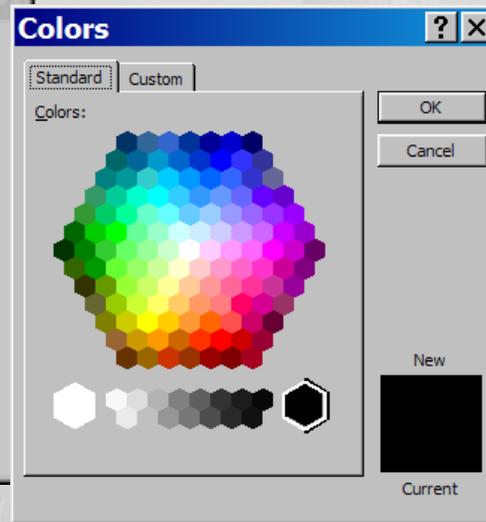
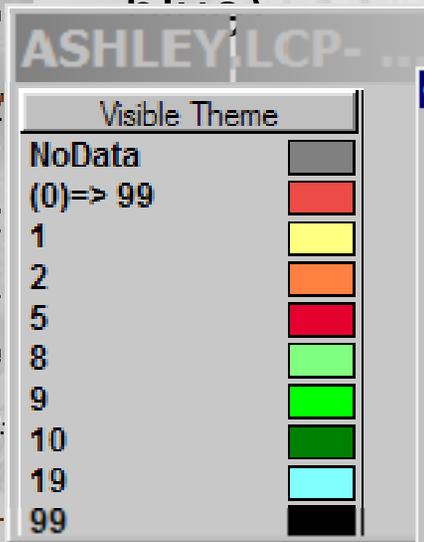
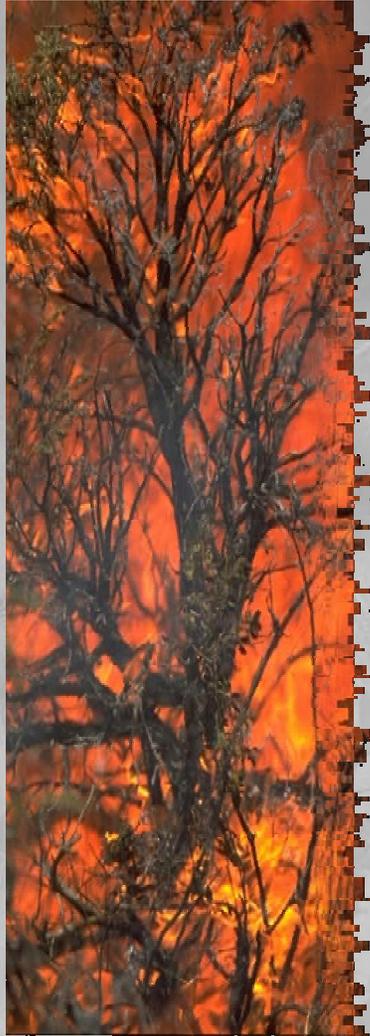


## Need

- Cover wider range of seasons
- Fill gaps in each fuel type
- Better simulate fuel treatments
- Better drive crown fire initiation models
- Reduce need for custom fuel models

# New set: characteristics

- New set is like a larger color palette (various combinations of red, green and blue)





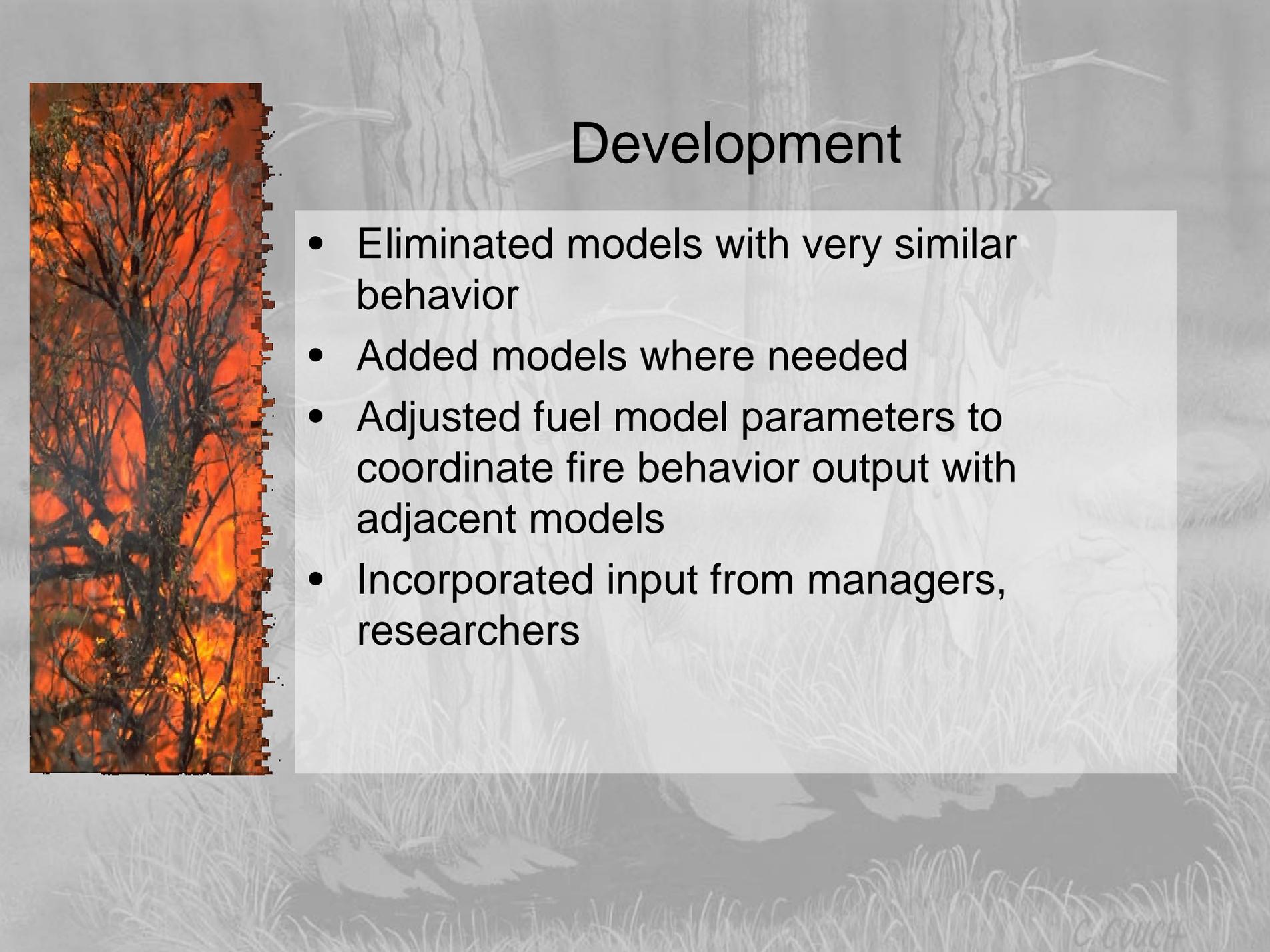
# Scope

- Not *fire* modeling
- Surface fuel only, not ground or canopy
- Rothermel's surface fire spread model only, not fuel consumption, smoke, fire effects or fire danger models
- Same fuelbed assumptions: uniform, homogeneous, continuous

# Development

- Compiled Natural Fuels Photo Series and other surface fuel complex data to suggest range of fuel conditions
- Grouped data subjectively by extinction moisture, major fire-carrying fuel type, fine fuel load, *etc.* (50-60 groups)
- Created draft fuel models based loosely on data from each group





# Development

- Eliminated models with very similar behavior
- Added models where needed
- Adjusted fuel model parameters to coordinate fire behavior output with adjacent models
- Incorporated input from managers, researchers



# Characteristics

- Designed to stand alone
  - Original 13 not repeated exactly in new set
  - Fuel model selection guide points to new models only
  - Developed independent of the original 13
- Original 13 still available
  - No immediate need to convert existing maps or guides that work well
  - New projects should consider using new set
  - Crosswalk: one-to-many

# Characteristics

- Specifies fuelbeds not vegetation
  - One fuel model can be applied in many vegetation types
  - New set: “heavy load tall shrub”, not “Chaparral”
  - Vegetation type not in the fuel model selection guide
  - guides or crosswalks from vegetation to fuel model can be made regionally or locally



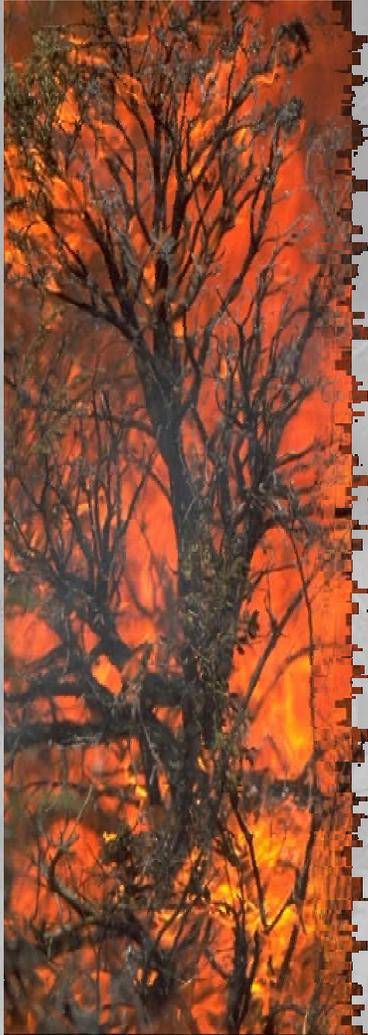


# Naming

- Fuel model code
  - 3-digit alphanumeric code for user communication (GR1 = “Grass One”)
  - Alpha-characters indicate fire-carrying fuel type
  - Numeric-values roughly indicate relative load/fire behavior, ranked by HPA at certain MC
  - Original 13 models are still 1 – 13 for backward compatibility with existing processors

# Naming

| fuel type | fuel model number block | used in new set | reserved for future standard fuel models | available for custom fuel models |
|-----------|-------------------------|-----------------|--|----------------------------------|
|           | 1-13                    | 1-13            |  |                                  |
|           | 14-89                   |                 |  | 14-89                            |
| NB        | 90-99                   | 91-95           | 96-97                                    | 90, 98-99                        |
| GR        | 100-119                 | 101-109         | 110-112                                  | 100, 113-119                     |
| GS        | 120-139                 | 121-124         | 125-130                                  | 120, 131-139                     |
| SH        | 140-159                 | 141-149         | 150-152                                  | 140, 153-159                     |
| TU        | 160-179                 | 161-165         | 166-170                                  | 160, 171-179                     |
| TL        | 180-199                 | 181-189         | 190-192                                  | 180, 193-199                     |
| SB        | 200-219                 | 201-204         | 205-210                                  | 200, 211-219                     |
|           | 220-255                 |                 |  | 220-255                          |





# Naming

- Fuel model code
- Fuel model number
- Fuel model name
  - Descriptive name for fuel model



# Naming

- Fuel model file contains all three labels
- FARSITE/FlamMap, NEXUS to use common ASCII file format based on FARSITE 4, others encouraged to use same format
- BehavePlus exports this format

| fuel<br>model<br>number | fuel<br>model<br>code | 1-hr<br>fuel<br>load | 10-hr<br>fuel<br>load | 100-hr<br>fuel<br>load | live                 | live                  | fuel<br>model<br>type | 1-hr                         | herb.                        | live                                  | Fuel<br>Bed<br>Depth | Dead                        | dead                    | live                    |
|-------------------------|-----------------------|----------------------|-----------------------|------------------------|----------------------|-----------------------|-----------------------|------------------------------|------------------------------|---------------------------------------|----------------------|-----------------------------|-------------------------|-------------------------|
|                         |                       |                      |                       |                        | herb<br>fuel<br>load | woody<br>fuel<br>load |                       | surface<br>area/vol<br>ratio | surface<br>area/vol<br>ratio | woody<br>surface<br>area/vol<br>ratio |                      | fuel<br>moisture<br>of Ext. | fuel<br>heat<br>content | fuel<br>heat<br>content |
| 101                     | GR1                   | 0.10                 | 0.00                  | 0.00                   | 0.30                 | 0.00                  | dynamic               | 2200                         | 2000                         | 9999                                  | 0.4                  | 15                          | 8000                    | 8000                    |
| 102                     | GR2                   | 0.10                 | 0.00                  | 0.00                   | 1.00                 | 0.00                  | dynamic               | 2000                         | 1800                         | 9999                                  | 1.0                  | 15                          | 8000                    | 8000                    |
| 103                     | GR3                   | 0.10                 | 0.40                  | 0.00                   | 1.50                 | 0.00                  | dynamic               | 1500                         | 1300                         | 9999                                  | 2.0                  | 30                          | 8000                    | 8000                    |
| 104                     | GR4                   | 0.25                 | 0.00                  | 0.00                   | 1.90                 | 0.00                  | dynamic               | 2000                         | 1800                         | 9999                                  | 2.0                  | 15                          | 8000                    | 8000                    |
| 105                     | GR5                   | 0.40                 | 0.00                  | 0.00                   | 2.50                 | 0.00                  | dynamic               | 1800                         | 1600                         | 9999                                  | 1.5                  | 40                          | 8000                    | 8000                    |
| 106                     | GR6                   | 0.10                 | 0.00                  | 0.00                   | 3.40                 | 0.00                  | dynamic               | 2200                         | 2000                         | 9999                                  | 1.5                  | 40                          | 9000                    | 9000                    |
| 107                     | GR7                   | 1.00                 | 0.00                  | 0.00                   | 5.40                 | 0.00                  | dynamic               | 2000                         | 1800                         | 9999                                  | 3.0                  | 15                          | 8000                    | 8000                    |
| 108                     | GR8                   | 0.50                 | 1.00                  | 0.00                   | 7.30                 | 0.00                  | dynamic               | 1500                         | 1300                         | 9999                                  | 4.0                  | 30                          | 8000                    | 8000                    |
| 109                     | GR9                   | 1.00                 | 1.00                  | 0.00                   | 9.00                 | 0.00                  | dynamic               | 1800                         | 1600                         | 9999                                  | 5.0                  | 40                          | 8000                    | 8000                    |
| 121                     | GS1                   | 0.20                 | 0.00                  | 0.00                   | 0.50                 | 0.65                  | dynamic               | 2000                         | 1800                         | 1800                                  | 0.9                  | 15                          | 8000                    | 8000                    |
| 122                     | GS2                   | 0.50                 | 0.50                  | 0.00                   | 0.60                 | 1.00                  | dynamic               | 2000                         | 1800                         | 1800                                  | 1.5                  | 15                          | 8000                    | 8000                    |
| 123                     | GS3                   | 0.30                 | 0.25                  | 0.00                   | 1.45                 | 1.25                  | dynamic               | 1800                         | 1600                         | 1600                                  | 1.8                  | 40                          | 8000                    | 8000                    |
| 124                     | GS4                   | 1.90                 | 0.30                  | 0.10                   | 3.40                 | 7.10                  | dynamic               | 1800                         | 1600                         | 1600                                  | 2.1                  | 40                          | 8000                    | 8000                    |
| 141                     | SH1                   | 0.25                 | 0.25                  | 0.00                   | 0.15                 | 1.30                  | dynamic               | 2000                         | 1800                         | 1600                                  | 1.0                  | 15                          | 8000                    | 8000                    |
| 142                     | SH2                   | 1.35                 | 2.40                  | 0.75                   | 0.00                 | 3.85                  | N/A                   | 2000                         | 9999                         | 1600                                  | 1.0                  | 15                          | 8000                    | 8000                    |
| 143                     | SH3                   | 0.45                 | 3.00                  | 0.00                   | 0.00                 | 6.20                  | N/A                   | 1600                         | 9999                         | 1400                                  | 2.4                  | 40                          | 8000                    | 8000                    |
| 144                     | SH4                   | 0.85                 | 1.15                  | 0.20                   | 0.00                 | 2.55                  | N/A                   | 2000                         | 1800                         | 1600                                  | 3.0                  | 30                          | 8000                    | 8000                    |
| 145                     | SH5                   | 3.60                 | 2.10                  | 0.00                   | 0.00                 | 2.90                  | N/A                   | 750                          | 9999                         | 1600                                  | 6.0                  | 15                          | 8000                    | 8000                    |
| 146                     | SH6                   | 2.90                 | 1.45                  | 0.00                   | 0.00                 | 1.40                  | N/A                   | 750                          | 9999                         | 1600                                  | 2.0                  | 30                          | 8000                    | 8000                    |
| 147                     | SH7                   | 3.50                 | 5.30                  | 2.20                   | 0.00                 | 3.40                  | N/A                   | 750                          | 9999                         | 1600                                  | 6.0                  | 15                          | 8000                    | 8000                    |
| 148                     | SH8                   | 2.05                 | 3.40                  | 0.85                   | 0.00                 | 4.35                  | N/A                   | 750                          | 9999                         | 1600                                  | 3.0                  | 40                          | 8000                    | 8000                    |
| 149                     | SH9                   | 4.50                 | 2.45                  | 0.00                   | 1.55                 | 7.00                  | dynamic               | 750                          | 1800                         | 1500                                  | 4.4                  | 40                          | 8000                    | 8000                    |
| 161                     | TU1                   | 0.20                 | 0.90                  | 1.50                   | 0.20                 | 0.90                  | dynamic               | 2000                         | 1800                         | 1600                                  | 0.6                  | 20                          | 8000                    | 8000                    |
| 162                     | TU2                   | 0.95                 | 1.80                  | 1.25                   | 0.00                 | 0.20                  | N/A                   | 2000                         | 9999                         | 1600                                  | 1.0                  | 30                          | 8000                    | 8000                    |
| 163                     | TU3                   | 1.10                 | 0.15                  | 0.25                   | 0.65                 | 1.10                  | dynamic               | 1800                         | 1600                         | 1400                                  | 1.3                  | 30                          | 8000                    | 8000                    |
| 164                     | TU4                   | 4.50                 | 0.00                  | 0.00                   | 0.00                 | 2.00                  | N/A                   | 2300                         | 9999                         | 2000                                  | 0.5                  | 12                          | 8000                    | 8000                    |
| 165                     | TU5                   | 4.00                 | 4.00                  | 3.00                   | 0.00                 | 3.00                  | N/A                   | 1500                         | 9999                         | 750                                   | 1.0                  | 25                          | 8000                    | 8000                    |

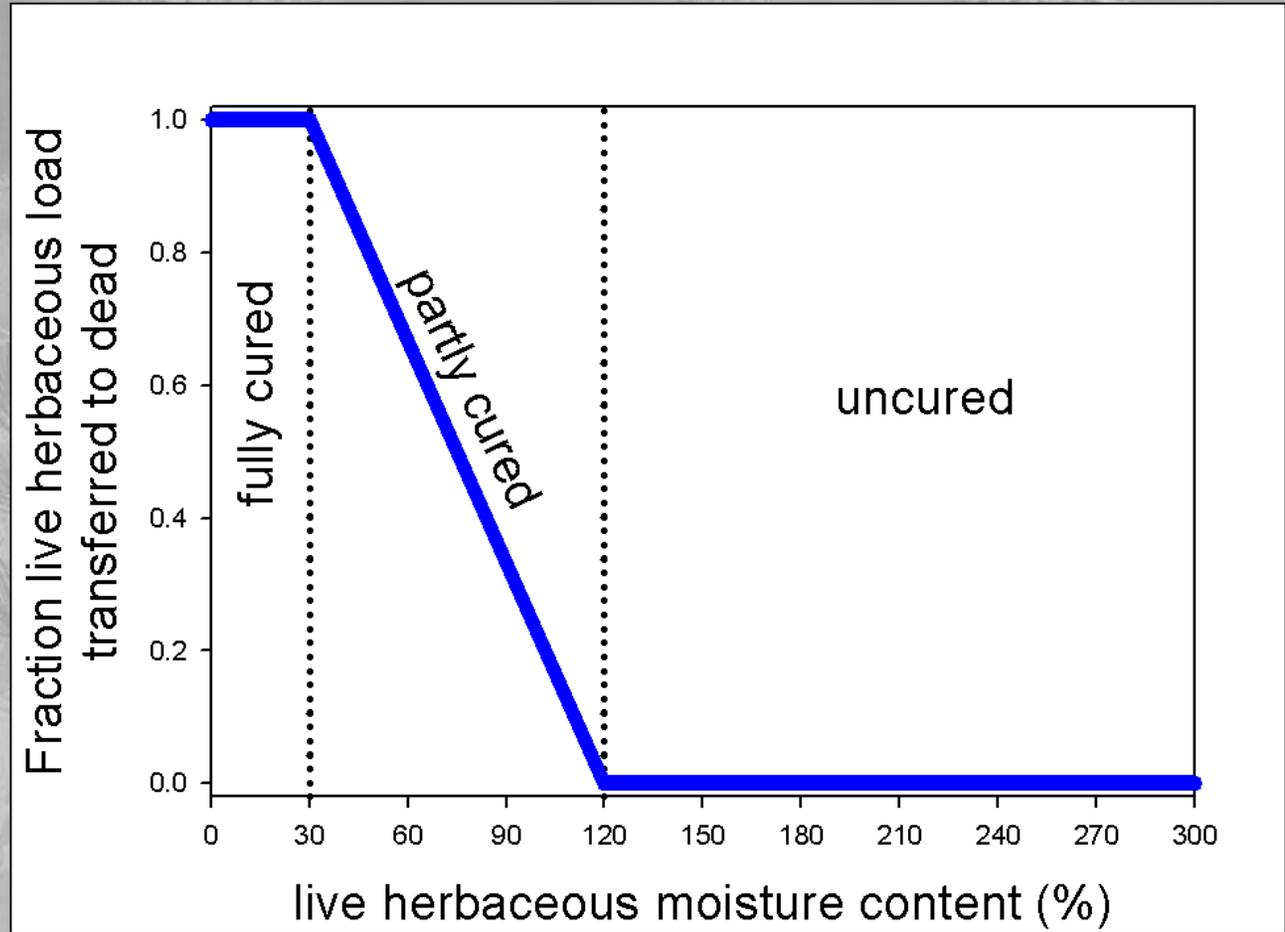
# Dynamic fuel models

- Dynamic fuel models – live herbaceous load transferred to dead
  - Function of live herbaceous MC
  - Takes on 1-hr MC
  - Preserves live herbaceous SAV ratio
  - Requires changes in fire behavior processor
  - Improves ability (and difficulty)





# Dynamic fuel models



# Dynamic fuel models



| 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                       |

# Publications

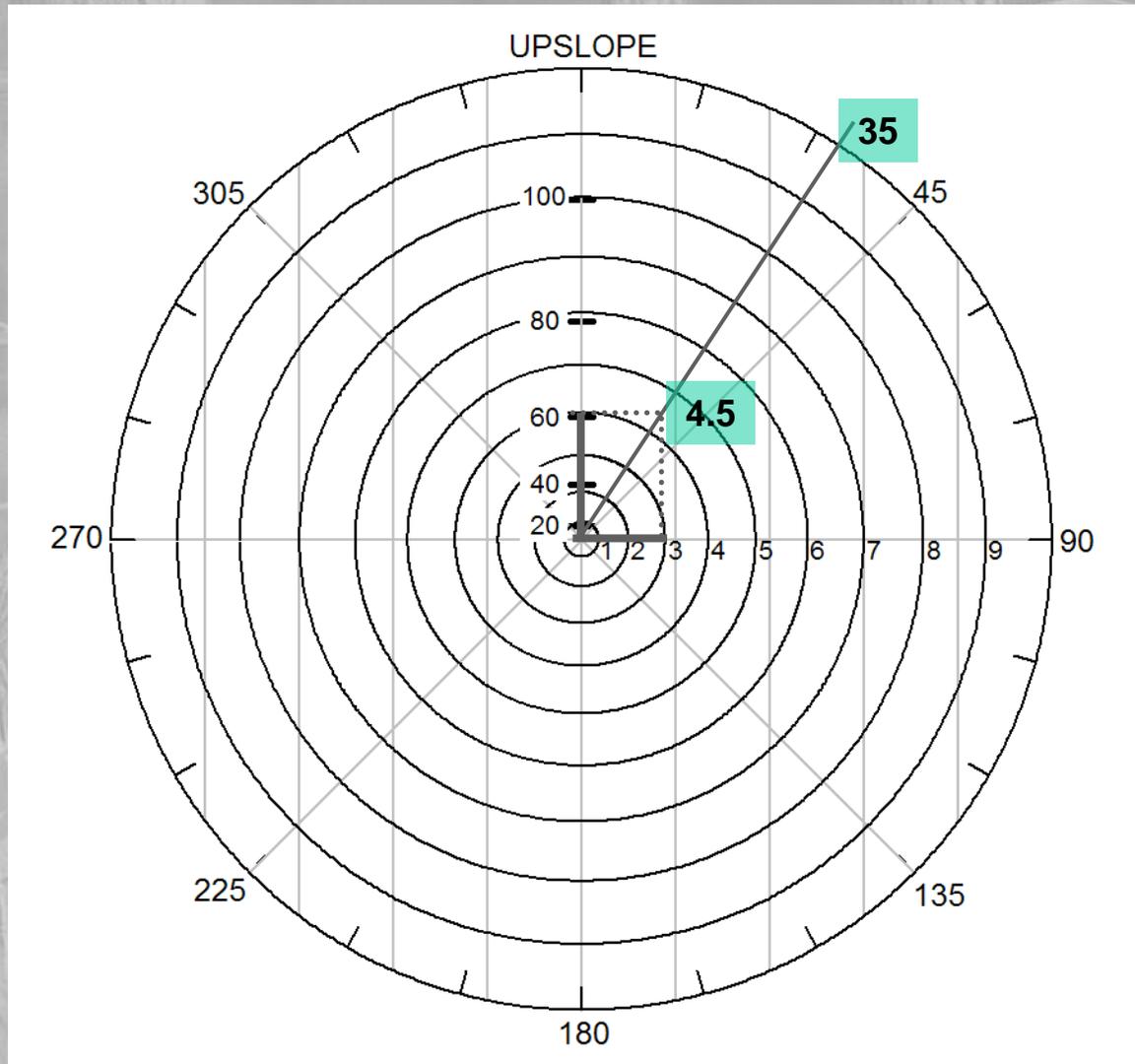
- Two manuscripts
  - Printed GTR: includes photos, selection guide, crosswalks, fuel model descriptions, predicted fire behavior charts ([www.treesearch.fs.fed.us](http://www.treesearch.fs.fed.us))
  - HTML tech transfer document: includes content of printed GTR (hyperlinked) plus comprehensive set of fire behavior charts, a Q&A section, quiz and exercises. (fuels section of [frames.nbii.gov](http://frames.nbii.gov)) [DEMO](#)
  - Nomographs: easier-to-use new style

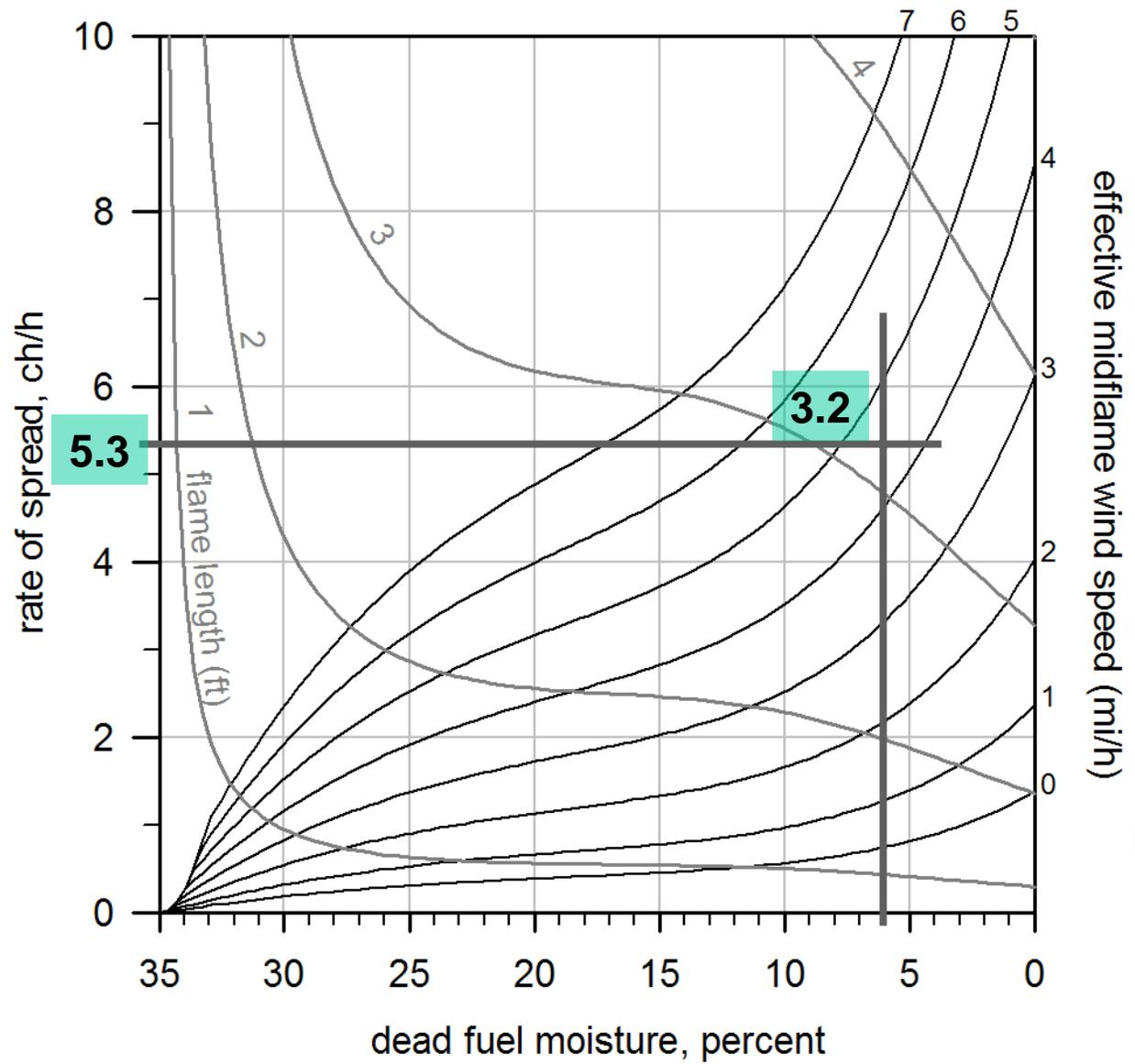


# Nomographs

- New style for new and original fuel models
- Example
  - fuel model = TL8 (188)
  - Fine dead fuel moisture (1-hr) = 6 percent
  - Midflame wind speed = 3 mi/h
  - Slope = 60 percent
  - Wind direction = cross-slope



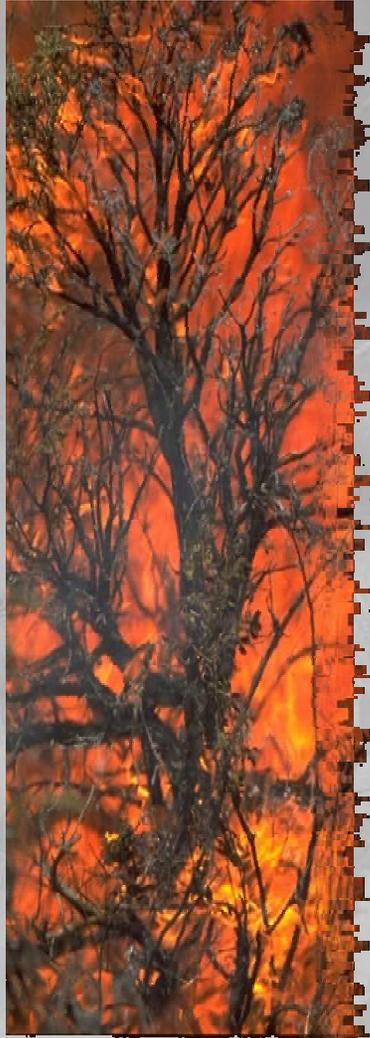






# Example applications

- Fuel model guide to SE coastal plain
- Local/regional lookup tables
  - Incidents (FARSITE/FlamMap users)
  - Individual projects (Yosemite, SEKI parks)
- LANDFIRE fuel maps



C. COUCH