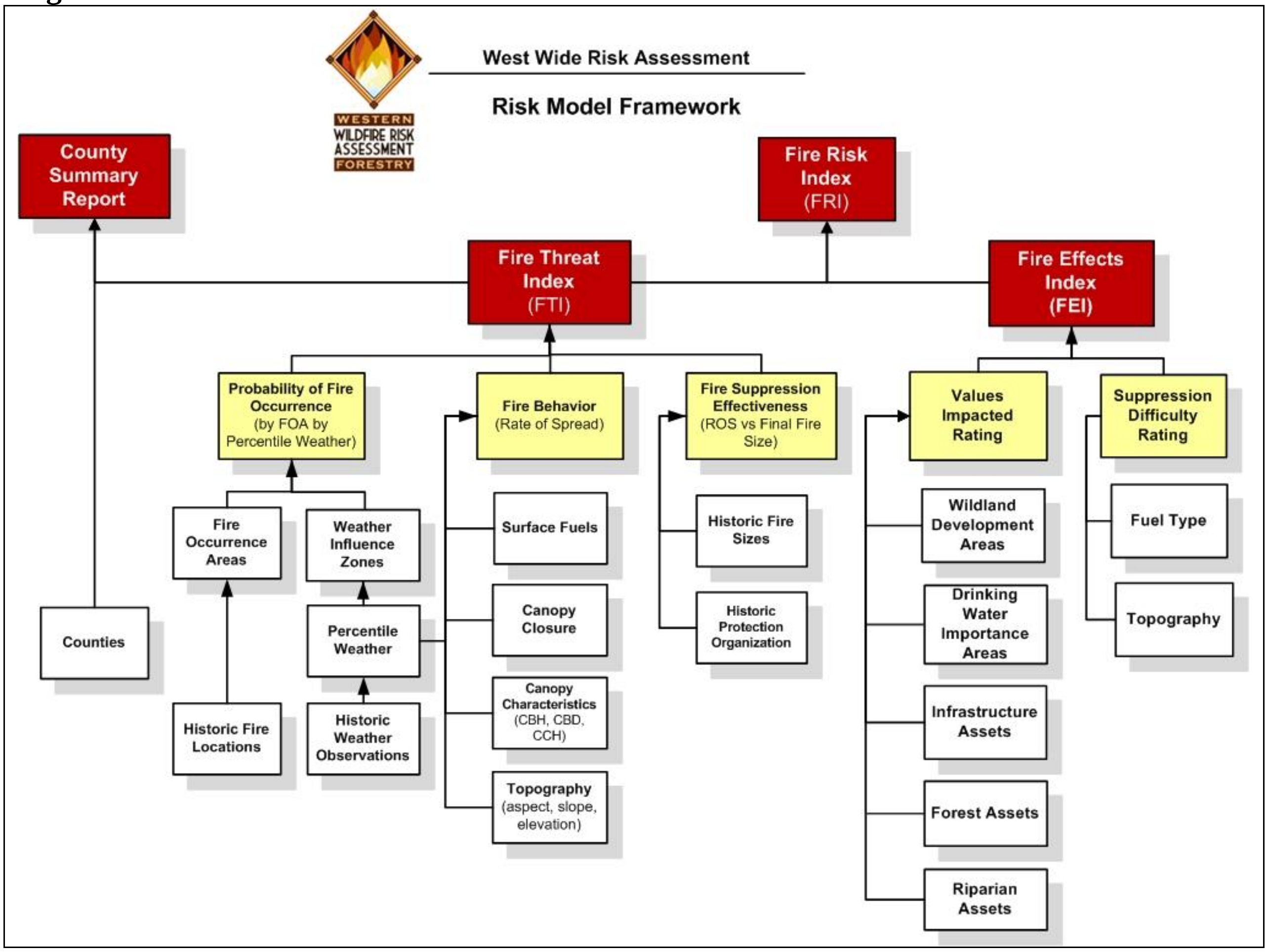
West Wide Risk Assessment
Detailed Project Process Description

This section contains a detailed description of the analysis process to quantify wildfire risk.

Within the WWA, the data layer that defines wildland fire risk is the Fire Risk Index (FRI), (Figure 1). The Fire Risk Index is calculated from the Fire Threat Index (FTI), and the Fire Effects Index (FEI). The FEI is the potential expected effects of the fire as defined via response functions. The final calculation is FRI = FTI * FEI*10,000. The scalar is included to make the values a bit larger to enhance understanding. The description of the process that follows will describe initially the development of the Fire Threat Index. This will be followed by descriptions of the Fire Effect Index and then how these are combined to create the Fire Risk Index.

Figure 1



Index, Rating And Scores As Well As Fire Occurrence Area Data Categories (color ramps)

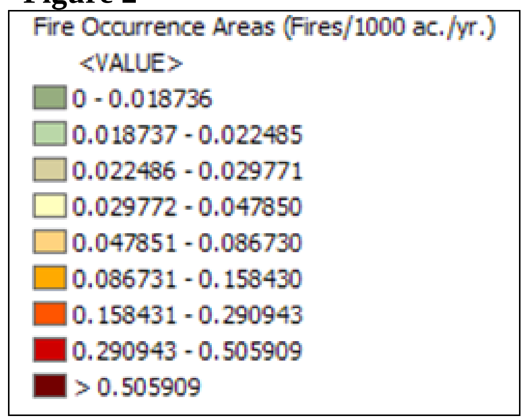
Indices and rating scores as well as the fire occurrence area data layers are continuous data with many data values. For example, for the fire occurrence area data layer, there are 732,387 unique cellular fire occurrence rate values. Hence, it is necessary to group these values into classes or categories. For consistency, nine categories have been built. Also for consistency, the breakpoints between categories use a consistent target cumulative percentile value as shown in Table 1.

Table 1

Category	% Range	Cumm. %	Cat. %
1	0 – 32.9%	32.9%	32.9%
2	33.0 - 63.5%	63.5%	30.5%
3	63.5% -70.0%	70.0%	6.5%
4	70.0 - 77.5%	77.5%	7.5%
5	77.5 - 85.5%	85.5%	8.0%
6	85.5 - 92.5%	92.5%	7.0%
7	92.5 - 96.5%	96.5%	4.0%
8	96.5 - 98.5%	98.5%	2.0%
9	98.5 - 100.0%	100.0%	1.5%

By design, the categories were developed to display the highest rated 14.5% of the cells in categories 6-9. The highest rated 22.5% of the cells are in categories 5-9. A consistent color has been applied to each of the nine categories. The "color ramp" used is shown in Figure 2, with the example being from the Fire Occurrence Area (FOA) data set. Notice this places the highest rated cells into just about half of the categories (5-9) where the user would truly locate the differences within these highly rated cells.

Figure 2



Fire Threat

Webster's dictionary defines risk as "the possibility of suffering harm or loss." The fire threat component of the fire risk assessment process is called the Fire Threat Index (Figure 1). It is calculated as a number greater than zero (0) but less than or equal to one (1). The process used relies on the analytical methods that would be used to calculate the probability of an acre burning. The FTI integrates the probability of an acre igniting and the expected final fire size based on the rate of spread in four weather percentile categories. Due to some necessary assumptions, mainly fuel homogeneity, it is not the true probability. But since all areas within the analysis area have this value determined consistently, it allows for comparison and ordination of areas as to the likelihood of an acre burning.

Fire Occurrence

Wildland fire occurrence data for the WWA project is required to be spatially referenced fire ignition point locations. Additional associated fire report attributes are needed. The flow chart in Figure 3 shows where this data is used in support of the development of the Fire Threat Index. To develop the FTI, the first task is to gather past fire occurrence information. The goal is to use this information to define areas of uniform probability of an acre igniting. These areas are called Fire Occurrence Areas (FOA). Figure 4 shows an example of spatial fire occurrence data and Figure 5 shows what the Fire Occurrence Area map might look like using the spatial fire occurrence data.

Figure 3, Fire Occurrence Data Inputs For The Fire Threat Model

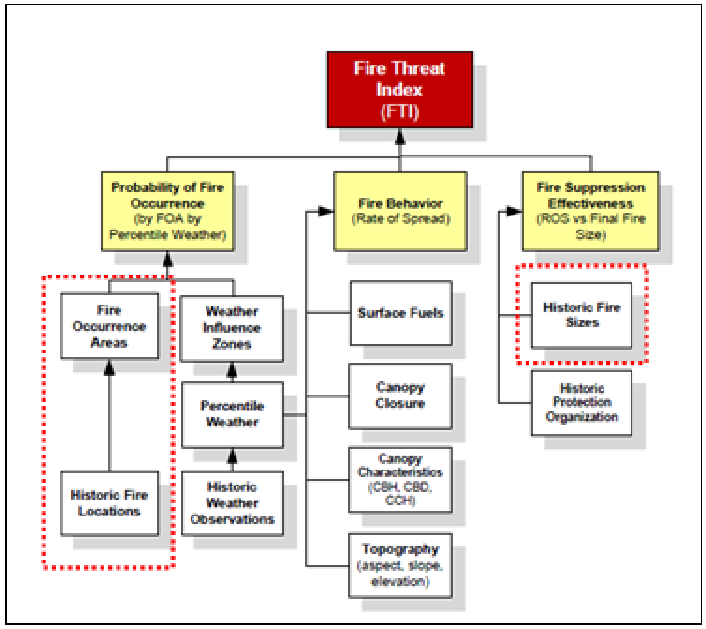


Figure 4, Fire Ignition Locations

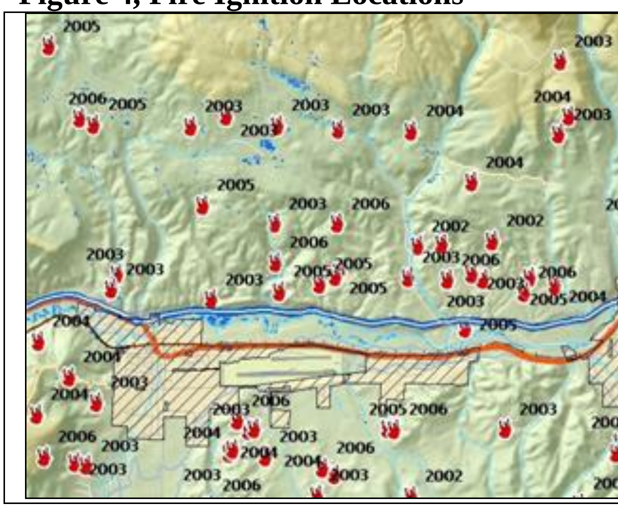
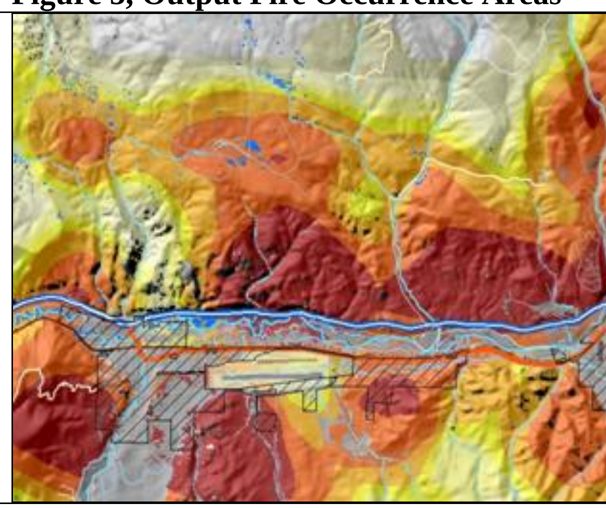


Figure 5, Output Fire Occurrence Areas



Fire occurrence report data was gathered from the states, the federal government and from the National Fire Incident Reporting System (NFIRS). As a standard, the WWA requested fire occurrence fire report data from the agency that has the statutory responsibility for fire protection. In some locations, the agency that has the statutory responsibility for fire protection via agreements has a different agency actually going the initial attack of fires on their lands. This request was made to minimize the obtaining of duplicate fire reports that the project might receive.

To support the gathering of fire occurrence data from the states, a Fire Occurrence Data Briefing Paper was developed. The data fields and the format of the data requested was communicated to the states. Conference calls were held to accomplish the transfer of this data request. The data was to be “cleaned” by state representatives in order to remove duplicate fire locations and erroneous fire locations and related report information. Project staff worked with the state representatives and provided guidance and quality control on wildland fire ignition location data. Project staff did spend significant time to insure, as best as can be determined, that duplicate fire reports were identified for fires with a final fire size greater than 100 acres.

For each wildland fire ignition, the following data fields were requested.

- Discovery Date
- Unit Organizational Code
- Fire Number Or ID
- Total Acres Burned
- Fire Cause Code
- DATUM
- Latitude
- Longitude
- Discovery Time
- Contained Date
- Contained Time
- Control Date
- Control Time

Those states that did not collect all of the attributes requested were asked to provide as many of the requested attributes as possible. As a minimum for each wildland fire, the year of the fire and the location of the fire described by latitude/longitude was needed.

These same data fields were also gathered from the federal fire occurrence data on lands protected by the following agencies: USDA U.S. Forest Service, DOI Bureau of Land Management, DOI Bureau of Indian Affairs, DOI U.S. Fish and Wildlife Service and DOI National Park Service. The primary sources of the fire occurrence reports was from the U.S. Forest Service’s Fire and Aviation Management Web Applications (FAMWEB) web site.

Since the state fire occurrence reports are only for lands that the state has the statutory responsibility for fire protection, it was necessary to obtain fire occurrence data for other privately owned lands. Most of these lands have the wildland fire protection provided by an urban or rural fire protection district. These fire protection districts have been requested to report all fires including wildland fire to the U.S. Department of Homeland Security National Fire Incident Reporting System (NFIRS).

The project contacted the Department of Homeland Security and obtained the NFIRS fire report databases for the years 1999 through 2009. A custom program was written to extract from these yearly databases the fire report data defined above for all wildland fires (Incident Types 140-143), special outside fires (Incident Type 160) and agriculture fires (Incident Types 170-173).

Almost all of the fire reports from NFIRS did not contain a location defined by latitude/longitude or township/range/section. This requires the reporting fire department to complete the optional locations section of the report. Almost without exception, the fire departments are completing this section with only a field with a street address, town, state and zip code. Hence for all fires reported via NFIRS, the fire was located on the landscape by assigning it to a postal service zip code. All fires within a zip code were then uniformly distributed to the cells within the postal service zip code. This allows for the accounting of the fire in the FOA development process but on a less spatial basis than fire reported by the states and federal agencies. Note that in Colorado, the fire occurrence data was such that no NFIRS data was used.

The years where fire reports were provided varied based on availability. For the five federal agencies, fire reports from 1999 –2008 were used. For the states, the data varied with different year time periods. The time periods were between 1999 and 2009. The maximum period used was 10 years. For the NFIRS data, it became apparent that by 2004, the number of fire reports by state indicated implementation of the reporting process was in place. Also, the reporting by fire protection districts is voluntary in most states. Hence, a complete set of reports is not available but the project used what was available. For the reports that were available, the period 2004 – 2009 was used. In all cases, the process annualizes the fire occurrence.

Fire Occurrence Areas (FOA)

A Fire Occurrence Area (FOA) is an area where the probability of each acre igniting is the same. Pictorially, if one were to locate the point location for historic ignitions on a map of an FOA, the points would appear to be equally spaced.

This data layer is a surface grid of calculated mean ignition rates that represent the probability of a wildland fire igniting. It was developed using the historical fire ignition data. Resultant fire ignition rates are measured in fires per 1,000 acres per year. Figure 6 shows Jackson County, Oregon, with fire ignition location points.

The key input data used to develop the Fire Occurrence Areas (FOA) data set is historical fire ignition locations. These are spatially referenced x, y coordinates (point locations) of the recorded ignition origin of historical fires. Ignition locations are often recorded as latitude and longitude format or using a township/range/section format.

For fire reports obtained from the NFIRS database, all fires were assigned to a postal zip code as neither location format was used. The density of fires is evenly distributed within the zip code.

Prior to developing the FOAs, the fire locations were reviewed for quality assurance. The first step was to review the data spatially. Fire locations that were outside the jurisdiction of the reporting agency were deleted. The assumption here is that the legal description, latitude/longitude, is incorrect and there is no reasonable way to find the correct location.

The second step in reviewing the fire reports was to remove any apparent duplicate fire reports. Duplicate fire reports can occur if more than one agency responds to the same fire and each agency submits a report. For this reason, the project staff compiled from each agency only fire reports for fires for which the agency has statutory responsibility.

Duplicates can frequently be recognized by comparing the fire start date, fire size and latitude/longitude. Identifying duplicate fires was done by sorting the data and identifying those fires with the same date and then comparing the fire size and coordinate locations.

All processing was done using grid-based modeling using floating point calculations to facilitate greater numerical precision. The modeling process is designed to distribute the fire frequency across the burnable area within a one mile by one mile grid. Neighborhood modeling functions are applied to derive an ignition rate for every burnable cell in a grid using raster processing techniques. Detailed steps for developing FOA are the Appendices. Figure 6a and 6b show Jackson County, Oregon, with fire ignition locations and fire occurrence areas.

Figure 6a, Fire Ignition Locations Points

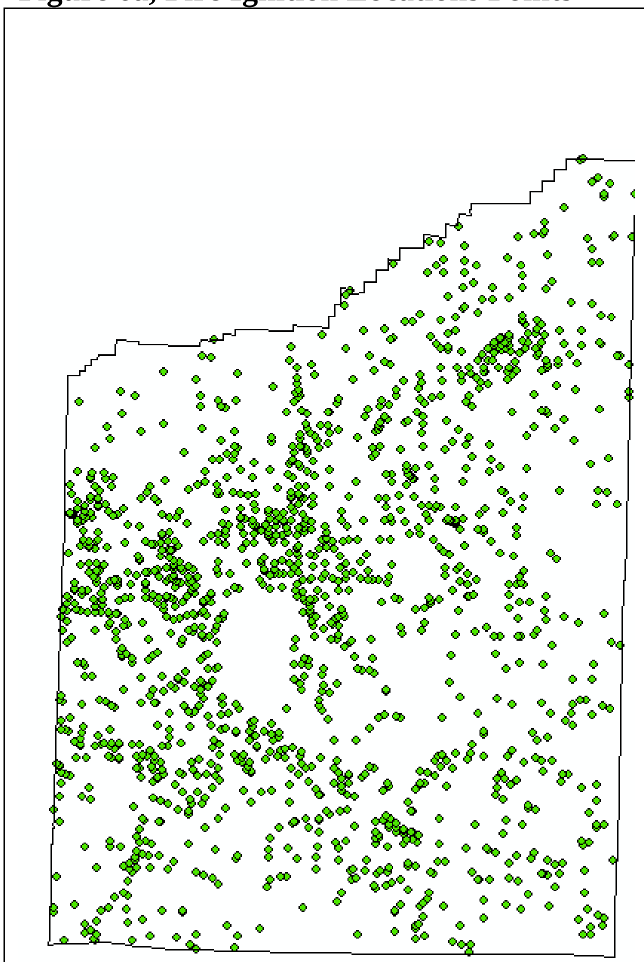
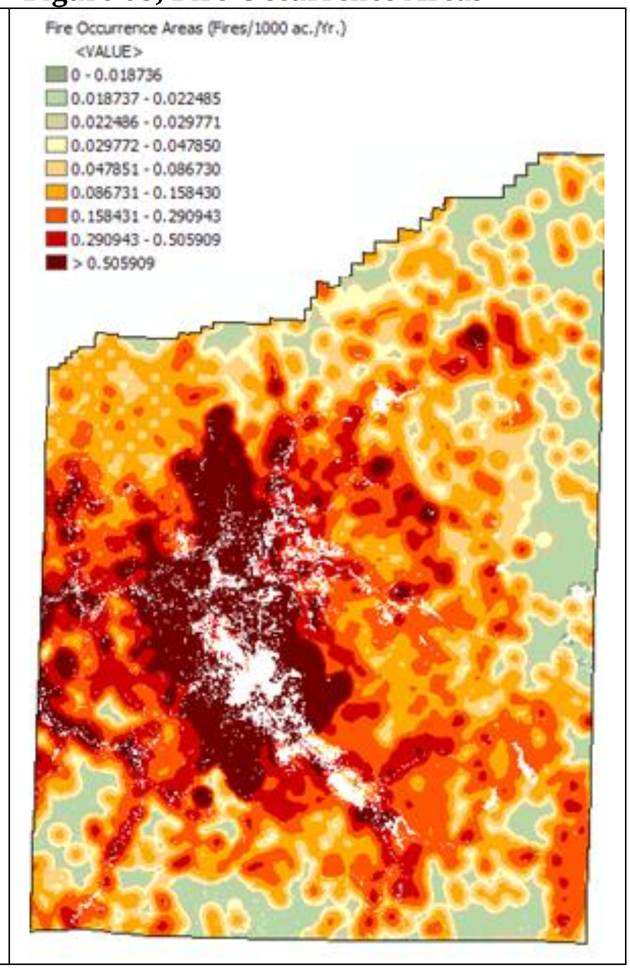


Figure 6b, Fire Occurrence Areas



Fire Behavior
Fire behavior prediction was estimated using methods defined in the Fire Behavior Prediction System (Rothermel 1983, Scott and Reinhardt 2001, Andrews 2007, Heinsch and Andrews 2010). Fire behavior was predicted for surface and canopy fires types. The prediction system requires that data be gathered and mapped for fuels and topography at a local scale. For the WWA, the mapping scale for fuels and topographic data is at a 30-meter by 30-meter resolution or approximately 100 feet by 100 feet. On a larger but uniform scale, the weather needs to be defined.

Weather
Weather throughout the project area varies considerably based upon geography. Weather Influence Zones (WIZ) were developed and represent areas of relatively homogenous weather or climatology. Each state provided a fire weather meteorologist contact for coordination with the project staff meteorologist in the development of Weather Influence Zones.

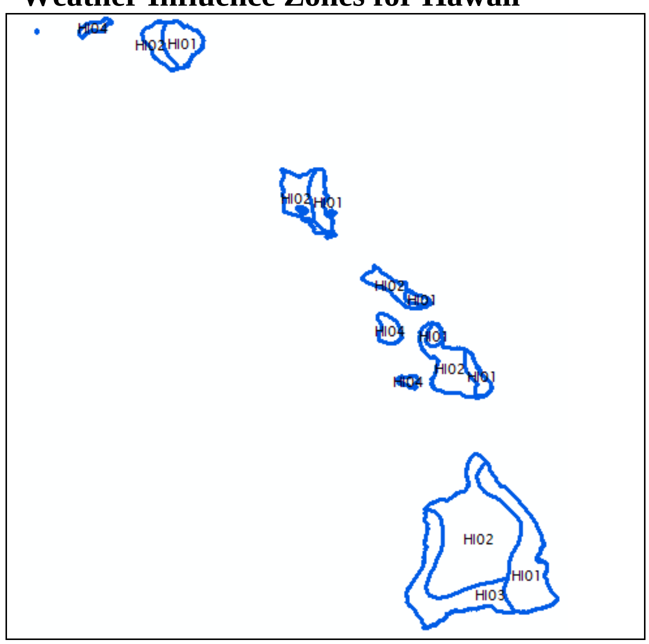
The following criteria were used to determine WIZ boundaries.

- Topographic features: mountain ranges (location, elevation, slope orientation), river basins
- Precipitation climatology (annual, fire season)
- Existing weather forecast areas such as Predictive Service Areas
- Percentile weather at weather stations
- Fire danger ratings that are similar throughout the WIZ
- State boundaries

Figures 7 through 9 show the Weather Influence Zones for Hawaii, the contiguous 15 western states and Alaska.

A search of land management agency fire weather stations and National Oceanographic and Atmospheric Administration (NOAA) surface observations was conducted to establish a quality, long-term weather data set. The primary sources of this data are: the U.S. Forest Service's Fire and Aviation Management Web Applications (FAMWEB) web site, the Western Regional Climate Center Fire Program Analysis historical weather data delivery system and NOAA's National Climate Data Center. The preferred length of record for these stations was 20 years, but stations with fewer years were used if necessary.

Figure 7,
Weather Influence Zones for Hawaii



The weather station catalog was obtained from the U.S. Forest Service's Fire and Aviation Management Web Applications (FAMWEB) web site. Except for the assigned fuel model, the catalog information was used as stated by the station's maintaining agency.

WWA staff gathered weather observations from weather stations. These weather observations were used to select a weather station that best represented the weather in the Weather Influence Zone. Using the weather observation for the best fit station, fuel moisture values and wind speed values were determined for four percentile weather categories, Low (15% of days), Moderate (75% of days), High (7% of days) and Extreme (3% of days).

Weather observation data was gathered for 2,144 weather stations. The fire season was defined by Weather Influence Zone. This data was checked for errors and then imported into the a custom built a program named WRISK which is based on USDA-Forest Service's FireFamilyPlus program. The WRISK program was specifically tailored to the needs of the WWA and uses the same equations as the FireFamilyPlus program.

Figure 8, Weather Influence Zones for the Contiguous 15 Western States

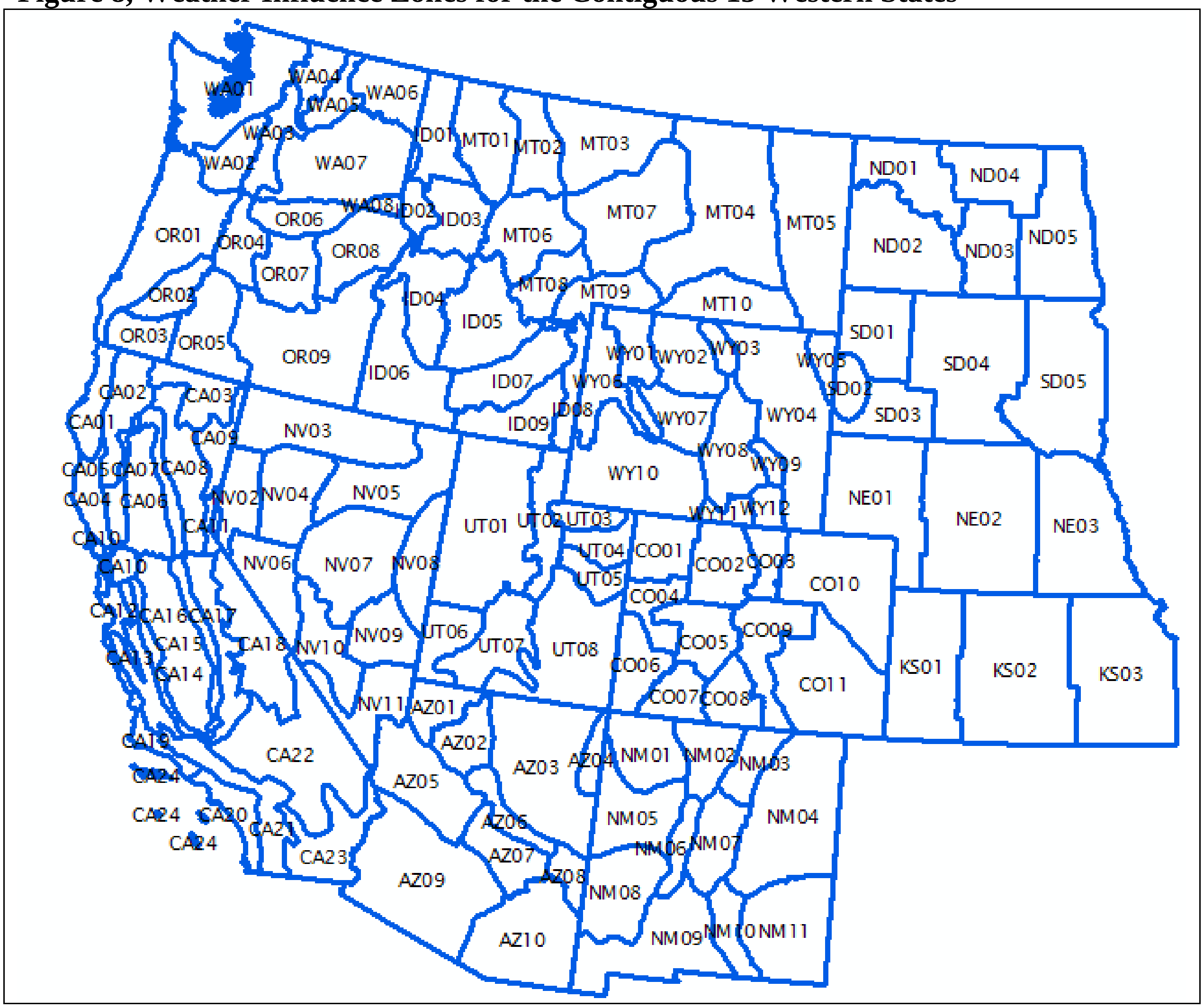
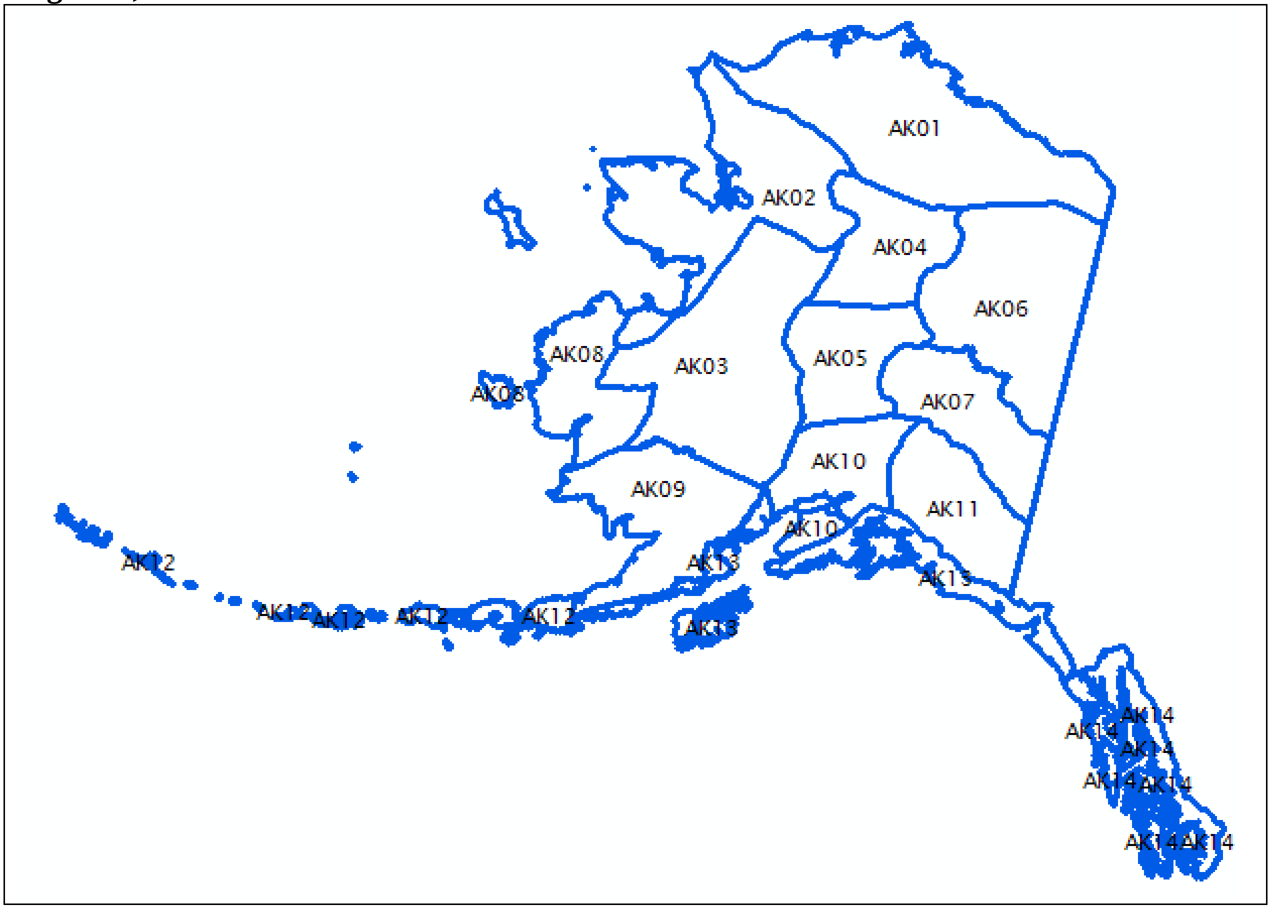


Figure 9, Weather Influence Zones for Alaska



The National Fire Danger Rating System (NFDRS) index Spread Component (SC) was calculated for each day. For each weather station, the Spread Component was calculated using the NFDRS fuel model G. Fuel model G contains fuel loading values in all of the dead (1-h, 10-h and 100-h) and live (herbaceous and woody) fuel categories. This allows for the influence in the Spread Component calculation of the fuel moisture values in all of the fuel categories. In this calculation, the climate class and slope class defined in the station catalog were used. The grass type was assumed to be perennial.

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

An example printout and screen capture (Figure 10) of percentile weather values from the FireFamilyPlus program for a weather station. An example station named Pine Hills Fire Station weather station is shown for reference to the program outputs of percentile weather. The WRISK program does not have these printouts or screens. Showing the screens from the FireFamilyPlus program is done for explanation purposes.

Figure 10, Percentile Weather Report from FireFamilyPlus

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FireFamily Plus Percentile Weather Report for RERAP

 Station: 045711: PINE HILLS FIRE STA    Variable: SC
 Model: 7G3PE2
         Data Years: 1980 - 2009
         Date Range: May 1 - December 15
Wind Directions: N, NE, E, SE, S, SW, W, NW

Percentiles, Probabilities, and Mid-Points
    Variable/Component Range        Low        Mod        High       Ext
            Percentile Range      0 - 15    16 - 89    90 - 97    98 - 100
       Climatol. Probability        15         75         7          3
          Mid-Point     SC        4 -   4    8 -   8   14 -  14   22 -  99
            Num Observations       309       1013        242        60
     Calculated Spread Comp.        4          8         14         27
              Calculated ERC       28         50         64         59

Fuel Moistures
        1 Hour Fuel Moisture      10.27       5.73       3.50       3.25
       10 Hour Fuel Moisture      13.37       7.54       5.35       6.06
      100 Hour Fuel Moisture      16.68      11.39       8.37       8.96
    Herbaceous Fuel Moisture      95.59      64.60      50.32      46.85
         Woody Fuel Moisture     135.07      98.45      81.82      90.46
              20' Wind Speed       3.78       5.57       8.22      16.12
     1000 Hour Fuel Moisture      17.14      12.56      10.44      11.64

 4287 Weather Records Used, 4287 Days With Wind (100.00%)
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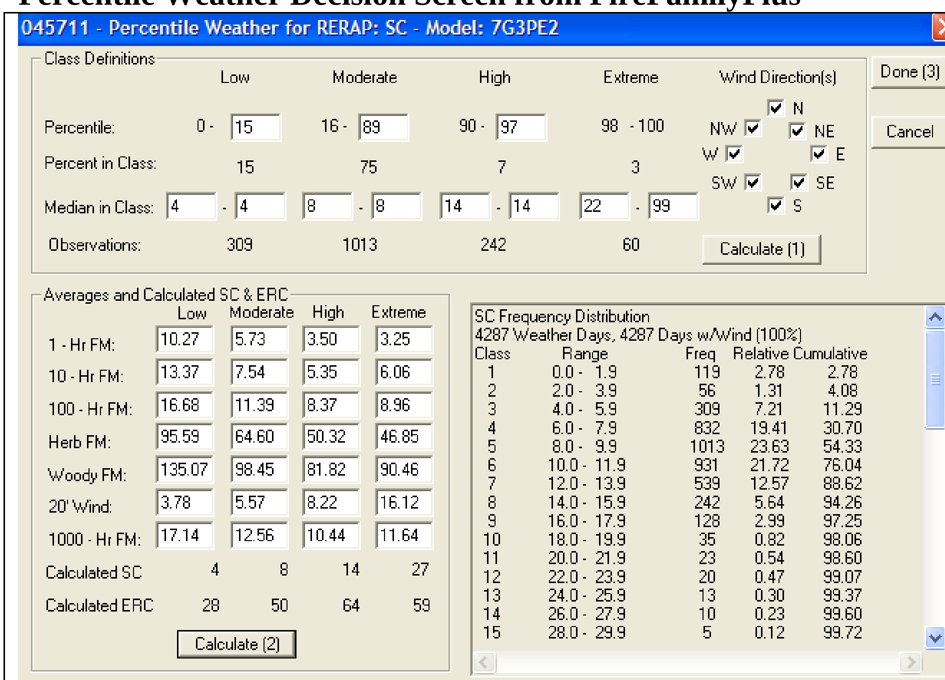
Percentile Weather Decision Screen from FireFamilyPlus



For each WIZ, one weather data set needed to be developed with a weather observation for each day. To do this, the most representative station within each WIZ was determined. The weather stations selected for each WIZ with the years of record is shown are in Addendum V.

For the live herbaceous fuel moisture, the values are based on the expected rate of curing of grasses in the climate class assigned to the representative weather station in each WIZ. Consistency is needed here as the grass fuel models in the 2005 FBPS Fuel Model Set are dynamic where grass loading is transferred from the herb to the 1-hr dead category based on the herb fuel moisture (Table 2).

Table 2, Herbaceous Curing and Fuel Moisture Assumptions

	Percentile Weather							
	Low		Moderate		High		Extreme	
Climate Class	Prop. Cured	Herb Moisture	Prop. Cured	Herb Moisture	Prop. Cured	Herb Moisture	Prop. Cured	Herb Moisture
1, 2	0.2	102%	0.6	66%	0.9	39%	1.0	30%
3, 4	0.1	111%	0.5	75%	0.8	48%	0.9	39%

An example set of percentile fuel moisture values for a weather stations with the 1-h, 10-h, 100-h timelag fuel moisture, live woody fuel moisture and wind speed are shown in Figure 11. The percentile weather fuel moistures and wind speeds for the representative weather stations selected for each WIZ is in Final Report, Addendum V.

Figure 11, Example Percentile Fuel Moisture and Wind speed Values

	1-hr Timelag				10-hr Timelag				100-hr Timelag			
WIZ	L	M	H	E	L	M	H	E	L	M	H	E
3504	6.8	4.5	5.2	4.5	8.5	6.2	6.8	5.2	11.5	8.6	7.5	6.9
	Herbaceous				Woody				20 foot Wind Speed			
WIZ	L	M	H	E	L	M	H	E	L	M	H	E
3504	102	66	39	30	96	76	71	70	2.6	4.5	8.8	11.0

If 15 percent of the days during the fire season are in the Low Percentile Weather Category, one cannot assume that 15 percent of the fires during the fire season will occur on the days in this Weather Category. The Low, Moderate, High and Extreme weather categories contain 15%, 75%, 7% and 3% of the days respectively. Notice that the proportion of fires that occur can vary from this nominal percentage of days by category. Hence the next task is to determine the probability of a fire occurring under each percentile weather category.

For each day within fire season, the NFDRS Spread Component was calculated using the WRISK program. Each historic fire was assigned a Spread Component based on the fire's start date. The four percentile weather categories were also developed using the same assumptions for spread component and the four percentile weather categories have spread component ranges. Hence, a correlation was made assigning each historic fire to one of the four percentile weather categories.

From these assignments, the proportion of fires that occurred in each percentile weather category by WIZ was determined for the project area. An example is shown in Figure 12. The values for each Weather Influence Zone are shown in Addendum V.

Figure 12, Example Proportion of Fires by Percentile Weather Category

	Percentile Weather			
WIZ	Low	Mod	High	Ext
3504	0.188	0.696	0.093	0.023

To assist in the adjustment of weather observations to a ground level reference for fire behavior calculations, the canopy ceiling height (stand height) and canopy cover data layers were used. Together with the canopy base height data layer, this allowed for the prediction of canopy fire occurrence within a percentile weather category in a cell.

In the canopy fire calculation, the foliar moisture content for all percentile weather categories was set at 100%.

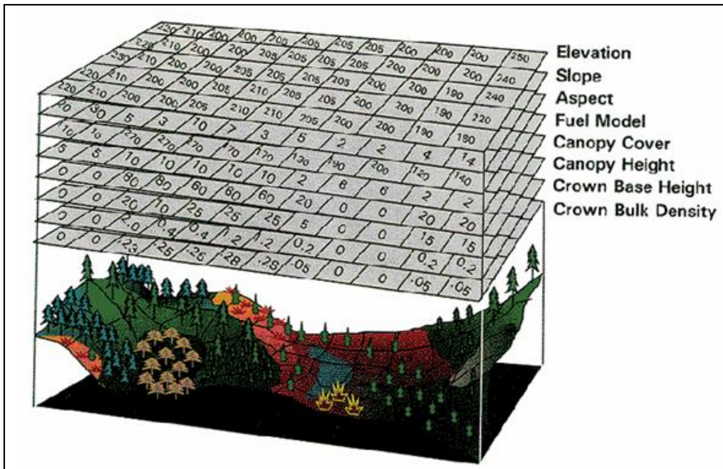
Fuels and Topography

Software is used to generate fire behavior data that is comparable across the landscape for a given set of weather, fuels and fuel moisture data inputs. Fire behavior data can be generated by programs like *FARSITE* (Fire Area Simulator) (Finney 1998) and *FlamMap* Finney (2004). To facilitate these calculation, custom fire behavior prediction software was built that has equations consistent to those developed and used in *FARSITE* and *FlamMap* Finney. This custom software was built to provide a seamless access by GIS software to fire behavior values for a cell.

GIS data is required for five data themes; elevation, slope, aspect, surface fuel model and canopy cover (Figure 13). Three additional optional data themes are as follows: canopy height, canopy base height and canopy bulk density.

All fuels and topographic data used in the WWA was gathered from the LANDFIRE project. The version of this data is called the Refresh (LF 1.1.0) data set and maps the data layers to a benchmark year of 2008.

Figure 13, Diagram with GIS Data Layers for Fire Behavior Prediction



Surface Fuels

To predict surface fire behavior, the 2005 Fire Behavior Prediction System fuel model set was used. The fuel model set included 40 fuels models as defined by Scott and Burgan (2005). The LANDFIRE surface fuel model data also included areas which are considered non-burnable; urban, agriculture, barren and water.

For the areas mapped with a burnable fuel model by the LANDFIRE project, it was determined by the WWA staff that some of these areas were actually in core urban areas. Figure 14 shows an example of fuel model TL-6 assigned to urban areas between the non-burnable streets (true urban).

The WWA staff, in coordination with state representatives and the project manager, developed rule sets and a process to reassign some of these burnable areas to a non-burnable fuel model, urban (91).

Figure 14, Burnable Fuel Model Inside Urban Area

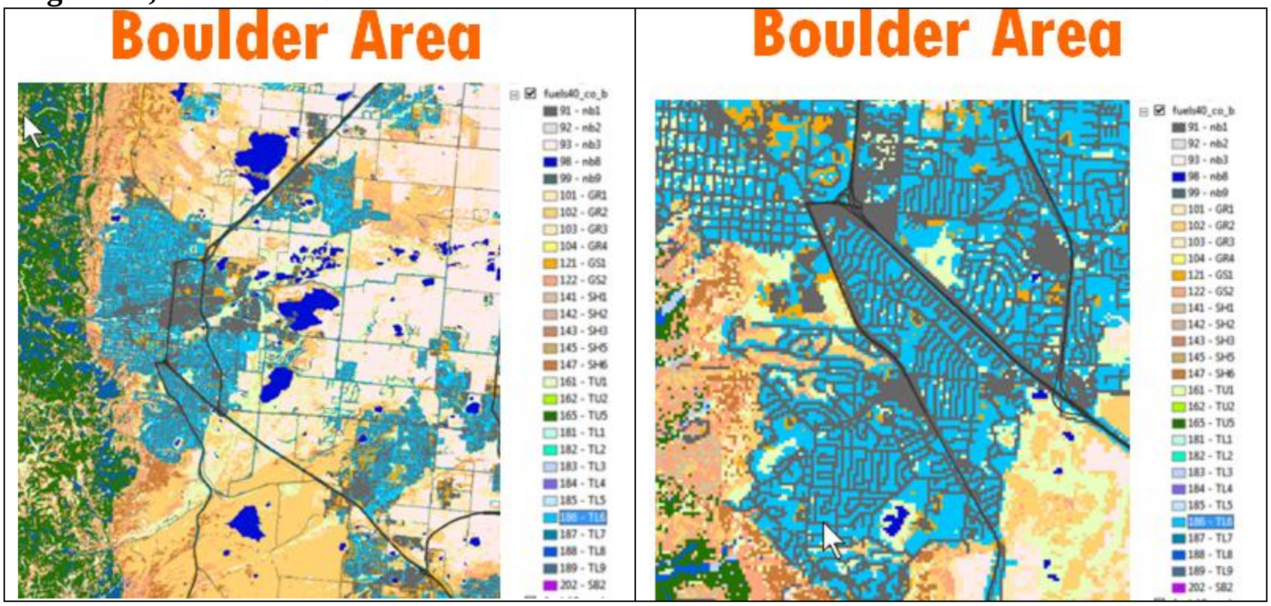
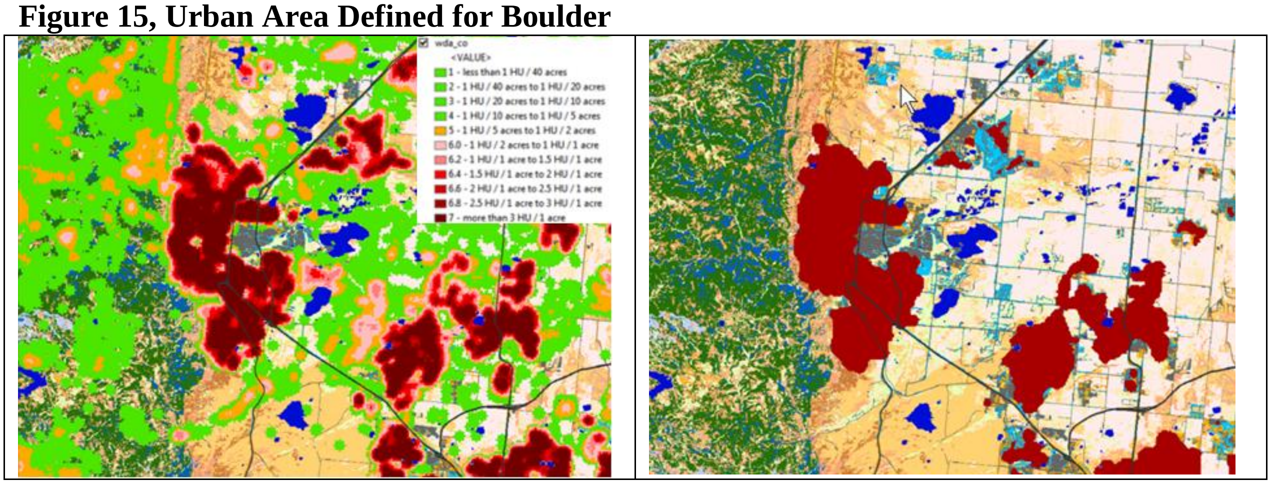


Figure 15 shows the result of the area that was defined as urban in the Boulder, Colorado, area (Figure 14). The area defined as urban had areas, which intersect all Where People Live (WPL) class 7 > 640 acres with all Where People Live (WPL) class 6.2 (Figure 15) and greater that is also larger than 640 acres. Class 6.2 is 1 housing unit per acre to 1.5 housing unit per acre.

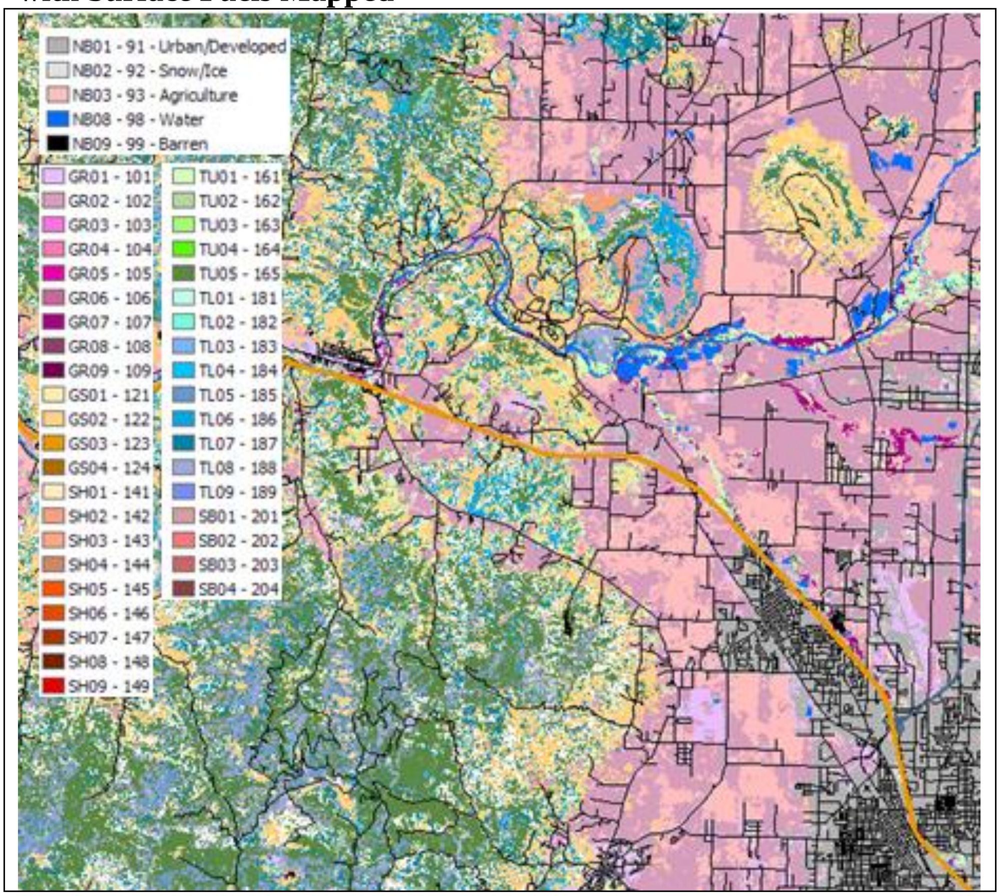
Figure 15, Urban Area Defined for Boulder



This effort allowed for the adding of additional area to the LANDFIRE Refresh surface fuel model urban (91) data to better reflect the urban areas. A deliverable for the project was a data layer with the 1982 FBPS fuel model set (Anderson 1982). This data set was provided but not used in the analysis work. The urban fuel model in the 1982 FBPS fuel model set was also modified as described.

In Figure 16, an area of Jackson, County, Oregon, has the surface fuels mapped using the 2005 FBPS fuel model set. The area in the lower right is Medford. Note the more uniform definition of this area as an urban fuel model (91).

Figure 16, Area of Jackson County, Oregon, with Surface Fuels Mapped



Topography

The slope, aspect and elevation values were also gathered from the LANDFIRE project Refresh (LF 1.1.0) data set.

For each 30-meter by 30-meter cell in the LANDFIRE data, the rate of spread, flame length and fire type (surface or canopy) was calculated using the equations in the Fire Behavior Prediction System. This calculation was done for all four percentile weather categories.

Canopy

To model canopy (crown) fire occurrence and behavior, the following data layers were used: canopy base height and canopy bulk density. Examples for canopy base height and canopy bulk density are shown for a section of Jackson County, Oregon, in Figures 17 and 18. Canopy base height is shown on the units of feet times 10. In Figure 17, divide the unit shown in the legend by 10 to get units in feet. For example, 3 in the legend means 0.3 feet on the ground. The units for canopy bulk density are in kilograms per cubic meter (kg/m3) times 100. For example, 10 in the legend means 0.10 kg/m3 on the ground. The use of the metric units here is common. To convert to pounds per cubic foot (lbs/ft3) multiply the kilograms per cubic meter by 0.062427885.

Figure 17, Canopy Base Height

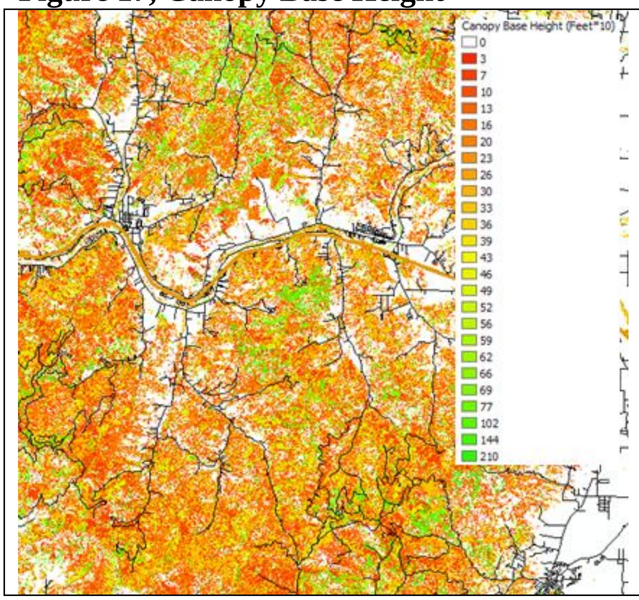
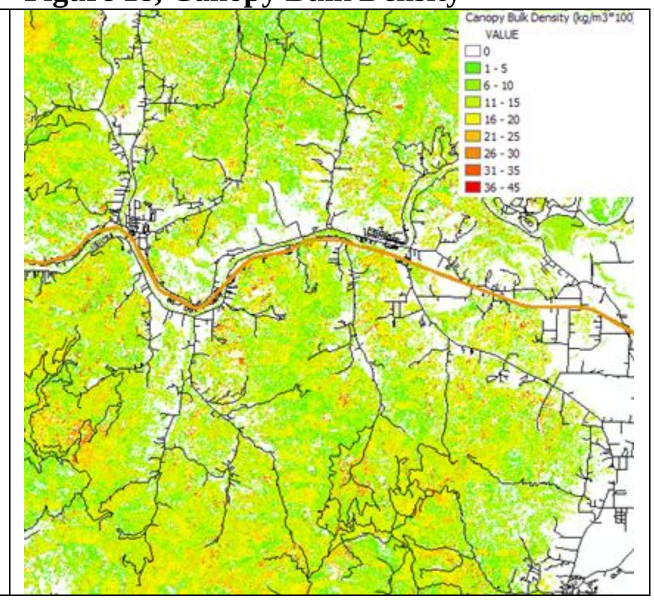


Figure 18, Canopy Bulk Density



There are three fire types: surface, passive and active. A surface fire is one that is spreading in the surface fuels or in the surface fuel model.

In areas where there is a tree canopy and where the needles or leaves of the trees can support fire movement vertically into the crowns of these trees, canopy fire occurrence can occur. The word canopy is used here as it refers to stands of trees, which have canopies, whereas individual trees have crowns.

If a fire spreads vertically into the crown of a tree or a group of tree crowns, this is called a passive fire type.

When a fire does spread vertically and due to the conditions present, generally high wind speeds or steep slopes or both, the fire then actually spreads laterally primarily through the canopy of the tree stand but with the support of the surface fire intensity, this is called an active fire type.

Figure 16 shows the predicted fire type (surface, passive or active) for an area of Jackson County, Oregon, under the high percentile weather category. The high percentile weather category is the 90-97% percentile condition. The fire type is predicted for all four percentile weather categories and data layers for each are provided in the published results (Figure 19).

In practical terms, what is important is if passive or active fire types are likely. Hence, these two fire types will be collectively referred to as canopy fire. Figure 20 shows the same area of Jackson County, Oregon, as Figure 19 but displays the probability of canopy fire occurrence under all four percentile weather conditions. As shown canopy fire can occur and in the example, it is predicted to occur greater than a 0.75 probability based on all four percentile weather conditions on many areas. A comparison shows almost the entire canopy fire occurrence is of the passive fire type.

Figure 19, Fire Type,
<u>High</u> Percentile Weather Category

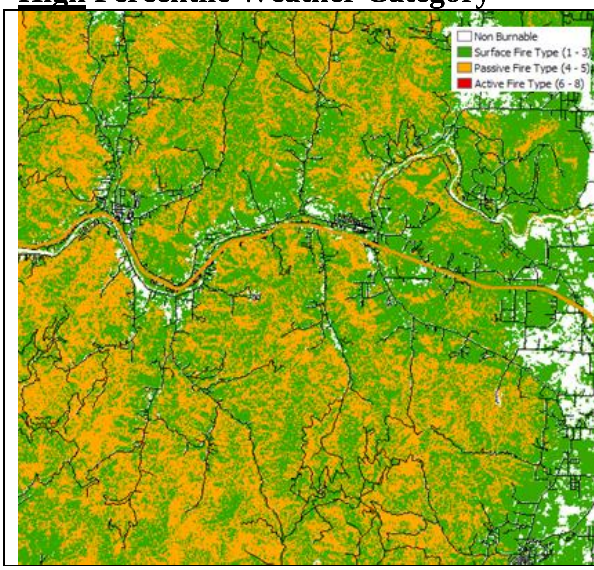
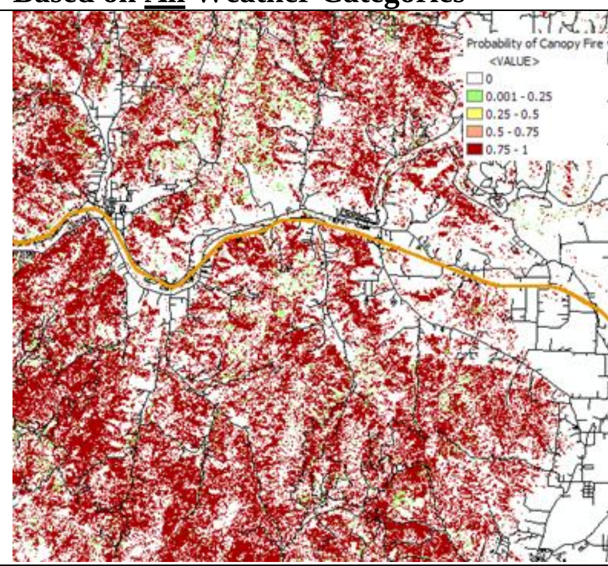


Figure 20, Probability of Canopy Fire
Based on <u>All</u> Weather Categories



<u>Resultant Fire Behavior</u>
For each of the four percentile weather categories, the key fire behavior outputs of rate of spread (chains/hr) and flame length (feet) were calculated and mapped by cell. Note a chain is a forestry unit of measure and is equal to 66 feet. For reference, feet per minute is equal to 1.1 times chains per hour. The resultant fire behavior includes the occurrence of canopy fire and its effect on the rate of spread and flame length.

For each percentile weather category, the rate of spread, flame length and fire type are provided in published results data layers. For the same area of Jackson County, Oregon, Figure 21 shows the rate of spread under the high percentile weather category, Figure 22 shows the flame length.

Figure 21, Surface Rate of Spread,
<u>High</u> Percentile Weather

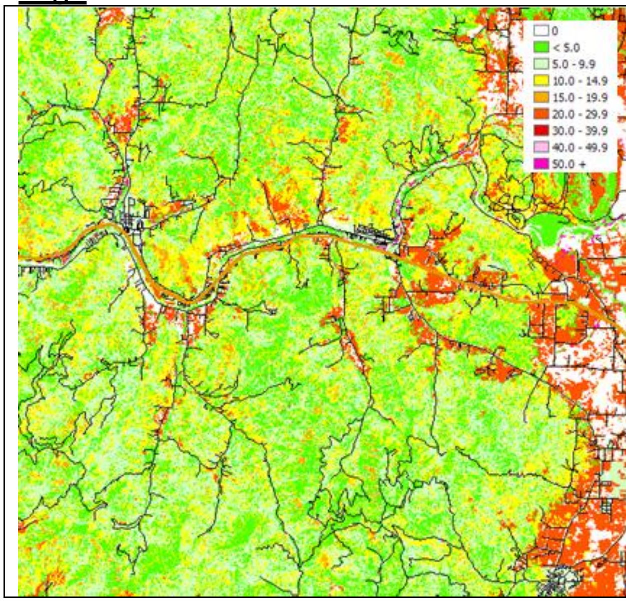
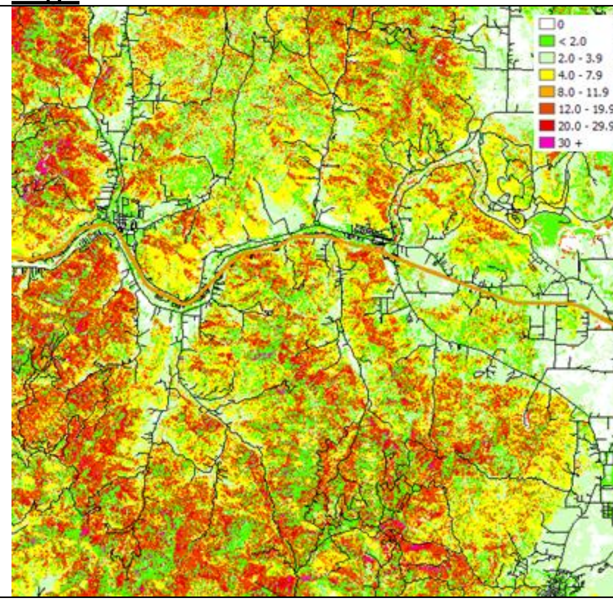


Figure 22, Flame Length,
<u>High</u> Percentile Weather



Using all four percentile weather category outputs and doing a weighted average of these outputs using the probability of a fire occurring in each percentile weather category, the "expected" values for each can be calculated. These are displayed in Figures 23 and 24.

Figure 23, Surface Rate of Spread,
<u>Expected</u>

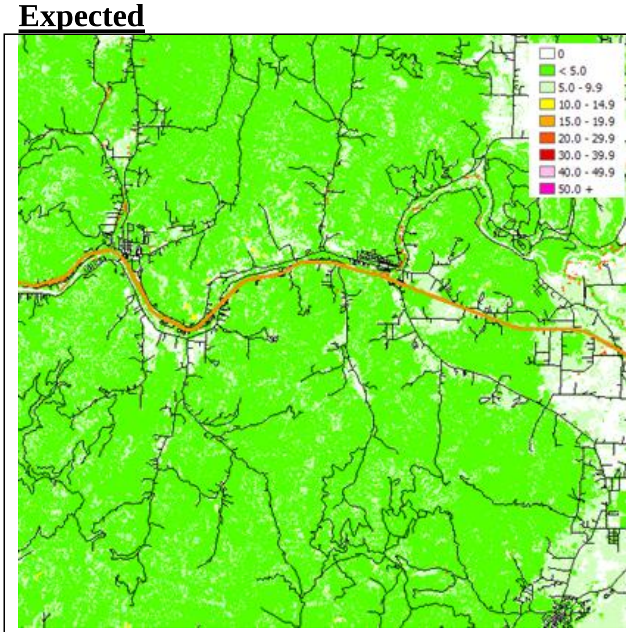
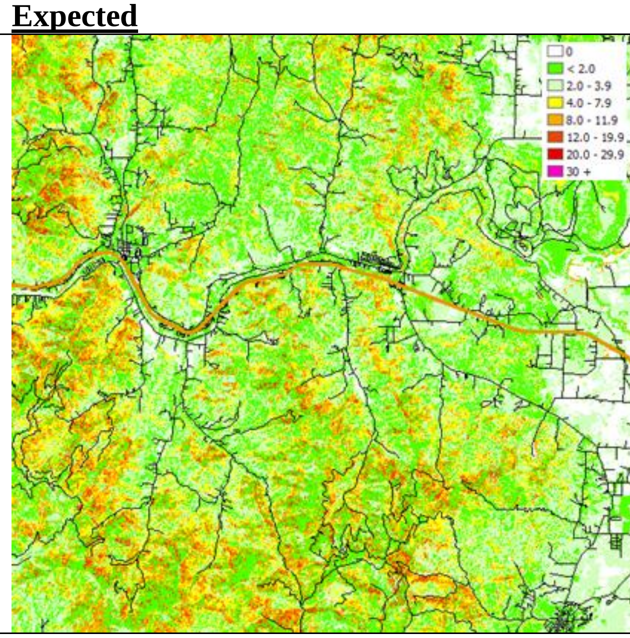


Figure 24, Flame Length,
<u>Expected</u>



Now that the likelihood of a cell igniting is known as well as the fire behavior, the next step is estimating what a resultant fire size might be.

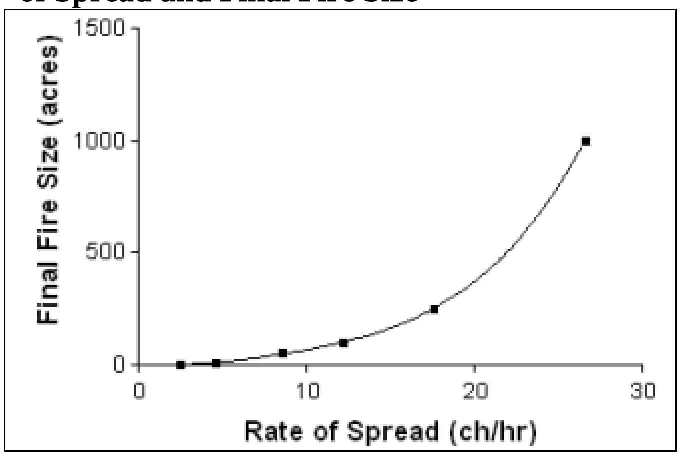
Fire Suppression Effectiveness

To calculate the Fire Threat, the expected size of a fire needs to be estimated to facilitate estimating a measure of the probability of an acre burning. To do this, it was necessary to develop relationships between fire spread rates and the potential expected final fire size. The inputs to this relationship are the expected fire behavior and a measure of suppression effectiveness of fire protection forces.

The fires occurring are assumed to be attacked under a full suppression philosophy. For each Weather Influence Zone, the fire occurrence reports were used to develop initial relationships. Via a calibration process, final relationships were developed. Following calibration for a Weather Influence Zone, the predicted annual acres burned are similar to the historic expected acres burned developed from the fire occurrence reports

For each Weather Influence Zone, a relationship between the rate of spread and final fire size was developed using the fire report data from the states and federal agencies for the period where a final fire size was recorded on the fire report. Figure 25 shows a stylized example. For NFIRS fire reports, final fire size was only entered on a small number of reports and hence this data was not used here. This relationship is applied to each Weather Influence Zone but the development was done over multiple zones based on the primary fire protection responsibility.

Figure 25, Generic Relationship Between Rate of Spread and Final Fire Size



Several fire size classes were used to estimate the amount of time from fire start to fire containment. The average fire rate of spread for each benchmark fire size was estimated by using the double ellipse area model developed by Fons (1946) as documented by Anderson (1983). The model calculates fire size (Area) as the a constant based on the midflame wind speed (K) times the distance the fire as traveled in a given time squared (D^2). The variable D is equal to rate of spread multiplied by the time in hours to obtain fire containment. Mid-flame windspeed categories were defined for benchmark sizes.

A relationship between the fire size and average rate of spread values for the benchmark fire sizes was developed using multi-variable regression. A power function was determined to be the best equation form to use:

$$Y = A + B*X^C + D*X^E$$

where X = rate of spread, Y is the expected fire size and A-E are the regression coefficients.

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

Fire Threat Index (FTI)

The Fire Threat Index is calculated for each percentile weather category for each 30-meter by 30-meter cell of burnable area within each state. The four values from the four percentile weather categories are summed to obtain the FTI for a cell. The calculation is done for cells within an FOA and WIZ intersection. Within this intersection, each cell has the same likelihood of igniting (FOA) as well as the expected weather (WIZ). When the calculation is done for a cell, it is assumed that all cells in the FOA and WIZ intersection have the attributes of the cell. In essence, one is asking, "What would be the expected probability of an acre burning if all cells in the FOA and WIZ intersection were the same at the selected cell?"

To assist in the understanding of the calculation, an example is presented. Assume that the calculation is being done for a cell in FOA 1, WIZ 1 (Figure 26). The data flow is shown via the example table below (Table 3). For the example, assume that the fire occurrence rate in FOA 1 is 0.1 fires / 1000 acres / year and assume there are 1,000,000 acres in the FOA 1, WIZ 1 intersection. This yields 100 fires per year in FOA 1.

Row 1 gives the proportion of fires that have historically occurred within each of the percentile weather categories.

Figure 26, Example WIZ and FOAs

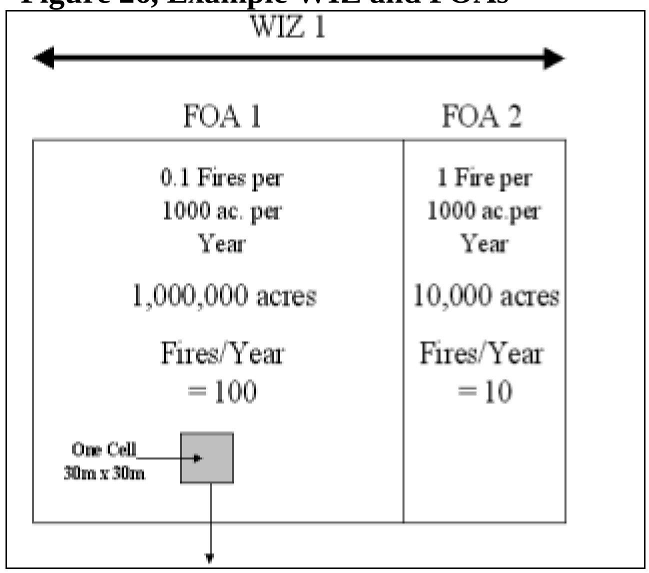


Table 3, Example Fire Threat Index Calculation

Row	Item	Percentile Weather				Total
		Low	Moderate	High	Extreme	
1	Proportion of Fires	0.10	0.80	0.08	0.02	1.00
2	Number of Fires	10	80	8	2	100
3	Rate of Spread (chains/hr)	2	5	12	24	N/A
4	Final Fire Size (acres)	1	6	98	900	N/A
5	Annual Acres Burned	10	480	784	1800	3074
6	WFSI	0.00001	0.00048	0.000784	0.00180	0.003074

Multiplying the proportion of fires in each percentile weather category by the total number of fires in the FOA 1 and WIZ 1 intersection (100 fires) allows for determination of the number of fires in each percentile weather category, row 2.

Assume that the fire behavior calculations program has calculated a rate of spread for each percentile weather category (row 3). Assume there are fire suppression effectiveness relationships built for use in the Weather Influence Zone, hence a final fire size (row 4) can be determined from the rate of spread (row 3).

Multiplying the number of fires per year in each percentile weather category (row 2) by the expected final fire size (row 4) yields the annual expected acres burned for each percentile weather category (Row 5).

Dividing the annual expected acres burned for each percentile weather category by the total acres within the FOA 1 and WIZ 1 intersection (1,000,000 acres) yields the nominal probability of a acre burning and the Fire Threat Index (FTI) within each percentile weather category (Row 6). The FTI for the cell is the sum of the four percentile weather category FTI values.

The calculation described results in the calculation of a cell-based TFI (Figure 27). To consider the flammability of cells in the area of a given cell, a roving window is drawn around each cell. The "average" FTI for all of the cells within a roving window is determined resulting in the "roving window FTI" (Figure 28). The radius of the roving window circle is 8 30-meter cells. This is a radius of 787 feet and the circle contains 14.23 acres. This is the FTI value assigned to each burnable cell in the project area.

Figure 27, Cellular FTI

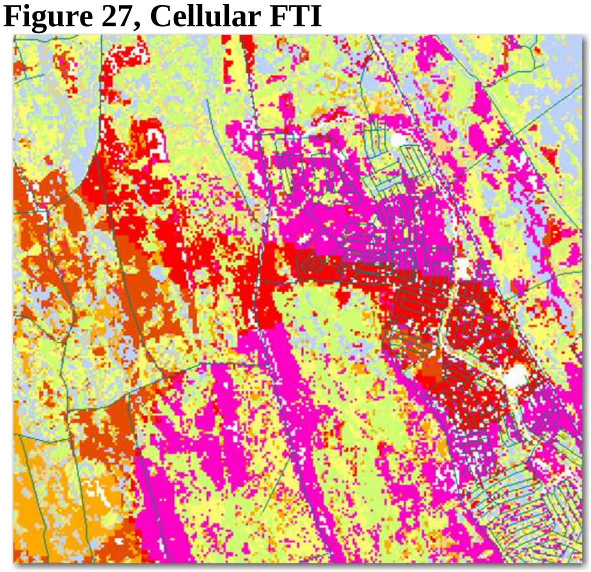


Figure 28, Roving Window FTI

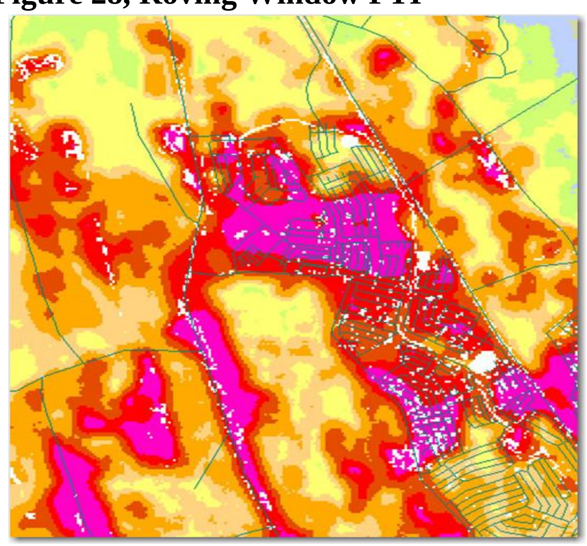
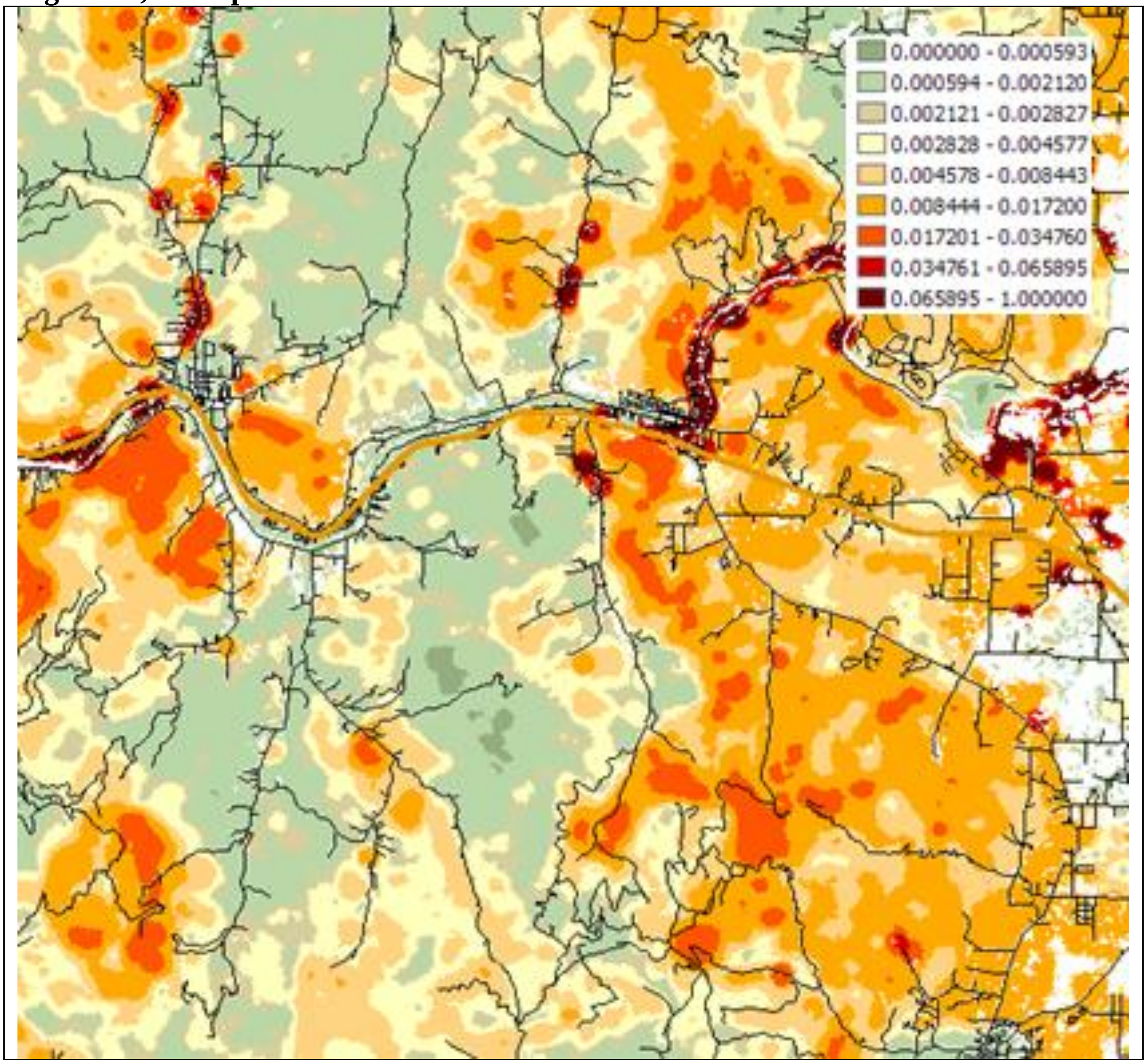


Figure 29 shows an example of the Fire Threat Index data layer for an area of Jackson County, Oregon.

Figure 29, Example Of the Fire Threat Index



Fire Effects

The Fire Effects component of the risk assessment involves integrating several input data sets to derive a Values Impacted Rating (VIR) and Suppression Difficulty Rating (SDR). The purpose is to identify those areas that have important values that can be affected by fire. The purpose is also to identify those areas that are difficult or costly to suppress. The Values Impacted Rating and the Suppression Difficulty Rating are weighted to calculate the Fire Effects Index (FEI).

$$FEI = \frac{(VIR) * (VIR\ weight) + (SDR) * (SDR\ weight)}{100}$$

The VIR and SDR weights in this formula are integers that sum to 100, hence the reason for the denominator of 100. In short, the FEI is the weighted average of the VIR and SDR.

The potential effects from a wildfire were defined into two areas, Values Impacted and Fire Suppression Difficulty. Five separate "values that potentially could be impacted by fire," are defined and called Values Impacted. These Values Impacted include the following.

- Infrastructure Assets
- Drinking Water Importance Areas
- Forest Assets
- Riparian Assets
- Wildland Development Areas (Housing Units per Acre)

The potential effects are measured using a response function score (Calkin, Ager, and Gilbertson-Day 2010).

Following will be a description of how the response function score and relative importance values were defined and gathered from the states. This will be followed with a description of each of the values impacted and the derivation of suppression difficulty.

Response Function Scores

Calculating effects at a given location requires estimating of the effects if a fire burning with a known intensity of fire in the identified resource category. Based on investigations conducted by the WWA technical team, a response function approach was selected to define the effects. This is used to determine an aggregate Values Impacted Rating for all values impacted that might reside within a cell. For consistency, the same scoring system was used to develop the Suppression Difficulty Rating.

Response functions translate fire effects into net value change to the described resource. In each response function, net value change is based on the flame length (intensity) of the fire and represents both beneficial and adverse effects to the resource (Calkin, Ager, and Gilbertson-Day 2010). Although fire outcomes could be related to any fire characteristic, response is typically related to some measure of fire intensity such a flame length. Fire intensity is a robust fire characteristic because it integrates two important fire characteristics, fuel consumption and spread rate. (Ager and others 2007; Finney 2005).

The fire response function scores for the WWA are measured as a number from 0 to –9 (negative effect). This indicates a negative impact from fire. In applying the concept of response functions, the design is to also use positive values from +9 to 0 to define when and to what extent there is a positive effect from fire. After review of the initial state input, it was decided to only assign negative response function score values to values impacted.

Each state completed a matrix showing for each value impacted a defined response function value for each value impacted category and fire intensity class (flame length class). An example for the value impacted Drinking Water Importance is shown in Figure 30.

Figure 30, Example Response Function Values for Drinking Water Importance Areas

Value Impacted	FIL Class	1 0-2	2 2-4	3 4-6	4 6-8	5 8-12	6 12+	RI
	Category	Flame length/FIL class						
Drinking Water	1	0.00	-0.30	-0.50	-0.70	-0.90	-0.90	10
	2	0.00	-0.60	-1.00	-1.40	-1.80	-1.80	20
	3	0.00	-0.90	-1.50	-2.10	-2.70	-2.70	30
	4	0.00	-1.20	-2.00	-2.80	-3.60	-3.60	40
	5	0.00	-1.50	-2.50	-3.50	-4.50	-4.50	50
	6	0.00	-1.80	-3.00	-4.20	-5.40	-5.40	60
	7	0.00	-2.10	-3.50	-4.90	-6.30	-6.30	70
	8	0.00	-2.40	-4.00	-5.60	-7.20	-7.20	80
	9	0.00	-2.70	-4.50	-6.30	-8.10	-8.10	90
	10	0.00	-3.00	-5.00	-7.00	-9.00	-9.00	100

The format shown in Figure 30 was provided to each state for each value impacted. The states completed the entry of the response function scores in one of two ways.

One was to enter the values as desired.

The other was to enter the response function scores for the most affected value impacted category and then to assign a value impacted relative importance value for each of the other value impacted categories. In the example in Figure 30, the most affected value category is category 10. The response function scores assigned by flame length category are shown in yellow highlighted boxes. The value impacted relative importance value for each of the other value impacted categories is shown in the orange highlighted boxes (RI titled column). Note that the value impacted relative importance value for category 10 is 100 and the others are defined from 0 to 100 based on the benchmark value of 100. The resultant response function score is the product of the response function score for the most affected category (category 10 in Figure 30) and the value impacted relative importance value for a value impacted category divided by 100. For example using Figure 30, the response function score for category 5 and flame length category 3 is –2.50, which is –5.00 times 50/100.

The project area response function scores were then determined by averaging the individual state response functions scores. As an example of the process used, Figure 31 contains the resultant and used project area's response function score matrix for the value impacted Drinking Water Importance Areas.

Figure 31, Response Function Values for Drinking Water Importance Areas

Value Impacted	FIL Class	Flame length/FIL class 1 0-2	2 2-4	3 4-6	4 6-8	5 8-12	6 12+
	Category						
Drinking Water	1	-0.01	-0.20	-0.45	-0.66	-0.80	-0.86
	2	-0.08	-0.42	-0.84	-1.21	-1.50	-1.61
	3	-0.18	-0.63	-1.20	-1.76	-2.19	-2.35
	4	-0.38	-1.04	-1.84	-2.61	-3.19	-3.43
	5	-0.48	-1.34	-2.20	-3.14	-3.86	-4.15
	6	-0.67	-1.57	-2.55	-3.68	-4.53	-4.87
	7	-0.77	-1.79	-2.89	-4.19	-5.18	-5.57
	8	-0.90	-2.13	-3.48	-4.96	-6.10	-6.54
	9	-1.00	-2.36	-3.84	-5.51	-6.79	-7.28
	10	-1.11	-2.59	-4.20	-6.06	-7.48	-8.03

The next task is to develop the values impacted "score" for each of the values impacted in a cell. For each cell, flame length is calculated for each of the 4 percentile weather categories.

Figure 32, - Example of Calculation of Value Impacted Score

Variable		Percentile Weather Low	Mod	High	Ext	FTI
Fire Threat Index		0.00001	0.04800	0.00780	0.00100	0.0568
FL (ft) (CFL)		2.2	6.2	11.0	51.6	
FL class (FIL)		2	4	5	6	
	VI Category					
Infrastructure Assets	0	1 = near road, railroad, school, airport, hospital				
Wildland Development Areas	0	1-7: density classes from low to high				
Drinking Water Importance Areas	9	1-10: classes based on population served				
Forest Assets	0	Example is 1= Sensitive, 0-10 m., closed;				
Riparian Assets	0	1 = less important; 2 = moderately important; 3 = important				
	(FTI Wted)	Response Function Values				
	RF Scores	Low	Mod	High	Ext	
Infrastructure Assets	0.000	0.00	0.00	0.00	0.00	
Wildland Development Areas	0.000	0.00	0.00	0.00	0.00	
Drinking Water Importance Areas	-5.719	-2.36	-5.51	-6.79	-7.28	
Forest Assets	0.000	0.00	0.00	0.00	0.00	
Riparian Assets	0.000	0.00	0.00	0.00	0.00	

In the example shown in Figure 32, the flame length are 2.2 feet, 6.2 feet, 11.0 feet and 51.6 feet for the low, moderate, high and extreme percentile weather categories. In the example, the cell is within the buffer of a Drinking Water Importance Asset only. Based on the flame length under each percentile weather category, the response function values would be the following values -2.36, -5.51, -6.79 and –7.28 (Figure 26) respectively for the low, moderate, high and extreme percentile weather categories. The Fire Threat Index, a measure of probability of an acre burning, for the low, moderate, high and extreme percentile weather categories is 0.00001, 0.04800, 0.00780 and 0.0010 respectively. To obtain the Drinking Water Importance Asset Response Function Score for the cell, the Fire Threat Index values for each percentile weather category are multiplied by the response function scores in the respective category.

$$\text{DRWI Score} = [(0.00001)*(-2.36) + (0.048)*(-.51) + (0.0078)*(-6.79) + (0.001)*(-7.28)]/[0.0023] \sim -5.7$$

Values Impacted

As mentioned, five separate "values that potentially could be impacted by fire," are defined and called Values Impacted. These Values Impacted include the following.

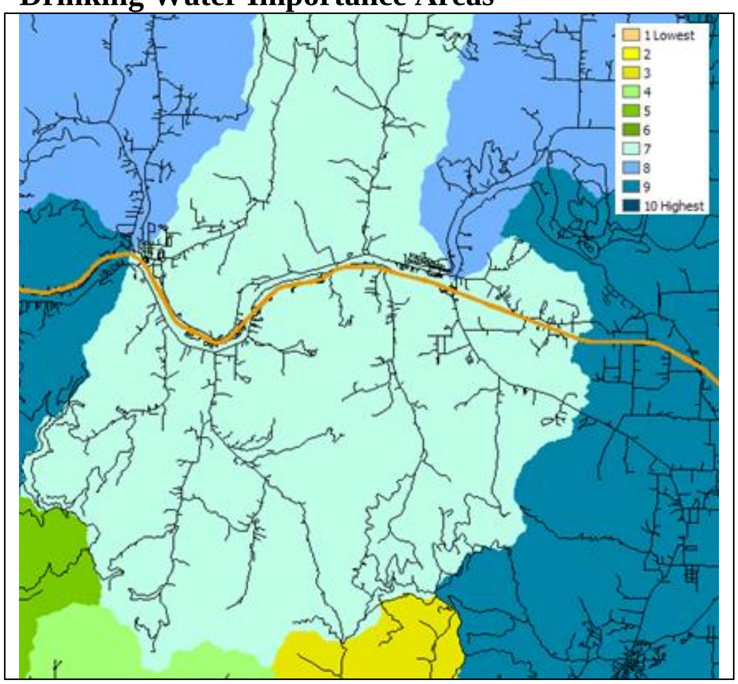
- Drinking Water Importance Areas
- Forest Assets
- Infrastructure Assets
- Riparian Assets
- Wildland Development Areas (Housing Units per Acre)

Each Value Impacted is described together with the project area response function values.

Drinking Water Importance Areas

This layer identifies an index of surface drinking water importance, reflecting a measure of water quality and quantity, characterized by Hydrologic Unit Code 12 (HUC 12) watersheds. The Hydrologic Unit system is a standardized watershed classification system developed by United States Geological Survey (see Web Links section). Areas that are a source of drinking water are of critical importance and adverse effects from fire are a key concern.

Figure 33, Example of the Mapping of Drinking Water Importance Areas

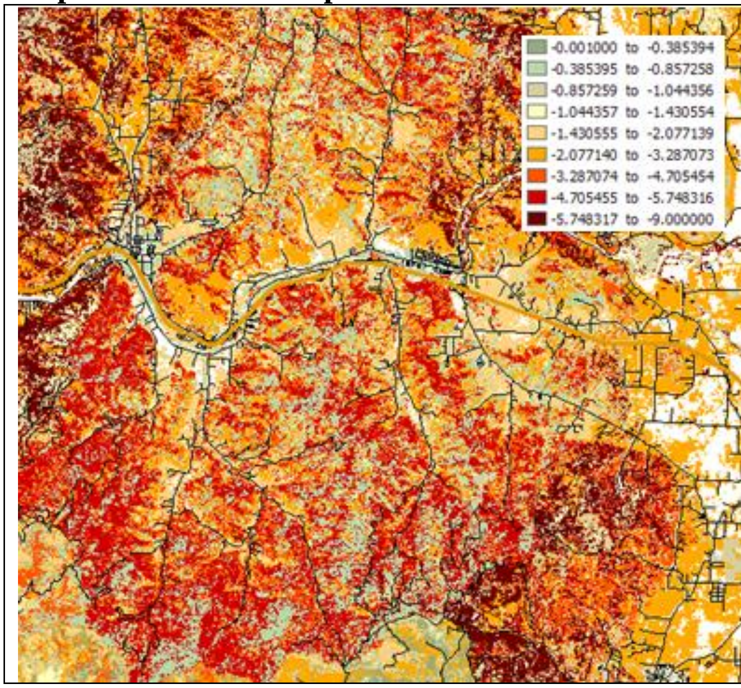


The U.S. Forest Service Forests to Faucets (F2F) project is the primary source of the drinking water data set (see Web Links section). This project used geo-spatial (GIS) modeling to develop an index of importance for supplying drinking water using HUC 12 watersheds as the spatial resolution. Watersheds are ranked from 1 to 100 reflecting relative level of importance, with 100 being the most important and 1 the least important.

Several criteria were used in the F2F project to derive the importance rating including water supply, flow analysis, and downstream drinking water demand. The final model of surface drinking water importance used in the F2F project combines the drinking water protection model, capturing the flow of water and water demand, with a model of mean annual water supply. The values generated by the drinking water protection model are simply multiplied by the results of the model of mean annual water supply to create the final surface drinking water importance index (Weidner 2011). An example of Drinking Water Importance categories for an area of Jackson County, Oregon, is shown in Figure 33.

The F2F data was not produced for Alaska and Hawaii. An U.S. Environmental Protection Agency Municipal Watersheds data set and a State of Hawaii Department of Land and Natural Resources Watershed Protection Areas data set were used to develop the Drinking Water layer in Hawaii. A data set from the State of Alaska, Department of Environmental Conservation Drinking Water Program, Environmental Conservation was used for Alaska.

Figure 34, Example of the Drinking Water Importance Areas Response Function Scores



The project area response function scores were then determined by averaging the individual state response functions scores. Figure 31 contains the project area's response function score matrix for the value impacted Drinking Water Importance. Figure 34 presents an example of the Drinking Water Importance Area response function scores for an area of Jackson County, Oregon. Fire behavior from fuels and the Drinking Water Importance Area category is the main reason for differences between Drinking Water Importance Area categories (Figure 33 and 34).

Infrastructure Assets

This layer identifies key infrastructure assets, such as schools, airports, hospitals, roads and railroads that are susceptible to adverse effects from wildfires. These features are combined into a single data set and buffered to reflect areas of concern surrounding the assets. Roads and railroads use a 300-meter buffer while schools, airports and hospitals use a 500-meter buffer. Figure 35 presents an example of the Infrastructure data layer for an area of Jackson County, Oregon.

A cell is in the buffer area for at least one of the features or not. By default, the Value Impacted Category 0 represents a cell not in a buffer of at least one feature. Value Impacted Category 1 is for a cell that is within one or more buffers of defined infrastructure.

If a cell was inside of a buffer area, it was assigned a response function value by flame length class by each state. The average of the state values was used to define the project area response function value. Figure 36 contains the project area's response function score matrix for the value impacted category Infrastructure. Figure 37 presents an example of the Infrastructure Assets response function scores for an area of Jackson County, Oregon.

Figure 35, Example of the Mapping of Infrastructure Asset Buffers

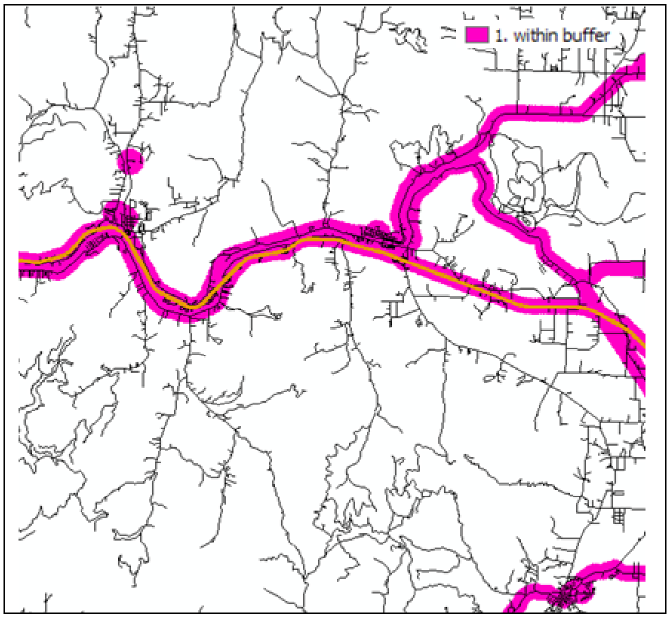
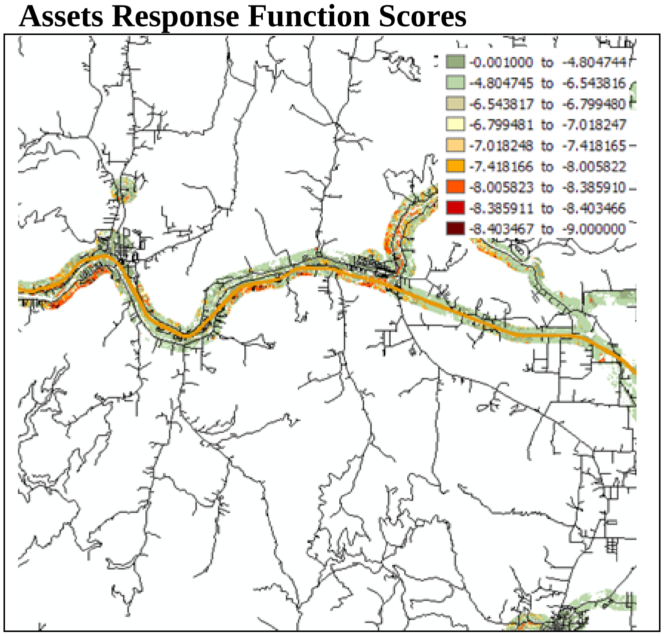


Figure 36, Project Area Response Functions Scores for Infrastructure Assets

Value Impacted		Flame length/FIL class					
	FIL	1	2	3	4	5	6
	Class	0-2	2-4	4-6	6-8	8-12	12+
	Category						
Infrastucture	0	0.00	0.00	0.00	0.00	0.00	0.00
	1	-3.48	-4.97	-6.33	-7.31	-8.23	-8.41

Figure 37, Example of the Infrastructure Assets Response Function Scores



Forest Assets

The Forest Assets data layer identifies forestland categorized by its cover, height and susceptibility or response to fire. These characteristics allow for the prioritization of landscapes reflecting forest assets that would be most adversely affected by fire. The LANDFIRE Refresh data set (see Web Links section) was used to map stand height, canopy cover and the existing vegetation type (EVT).

Canopy cover from LANDFIRE was re-classified into two categories, open or sparse and closed. Areas classified as open or sparse have a canopy cover less than 60%. Areas classified as closed have a canopy cover greater than 60%. An example of canopy cover for an area of Jackson County, Oregon, is shown in Figure 38.

Canopy height from LANDFIRE was classified into two categories, 0-10 meters and greater than 10 meters. An example of canopy height for an area of Jackson County, Oregon, is shown in Figure 39.

Response to fire was developed from the LANDFIRE existing vegetation type (EVT) data set. There are over 1,000 existing vegetation types in the project area. Using a crosswalk defined by project ecologists, a classification of susceptibility and response to fire was defined and documented by fire ecologists into the three fire response classes. These three classes are sensitive, resilient and adaptive.

Figure 38, Example of the Mapping of Canopy Cover

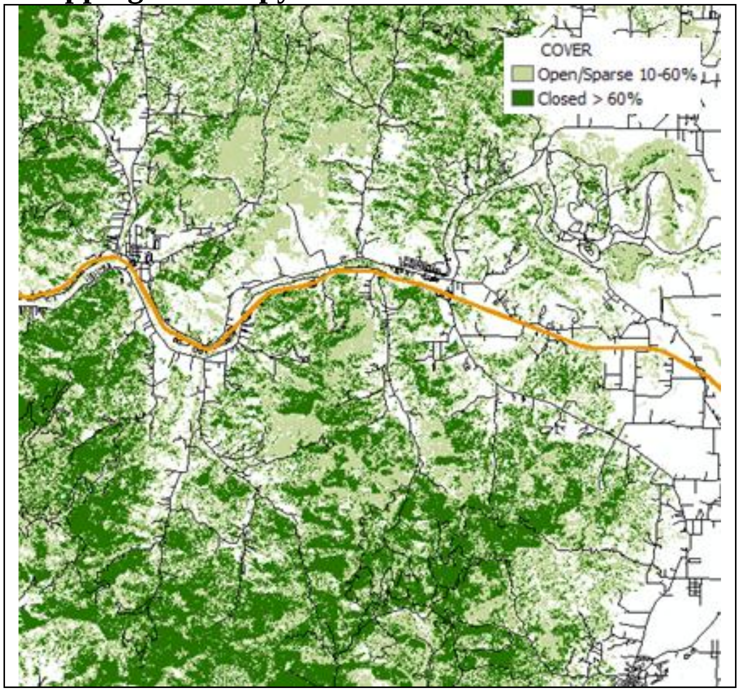
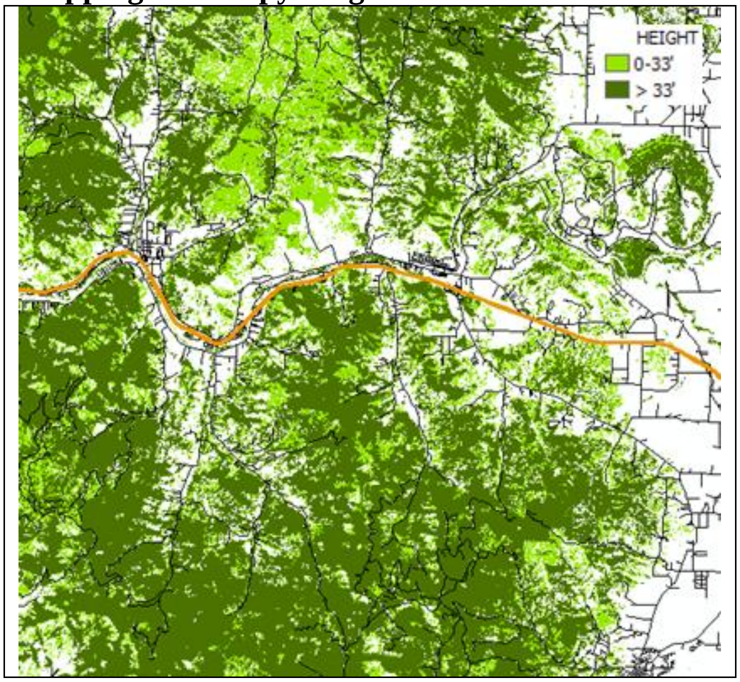
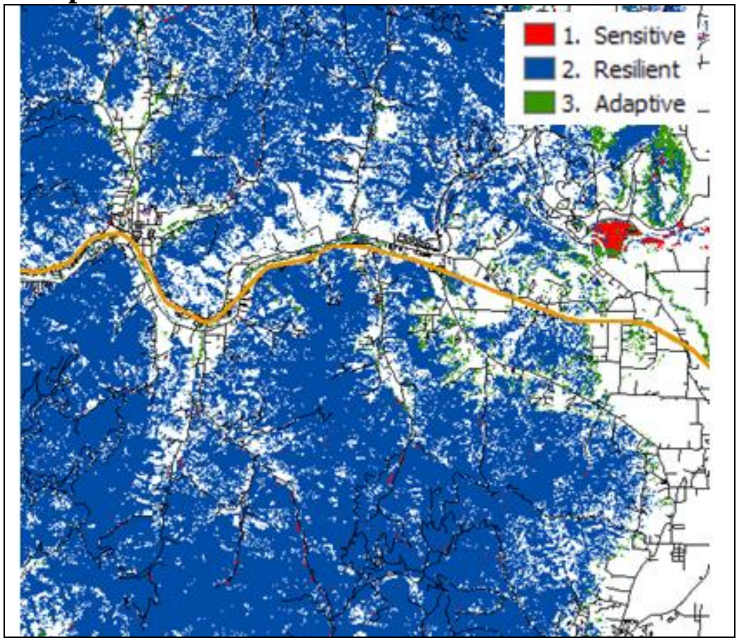


Figure 39, Example of the Mapping of Canopy Height



- Sensitive - These are tree species that are intolerant or sensitive to damage from fire with low intensity.
- Resilient - These are tree species that have characteristics that help the tree resist damage from fire and whose adult stages can survive low intensity fires.
- Adaptive – These are tree species adapted with the ability to regenerate following fire by sprouting or serotinous cones.

Figure 40, Example of the Response to Fire



An example of response to fire for an area of Jackson County, Oregon, is shown in Figure 40. Figure 41 contains the project area's response function score matrix for the value impacted category Forest Assets.

Figure 41, Project Area Response Functions Scores for Forest Assets

Value Impacted					FIL	Flame length/FIL class					
					FIL	1	2	3	4	5	6
					Class	0-2	2-4	4-6	6-8	8-12	12+
					Category						
Forest Assets		Sensitive	Closed	0-10 m	1	-2.61	-3.84	-5.52	-7.13	-8.11	-8.34
		Sensitive	Closed	10+m	2	-1.93	-2.96	-4.45	-6.01	-7.05	-7.35
		Sensitive	Open/Sp	0-10 m	3	-1.20	-1.77	-2.54	-3.29	-3.73	-3.82
		Sensitive	Open/Sp	10+m	4	-0.89	-1.36	-2.05	-2.77	-3.24	-3.36
		Resilient	Closed	0-10 m	5	-1.23	-2.00	-3.33	-4.94	-6.48	-7.22
		Resilient	Closed	10+m	6	-0.60	-1.17	-1.99	-2.93	-4.10	-4.65
		Resilient	Open/Sp	0-10 m	7	-0.56	-0.92	-1.54	-2.29	-3.00	-3.34
		Resilient	Open/Sp	10+m	8	-0.27	-0.53	-0.90	-1.33	-1.87	-2.12
		Adaptive	Closed	0-10 m	9	-0.98	-1.75	-2.95	-4.00	-5.67	-6.66
		Adaptive	Closed	10+m	10	-0.43	-1.03	-1.96	-2.53	-3.68	-4.33
		Adaptive	Open/Sp	0-10 m	11	-0.45	-0.78	-1.33	-1.81	-2.59	-3.04
		Adaptive	Open/Sp	10+m	12	-0.19	-0.46	-0.88	-1.13	-1.66	-1.96

Figures 42 present an example of the Forest Assets data layer categories for an area of Jackson County, Oregon, using two different ways to display the data. Figure 43 presents an example of the Forest Assets response function scores for the same area.

Figure 42, Example of the Forest Assets Categories A

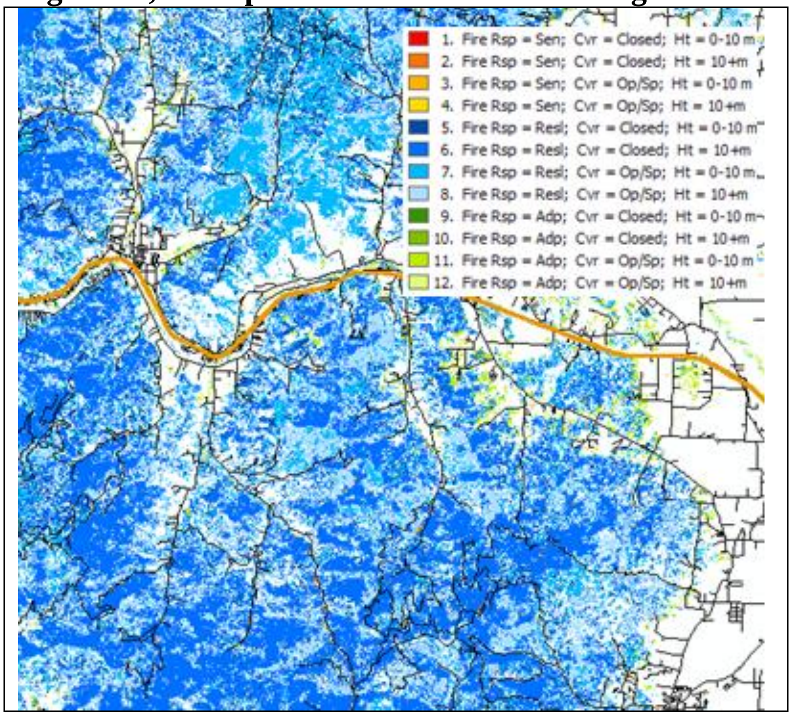
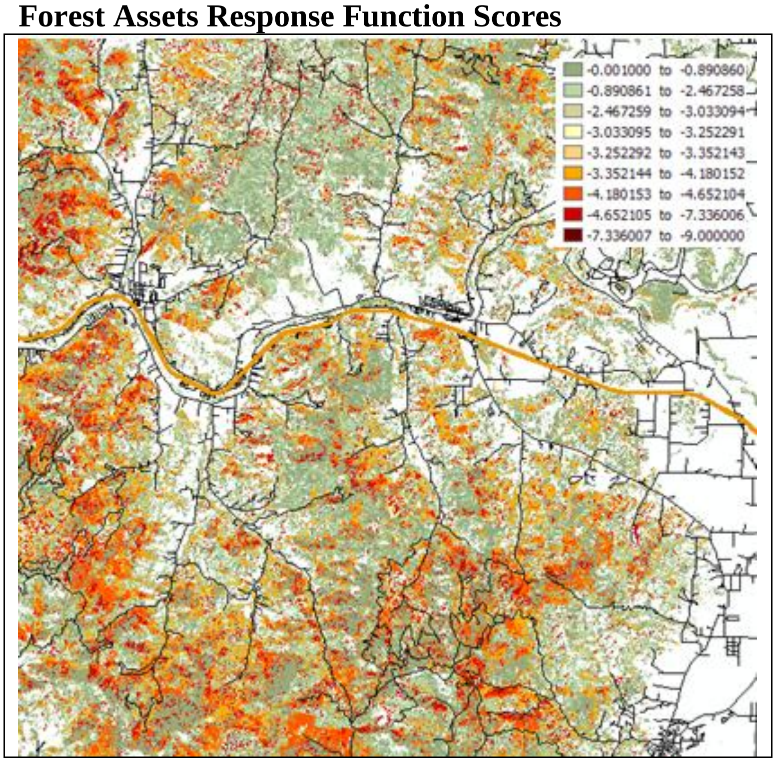


Figure 43, Example of the Forest Assets Response Function Scores



Riparian Assets

This layer identifies riparian areas that are important as a suite of ecosystem services, including both terrestrial and aquatic habitat, water quality, water quantity, and other ecological functions. Riparian areas are considered an especially important element of the landscape in the West. Accordingly, a separate data set has been compiled to provide state representatives the opportunity to consider the impact from fire in riparian areas.

The process for defining these riparian areas was complex. It involved identifying the riparian footprint and then assigning a rating based upon two important riparian functions. These functions are water quantity and quality together as well as ecological significance. The WWA technical team developed the Riparian Assets data layer model with in-kind support from state representatives. Input data sets used in the model included the National Hydrography Data Set (NHD) and the National Wetlands Inventory (NWI).

The National Hydrography Data Set (NHD) was used to represent hydrology. A subset of streams and water bodies, which represents perennial, intermittent, and wetlands, was created. The NHD water bodies' data set was used to determine the location of lakes, ponds, swamps, and marshes (wetlands).

The U.S. Fish and Wildlife Service has posted the National Wetlands Inventory (NWI) to the Internet (see Web Links section). This is a comprehensive data set covering the entire United States that explicitly maps wetland areas. This data set was used in two ways. The first way was to establish a wetland riparian footprint. The second way was to provide value information about the condition of the wetland riparian area. The NWI contains five categories: marine, estuarine, riverine, lacustrine, and palustrine. To avoid overlap with the wetland areas already identified, the only system used from the NWI is palustrine.

After selecting the correct features from the NHD and NWI, they were buffered to create the riparian footprint. Buffering these spatial features approximately 150 feet created footprints for perennial streams and wetlands. Seasonal watercourse extent was created based on 75-foot buffers. Development of a rating of impact for Riparian Assets was then done by initially considering water quality and quantity as measured by erosion potential, annual average precipitation and slope. In addition, ecological significance was included as measured by LANDFIRE vegetation classification to depict habitat quality and susceptibility to fire.

The model created values impacted categories 1, 2 and 3 representing increasing importance of the riparian area as well as sensitivity to fire-related impacts on the suite of ecosystem services. A Value Impacted Category 3 generally represents riparian areas with conifer, hardwood, or riparian vegetation on steeper slopes, erodible soils and areas of higher annual rainfall. A Value Impacted Category 1 generally represents riparian areas with exotic or grass vegetation types, on flatter slopes, in areas of low annual rainfall.

Figure 44 contains the project area's response function score matrix the Value Impacted category Riparian Assets.

Figure 44, Project Area Response Functions Scores for Riparian Assets

Value Impacted		Flame length/FIL class					
	FIL	1	2	3	4	5	6
	Class	0-2	2-4	4-6	6-8	8-12	12+
	Category						
Riparian Assets	1	-0.30	-0.88	-1.53	-2.23	-2.91	-3.20
	2	-0.25	-1.09	-2.05	-3.13	-4.24	-4.78
	3	-0.17	-1.41	-2.83	-4.63	-6.67	-7.66

Figure 45 presents an example of the Riparian Assets data layer categories for an area of Jackson County, Oregon.

Figure 45, Example of the Riparian Assets Categories

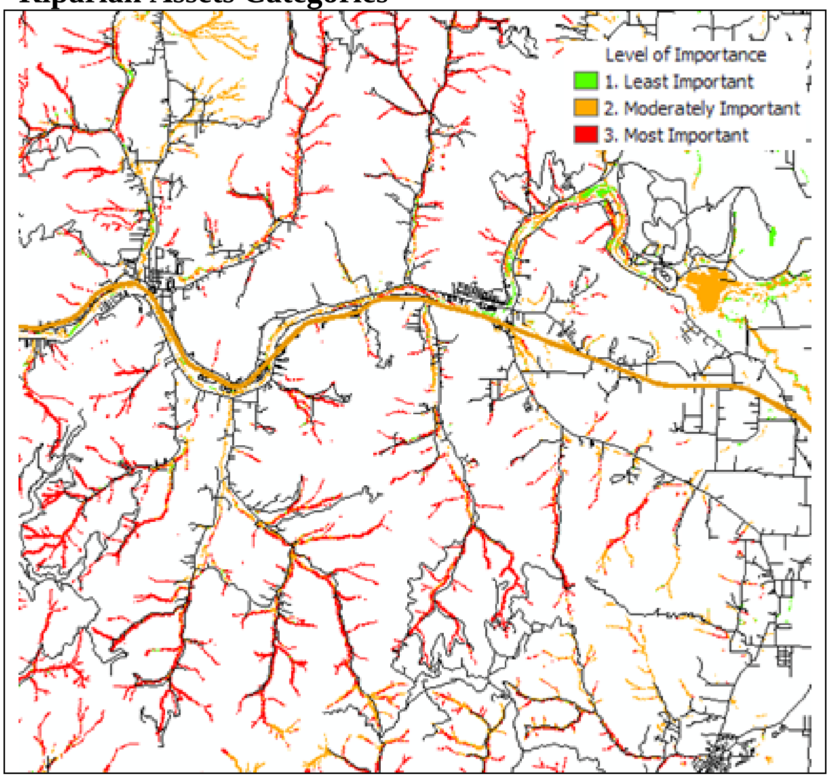


Figure 46 has a drainage size area within the area in Figure 46 to allow for a more detailed display of the categories. Figure 47 shows the Riparian Assets response function scores of the area shown in Figure 46.

Figure 46, Example of a Drainage Showing Riparian Assets Categories

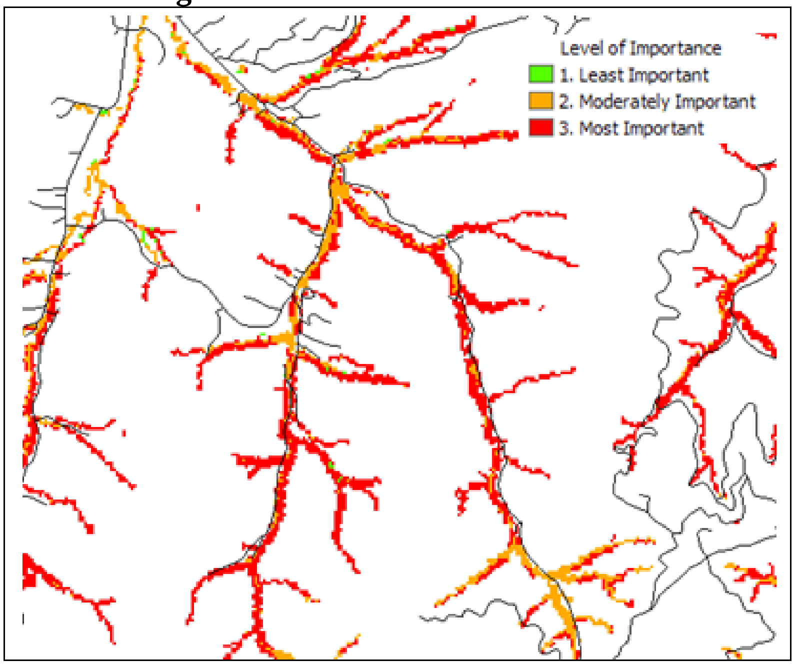
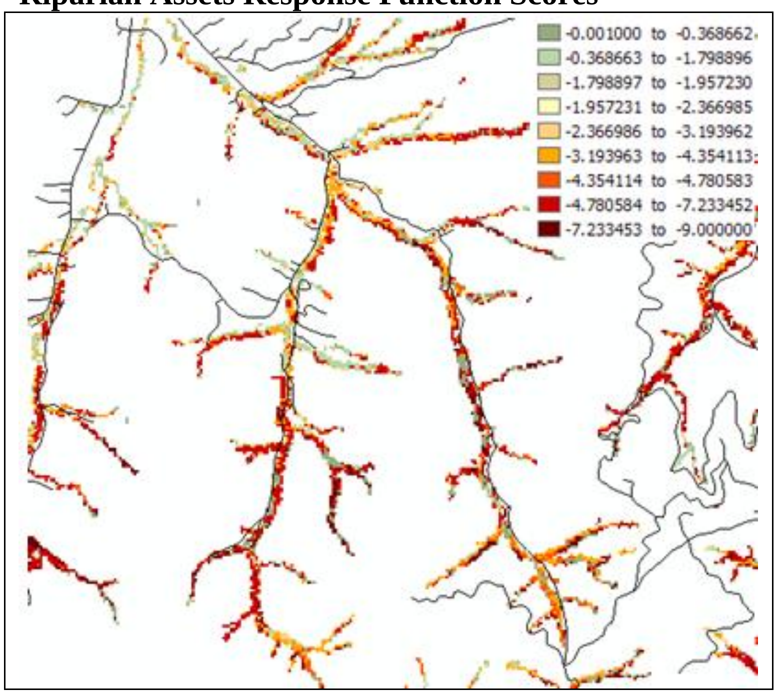


Figure 47, Example of the Riparian Assets Response Function Scores



Where People Live (Housing Units per Acre)

The location of people living in wildland and rural areas is key information for defining potential impacts to people and homes threatened by fire from wildland fuels. This is an intermediate data set that was developed so that the Wildland Development Areas could be developed.

The Where People Live (WPL) data set was developed using advanced modeling techniques based on the LandScan population count data available from the Department of Homeland Security, HSIP Freedom Data Set. The HSIP Freedom data set was available at no cost to U.S. local, state, territorial, tribal and Federal government agencies (see Web Links section).

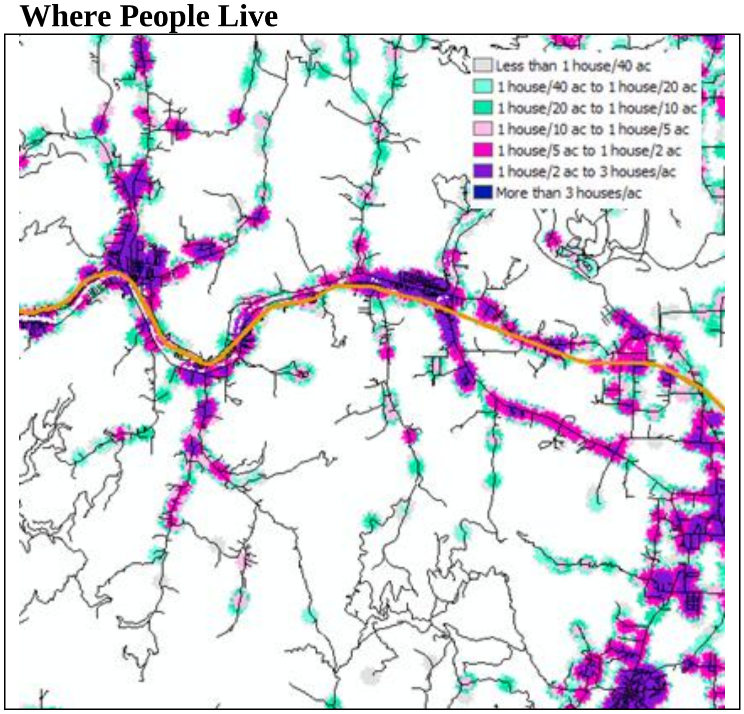
Developed by the Oak Ridge National Laboratory, LandScan has been developed using sophisticated algorithms that integrate high-resolution imagery, nighttime lights imagery and other local spatial data to identify daytime and nighttime population distributions. The Oak Ridge National Laboratory LandScan web site has a more detailed description of the data set (see Web Links section).

Table 4, Housing Density

Category	Housing Units per acre
1	Less than 1 HU / 40 ac.
2	1 HU/40 acres to 1 HU/20 ac.
3	1 HU/20 acres to 1 HU/10 ac.
4	1 HU/10 acres to 1 HU/5 ac.
5	1 HU/5 acres to 1 HU/2 ac.
6	1 HU/2 acres to 3 HU/ac.
7	More than 3 HU/ac.

The Where People Live data layer includes categories up to or greater than three housing units per acre (Table 4). This is greater than one housing unit on 1/3rd of an acre. This, in many cases, includes dense urban areas. Figure 48 presents an example of the Where People Live data layer categories for an area of Jackson County, Oregon.

Figure 48, Example of the Where People Live



Wildland Development Areas (Housing Units per Acre)

The location of people living in Wildland Urban Interface and rural areas is key information for defining potential impacts to people and homes from fire. This data layer will be called Wildland Development Areas (WDA) and to develop this data layer, there was a need to develop the Where People Live (WPL) data layer first.

Using the Where People Live data set, the WWA staff, in coordination with state representatives and the project manager, developed rule sets and a process to define areas where people and homes are threatened by fire from wildland fuels. This process coincided with the one described in the description of surface fuels. Figure 49 shows areas near Boulder, Colorado. Figure 50 shows the result of the areas that was defined as urban in the Boulder area. The area defined as urban had areas, which intersect all Where People Line (WPL) class 7 > 640 ac with all Where People Line (WPL) class 6.2 and greater that is also larger than 640 acres. The remaining areas with Where People Live data set that were not inside the area now defined as urban become part of the Wildland Development Areas data set.

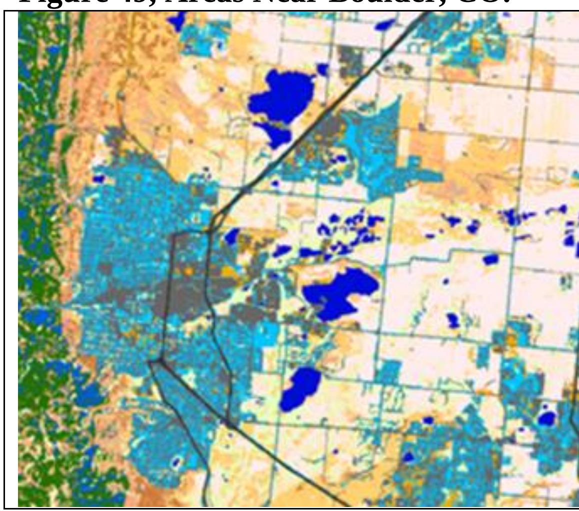
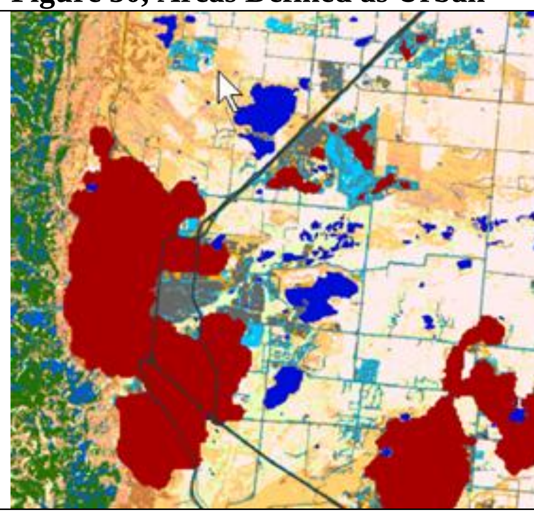
Figure 49, Areas Near Boulder, CO.	**Figure 50, Areas Defined as Urban**
	

Figure 51 shows the Portland OR., area with the areas remaining from the WPL data set that are in the WDA data set and defines where people and homes that are threatened by fire from wildland fuels.

Figure 51, WPL and WDA Data Layers

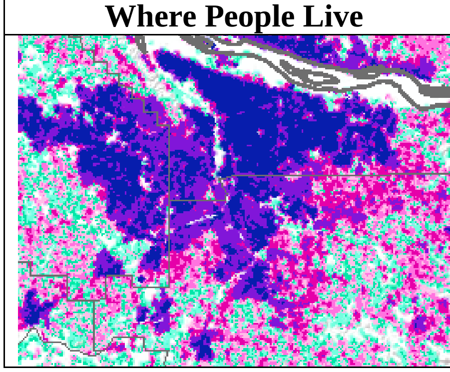
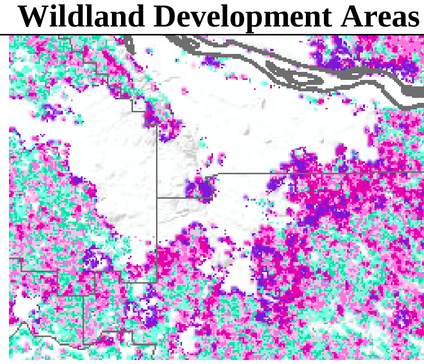
Where People Live	Wildland Development Areas	Categories
		Less than 1 house/40 ac 1 house/40 ac to 1 house/20 ac 1 house/20 ac to 1 house/10 ac 1 house/10 ac to 1 house/5 ac 1 house/5 ac to 1 house/2 ac 1 house/2 ac to 3 houses/ac More than 3 houses/ac

Figure 52 shows an example of the Wildland Development Area data layer categories for an area of Jackson County, Oregon. Figure 53 shows the response functions for this area.

Figure 52, Example of the Wildland Development Areas

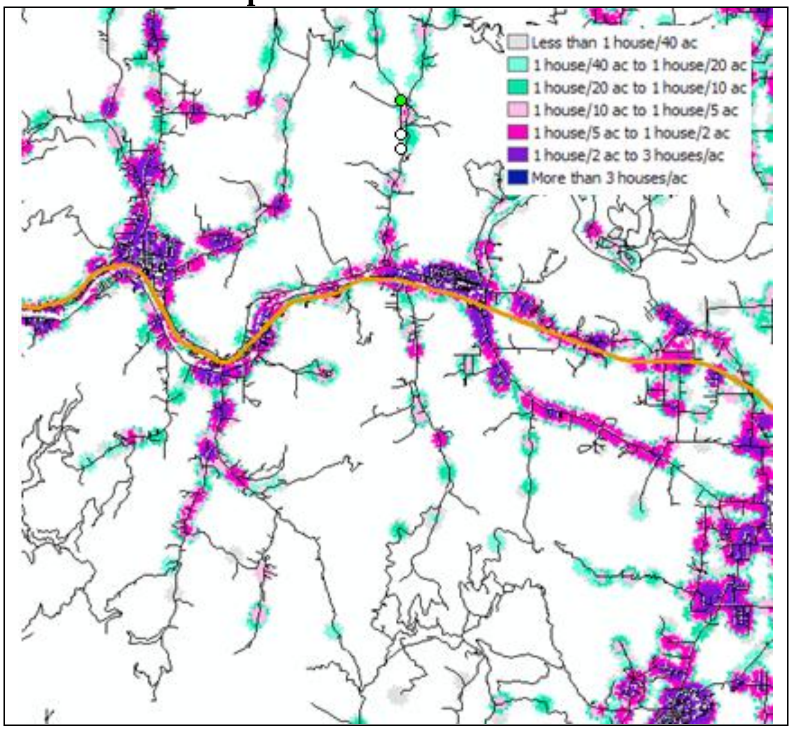
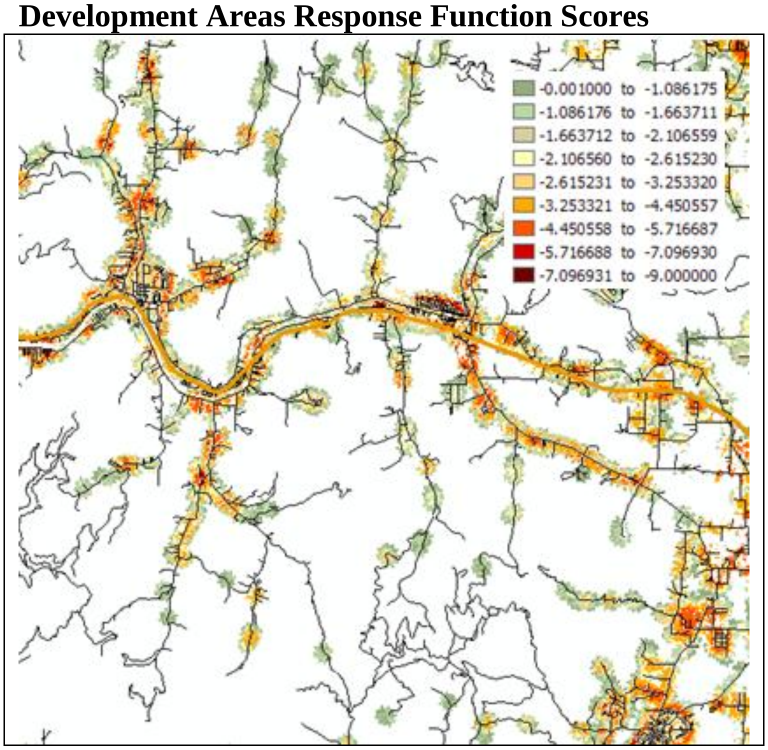


Figure 53, Example of the Wildland Development Areas Response Function Scores



Value Impacted Rating (VIR)

For a cell on the landscape, a Value Impacted Score for a value impacted was developed and described earlier. This is shown in the RF Scores column in Figure 54.

Each state also provided a measure for the relative importance of each value impacted in relation of the other values impacted. The average of these importance numbers by value impacted was then developed. It together with the acres in each value impacted category was then used to develop the weight the Response Function Scores for all value impacted categories. This aggregate score was calculated for the Value Impacted Rating using the relative extent process (Thompson, et. Al. In Press). The relative extent is determined using the west wide state provided relative importance weight for each value impacted and the total burnable acres west wide occupied by each value impacted category. The WWA-wide value impacted weights are: Infrastructure Assets, 46.2%; Wildland Development Areas, 44.7%; Drinking Water Importance Areas, 1.0%; Forest Assets, 3.6%; and Riparian Assets, 4.5%.

Figure 54 shows an example of the calculation of the Value Impacted Rating. It does show that each value impacted occurs with the example cell. This is very unlikely on the landscape and is shown here for description purposes only.

Figure 54, Example of Calculation of Value Impacted Rating

Variable		Percentile Weather				
		Low	Mod	High	Ext	FTI
Fire Threat Index		0.00001	0.04800	0.00780	0.00100	0.0568
FL (ft) (CFL)		2.2	6.2	11.0	51.6	
FL class (FIL)		2	4	5	6	
	VI Category					
Infrastructure Assets	1	1 = near road, railroad, school, airport, hospital				
Wildland Development Areas	7	1-7: density classes from low to high				
Drinking Water Importance Areas	9	1-10: classes based on population served				
Forest Assets	1	Example is 1= Sensitive, 0-10 m., closed;				
Riparian Assets	3	1 = less important; 2 = moderately important; 3 = important				
	(FTI Wted)	Response Function Values				Weighting
	RF Scores	Low	Mod	High	Ext	Factor
Infrastructure Assets	-7.458	-4.97	-7.31	-8.23	-8.41	46.2%
Wildland Development Areas	-7.922	-4.88	-7.75	-8.84	-9.00	44.7%
Drinking Water Importance Areas	-5.719	-2.36	-5.51	-6.79	-7.28	1.0%
Forest Assets	-7.281	-3.84	-7.13	-8.11	-8.34	3.6%
Riparian Assets	-4.959	-1.41	-4.63	-6.67	-7.66	4.5%
Values Impacted Rating	-7.529					

The Value Impacted Rating calculation in the example is shown below.

VIR=[(0.462)*(-7.458) + (0.447)*(-7.922) + (0.01)*(-5.719) + (0.036)*(-7.281) + (0.045)*(-4.959) ~ -7.5

Fire Suppression Difficulty

The difficulty and potential for the cost for a wildfire to be suppressed is defined as fire suppression difficulty. Two data sets together are used to develop a Fire Suppression Difficulty Rating, surface model and slope.

<u>Surface Fuel Model</u>

The surface fuels affect the ability of firefighters to construct and hold fireline. Surface fuels data used in the WWA was gathered from the LANDFIRE project, Refresh (LF 1.1.0) (see Web Links section). The fuel model set used is defined by Scott and Burgan (2005) and is referred to as the 2005 FBPS fuel model set.

The fireline production rates from the NWCG Fireline Handbook (National Wildfire Coordinating Group 2004) as well as the Fire Program Analysis (FPA) project (see Web Links section) were used to group the surface fuel models from the 2005 Fire Behavior Prediction System fuel model set developed (Scott and Burgan 2005) into three fireline production rate categories: Slow, Medium and Fast (Figure 55).

Figure 55, Fireline Production Rate Categories

Grass	Grass/ Shrub	Shrub	Timber Litter/ Understory	Timber Litter	Slash
gr1	gs1	sh1	tu1	tl1	sb1
gr2	gs2	sh2	tu2	tl2	sb2
gr3	gs3	sh3	tu3	tl3	sb3
gr4	gs4	sh4	tu4	tl4	sb4
gr5		sh5	tu5	tl5	
gr6		sh6		tl6	
gr7		sh7		tl7	
gr8		sh8		tl8	
gr9		sh9		tl9	

Key	
	Fast
	Medium
	Slow

<u>Slope</u>

The Fireline Handbook Appendix A, page A-34, defines four slope classes as follows: 0-25%, 26-40%, 41-55% and 56-74%. A fifth class or 75% or greater was added for WWA use.

<u>Fire Suppression Difficulty Rating (SDR)</u>

Based on the fireline production rate categories and slope category combinations, a suggested rating scale was developed. It uses the same range of numeric values used for the response function scores for values impacted. This range is from 0 to –9.0. The suppression difficulty rating was calculated for each combination of fireline and slope steepness categories as the average of the state provided ratings (Figure 56).

Figure 56, Fireline Production Rate Categories

Suppression Difficulty	Production Rate	Code	Slope Steepness				
			0-25	26-40	41-55	56-74	75+
			1	2	3	4	5
	Fast	1	-1.50	-3.96	-7.04	-8.74	-9.00
	Medium	2	-3.19	-5.19	-7.64	-8.54	-8.88
	Slow	3	-4.49	-6.16	-8.06	-8.91	-9.00

Figure 57 shows an example of the Value Impacted Rating data layer for an area of Jackson County, Oregon. Figure 58 shows an example of the Suppression Difficulty Rating data layer for an area of Jackson County, Oregon.

Figure 57, Example of the Value Impacted Rating

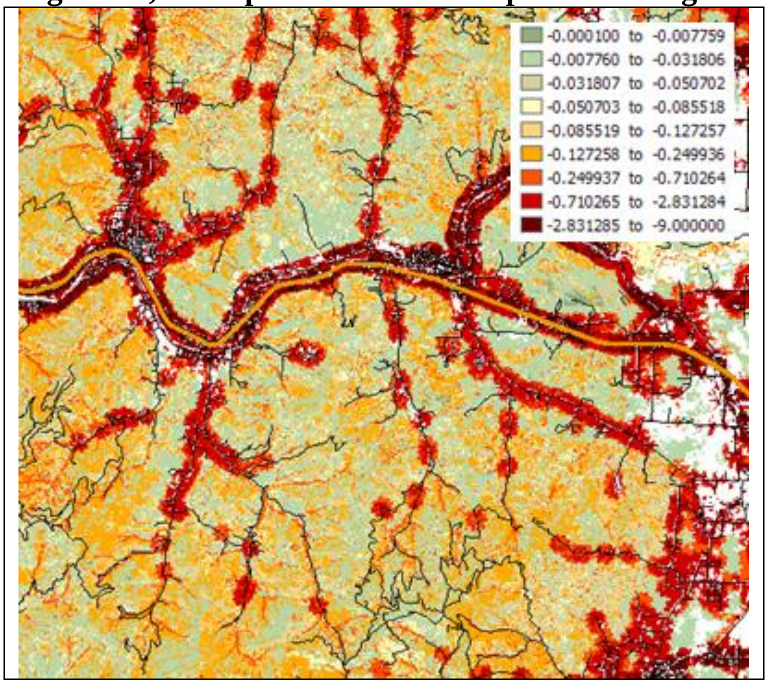
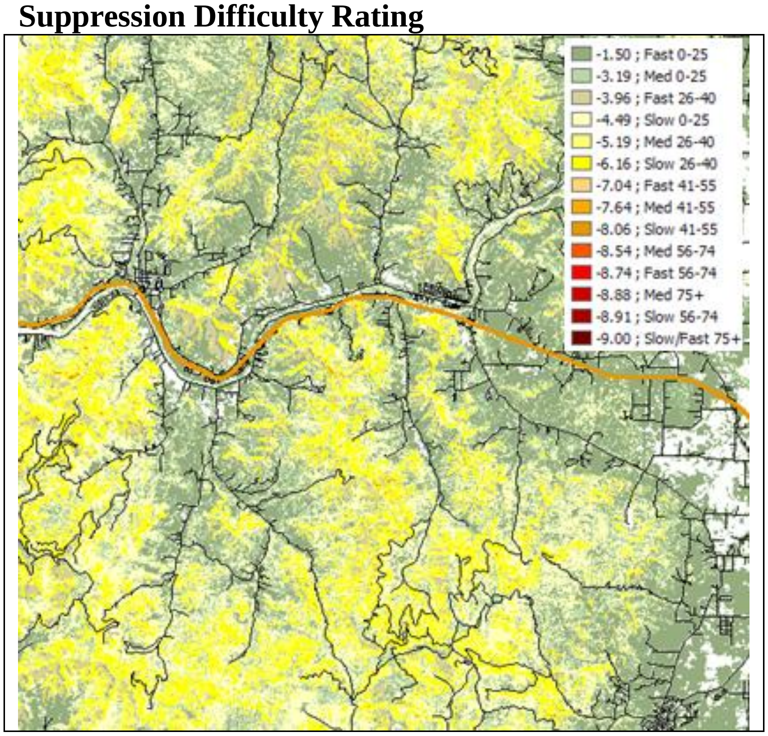


Figure 58, Example of the Suppression Difficulty Rating



Fire Effects Index (FEI)

The Fire Effects component of the risk assessment involves integrating the Values Impacted Rating and Suppression Difficulty Rating. The purpose was to identify those areas that have important values that can be affected by fire. The purpose was also to identify those areas that are difficult or costly to suppress. The Values Impacted Rating (VIR) and the Suppression Difficulty Rating (SDR) are weighted to calculate the Fire Effects Index (FEI).

FEI = [(VIR) * (VIR weight) + (SDR) * (SDR weight)] / 100

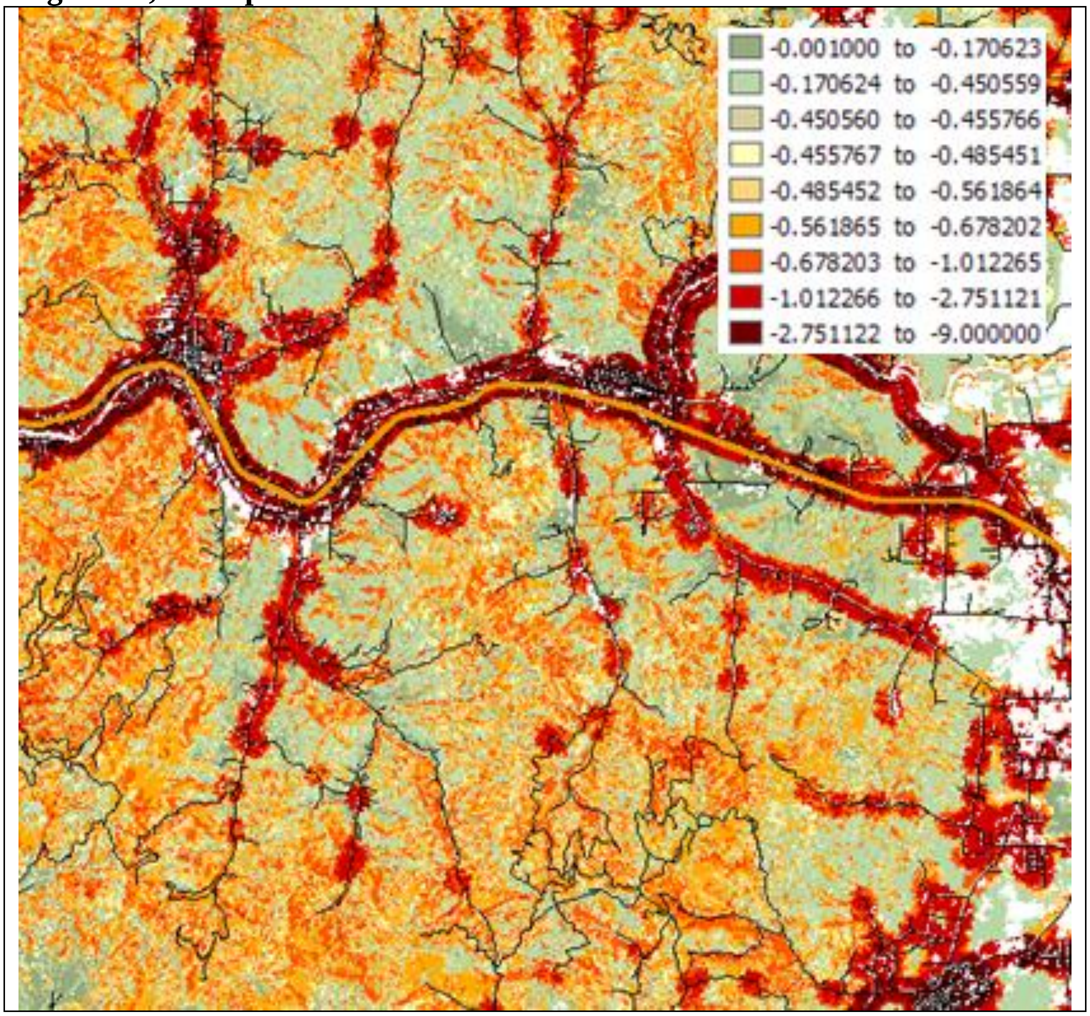
The VIR weight plus the SDR weight did total to 100%. The states provided input to these weights. Once the VIR and SDR values were determined and the input from the states was averaged, the final weights were VIR, 90%, and SDR, 10%. The resultant Fire Effects Index is a value theoretically between –0.01 and –9.0. Figure 59 shows an example of the calculation of the Fire Effects Index.

Figure 59 - Example of Calculation of the Fire Effects Index

Variable		Percentile Weather				
		Low	Mod	High	Ext	FTI
Fire Threat Index		0.00001	0.04800	0.00780	0.00100	0.0568
FL (ft) (CFL)		2.2	6.2	11.0	51.6	
FL class (FIL)		2	4	5	6	
	VI Category					
Infrastructure Assets	1	1 = near road, railroad, school, airport, hospital				
Wildland Development Areas	7	1-7: density classes from low to high				
Drinking Water Importance Areas	9	1-10: classes based on population served				
Forest Assets	1	Example is 1= Sensitive, 0-10 m., closed;				
Riparian Assets	3	1 = less important; 2 = moderately important; 3 = important				
	(FTI Wted)	Response Function Values				Weighting
	RF Scores	Low	Mod	High	Ext	Factor
Infrastructure Assets	-7.458	-4.97	-7.31	-8.23	-8.41	46.2%
Wildland Development Areas	-7.922	-4.88	-7.75	-8.84	-9.00	44.7%
Drinking Water Importance Areas	-5.719	-2.36	-5.51	-6.79	-7.28	1.0%
Forest Assets	-7.281	-3.84	-7.13	-8.11	-8.34	3.6%
Riparian Assets	-4.959	-1.41	-4.63	-6.67	-7.66	4.5%
Values Impacted Rating	-7.529					
Slope Class	1	1 = flat; 5 = steepest				
Fuel Type	3	1=Grass; 2 = Timber Litter; 3=Brush;				
Suppression Difficulty Rating	-4.49					
Suppression Difficulty Weight	10					
Values Impacted Weight	90					
Fire Effects Index	-7.225					

Figure 60 shows an example of the Fire Effects Index data layer for an area of Jackson County, Oregon.

Figure 60, Example of the Fire Effects Index



Fire Risk

As mentioned, this data layer that defines wildland fire risk as the Fire Risk Index (FRI), (Figure 1).

Fire Risk Index (FRI)

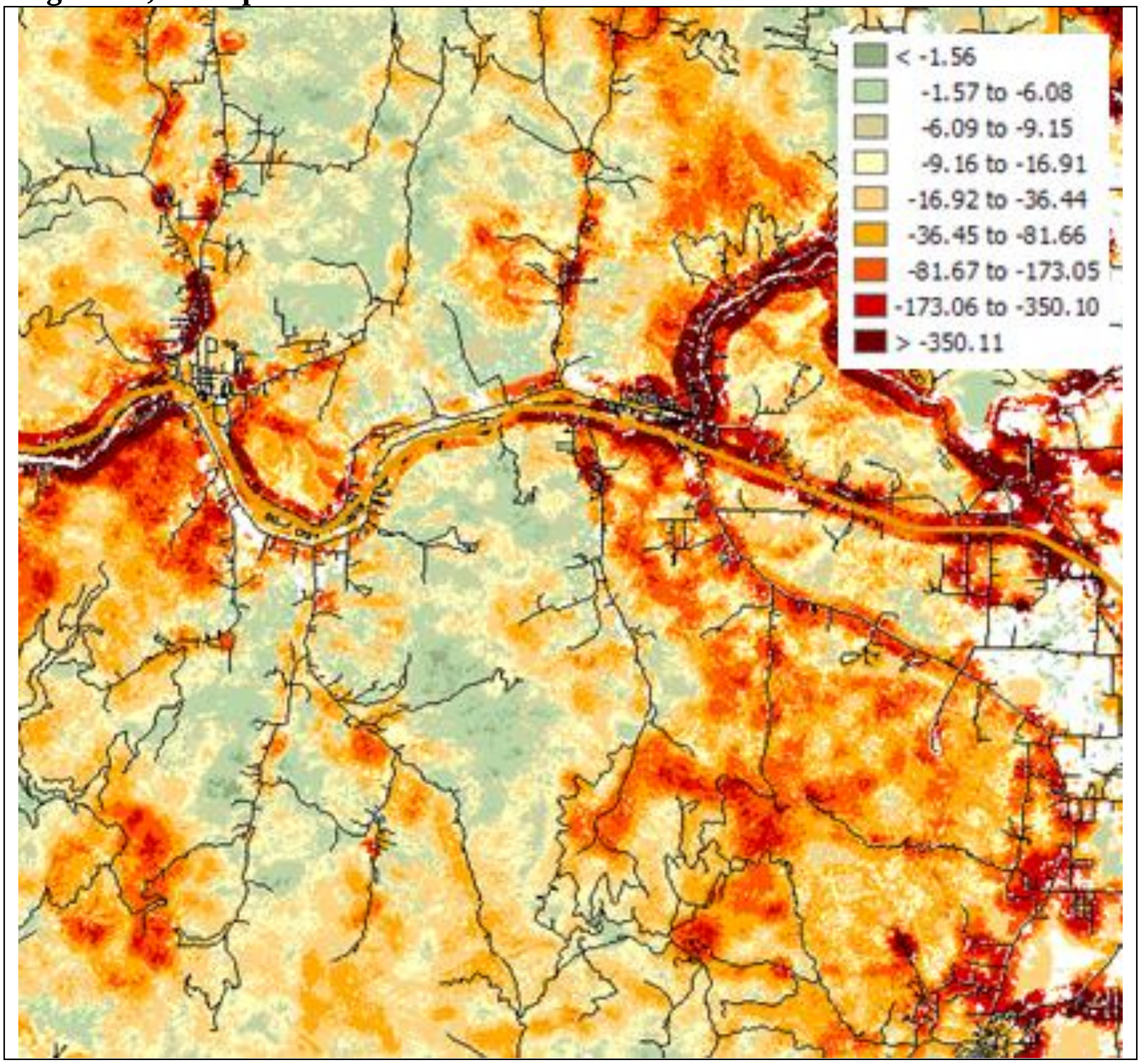
The Fire Risk Index is calculated from the Fire Threat Index (FTI), and the Fire Effects Index (FEI). The FEI is the potential expected effects of the fire as defined via response functions. The initial calculation is IFRI = FTI * FEI. The Fire Effects Index is a value theoretically between –0.01 and –9.0 while the Fire Threat Index is a value between 0.0 and 1.0. This product results in an "expected fire effects value" less than 0 but greater than or equal to –9.0. An "expected" value is a measure of the likelihood of an effect occurring. Since the initial calculation frequently results in a small negative value, the final FRI calculation includes 10,000 as a scalar multiplier: FRI = FTI * FEI * 10,000. The scalar is included to make the values a bit larger to enhance understanding. Figure 61 shows an example of the calculation of the Fire Risk Index.

Figure 61 - Example of Calculation of the Fire Risk Index

Variable		Percentile Weather				
		Low	Mod	High	Ext	FTI
Fire Threat Index		0.00001	0.04800	0.00780	0.00100	0.0568
FL (ft) (CFL)		2.2	6.2	11.0	51.6	
FL class (FIL)		2	4	5	6	
	VI Category					
Infrastructure Assets	1	1 = near road, railroad, school, airport, hospital				
Wildland Development Areas	7	1-7: density classes from low to high				
Drinking Water Importance Areas	9	1-10: classes based on population served				
Forest Assets	1	Example is 1= Sensitive, 0-10 m., closed;				
Riparian Assets	3	1 = less important; 2 = moderately important; 3 = important				
	(FTI Wted)	Response Function Values				Weighting
	RF Scores	Low	Mod	High	Ext	Factor
Infrastructure Assets	-7.458	-4.97	-7.31	-8.23	-8.41	46.2%
Wildland Development Areas	-7.922	-4.88	-7.75	-8.84	-9.00	44.7%
Drinking Water Importance Areas	-5.719	-2.36	-5.51	-6.79	-7.28	1.0%
Forest Assets	-7.281	-3.84	-7.13	-8.11	-8.34	3.6%
Riparian Assets	-4.959	-1.41	-4.63	-6.67	-7.66	4.5%
Values Impacted Rating	-7.529					
Slope Class	1	1 = flat; 5 = steepest				
Fuel Type	3	1=Grass; 2 = Timber Litter; 3=Brush;				
Suppression Difficulty Rating	-4.49					
Suppression Difficulty Weight	10					
Values Impacted Weight	90					
Fire Effects Index	-7.225					
Initial Fire Risk Index	-0.410					
Fire Risk Index	-4104.4					

Figure 62 shows an example of the Fire Risk Index data layer for an area of Jackson County, Oregon.

Figure 62, Example of Calculation of Fire Risk Index



Interrogating Layers

Many data layers are included in the risk assessment process. When the inputs for results are defined and compared, the relationship inputs and outputs data layer values can answer questions. As an example, Figures 63 through 66 show the Fire Occurrence Area, Fire Threat Index, Fire Effects Index and Fire Risk Index for an area of Jackson County, Oregon.

Figure 63, Fire Occurrence Area

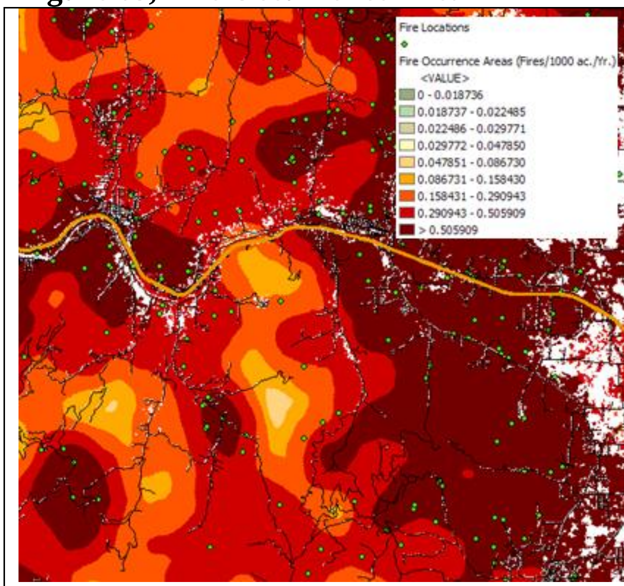


Figure 64, Fire Threat Index

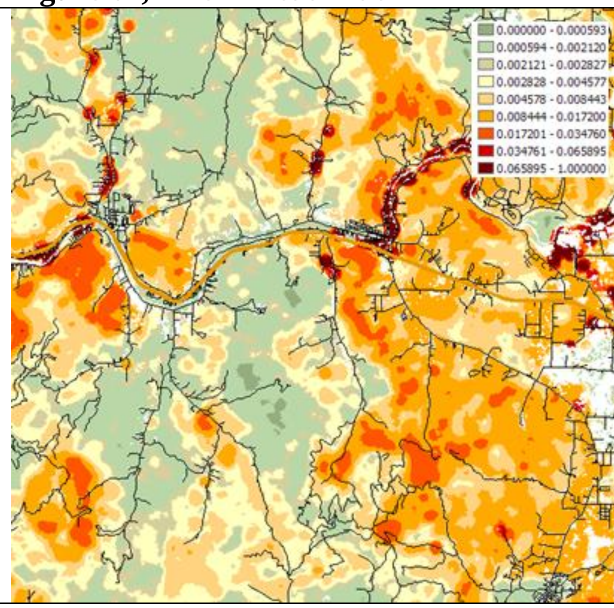


Figure 65, Fire Effects Index

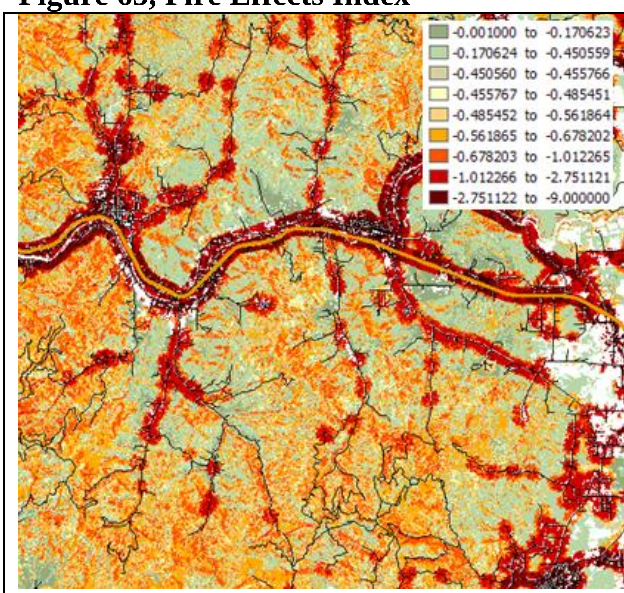
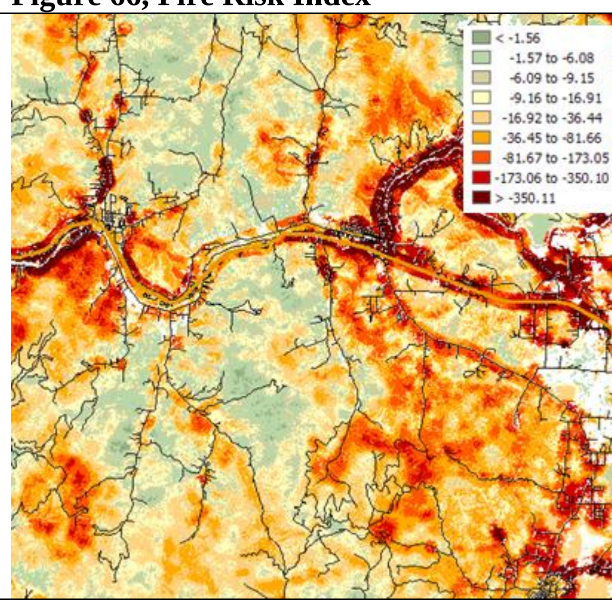


Figure 66, Fire Risk Index



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Forests to Faucets - http://www.fs.fed.us/ecosystemservices/FS_Efforts/forests2faucets.shtml

HSIP Freedom - http://www.dhs.gov/files/programs/gc_1156888108137.shtm

LANDFIRE - http://www.landfire.gov/

LANDFIRE data - http://www.landfire.gov/data_overviews.php

Oak Ridge National Laboratory LandScan - http://www.ornl.gov/sci/landscan/

U.S.G.S. Hydrologic Unit System - http://nwis.waterdata.usgs.gov/tutorial/huc_def.html

National Wetlands Inventory (NWI) http://www.fws.gov/wetlands/index.html