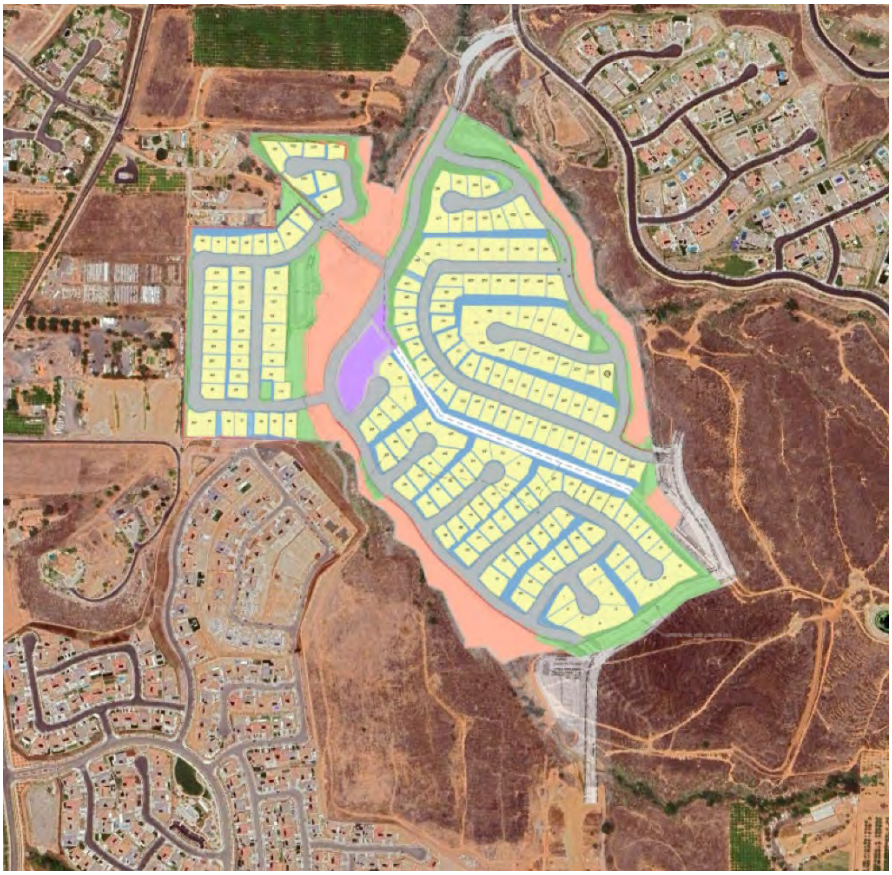
Preliminary Fire Protection Plan
Willow Creek
Tentative Tract 38927



Prepared for:
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6879 Airport Dr.
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Riverside, CA 92501

Prepared by:

firesafe
::PLANNING SOLUTIONS

08/19/25

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Purpose of Report

Firesafe Planning Solutions assessed the risks related to wildland fire and to establish the appropriate criteria for a defensible space installation and maintenance program that will reduce the intensity of a wildfire approaching the Willow Creek residential community. This report will provide the assessment results and provide objective support for the defensible space installation and maintenance program for this community that is equal to or greater than the risk encountered in a worst-case scenario. The study takes into consideration existing/future vegetative interface fuels, topography, and weather conditions during a fire. The report provides results of computer calculations that measured the fire intensity from a worst-case scenario wildfire in both the extreme (Santa Ana- NE wind) and the predominant (Onshore – SW wind) conditions. The results of fire behavior calculations will be incorporated into the fire protection design built into the Willow Creek development.

Geographic Description

The proposed project (red outline in Figure 1) is located north of Lake Mathews within the northwestern portion of Western Riverside County, California. The Project site is within the Gavilan Hills and is generally located south of the 91 Freeway, east of La Sierra Road, north of El Sobrante Road, and west of Van Buren Boulevard. The site is bounded by undeveloped land to the north), current/future development to the south, west, and east (Figure 2).

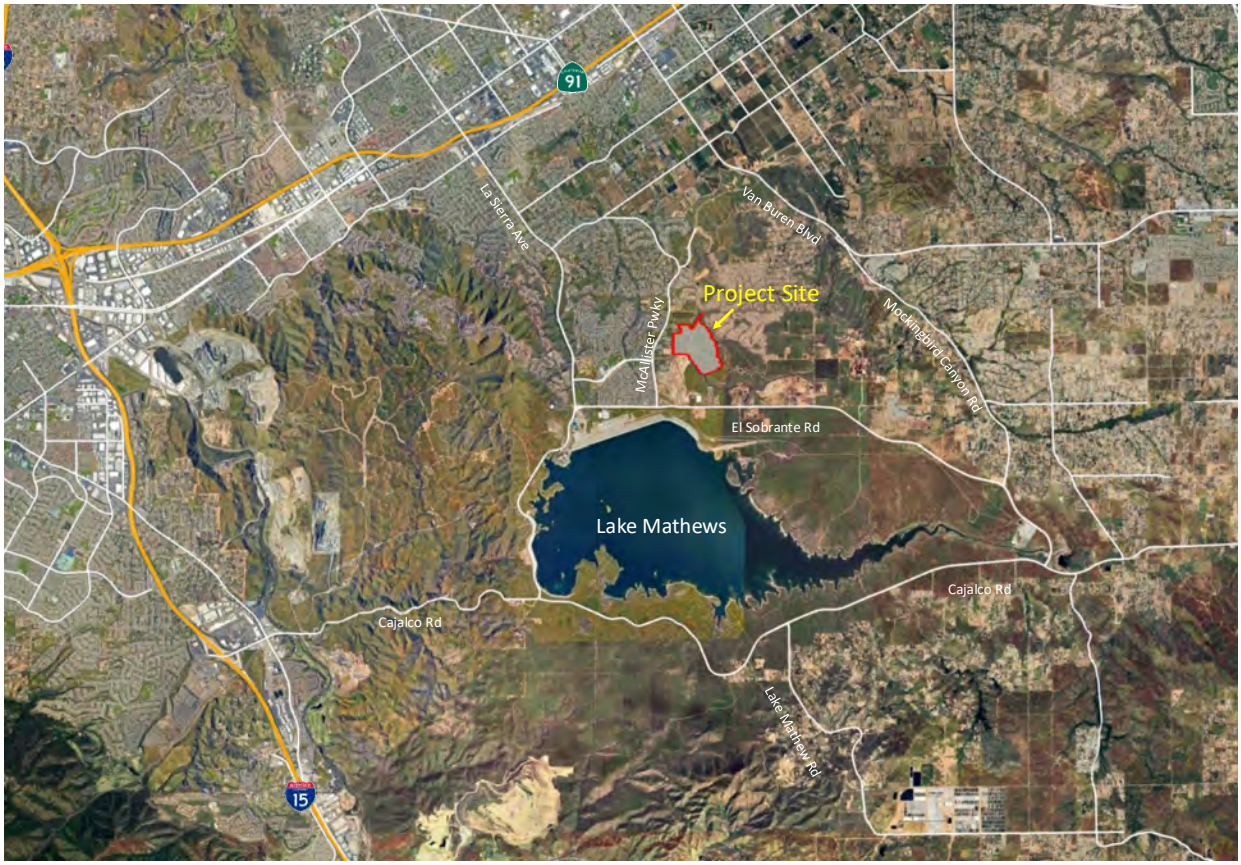


Figure 1 – Vicinity Map

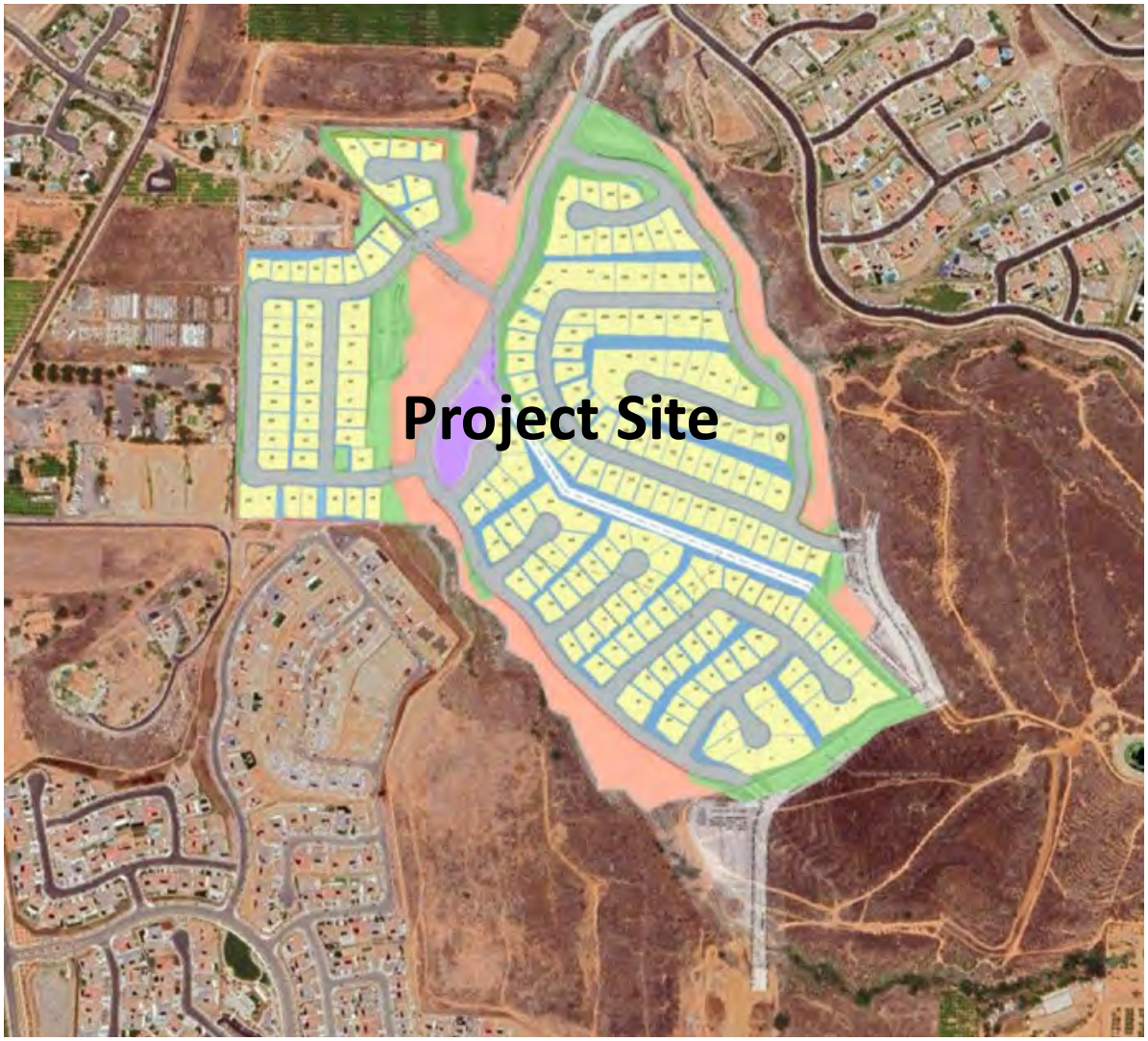


Figure 2 - Site Map

CAL FIRE State Responsibility Area Very High Fire Hazard Severity Zone Map

State law requires development in State Responsibility Area (SRA) within any fire hazard zone to comply with the WUI (Wildland Urban Interface) codes contained in the California Residential Code (Chapter 3, Section R337) , California Building Code (Chapter 7A) and California Fire Code (Chapter 49).

The previously adopted Fire Hazard Severity Map for this area (adopted in 2007) places the entire project in a Moderate hazard zone, as shown in Figure 3. As required by statute, the zones are periodically updated. The state of California has recently updated the SRA area (4/1/2024) and is following that effort with the Local Responsibility Area (LRA) updates, which will not impact this project site.

The Willow Creek site is located all three Fire Hazard Severity Zone on the current map (Figure 4). All portions of the project site are within a hazard zone and will be required to comply with the WUI codes cited above.

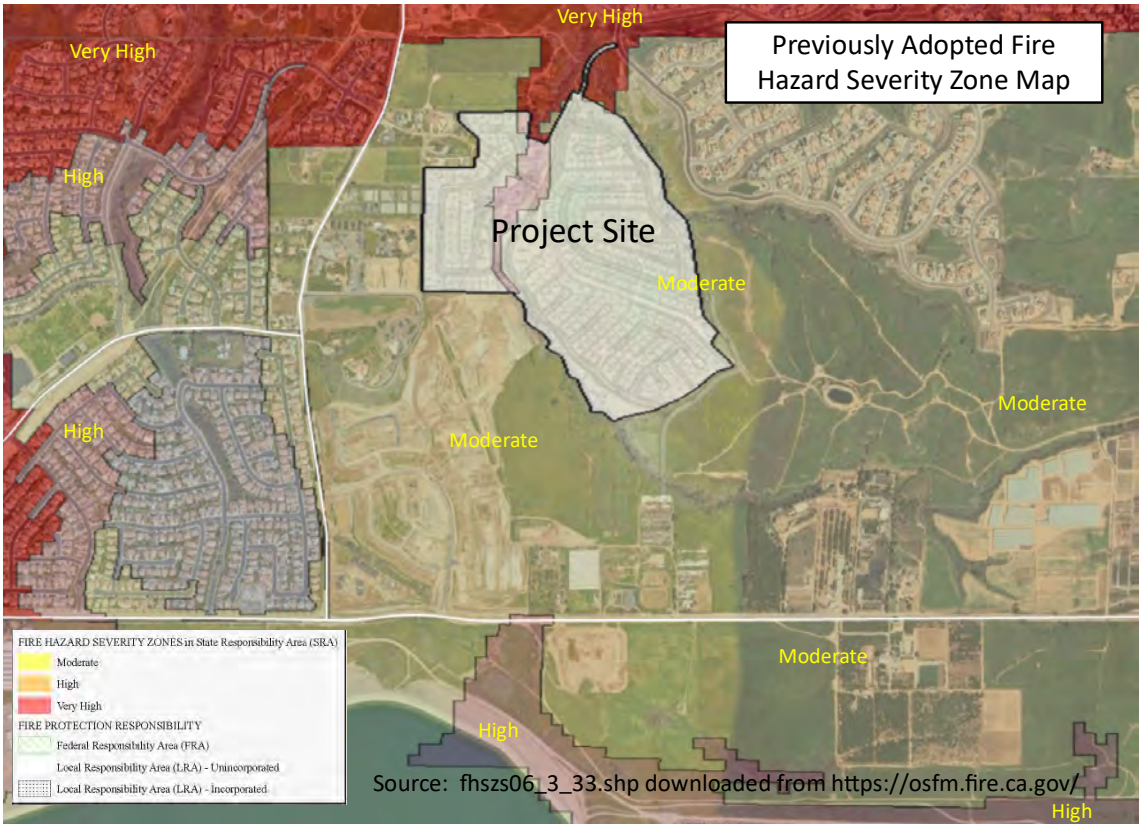


Figure 3 – Previous Fire Hazard Severity Zone Map

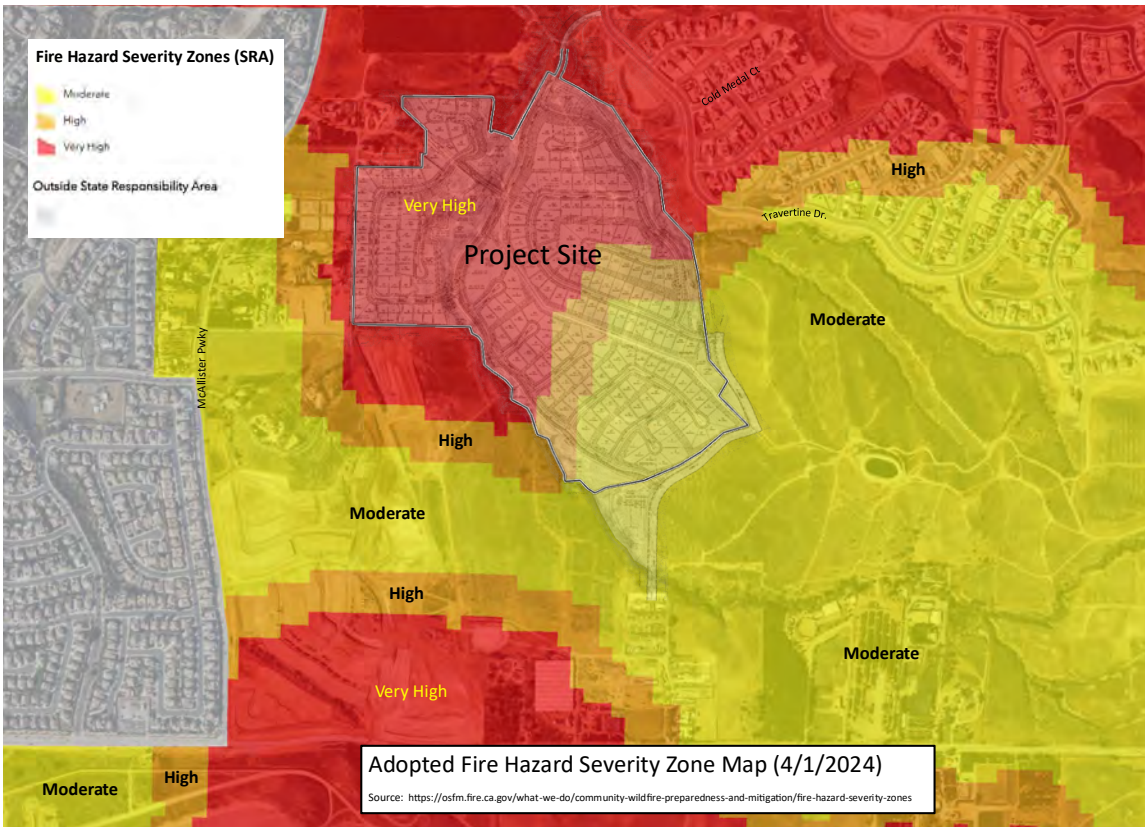


Figure 4 –Current Fire Hazard Severity Zone Map (2024)

Fire History

A review of the CalFire database (FRAP), which compiled this statewide spatial database of fire perimeters from BLM, NPS, and USFS fires 10 acres and greater in size, and CAL FIRE fires 300 acres and greater in size shows a picture of the project site as depicted e in Figure 5.

The project site development area has no recorded fire history in the CALFIRE database. In 1978, a non-named fire burned through a small area southeast of the project site but not over any of the proposed development areas. None of the fires adjacent to the project site have come within ¼ of a mile of the project site development envelopes with the exception of the 1978 fire. Of particular note, none of these fires are northeast or southwest of the project site (strongest wind directions).

All but three of the adjacent fires occurred over 30 years ago. In 1978, two fires (without names) occurred. The first burned 2,157.16 acres, and the second 507.21 acres. The next year (1979), the Steele Fire started on July 9th and burned 107.41 acres. The following year (1980), the Quail Fire started on July 6th and burned 200.85 acres, and the Pierce Fire started on July 9th of this same year and burned 985.28 acres. There was not another fire adjacent to the project site for 11 years until June 28th 2001 when the Cajalco Fire burned 224.96 acres. In 2005, the Knoll Fire, which started on April 20th burned 19.57 acres, and finally the Lakepointe Fire, which was over 1.5 miles away at its closed point (burned 256 acres in May of 2012). There have been no large fires near the project site since 2001 (over twenty years). Clearly historic fire corridors exist to the southeast and southwest of the project site, but none have impacted the project site during the time covered by the CALFIRE database.

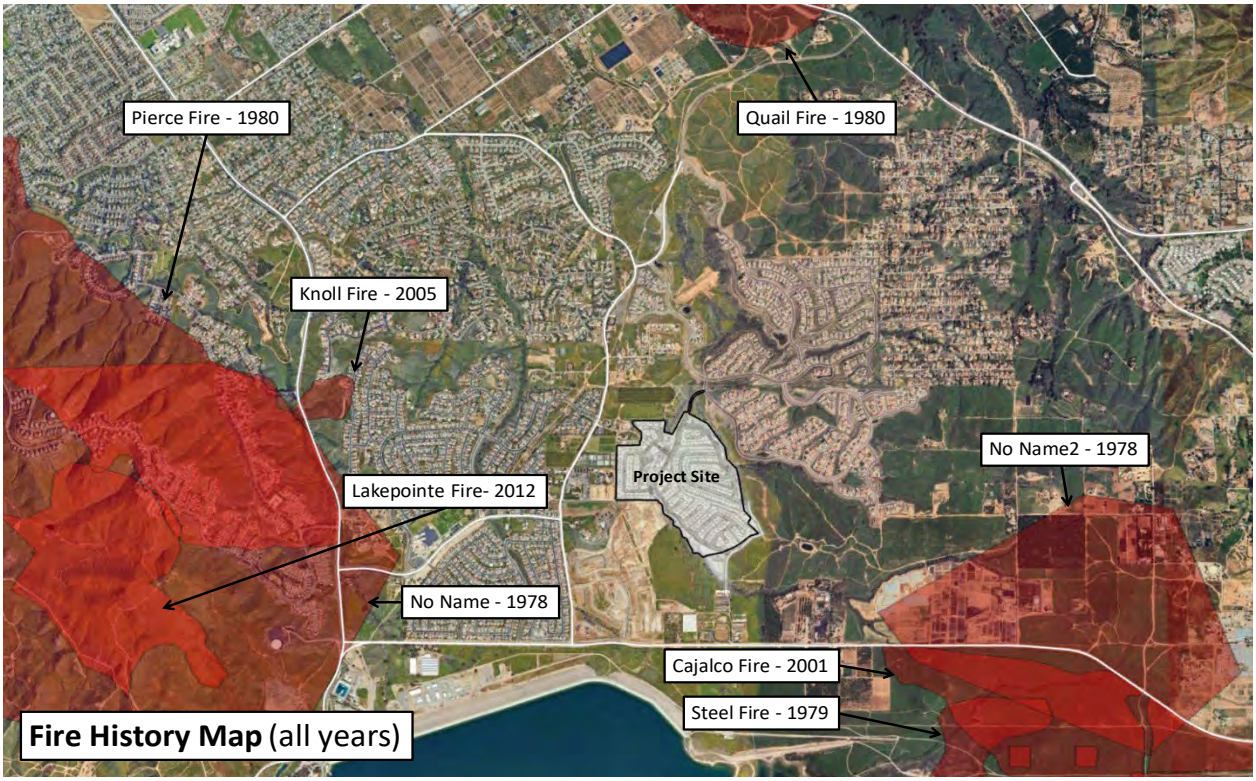


Figure 5 – Fire History Map

Note: Collection criteria for CAL FIRE fires changed in 2002 to include timber fires greater than 10 acres, brush fires greater than 50 acres, grass fires greater than 300 acres, fires destroying three or more structures, and fires causing $300,000 or more damage. In 2008, the collection criteria for CAL FIRE fires eliminated the monetary criterion and redefined the definition of structures.

Fire Behavior

Firesafe Planning Solutions used a computer software program titled "BehavePlus Fire Modeling System 6.0.0" to predict the level of wildfire intensity for a fire approaching the Willow Creek project site. BehavePlus, is a fire behavior prediction and fuel modeling system and is one of the most accurate methods for predicting wildland fire behavior. The BehavePlus fire behavior computer modeling system is utilized by wildland fire experts nationwide. Vegetative fuels are recognized as fuel models within the BehavePlus program. The fuel models in the computer program are also referenced from the book titled, "*Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model*". The fuel models were designed to aid in determining fuel types and are used in calculating and estimating fire behavior. We used BehavePlus to measure the intensity of a fire moving toward this development.

The fire model describes the fire behavior only within the flaming front of the fire. The primary moving force in the fire is dead fuel less than ¼" in diameter. These are the finest fuels that carry the fire. Fuels larger than ¼" contribute to fire intensity but not necessarily to fire spread as much as the fine fuels. The BehavePlus fire model describes a wildfire spreading through surface fuels, which are burnable materials within 6' of the ground and contiguous to the ground.

BehavePlus Related References:

1. Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model, Joe H. Scott, and Robert E. Burgan, United States Department of Agriculture - Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-153, June 2005

2. BehavePlus: Fire Behavior Prediction and Fuel Modeling System - BURN Subsystem. General Technical Report INT-194. Patricia L. Andrews, United States Department of Agriculture - Forest Service, Intermountain Station, Ogden, Utah 84401

Wildland Interface Fuel Types

For the purposes of modeling in the plan, the following fuel models were used:

Model GR1 (101) Dry Climate Grass is short, patchy, and possibly heavily grazed. Spread rate moderate; flame length low. Dynamic. Moisture of extinction is 15%. Fuel bed depth is 0.4 feet.

Model GR2 (102) Dry Climate - Moderately coarse continuous grass, average depth about 1 foot. Spread rate high; flame length moderate. Dynamic. Moisture of extinction is 15%. Fuel bed depth is 1.0 feet.

Model GS1 (121) Dry Climate - Shrubs are about 1-foot high, low grass load. Spread rate moderate; flame length low. Dynamic. Moisture of extinction is 15%. Fuel bed depth is 0.9 feet.

Model GS2 (122) Dry Climate - Shrubs are 1 to 3 feet high, moderate grass load. Spread rate high; flame length moderate. Dynamic. Moisture of extinction is 15%. Fuel bed depth is 1.5 feet.

Fuel **Model SH5 (145)** Dry Climate - Heavy shrub load, depth 4 to 6 feet. Spread rate very high; flame length very high. Moisture of extinction is 15%. Fuel bed depth is 6.0 feet.

Fuel **Model TL3 (183)** Fuelbed does not include coarse fuels. Moderate load conifer litter. Spread rate very low; flame length low. Moisture of extinction is 20%. Fuel bed depth is 0.3 feet.

Model TL6 (186) Fuelbed not recently burned. Fuelbed composed of broadleaf (hardwood) litter. Moderate load, less compact. Spread rate moderate; flame length low. Moisture of extinction is 25%. Fuel bed depth is 0.3 feet.

Wildland fuels, as indicated by the Landfire data (LCP_LF2022_FBFM40_230_CONUS.lcp) is depicted below in Figure 6.

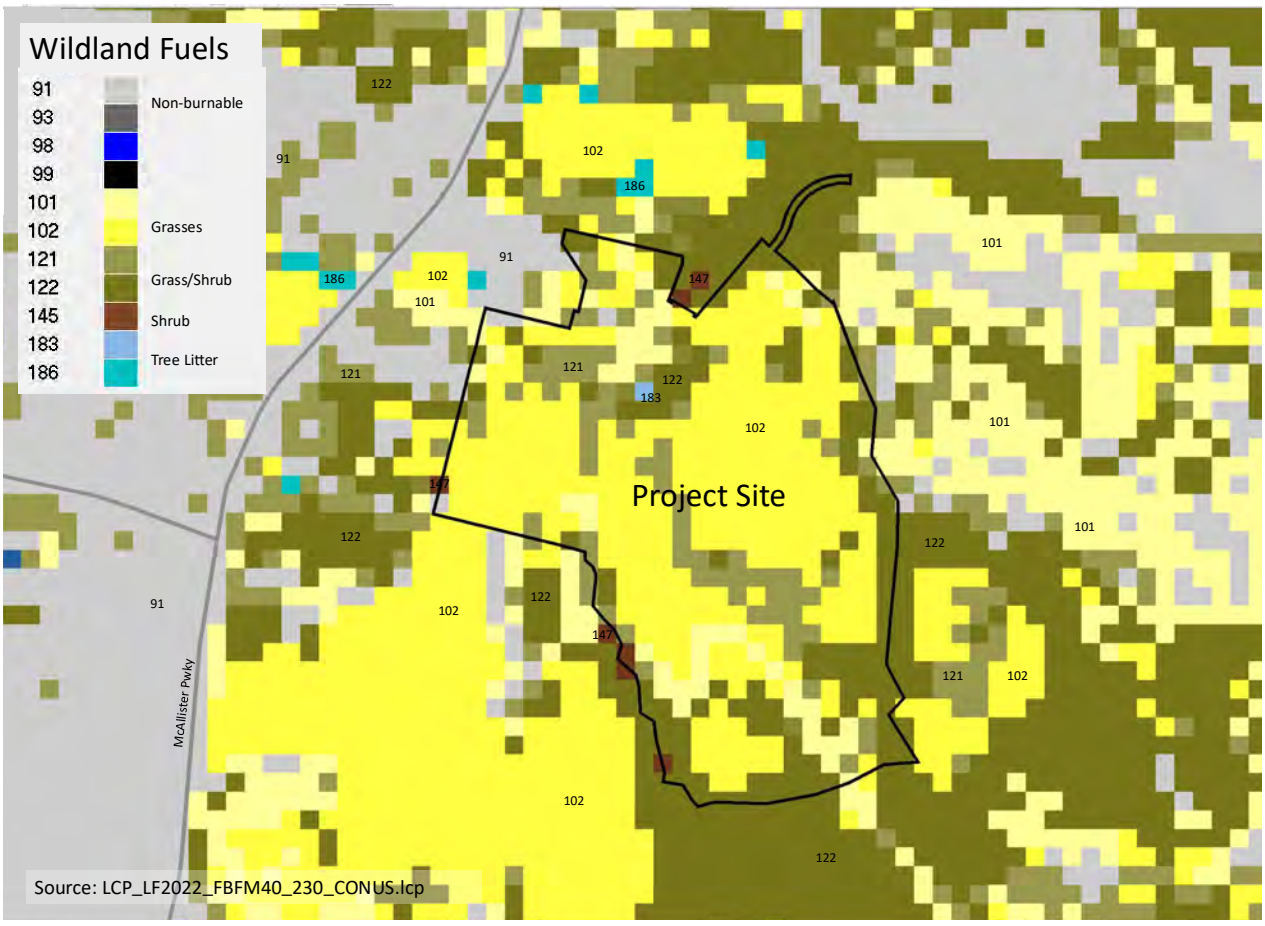


Figure 6 – Wildland Fuels Map – Landfire database

In Figure 6 (Wildland Fuels Map), the yellows are grasses (GR), the army greens are grass /scrub mixes (GS), the orange and brown are the scrub fuels (SH), and the blue/greens are the tree litter fuels (TL). It should be noted that only a few grids contain the SH5 (145) fuel designation, and they are all in the bottoms of the drainages.

As shown, the site is mostly grass and grass/shrub mixtures with smaller pockets of shrubs and trees as the predominant lifeform in the specific 30-meter grids shown in the graphic and used in the modeling software.

In addition to the models from the Landfire database, one custom Southern California fuel model will also be considered in the modeling:

Model SCAL18 is a southern California-specific model for coastal sage scrub and northern mixed chaparral with an average fuel depth of 3 feet. This has been used in place of the SH7 (147) as a more specific model in the worst-case scenario

Figure 7 indicates the existing vegetation class of wildland fuels as delineated by the Landfire database. In this graphic it is easier to see the difference between the grasslands, shrublands and tree canopy fuels. Figure 8, on the next page, provides the Existing Vegetation Types (EVT) as determined in the Landfire database for the EVT file.

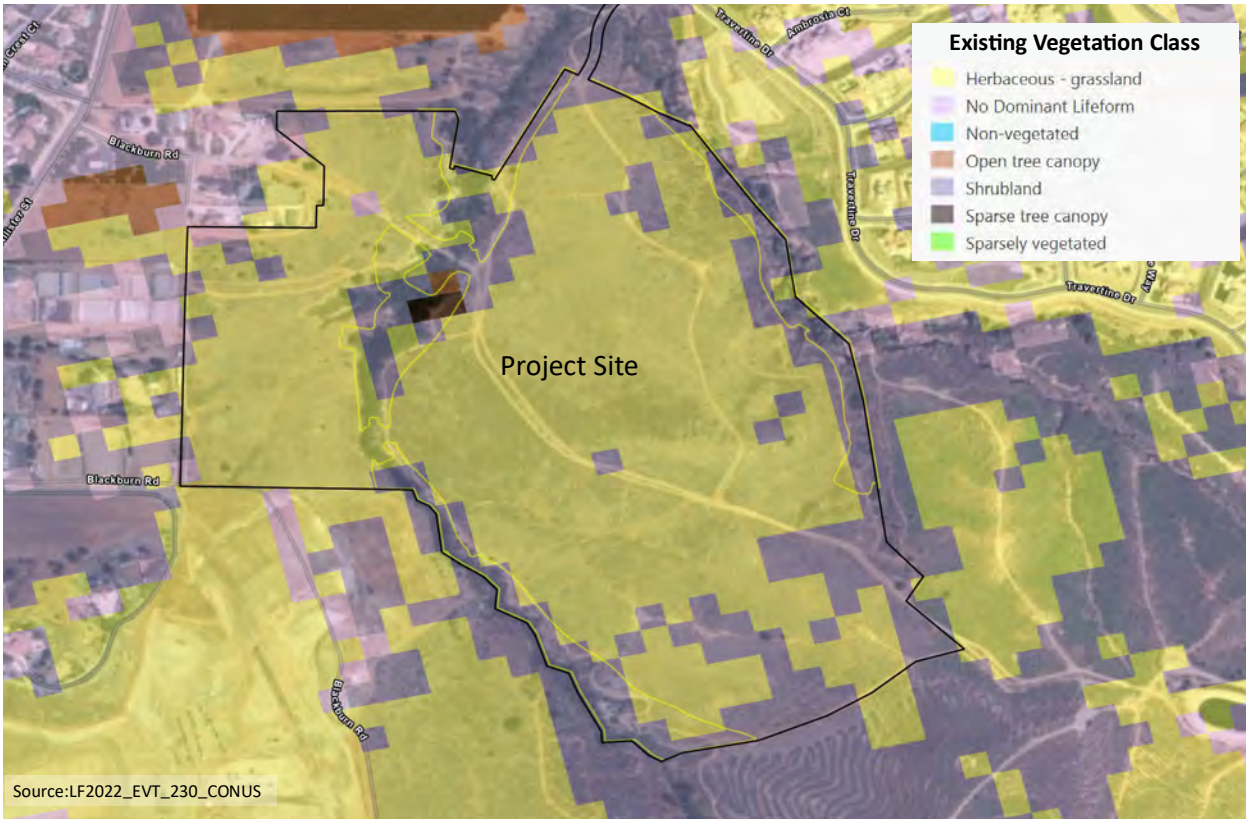


Figure 7 – Existing Vegetation Class – Landfire database

It should be noted that the areas to the northeast and southwest of the project site were and continue to be developed prior to the project site being developed. These adjacent developments have been superimposed on this area for reference (Figure 9). Citrus Heights (Northeast of Project Site) is completed, Lake Ranch has been graded, streets are in, and homes are being constructed.

The development of the area to the northeast has reduced the wildland interface between the two projects to a thin strip of riparian drainage that bisects the two projects. This is true to a lesser degree for the southwest project area, although a similar drainage exists to the west, southwest,

and south of the project site development area (mixed interface but still fragmented from a wildland fuel perspective).

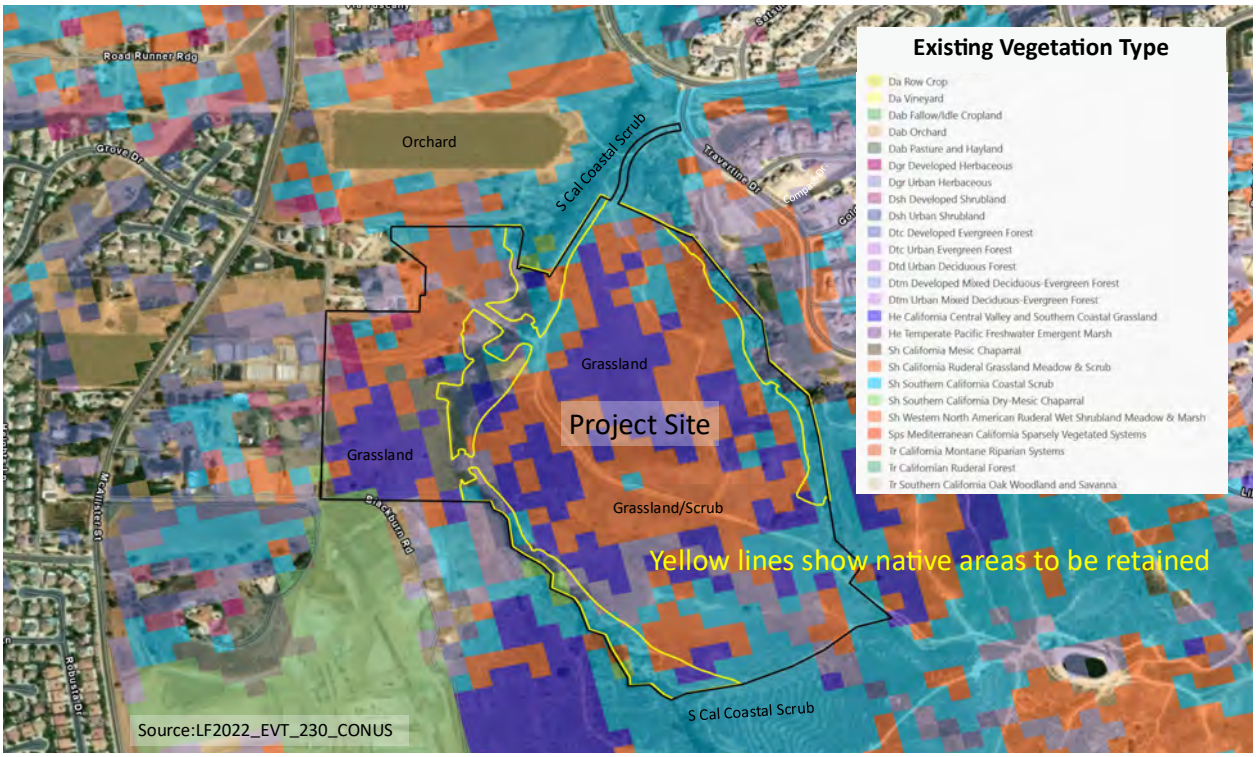


Figure 8 – Existing Vegetation Type– Landfire database



Figure 9 – Adjacent Communities Map

The new developments, El Sobrante Road, and the location of Lake Mathews combine to create a mosaic of fuel beds to the S, SW, and W of the Project Site. Large expansive runs of fuels are not as common and will continue to decline as more of the area is ultimately developed. The current conditions represent the worst-case scenario.

Fuels Summary

The predominant fuels in or near the project site are grasses, grass/scrub mixtures, and shrubs. At the bottom of each of the main drainages are willow trees, scrub, and nonnative vegetation, such as palm trees/ornamentals. Below and on the following pages, a series of photos are used to show the predominant vegetation on the site. More detailed photos are contained in Appendix B of this report. While all of the existing vegetation will be removed in the development areas, the drainages and areas adjacent to the project site to the north and east will be maintained as habitat/open space areas with little to no management of these areas other than the possible removal of nonnative species.

Photo 1 shows the typical interface with shrub fuels. Mostly, shrub fuels in this small pocket near the riparian to the south. This fuel type is limited to a few areas on the perimeter of the project site, with most of it being down within the drainage channel.



Photo 1 – Shrub Fuels

Fuels within the project site and adjacent to the project site are relatively sparse in most areas. Grasses will grow between the scrubs on wet years, but most years will have limited fine fuels to carry the fire from one group of scrubs to the next. Since the area has had no large fire history and little evidence is shown onsite of fire activity, it is safe to assume that this is the fuel configuration that will be present on the site.

Photo 2 shows the interface of the vast majority of the area around the project site. The area has been disked over time and maintained free of shrubs in most areas for some time. Currently this area is moderate grass and other herbaceous fuels. Much of the area is classified as either seasonal grasses or Southern California Coastal Scrub, with the possible development of a full SCAL18 fuel bed in periods where there is more rainfall.



Photo 2 – Grass and Grass/Shrub Fuels

Photo 3 (below) shows an example of the interface with the undeveloped project site and the existing fuel modification zones to the south (currently being installed). This portion of the project site will be fully graded and developed.



Photo 3 – Future Fuel Modification Zones (adjacent development)

Photo 4 (below) shows an example of an area of fuel on-site where the bottom of the drainages can have moderate to significant growth. These areas maintain their live fuel moisture year-round with urban runoff and other water sources. Exotic and invasive plants which are not native species will be removed from these areas.



Photo 4 – Drainage Fuels

The project site was photographed (Appendix A) and the wildland fuels were "groundtruthed" for accuracy. Most of the values were accurate with the exception of the 145 (SH5) which were not in the bottom of the drainages. Only a few grids have a 145 value and most of them are in the bottom of the drainage channels as indicated in Figure 10. Adjacent developments have been overlayed on the fuels map to indicate which of the fuel areas will remain after the grading and development have occurred.

No six-foot fuel beds were found on the slope areas or the flats. Figure 11 shows one specific area where the 145 was not present at the project site boundary, as shown in the database. This area is obviously not a SH5 fuel. As will be shown in the fire behavior section, SH5(145) and SCAL18 fuels produce similar flame lengths under similar wind conditions.

A SCAL18 fuel is more appropriate here, and that is what has been used for the Behave modeling.

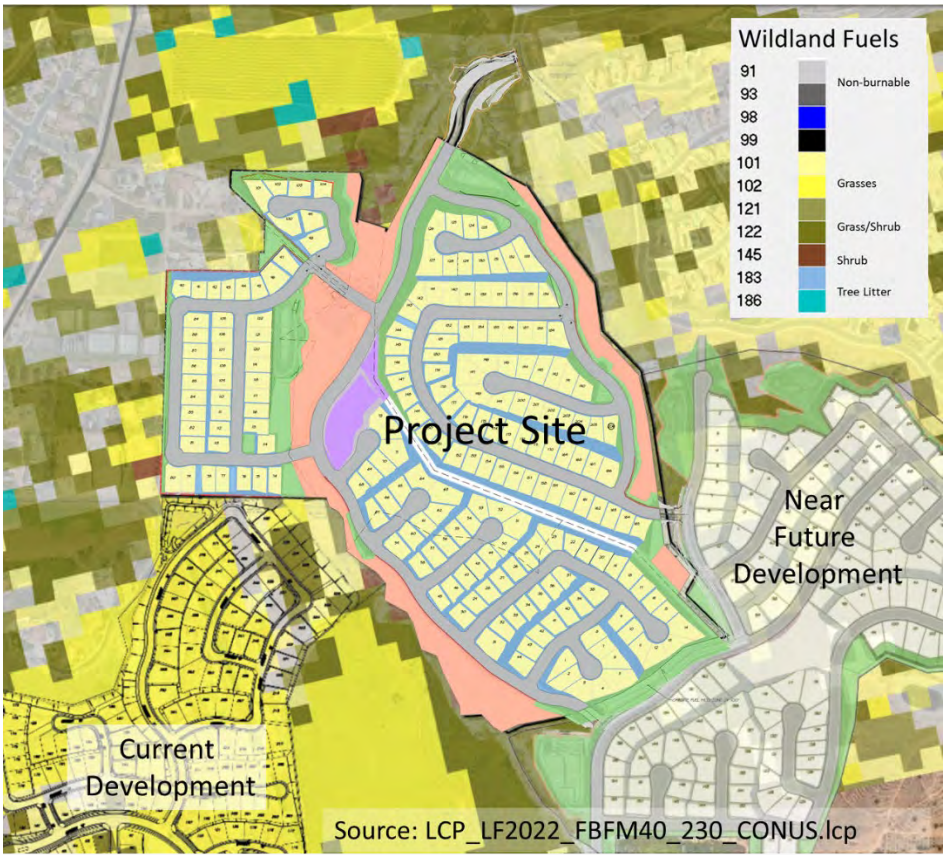


Figure 10 – Wildland Fuels with Development Overlayed

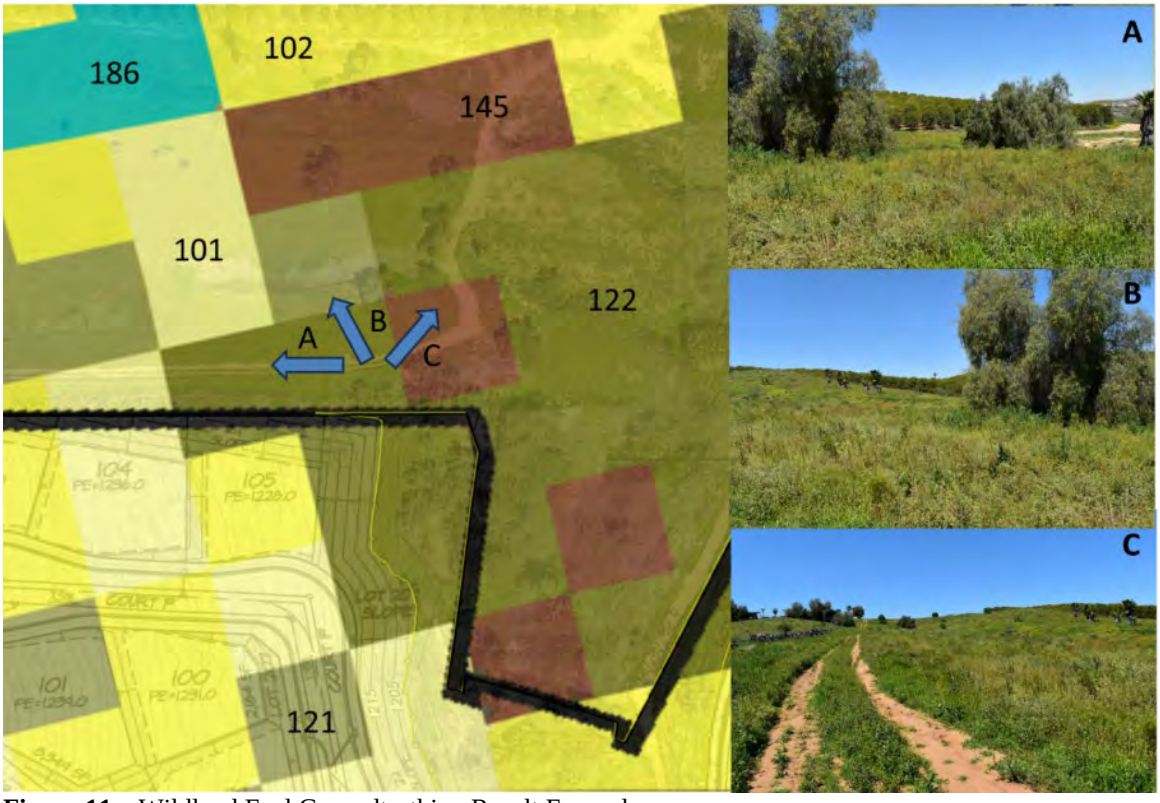


Figure 11 – Wildland Fuel Groundtruthing Result Example

Slope

Slope can influence the direction of travel, intensity, and rate of spread of a fire more than anything other than wind (within a given fuel type). The majority of the site interface with moderate fuel loading is the riparian drainage that runs on both sides (north and south) of the project site development area. For fire modeling purposes, the slope is averaged over 30-meter grids. Figure 12, on the next page, provides a graphic of the slope averages from the Landfire database. It should be noted that no areas within the graphic exceed 18% slope when averaged over the 30-meter grid. For the worst-case scenario, a slope of 50% will be used. Small areas of slope greater than 50% do exist on the banks of the riparian drainage but not in an amount sufficient enough to greatly impact fire behavior above the 50% impact being used for the modeling. Photo 4 above is a good example of this condition.

Aspect

Aspect is important, especially when it aligns with the fuel, wind, and slope. Figure 13 on the next page provides the slope aspects for the same 30-meter grids used in the slope and vegetation graphics. While there are areas where the aspect aligns with the wind, these areas are within the fuel modification zones and, as shown earlier in Slope Map (Figure 12), lack significant slope in the interface areas beyond the fuel modification zones, except in the riparian drainages. The limited slope (18%) reduces the overall impact of the aspect, as shaded areas on the northern faces are not created, and this does not produce conditions that increase fuel moisture due to the aspect.

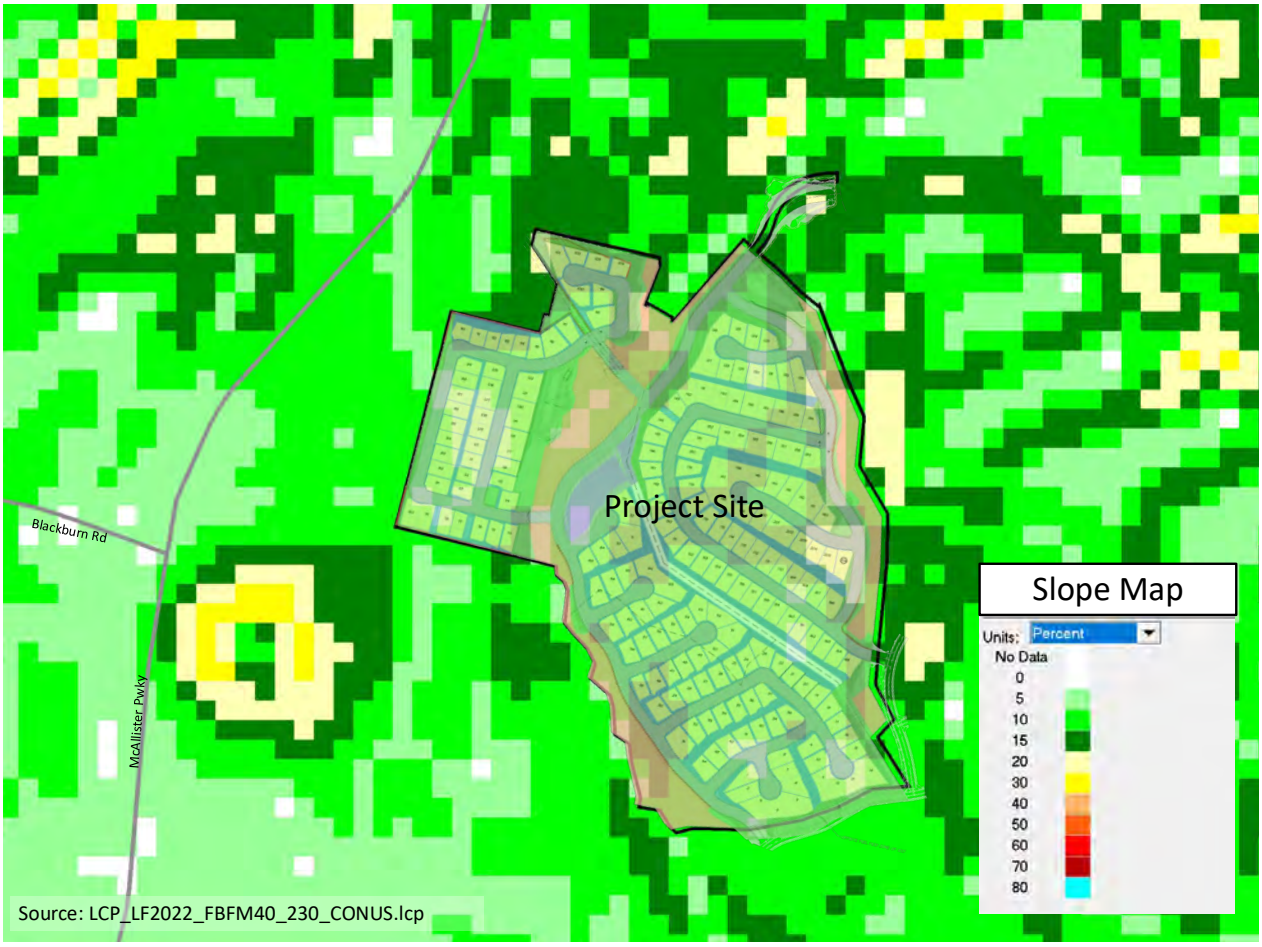


Figure 12 – Slope Map – Landfire database

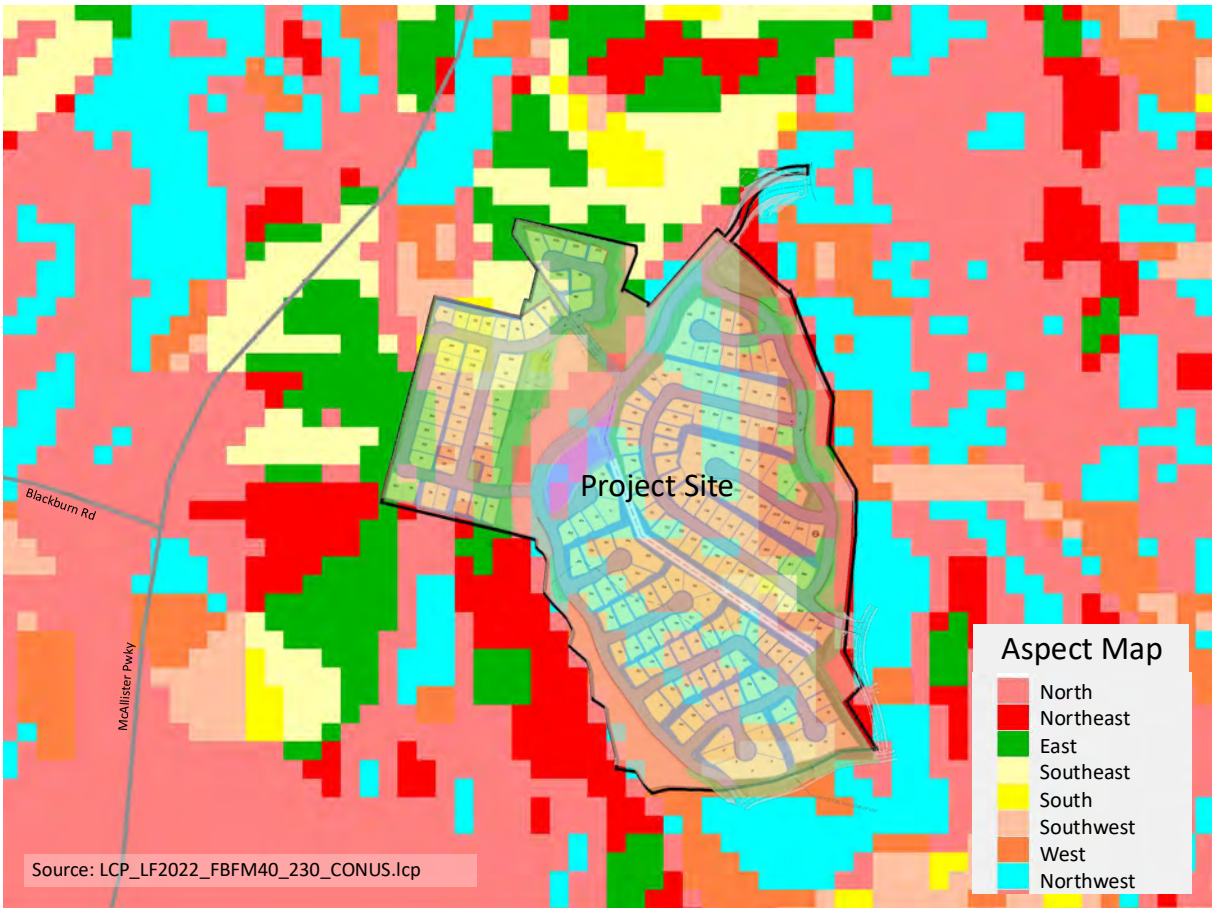


Figure 13 – Aspect Map - Landfire database

Wind Patterns and Weather Inputs

After a review of the local PWS (Private Weather Station) and RAWS (Remote Automated Weather Station) data, the most extreme wind patterns and speeds relating to wildfires were entered into the modeling programs (Behave and Wind Ninja). Lesser wind patterns and wind speeds normally produce less fire intensity based on a fire in wildland fuels and, as such, are not considered in the worst-case calculations.

Several PWS are available in the area of the project, but most have limited data. The closest PWS, with reliable data, is directly above the project site to the North of the project site (KCRIVER18). The site is 2.8 miles to the north.

The location is shown in Figure14. KCARIVER18 is actually not currently in service at the time of this report but historical data was available and has been used to illustrate some of the historical weather observations which are relevant to this analysis.

A summary graph (Figure 15) shows the predominant wind direction from the west at that location. The occasional Santa Ana Wind event brings a north or northeast wind. Note the higher wind gusts are associated with the east and northeast wind events. The maximum wind for the 7+year period shown was 27 mph with a 31-mph wind gust.

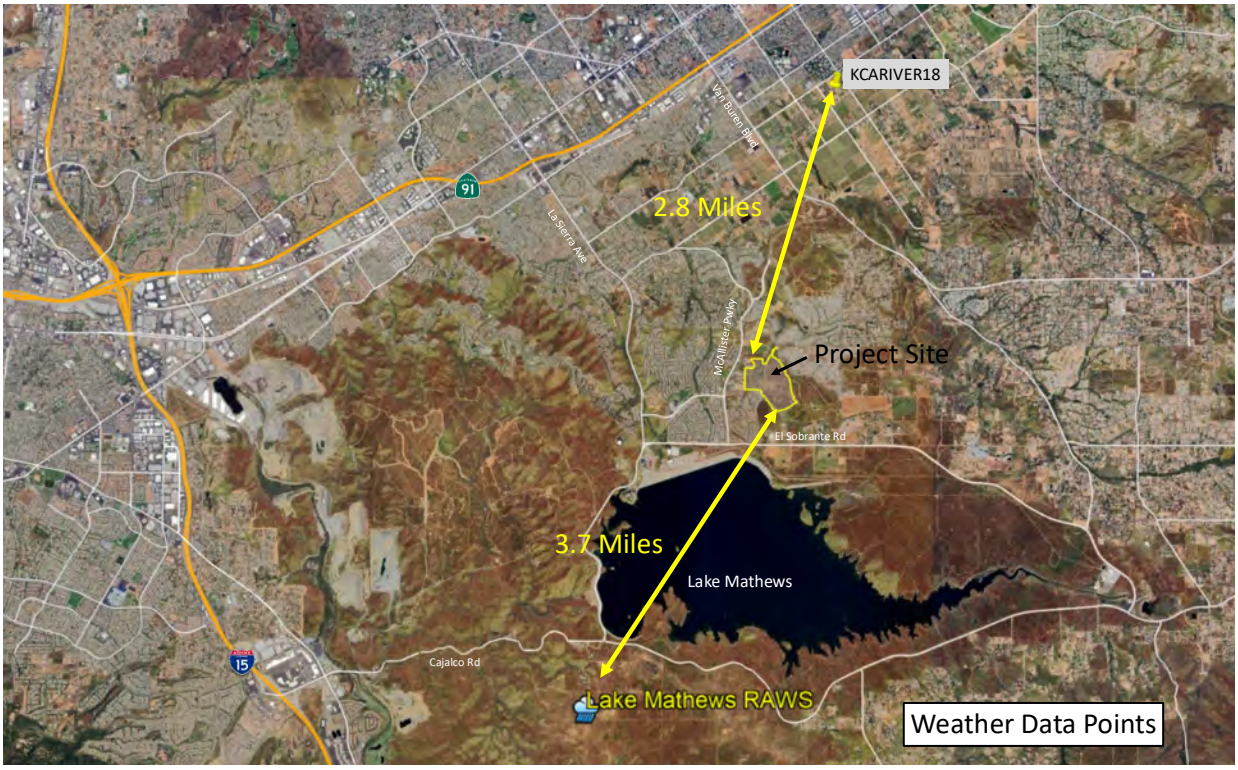


Figure 14 – Weather Data Location Map

The Lake Mathews RAWS is located 3.7 miles to the Southwest of the Project Site and has a large database. An 11-year period was used for the data analysis (Jan 2013 to Dec 2023). The results of that data analysis are provided in Figure 16 on the next page.

While the dataset shows a wind gust of 84 mph, it occurred only once in 11 years. Wind gusts greater than 50 mph occurred only seven times in this same period, which represents over 0.001% of the data points in the dataset. Sustained wind (Wind in this dataset) is the average wind speed of over two minutes, whereas wind gusts are a burst of wind that lasts less than 20 seconds.

When the wind data is analyzed by direction, it is clear that the stronger winds are from the N, NNE, and NE, as shown in Figure 17 and Figure 18. In Figure 17, the offshore wind is highlighted in light red, and the onshore flow is highlighted in yellow.

The predominant wind is from the NNW and NW (green highlighted in Figure 17). This is likely due to the influence of Temescal Canyon, which is west of the RAWS site.

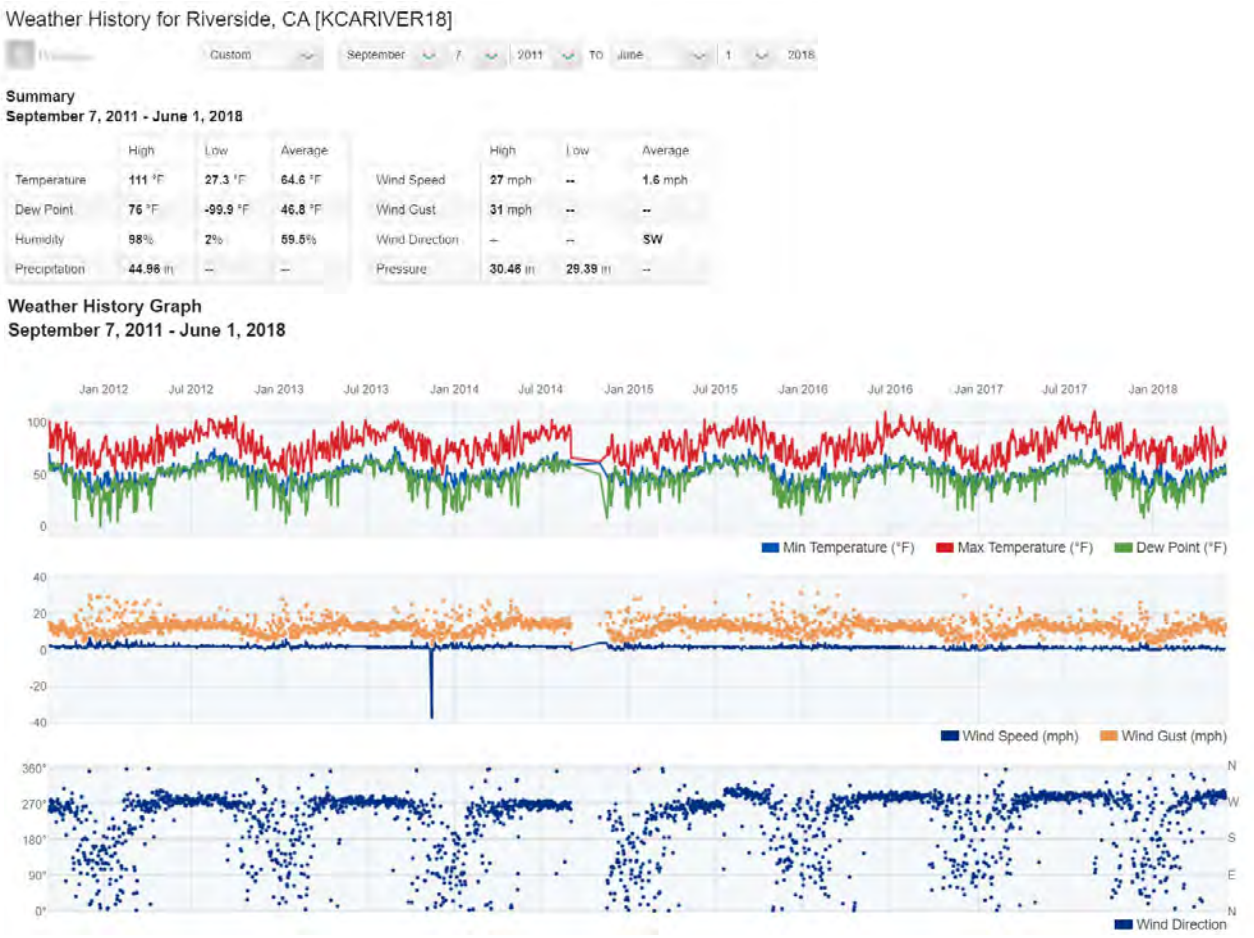


Figure 15 – PWS Data

Lake Mathews RAWS

	1/1/13 4:16	Start
STATION : MHEC1	12/31/23 3:16	End
STATION NAME: LAKE MATHEWS	4,016	Days
LATITUDE: 33.816940	11.0	Years
LONGITUDE: -117.463610		
ELEVATION [ft]: 1516.0	96,096	Data Points

	Temp	RH	Wind	Dir	Gust
Min	33	1	0.0	0.0	0.0
Max	114	100	50.0	360.0	84.0
Avg	66	53.4	6.1		11.0
99th	97	100.0	22.0		34.0
1st	42	7.0	0.0		3.0

Greater than	Wind		Gust	
90			-	
80			1	0.001%
70			1	0.001%
60			5	0.01%
50			33	0.03%
45	1	0.001%	94	0.1%
40	6	0.01%	319	0.3%
30	138	0.2%	1,762	1.8%
20	1,542	1.7%	11,250	11.8%
10	20,074	22.5%	44,425	46.4%
0	89,221		95,704	

Figure 16 - - Lake Mathews RAWS Data Summary

Lake Mathews RAWS										
				Wind Speed (mph)						
			Cardinal	<20	>20	>30	>40	>50	>60	>70
N	7,184	7.5%	N	7,059	125	9	1	-	-	-
NNE	7,197	7.5%	NNE	6,474	723	77	3	1	-	-
NE	5,679	5.9%	NE	5,527	152	19	2	-	-	-
ENE	5,661	5.9%	**ENE**	5,639	22	2	-	-	-	-
E	5,347	5.6%	**E**	5,303	44	9	-	-	-	-
ESE	3,266	3.4%	**ESE**	3,253	13	2	-	-	-	-
SE	3,580	3.7%	SE	3,551	29	1	-	-	-	-
SSE	5,637	5.9%	SSE	5,591	44	7	-	-	-	-
S	5,835	6.1%	S	5,815	20	3	-	-	-	-
SSW	2,290	2.4%	SSW	2,263	26	5	-	-	-	-
SW	1,558	1.6%	SW	1,532	26	1	-	-	-	-
WSW	1,877	2.0%	WSW	1,791	86	3	-	-	-	-
W	2,656	2.8%	**W**	2,571	85	-	-	-	-	-
WNW	5,923	6.2%	**WNW**	5,876	47	-	-	-	-	-
NW	12,821	13.3%	NW	12,764	57	-	-	-	-	-
NNW	14,259	14.8%	NNW	14,216	43	-	-	-	-	-
0	5,326	5.5%	**Null**	-	-	-	-	-	-	-
Blank	-	0.0%								
	96,096	100.0%		89,225	1,542	138	6	1	-	-
				92.85%	**1.60%**	**0.14%**	**0.01%**	**0.001%**		

Figure 17 - Lake Mathews RAWS Data Summary -Directional

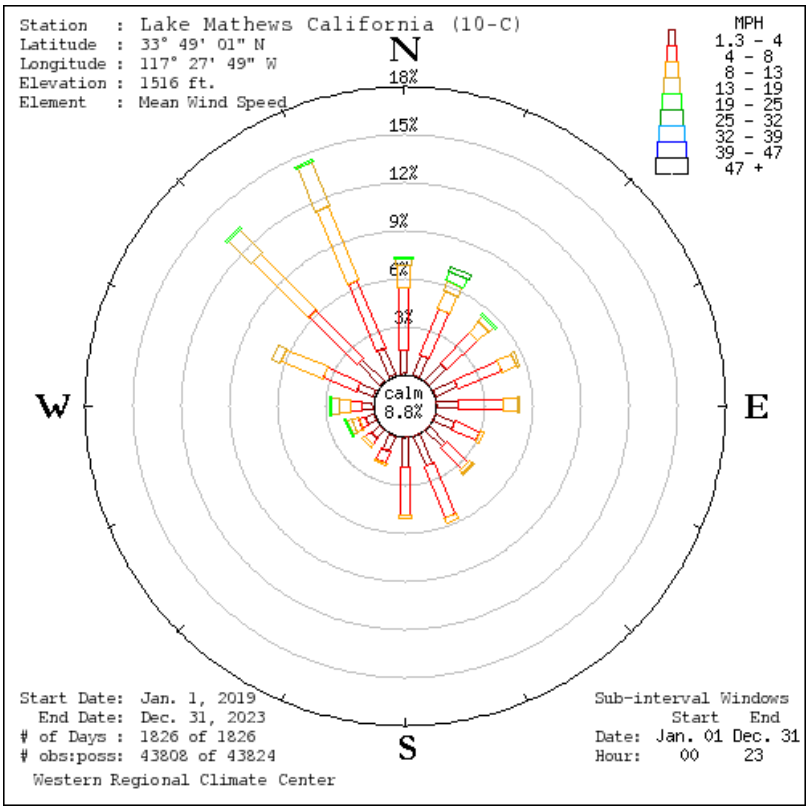


Figure 18 – Lake Mathews RAWS Wind Rose

Viewing the wind data by time of year (Figure 19), we see that the day/night patterns for the wind in the area of the project site are different in the fall. Wind from the NE increases, especially during the daytime period, as shown in Figure 19 on the next page. This is consistent with the stronger winds shown in Figure 17 above.

For the purposes of the modeling in this report to produce the worst-case scenario, offshore winds will be assumed to be 50 mph and the onshore winds 30 mph.

Lake Mathews California

Latitude : 33° 49' 01" N
Longitude : 117° 27' 49" W
Elevation : 1516 ft.
Element : Mean Wind Speed

Climate Data 2005 to 2015

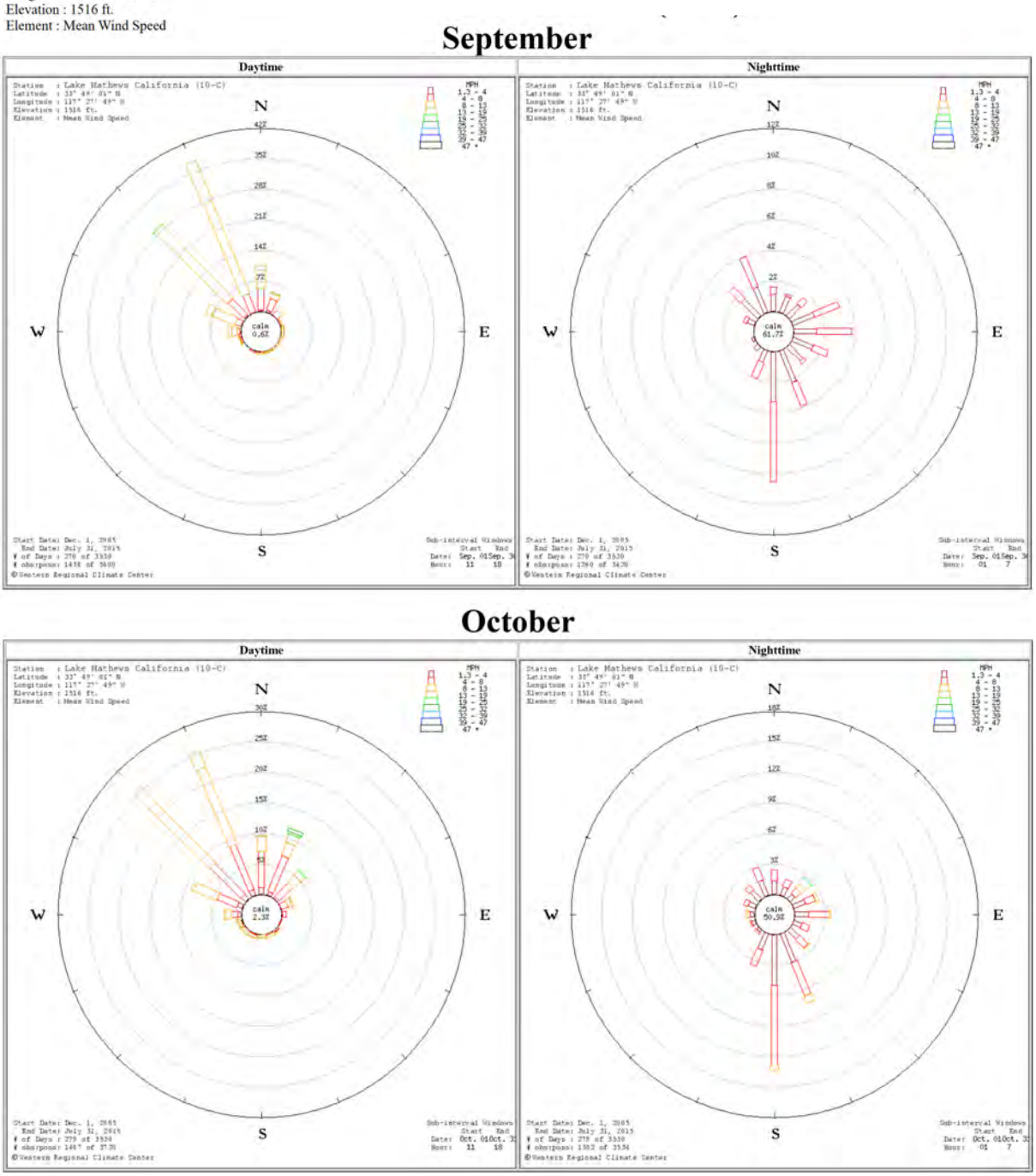


Figure 19 – Time Series Wind Direction 1

The four-month series shows the daytime/nighttime diurnal shift in wind flow and the increase in NE flow (NNE, NE, ENE) associated with the Santa Ana wind events that occur each fall (they can and do happen all year long but are most impactful in the fall). Stronger daytime winds during the daytime are very pronounced in the November/December timeframe at this location (for this ten-year period 2005-2015) and are consistent with the current winds data from the RAWS site.

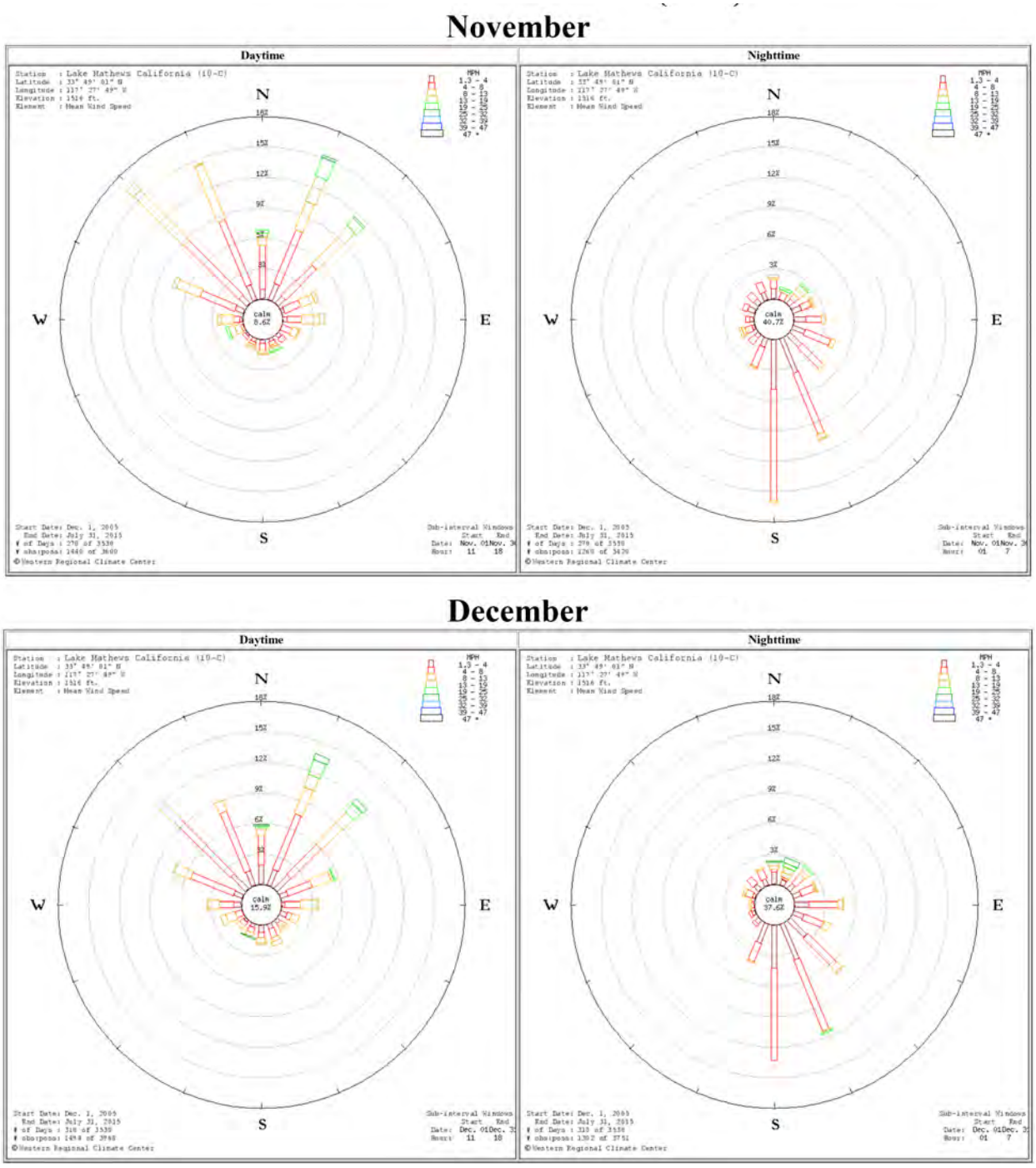


Figure 20– Time Series Wind Direction 2

Projecting these winds onto the topography is an essential step in the analysis of the potential impact on the project site. This has been accomplished using Wind Ninja software, downloaded from the US Forest Service site (Missoula Fire Sciences Laboratory at the Rocky Mountain Research Station (RMRS) within the Fire, Fuel, and Smoke Science (FFS) Program). Version 3.8.1 has been used for this report.

South Wind

The south wind is prominent in the nighttime periods of the database. The impacts on the project site are provided in Figure 21. Impact areas are primarily in the southeast interface. Wind acceleration occurs in the red areas of the Wind Ninja output (overlayed onto the project site). The blue areas are wind-sheltered (lower wind) and this occurs along the riparian drainage to the south for its entire length (interface). The topography does not channel the wind (change the direction) mostly due to the lack of significant changes in the elevation or large steep slope areas.

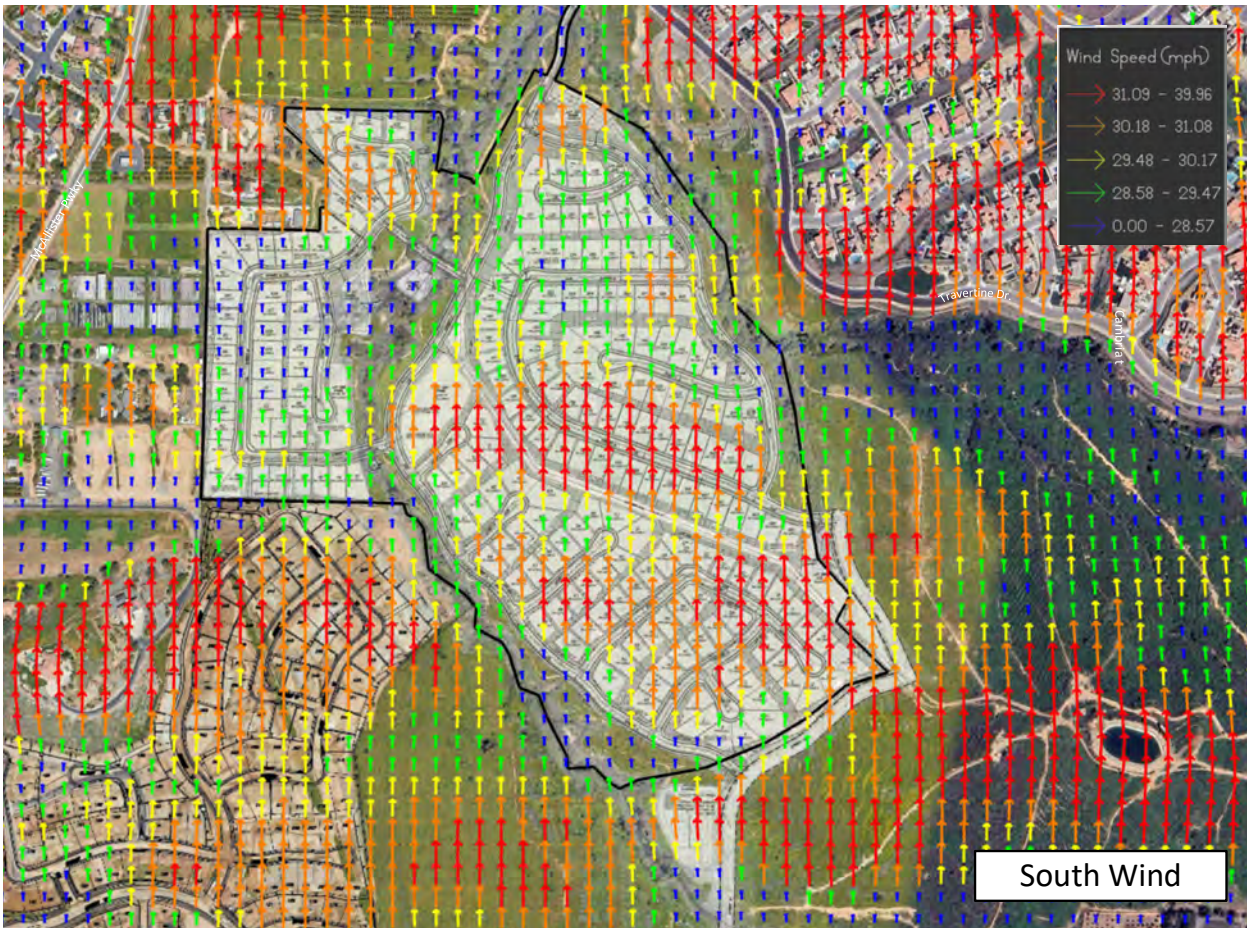


Figure 21 – South Wind

North Wind

The majority of the interface is wind-sheltered on the north side of the project (Figure 22). These riparian drainages are significantly lower than the adjacent areas in most of the interface. The development to the northeast is higher than the project site along the majority of the riparian drainage. The east end of this interface is flatter, and the wind is less sheltered at this point but most of this interface is or will be developed. This entire interface (northeast) abuts the fuel modification zones of the development to the north (Citrus Heights). The amount of wildland fuel in this interface is limited. The north wind takes fire away from the majority of the project site.

The north wind does run across the drainage to the north in a manner that intersects with a larger fuel bed. The area is wind sheltered but still bears potential for increased fire behavior.

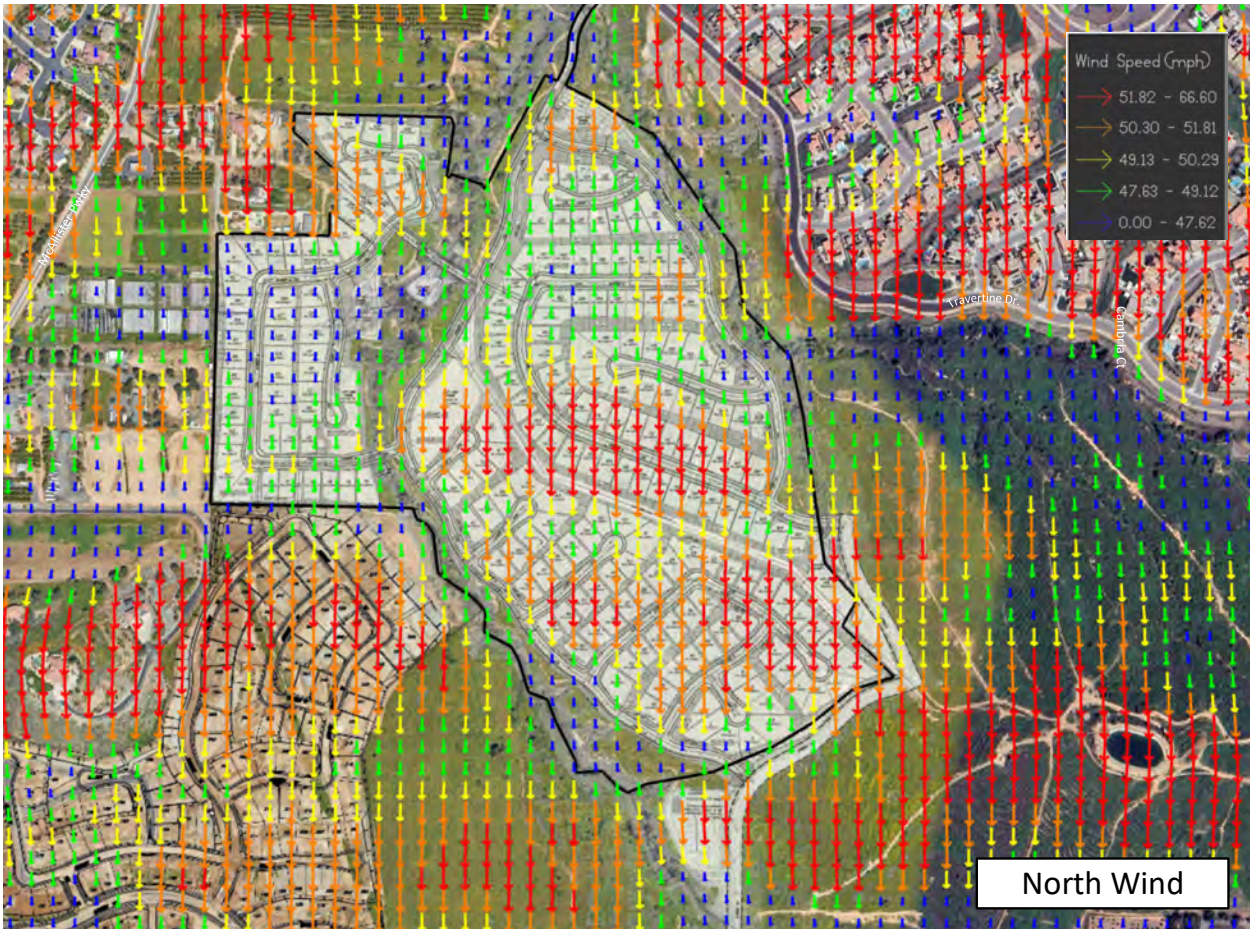


Figure 22 – North Wind

Northeast Wind

The northeast wind (Figure 23) also impacts the site mainly from the development area to the north and also has a large amount of wind sheltering along the riparian drainage for the same reasons as the north wind. The riparian area on the north (center of project site) has yellow arrows. While the wind is not accelerated, it is also not sheltered either. This area (entire drainage) is potentially the largest risk for the project site (Figure 24). This area is discussed in the fire behavior section of this report.

For the balance of the project site, the winds either take fire away from the side or run parallel to the project site structures. Impacts are lessened in this configuration. Santa Ana winds (hot and dry) will normally come from this direction.

These winds generally start from the north and move around to the ENE as they subside, with the NE flow being the strongest in most cases. The strongest winds measured at the Lake Mathews RAWS came from these Santa Ana conditions.

East Wind

East winds occur occasionally and are likely at the end of a Santa Ana wind event. These winds do not tend to be problematic for the project site as they either come from existing fuel modification areas or areas of low to moderated wildland fuels, as shown in Figure 25.

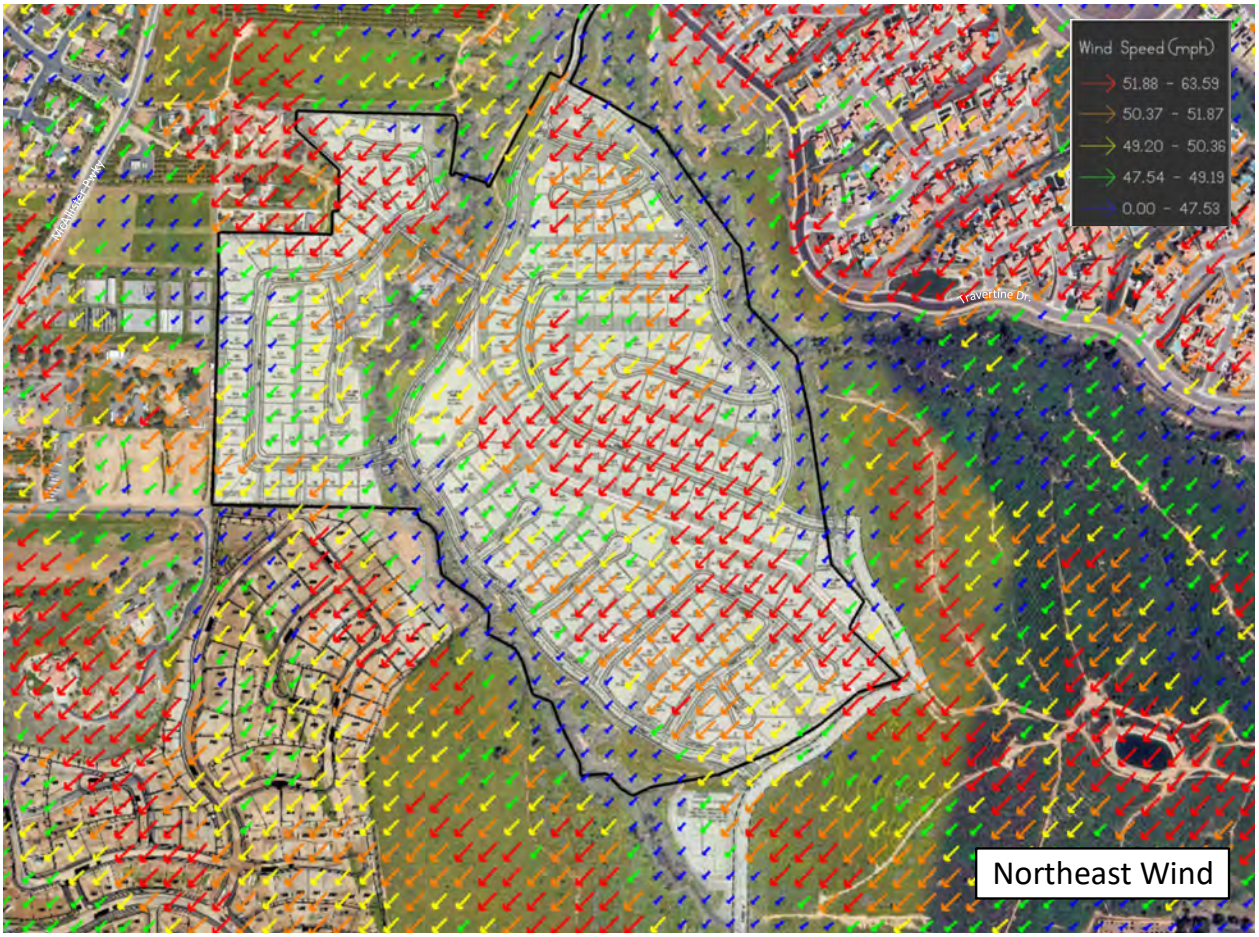


Figure 23 – Northeast Wind

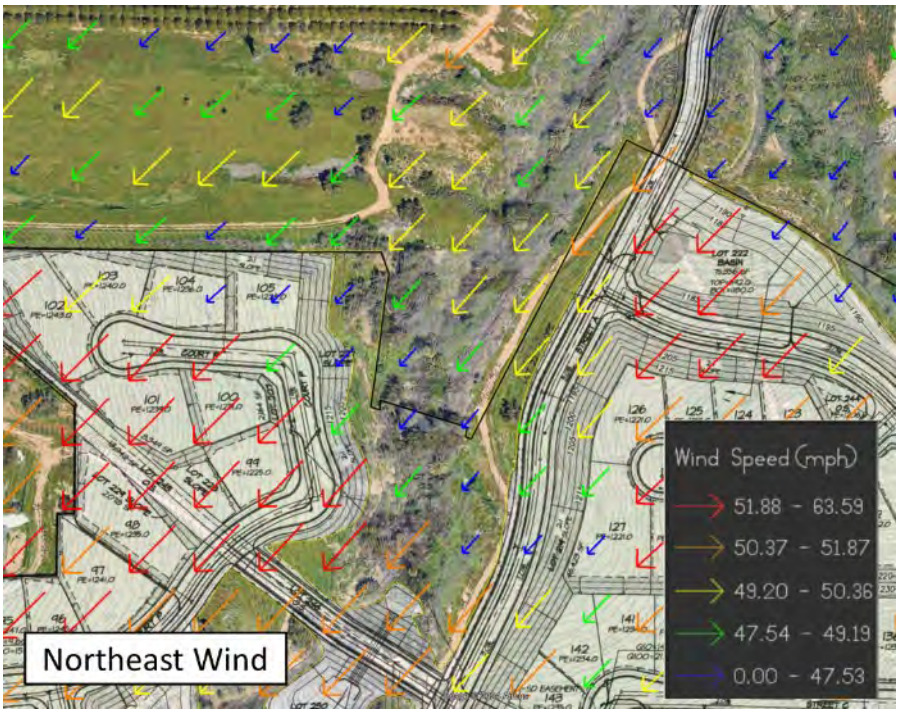


Figure 24 - Northeast Wind Impact Area

Much of the interface that has the denser fuel loading is wind-sheltered by the drainage itself or by the adjacent topography. To the north and northeast, the existing development (Citrus Heights) presents both a wind obstruction and a fuel break to the riparian interface that will remain. To the east and southeast, the future development will remove most of the wildland fuels in this interface. This provides a condition where a fire cannot burn into the project site from that direction as a "line of fire" as the fuels simply do not exist. A fire in this area must originate from an ember or brand and then progress in size as the fuels are available. This is covered in more detail in the next section. The impact of the topography (drainages) is readily apparent on the perimeter of the project site in this graphic (blue arrows).

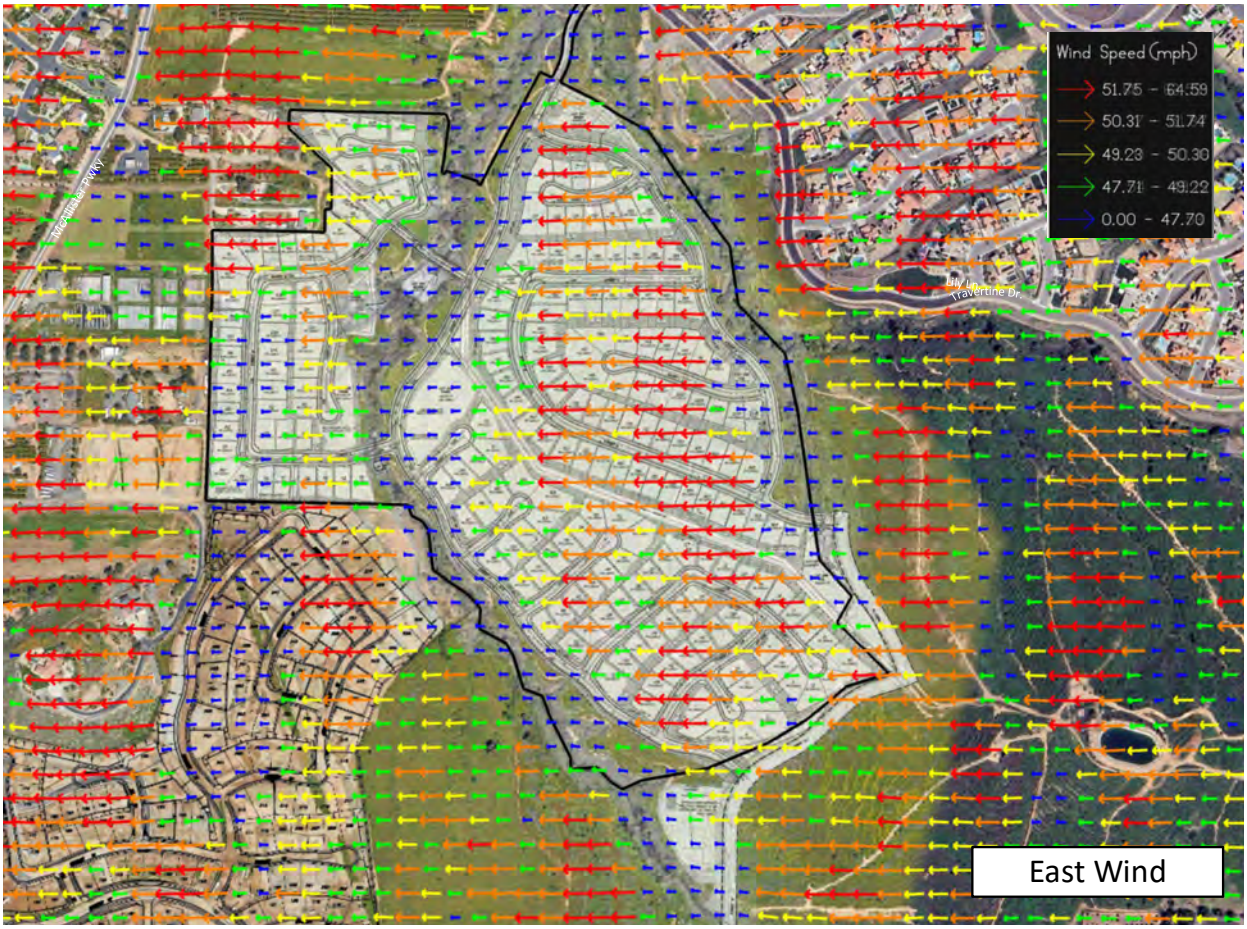


Figure 25 – East Wind

BehavePlus Fire Behavior Inputs and Results:

Inputs for the Behave Plus Fire Behavior Model were as follows:

Moisture scenarios used are extreme. One-hour fuels at 3%, ten-hour at 4% and hundred-hour at 5%. Herbaceous live fuels are modeled at fully cured (30%) and woody fuels at 50%. Model runs have been completed on the two wind scenarios.

Behave runs have been completed for the NE Santa Ana wind and the onshore W wind. The moisture scenarios are unchanged to simulate the rear dry onshore that can occur when the Santa Ana winds break down, and on-shore, flow is resumed, but the air immediately offshore is the dry air that has been pushed out to sea by the NE wind event. This condition is rare and only lasts for

a short period of time as the air further out to sea, will have increased moisture level when then return to the land by the onshore breeze. The inputs for the Behave runs are shown below (Figure 26).

The Behave outputs are attached in Appendix B but have been summarized here for discussion purposes (Figure 27).

Inputs: SURFACE

Input Variables		Units	Input Value(s)
Fuel/Vegetation, Surface/Understory			
	Fuel Model		gr2, gs2, sh2, scal18, tl6
Fuel Moisture			
	1-h Fuel Moisture	%	3
	10-h Fuel Moisture	%	4
	100-h Fuel Moisture	%	5
	Live Herbaceous Fuel Moisture	%	30
	Live Woody Fuel Moisture	%	50
Weather			
	20-ft Wind Speed	mi/h	30/50
	Wind Adjustment Factor		0.4
	Wind Direction (from north)	deg	225/45
Terrain			
	Slope Steepness	%	50
	Site Aspect	deg	225/45
Fire			
	Surface Fire Spread Direction (from north)	deg	0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, 180, 195, 210, 225, 240, 255, 270, 285, 300, 315, 330, 345, 360

Figure 26 – ***Behave Input Values***

Using the "Spread from Fire Perimeter" configuration for the modeling, it is possible to see how each portion of the fire line will be impacted by the wind and slope of the scenario provided. The fire has been modeled running directly uphill in alignment with the wind and slope. As expected, the head fires at 225 degrees (fire is from 45 degrees), and the maximum outputs are found.

As shown in Figure 27 and in Appendix B, in the grass/shrub mixtures (gs2) the maximum flame length under these conditions is 19.2 feet, while in the SCAL18 fuels, the maximum flame length is nearly twice that (39.4 feet). The SCAL18 fuel has more readily available fine fuels, dramatically increasing the flame production. The project site has little to fuel bed of six feet or greater (sh5 or sh7) and certainly none in large continuous fuel beds. The worst-case scenario has been completed using the SCAL18 fuels for this reason.

It should be noted that the Landfire database found only small pockets of shrub fuels (145 and 147), and these were all in or adjacent to the various riparian drainages around the project

perimeter. The Landfire database concluded that the project and most of its interface a gs2 (122) due to the short height of the fuels. The site visit confirmed this conclusion but also found conditions where SCAL18 is either currently being established or is likely to be established in the future if mitigation is not undertaken to prevent that from occurring. This analysis will assume the SCAL18 hazard is present in the worst-case scenario.

Willow Creek NE 50 mph
Spread from Fire Perimeter
Surface Fire Flame Length (ft)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh5	SCAL18	tl6
0	2.0	2.2	4.9	4.4	1.0
15	1.8	2.0	4.5	4.0	0.9
30	1.7	1.9	4.2	3.8	0.9
45	1.7	1.9	4.2	3.8	0.9
60	1.7	1.9	4.2	3.8	0.9
75	1.8	2.0	4.5	4.0	0.9
90	2.0	2.2	4.9	4.4	1.0
105	2.3	2.6	5.7	5.1	1.2
120	2.9	3.4	7.5	6.8	1.5
135	4.4	6.1	13.3	12.2	2.7
150	6.7	10.7	23.7	21.9	4.8
165	8.6	14.1	31.2	28.9	6.3
180	9.9	16.4	36.4	33.7	7.4
195	10.9	18.0	39.8	37.0	8.1
210	11.4	18.9	41.9	38.8	8.5
225	11.6	19.2	42.5	39.4	8.6
240	11.4	18.9	41.9	38.8	8.5
255	10.9	18.0	39.8	37.0	8.1
270	9.9	16.4	36.4	33.7	7.4
285	8.6	14.1	31.2	28.9	6.3
300	6.7	10.7	23.7	21.9	4.8
315	4.4	6.1	13.3	12.2	2.7
330	2.9	3.4	7.5	6.8	1.5
345	2.3	2.6	5.7	5.1	1.2
360	2.0	2.2	4.9	4.4	1.0

Willow Creek SW 30 mph
Spread from Fire Perimeter
Surface Fire Flame Length (ft)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh5	SCAL18	tl6
0	9.9	12.0	28.3	27.9	5.4
15	10.9	13.2	30.9	30.5	5.9
30	11.4	13.8	32.5	32.0	6.2
45	11.6	14.0	33.0	32.5	6.3
60	11.4	13.8	32.5	32.0	6.2
75	10.9	13.2	30.9	30.5	5.9
90	9.9	12.0	28.3	27.9	5.4
105	8.6	10.4	24.4	24.1	4.6
120	6.7	8.1	19.0	18.7	3.6
135	4.4	5.3	12.3	12.0	2.4
150	2.9	3.5	8.0	7.7	1.5
165	2.3	2.7	6.2	6.0	1.2
180	2.0	2.3	5.4	5.1	1.0
195	1.8	2.1	4.9	4.7	0.9
210	1.7	2.0	4.7	4.5	0.9
225	1.7	2.0	4.6	4.4	0.9
240	1.7	2.0	4.7	4.5	0.9
255	1.8	2.1	4.9	4.7	0.9
270	2.0	2.3	5.4	5.1	1.0
285	2.3	2.7	6.2	6.0	1.2
300	2.9	3.5	8.0	7.7	1.5
315	4.4	5.3	12.3	12.0	2.4
330	6.7	8.1	19.0	18.7	3.6
345	8.6	10.4	24.4	24.1	4.6
360	9.9	12.0	28.3	27.9	5.4

Figure 27 – Behave Results Summary

The NE wind at 50 mph results in a significant spread across the entire leading head of the fire as shown by the graphic below.

As shown on the charts and graphisc in Figure 27 and Figure 28, the calculated flame lengths for each of the directions of spread for the worst-case scenarios modeled produce a long, narrow fire pattern. We find that a maximum flame length of 39.4 feet is possible at the head of the fire when the fire is running directly upslope with a continuous fuel bed that is consistent enough to produce a self-sustaining, self-propagating fire. It is important to note that flames up to 45 degrees out of the perfect alignment of all the factors are still significant. Flanking and backing fire are significantly reduced, with only the backing fire capable of suppression with hand tools and hose lines.

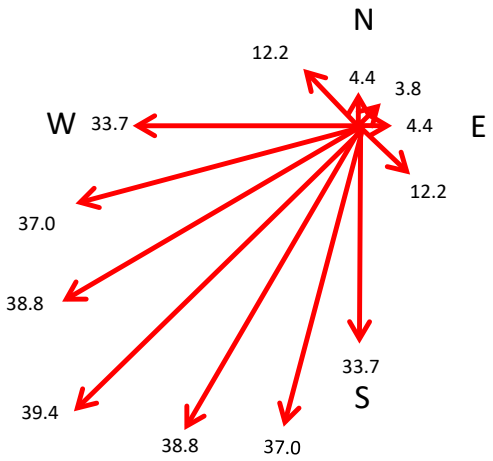


Figure 28 – Fire Direction Ellipse

The example shown is a 50-mph wind running upslope (50% slope) in full alignment with the wind, topography, and fuels using a SCAL18 fuel model. These outputs assume that the fire is burning at full equilibrium and that the worst-case factors are constant and continuous as the fire moves into the development area. Similar relationships exist between the rate of spread and the fireline intensity.

The general defensible space requirements have been based on the northeast winds and have resulted in the need for 80-foot fuel modification areas adjacent to the SCAL18 fuels. Still, these are reduced to 50 for the sh2 and gs2 fuels (16.0/19.2-foot maximum flame length respectively). Grass-only interfaces are not currently present in large areas and are unlikely to be present in the future as the interface pushes out to the riparian areas. Most of the interface areas will be on slopes. A grass-only interface is not a recommendation that can be made from the modeling and factors found in this report.

Results for the 30 mph west or southwest winds (onshore) are similar, but flame lengths are slightly less. The SCAL18 maximum is 32.5 (requiring a 65-foot fuel modification area from the onshore wind), the sh2 is 11.9, and the gs2 is 14.0. This report does not recommend a distance less than 50 feet, regardless of the modeling results, unless a physical barrier is provided to shield the subject lot from the radiant heat of a fire in the native fuels. This will be covered in more detail in the location-specific discussion later in this report.

Application of Findings

The subsequent analysis in the determination of the fire hazard profile is to examine the potential for a fire within the interface to damage or ignite a structure within the Project Site. This can happen in one of four ways. First is direct contact with the fire. The maximum flame length is 40 feet (39.4 feet). Any distance greater than this will keep the flames off of the structure. Second is radiant heat. The laws of physics indicate that the decay of radiant heat is calculated by dividing the energy produced by the square of the distance from the heat source. While this is simplified, it is overall very accurate.

The NFPA Fire Protection Research Foundation published a report entitled *Pathways for Building Fire Spread at the Wildland Urban Interface,* in 2015. The work was done by staff at the University of Maryland. The report states:

> *The first is radiant exposure. Unlike convection heat transfer, which requires a moving fluid medium, radiation can travel relatively undeterred until impeded by a solid object, typically thought of here as the exterior of a home, which may potentially ignite. As the separation distance from the home to the fire increases, the radiant exposure significantly decreases (**proportional to one over the distance squared**), eventually making it impossible at some distance to ignite. This analysis is often used for the assessment of safe separation distances between structures and potential fuels.*
>
> Michael J. Gollner, Raquel Hakes, Sara Caton, and Kyle Kohler, *Pathways for Building Fire Spread at the Wildland Urban Interface, Final Report*, prepared by: Department of Fire Protection Engineering, University of Maryland, Published by Fire Protection Research Foundation/NFPA March 2015, Page 26

In Figure 29, this principle has been applied to the heat generated by the worst-case fire scenarios. In this matrix, the remaining energy at specific distances is provided in the colored boxes. Green boxes have an energy level at or below 10 kW/m^2 (generally considered safe for hardened structures) and those in the red boxes are more than 20 kW/m^2 (the level at which structures may ignite with extended exposure). Figure 30 provides a chart to show the impacts of selected energy rates.

It cannot be understated that this applies to structure and not to people. While a structure could take a radiant heat rate of 20 kW/m^2, and not ignite for over five minutes, at 18 kW/m^2, 50% of the people exposed to this rate will die after 30 seconds. At 12.5 kW/m^2, this level of heat will produce second-degree burns in 8 seconds but will take 20 minutes to ignite exposed wood.

Jack Cohen's Structural Ignition Assessment Model (SIAM) also provided data on radiant heat flux as a factor of the amount of time for which the exposure to radiant heat impacted the ignition of the building material. In the example shown in Figure 31, as the temperature decreases, the time to ignition increases dramatically.

For reference, it should be noted again that the same level of radiant heat (16 kW/m^2) that will produce 2nd degree burns on exposed skin in five seconds requires 27 minutes to ignite a wood wall in Jack Cohen's testing of radiant heat flux. This is about time and distance. The values shown in Figure 32 (Table 1 from Cohen's report) show the various heat flux values that have been used as thresholds for many of the fire safety zone studies and radiant heat studies on structures. These come from *Modeling Potential Structure Ignitions from Flame Radiation Exposure with Implications for Wildland/Urban Interface Fire Management*, by Jack D. Cohen and Bret W. Butler, presented at the13th Fire and Forest Meteorology 81 Conference. Lorne, Australia 1996 and are in line with the values used from several sources to produce Figure 32.

	Fuel Model	gs2			Distance to Fire (ft)																				
		Fireline																							
20-ft Wind	Flame	Intensity	Flame		Flame	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
Wind	Length (ft)	(kW/m^2)	Angle		Height	100	225	400	625	900	1225	1600	2025	2500	3025	3600	4225	4900	5625	6400	7225
0	5.1	677	90	1.000000	5.1	7	3	2	1	1	1	0	0	0	0	0	0	0	0	0	0
10	7.9	1,775	30	0.500000	4.0	18	8	4	3	2	1	1	1	1	0	0	0	0	0	0	0
20	11.1	3,692	15	0.258819	2.9	37	16	9	6	4	3	2	2	1	1	1	1	1	1	1	1
30	14.0	6,122	10	0.173648	2.4	61	27	15	10	7	5	4	3	2	2	2	1	1	1	1	1
40	16.7	8,960	10	0.173648	2.9	90	40	22	14	10	7	6	4	4	3	2	2	2	2	1	1
50	19.2	12,145	10	0.173648	3.3	121	54	30	19	13	10	8	6	5	4	3	3	2	2	2	2
3, 4, 5, 30, 50 moisture scenario, 0.5 wind adjustment, 50% slope																					

	Fuel Model	sh5			Distance to Fire (ft)																				
		Fireline																							
20-ft Wind	Flame	Intensity	Flame		Flame	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
Wind	Length (ft)	(kW/m^2)	Angle		Height	100	225	400	625	900	1225	1600	2025	2500	3025	3600	4225	4900	5625	6400	7225
0	12.2	4,557	90	1.000000	12.2	46	20	11	7	5	4	3	2	2	2	1	1	1	1	1	1
10	20.5	13,956	30	0.500000	10.3	140	62	35	22	16	11	9	7	6	5	4	3	3	2	2	2
20	27.3	25,983	15	0.258819	7.1	260	115	65	42	29	21	16	13	10	9	7	6	5	5	4	4
30	33.0	39,251	10	0.173648	5.7	393	174	98	63	44	32	25	19	16	13	11	9	8	7	6	5
40	38.0	53,397	10	0.173648	6.6	534	237	133	85	59	44	33	26	21	18	15	13	11	9	8	7
50	42.5	68,233	10	0.173648	7.4	682	303	171	109	76	56	43	34	27	23	19	16	14	12	11	9
3, 4, 5, 30, 50 moisture scenario, 0.5 wind adjustment, 50% slope																					

	Fuel Model	SCAL18			Distance to Fire (ft)																				
		Fireline																							
20-ft Wind	Flame	Intensity	Flame		Flame	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
Wind	Length (ft)	(kW/m^2)	Angle		Height	100	225	400	625	900	1225	1600	2025	2500	3025	3600	4225	4900	5625	6400	7225
0	13.1	5,314	90	1.000000	13.1	53	24	13	9	6	4	3	3	2	2	1	1	1	1	1	1
10	22.6	17,212	30	0.500000	11.3	172	76	43	28	19	14	11	8	7	6	5	4	4	3	3	2
20	28.2	27,891	15	0.258819	7.3	279	124	70	45	31	23	17	14	11	9	8	7	6	5	4	4
30	32.5	38,152	10	0.173648	5.6	382	170	95	61	42	31	24	19	15	13	11	9	8	7	6	5
40	36.2	48,152	10	0.173648	6.3	482	214	120	77	54	39	30	24	19	16	13	11	10	9	8	7
50	39.4	57,962	10	0.173648	6.8	580	258	145	93	64	47	36	29	23	19	16	14	12	10	9	8
3, 4, 5, 30, 50 moisture scenario, 0.5 wind adjustment, 50% slope																					

	Fuel Model	tu6			Distance to Fire (ft)																				
		Fireline																							
20-ft Wind	Flame	Intensity	Flame		Flame	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
Wind	Length (ft)	(kW/m^2)	Angle		Height	100	225	400	625	900	1225	1600	2025	2500	3025	3600	4225	4900	5625	6400	7225
0	2.5	141	90	1.000000	2.5	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	3.6	317	30	0.500000	1.8	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
20	5.0	641	15	0.258819	1.3	6	3	2	1	1	1	0	0	0	0	0	0	0	0	0	0
30	6.3	1,062	10	0.173648	1.1	11	5	3	2	1	1	1	1	0	0	0	0	0	0	0	0
40	7.5	1,561	10	0.173648	1.3	16	7	4	2	2	1	1	1	1	1	0	0	0	0	0	0
50	8.6	2,127	10	0.173648	1.5	21	9	5	3	2	2	1	1	1	1	1	1	0	0	0	0
3, 4, 5, 30, 50 moisture scenario, 0.5 wind adjustment, 50% slope																					

Figure 29 – Heat Decay Matrix

In the test fires that Jack Cohen used for this study, a fire that was 2.5-meter-wide, and 20 meters high was used to show the impacts on radiant heat flux of spacing within the fuel bed. All four burn scenarios had radiant heat flux values of 20 kW/m^2 or less at a distance of 40 meters (2 times the flame height), as shown in Figure 33.

The conclusion Jack Cohen reached was that after 40 meters, radiant heat was no longer a problem, regardless of the size of the fire. At 30 meters and about 30 kW/m^2, the ignition time was only 90 seconds, but at 40 meters and 20kW/m^2, the ignition time was over 800 seconds. In this test, the flame was 20m high and 50m wide. The 2x flame length ratio was achieved in this test fire as well. See Figure 34 for a graphic example of this conclusion.

Btu/s/ft²	kW/m²	Time to Ignition		
Rate	Rate	seconds	minutes	
17.3	60	10	0.17	
14.4	50	16	0.27	
11.6	40	28	0.47	
10.7	37			Damage to process equipment and collapse of mechanical structures
9.0	31	60	1.00	
8.7	30	66	1.10	
6.4	22	210	3.50	
5.8	20	337	5.50	Piloted wood ignition after 5.5 minutes
5.2	18			Death in 50% of victims after 30 seconds
4.6	16			Blistering of exposed skin after 5 seconds
3.6	12.5	1,200	20.00	20 minutes to ignition/2nd degree burn in 8 seconds
2.9	10			Pain on exposed skin after 3 sec/ death in 1% of victims after 40 seconds
2.0	7			Max exposure in PPE for 90 sec
1.8	6.4			Pain on exposed skin after 8 sec
1.4	5.0			2nd degree burns on exposed skin in 40 seconds
1.2	4.3	18,000	300.00	5 hours to ignition
1.2	4.0			First degree burns after 20 seconds
0.7	2.3			Pain on exposed skin after 2 minutes
0.6	2.1			Minimum to cause pain after 60 second
0.5	1.7			Minimum to cause pain
0.3	1.0			Equal to the maximum radiant heat transfer on a clear sunny day

Figure 30 – Impact of Radiant Heat

The third method of fire encroachment is convected heat. This impact area is generally about 75% of the radiant heat impact zone. While small pulses of convected heat may exceed the radiant heat zone and be a danger to the respiratory tracts of firefighters, these pulses are not sufficient enough in duration to cause ignition of structural materials.

Convection exposure is a more complex issue as the science of this factor is limited, with current studies underway to expand further our knowledge of this area of wildland fire science. Some facts are known:

> Radiative heat fluxes peak between 20 and 300 kW/m^2. The convective heat flux is characterized by rapid fluctuation between positive and negative convective values owing to alternating packets of cool air intermingled with hot combustion products. The convective heat flux peaks between 22 and 140 kW/m^2. *Frankman 2013, Measurements of convective and radiative heating in wildland fires, CSIRO Publishing, International Journal of Wildland Fire http://dx.doi.org/10.1071/WF11097, page K.*

Jack Cohen's SAIM (Structural Ignition Assessment Model) uses a radiant heat flux threshold of 20 kWm2 for 5.5 minutes as the baseline for structure ignition. (Cohen, J. D., 1995, Structure Ignition Assessment Model (SAIM), USDA Forest Service Gen. Tech. Rep. PWS-GTR-158)

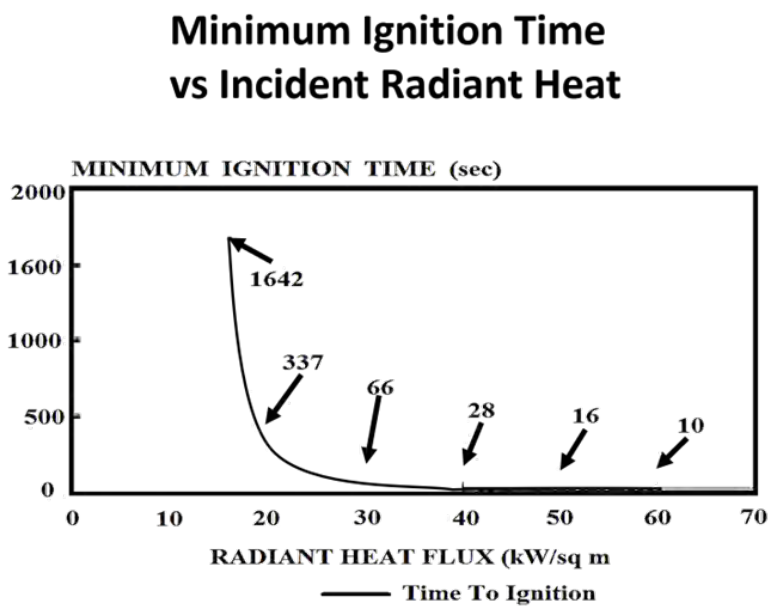


Figure 3. The minimum time for piloted wood ignition depends on the incident radiation heat flux (given as a constant_ that is greater than the critical heat flux of 13.1 kW/m².

Figure 31 – Radiant Heat vs. Minimum Ignition Time

Table 1. The effects of radiant exposure on human skin and wood indicate that humans are greatly more sensitive than wood during a WUI fire.

Heat Flux (kW/m^2)	Effect of Exposure
6.4	Pain on exposed skin after 8 secs. (Drysdale 1985).
7.0	Maximum estimated exposure for a firefighter wearing wildland firefighting clothing and head and neck protection over a period of approximately 90 secs, (Butler and Cohen 1997).
10.4	Pain on exposed skin after 3 sees. (Drysdale 1985)
16.0	Blistering of exposed skin after 5 secs. (Stoll 1969).
20.0	Piloted wood ignition after more than 5.5 minutes (ignition model).

Figure 32 - Jack Cohen, *Modeling Potential Structure Ignitions from Flame Radiation Exposure with Implications for Wildland/Urban Interface Fire Management Table 1*

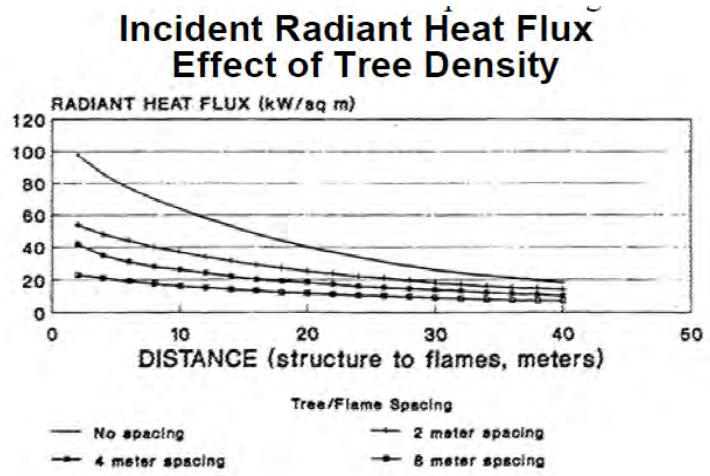


Figure 5. Given a constant flame size, the flame/trees are 2.5 meters wide, 20 meters high, and extend along a 50 meter flame front. The incident radiation heat flux depends on the flame-wall distance and the flame/tree spacing.

Figure 33 – Radiant Heat vs Distance

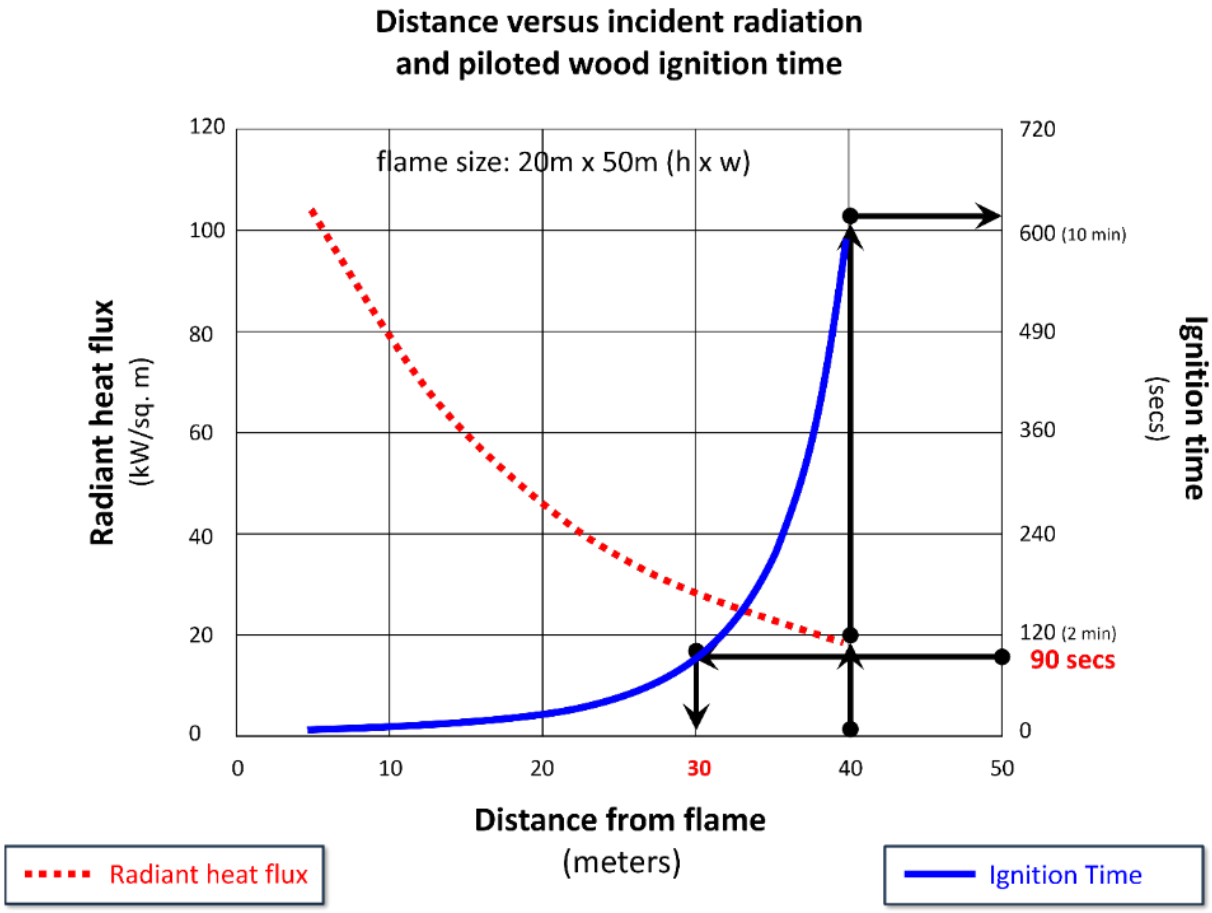


Figure 34 – SAIM Calculations for Radiant Heat Flux

In a time-resolved heat flux data study from two different locations and times in the same prescribed fire event, data was collected. They were grouped into a low-intensity set (hereafter labelled Burn 1) and a moderate-intensity set (hereafter labelled Burn 2). Both sets were evaluated to determine the effect of the sampling rate on the interpretation of convective and radiative heat fluxes. Findings from the analyses directly apply to measurement methods and interpretation of energy transport measurements in wildland fires. *Frankman 2013b, The effect of sampling rate on interpretation of the temporal characteristics of radiative and convective heating in wildland flames, CSIRO Publishing, International Journal of Wildland Fire 2013, 22, 168–173* *http://dx.doi.org/10.1071/WF12034*

Overall, fire convective energy is lower than fire radiative energy, but the peak energy pulses of the convective heat flux are more significant in the convective heat than in the radiant heat. Convective heat has pulses of cooler air, which lower the overall energy average, as shown in Figure 35.

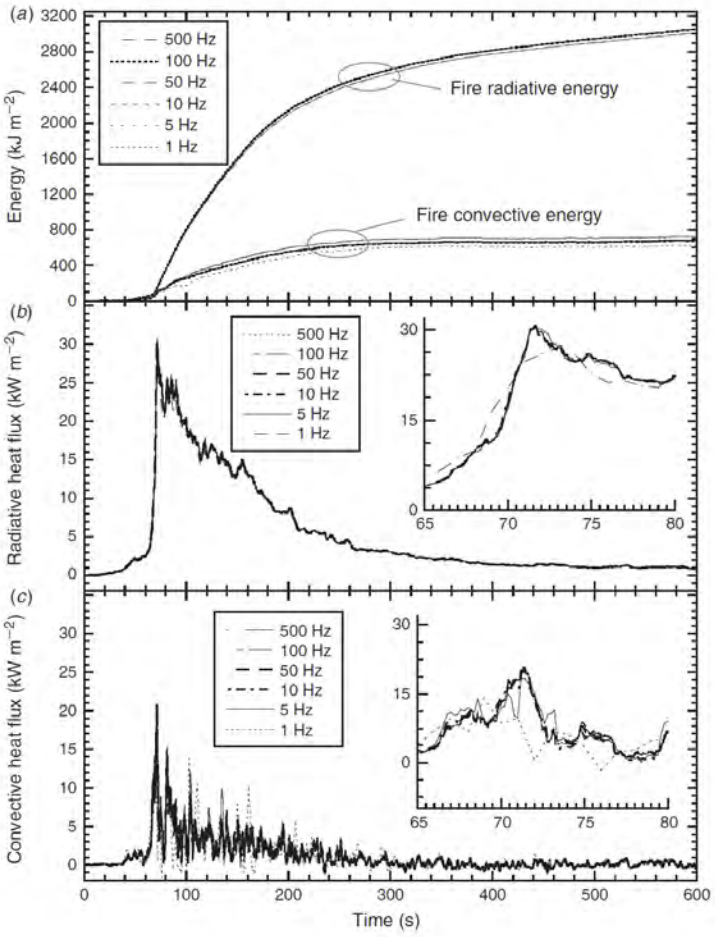


Fig. 2. Integrated energy and 2-s moving averages for Burn 2. (*a*) Fire radiative energy and convective energy calculated from integral of measured fluxes, (*b*) fluxes calculated using a 2-s moving average of the 500-, 100-, 50-, 10-, 5- and 1-Hz radiative flux signals, (*c*) fluxes calculated using a 2-s moving average the 500-, 100-, 50-, 10-, 5- and 1-Hz convective flux signals. Inset figures in (*b*) and (*c*) are included to further illustrate the difference in signal between the moving averages of the various sample rates over a short time frame.

Figure 35 – Convective Heat vs Radiant Heat

The point here is not to get into a discussion of how convective heat energy vs. radiant heat energy contributes to ignition of fuels but rather to show on the macro level that convective energy is not as likely to be a factor in structure ignition if the distance provided between the fire and structure are significant enough to stop radiant heat from igniting it.

In Figure 36, notice how the blue lines (convective heat) exceed the red lines (radiant heat), but the overall average is less for the blue line, AND the blue lines have negative (cooling) values, whereas the red lines do not. It is not that convective heating by superheated gases does not play a role in fire propagation or fire phenomena such as "area ignitions". They do, but the fuels and topography around the Project Site do not lend themselves to these issues.

The final method of fire encroachment would be embers and brands. The Institute for Business and Home Safety (IBHS) makes the following statement:

> Buildings are ignited by embers and flames during wildfires. Flying embers and wind-blown, ground-traveling burning debris are by far the most prevalent attack mechanisms threatening structures during a wildfire. CAL FIRE identified embers as the major cause of home loss (Mell et al., 2010). Potter and Leonard (2011) reported that "well over 90% of houses were ignited in the absence of direct flame attack or radiant heat (exceeding 12 kW/m2) from the main fire front." Hence, embers cause a great deal of damage, whether directly or indirectly. *WILDLAND FIRE EMBERS AND FLAMES: Home Mitigations That Matter, Faraz Hedayati, PhD, Stephen L. Quarles, PhD, Steven Hawks, IBHS Research, April 2023,page 6.*

Embers can and will travel great distances. The Project Site will be protected from this threat by compliance with California Building Code Chapter 7A and California Residential Code Section R337 throughout.

Fire Acceleration

Except in rare cases, fire starts as small ignition and grows into a larger fire unless they are suppressed or run out of fuel or oxygen. This process of growing is referred to as Fire Acceleration. It is an important concept in the understanding of how fire can impact an adjacent structure in the early stages or when spot fires occur, which is the same process as the original fire.

Fire acceleration can be defined as the rate of increase in spread rate/fire line intensity from a given source or as the rate of increase in spread rate from the current rate to an equilibrium spread rate under constant environmental conditions. Fire acceleration measures the amount of time required for a fire spread rate to achieve the theoretical steady state spread rate given: 1) current burning conditions and 2) constant environmental conditions. It should be noted that Fire acceleration is fuel-dependent but independent of fire behavior. Acceleration is significantly impacted by wind conditions. The incorporation of acceleration means that fire spread rates will not immediately adjust to the equilibrium spread rates when conditions change but will have some lag time in reaching the new equilibrium.

The rate of fire acceleration is dependent on a "rate factor". The default rate for acceleration to 90% of equilibrium rates is 20 minutes from a point source fire for brush and trees but less for grass fuels. Line source fires are known to accelerate much faster (Johansen 1987) than point source fires. Although the equilibrium spread rate is dependent on fuel conditions, the buildup or

acceleration rate has been found to be fuel-independent for a variety of fuel types (excelsior, pine needles, and conifer understories).

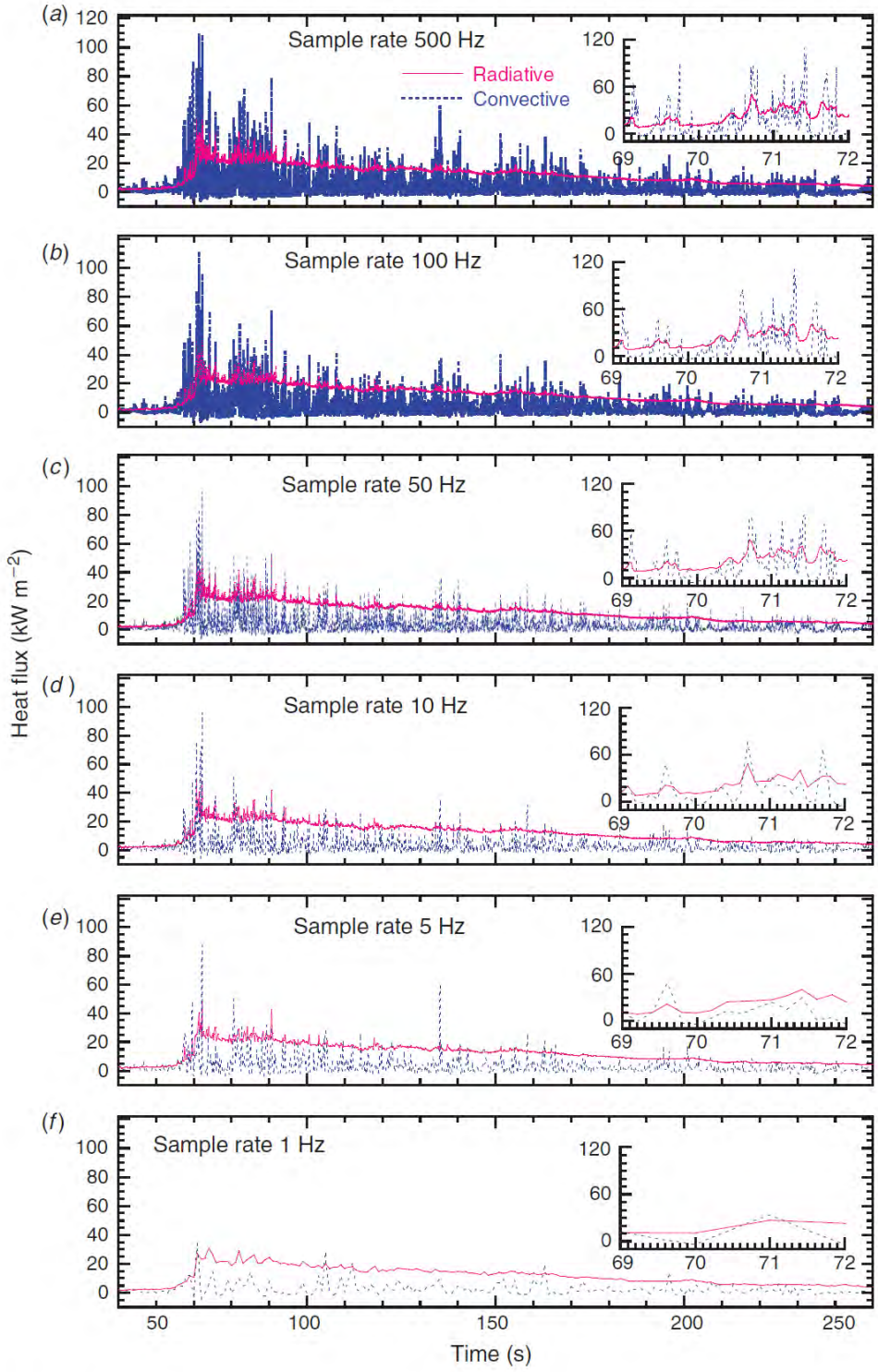


Fig. 1. The effect of sample rate on measured heat flux in Burn 2. (*a*) presents the initial signal captured at 500 Hz, (*b*) presents the 500-Hz signal down-sampled to 100 Hz and so on to 1 Hz for (*f*). The inset figures depict the signal over a 4-s time period centred at or near ignition.

Figure 36 – Convective Heat Rate

A single acceleration rate may not be accurate for all fuel types (McAlpine and Wakimoto 1991), especially between very different fuel types. Fire in grass fuels is expected to accelerate more rapidly than in slash fuels, but there is little data to guide these settings. Acceleration is presumed to be independent of fire behavior or eventual spread rate.

Fire acceleration is essential because the flame lengths that are being discussed from the modeling in the Behave program assume that the fire has reached a self-sustaining equilibrium state. In the smaller areas of the project site, where fire could establish itself within an area that is perpendicular to the wind, the fire will not reach this point before it runs out of fuel. This is the rationale for diminished distances for some of the defensible spaces from interior fuel beds, which are not directly connected to exterior fuel beds. In these instances, the fire must spot into the fuel bed, build to a steady burning state, and then continue to a state of equilibrium. When the amount of fuel is simply not available within the interface area, to complete this process, the over-risk can be adjusted to the actual risk present for these areas.

If we assume that a fire doubles in size (flame length) every two minutes during the acceleration phase (wind-driven fire), it is possible to see how far the fire might travel as it accelerates. Since the early acceleration does not use much fuel, we will begin to examine the fire when it reaches a five-foot flame length. At this point, it will be moving forward at about 3 feet per minute; two minutes later, it will be a ten-foot flame length and will be traveling at 14 feet per minute; two minutes more (six total), the flame length is now 20 feet, and the fire is moving at 53 feet per minute. Somewhere around the seven-minute mark, this fire will have consumed over 150 feet of fuel and will only have a 25-foot +/- flame length. It would not be possible to exceed the 40-foot flame length maximum used in this report. The calculations are provided in Figure 37, to the left.

	Flame Length			
	5	**10**	**20**	feet
	2.7	13	48	chains
	66	66	66	
	178	858	3,168	feet
	60	60	60	
	3	14	53	ft/min
	60	60	60	
	0.05	0.24	0.88	ft/sec
2 min	5.94			feet
4 min		28.6		feet
6 min			105.6	feet
Running total (distance)	5.94	34.54	140.14	feet

Figure 37

For fuel beds less than 150 feet in length, the available fuel would be consumed before a flame length over 25 feet could be achieved.

Fire Behavior Summary

Modeling indicates that flame lengths of approximately 40 feet (39.4 feet) are possible under perfect conditions within the fuels which are currently available on the project site. This scenario is possible in small areas on the project site at the site boundaries and within the riparian area interfaces. SCAL18 fuels exist or are expected to be present in wet years if not abated by discing or other mitigation measures. This fuel (SCAL18) is probable in the riparian areas. Six foot fuel beds required for the SH5 fuel are not present except at the bottom of the riparian areas and are not expect to be present in the future in any of the other interface areas.

For the majority of the development, a flanking fire of twelve feet or less is expected at the property line of the lots within the development or at the base of the fuel modification zones or radiant heat walls. However, the fire defense system has been developed to ensure it works in all conditions. For this reason, a fuel modification zone has been used in all areas where the interface has a direct impact on the adjacent structures. The distances vary depending on the adjacent fuels and the topography of the interface. Using a minimum 2x ratio of flame length to separation distance between the structures and the native fuels, a 50-foot zone is more than adequate in some areas, whereas 65-foot or 75-foot is more appropriate in other areas. All areas within this development area (perimeter) will have a fuel modification zone that starts at the edge of the pad. Defensible space will begin with the structure and move outwards to a distance of 100 feet or the property line in accordance with the Public Resources Code (PRC) Section 4291. Fuel Modification is a part of defensible space.

Fuel modification zone distances can be reduced by up to 50% in areas where a radiant heat fence is used as a physical barrier between the wildland and the development, but the overall distances between the native fuels and the structures should not be reduced without specific mitigation to achieve the "same practical effect" as the 100 feet required by the PRC. All areas not specifically referenced in this document for a reduced distance are assumed to require the prescriptive 100' distance.

While not currently required, Zone 0 will be applied to this project, either at the time of construction if the standards are approved at that time or retroactively, as the laws require this zone on existing structures one year after the implementation of new construction is in place.

Regardless of the modeling, when 100 feet is available to comply with the requirement of the PRC, the prescriptive level of protection should be applied as this provides for an additional level of protection beyond the level of protection provided by meeting the criteria in this report.

Integration of Additional Fire Protection Features

As indicated, a block wall/radiant heat wall may be constructed when a fuel modification zone is not possible without offsite improvements or due to the impacts of protected open space. In all cases where 100 feet of defensible space cannot be provided, the wall should be placed where the fuels are below or above the structures when in alignment with the Santa Ana winds or the predominant wind (W or SW). The required locations of these walls are indicated in Figure 38, on the next page.

The entire perimeter of the area west of the center riparian drainage will have radiant heat walls between the project site and current or future development areas and will achieve a full 100' distance on the riparian side. Within this area, the south and west interfaces will be on the project boundary with only defensible space requirements on the lots themselves as this area abuts existing, nonnative lots. On the north interface for this area, a forty-foot onsite buffer will be provided across the entire interface west of the center drainage.

All other locations for radiant heat walls will be in the typical configuration shown in Figure 39, with a radiant heat wall on the riparian side of a 40' or wider street with a minimum setback

distance from the street on the structure side of 10’ (it will be larger in most cases). In all of the these locations, the riparian area is lower than or level with the street.

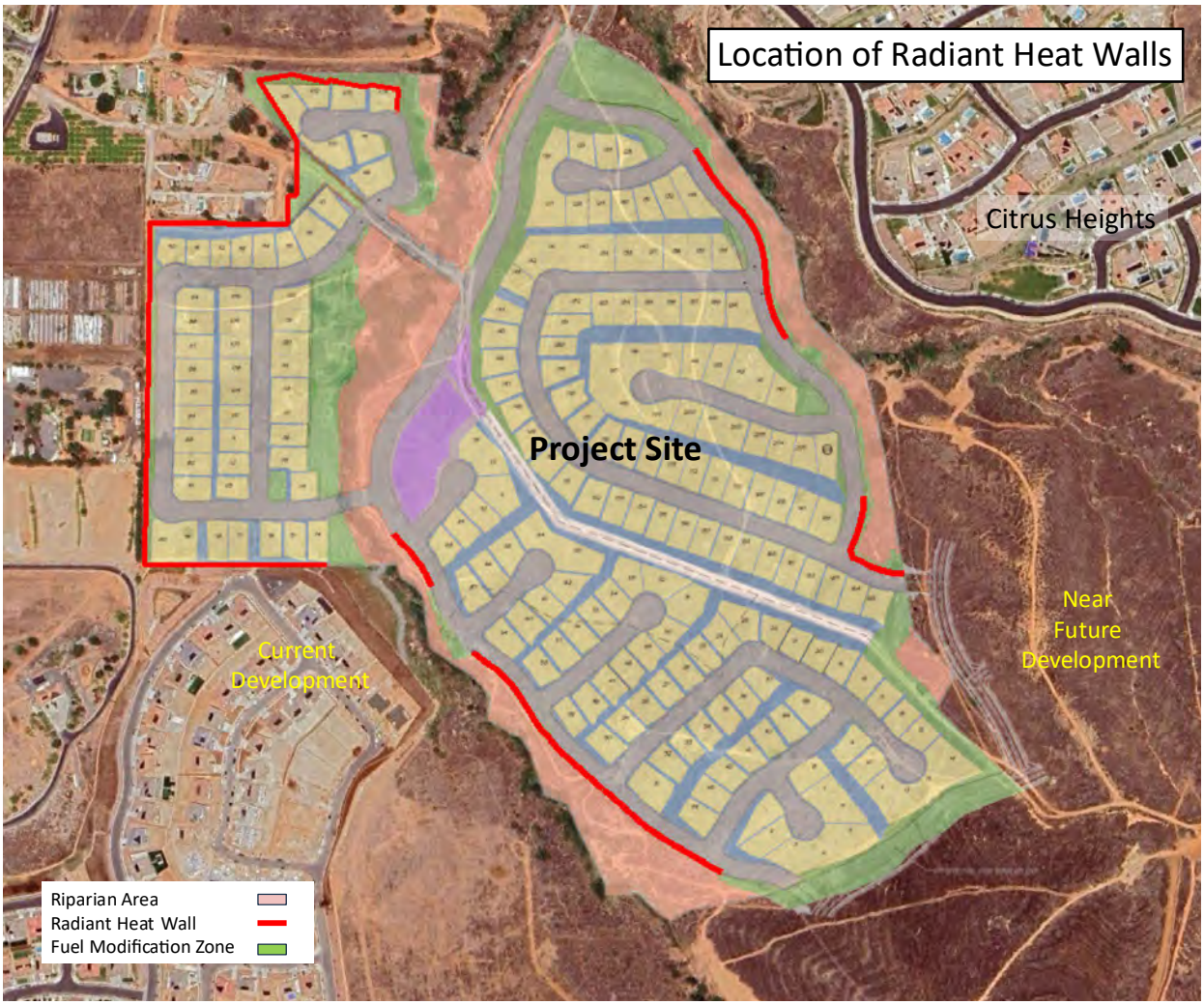


Figure 38 – Radiant Heat Wall Location

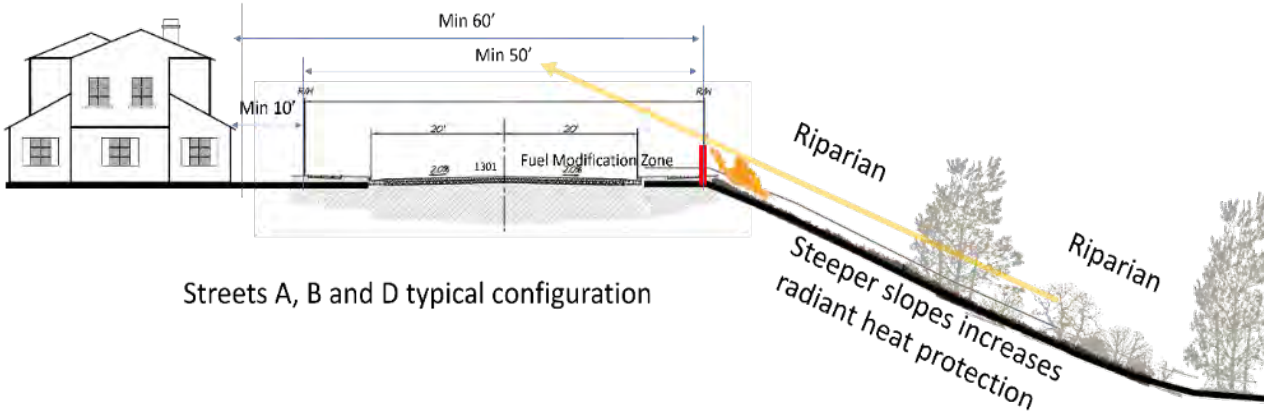


Figure 39 – Radiant Heat Wall Orientation

The radiant heat walls must be either block or tempered glass over block, similar to those shown below in Figure 40 .

These type of walls are incredibly effective when used at the top of the slope in light to moderate fuels. The extreme fire behavior that can be produced by high winds also bends the fire over making it travel more parallel to the ground. The harder the wind, the greater the flame angle will be and the more effective the radiant heat wall can become. Radiant heat walls cannot protect from extremely large flame lengths, radiant heat that is not shielded from impacting the structure, or embers/brands that are produced by upwind fire behavior. When placed strategically and appropriately, radiant heat walls are very effective in protecting structures from direct flame contact radiant heat and provide a "hard stop" on fire progression when utilized with fuel modification zone and fire resistive vegetation.

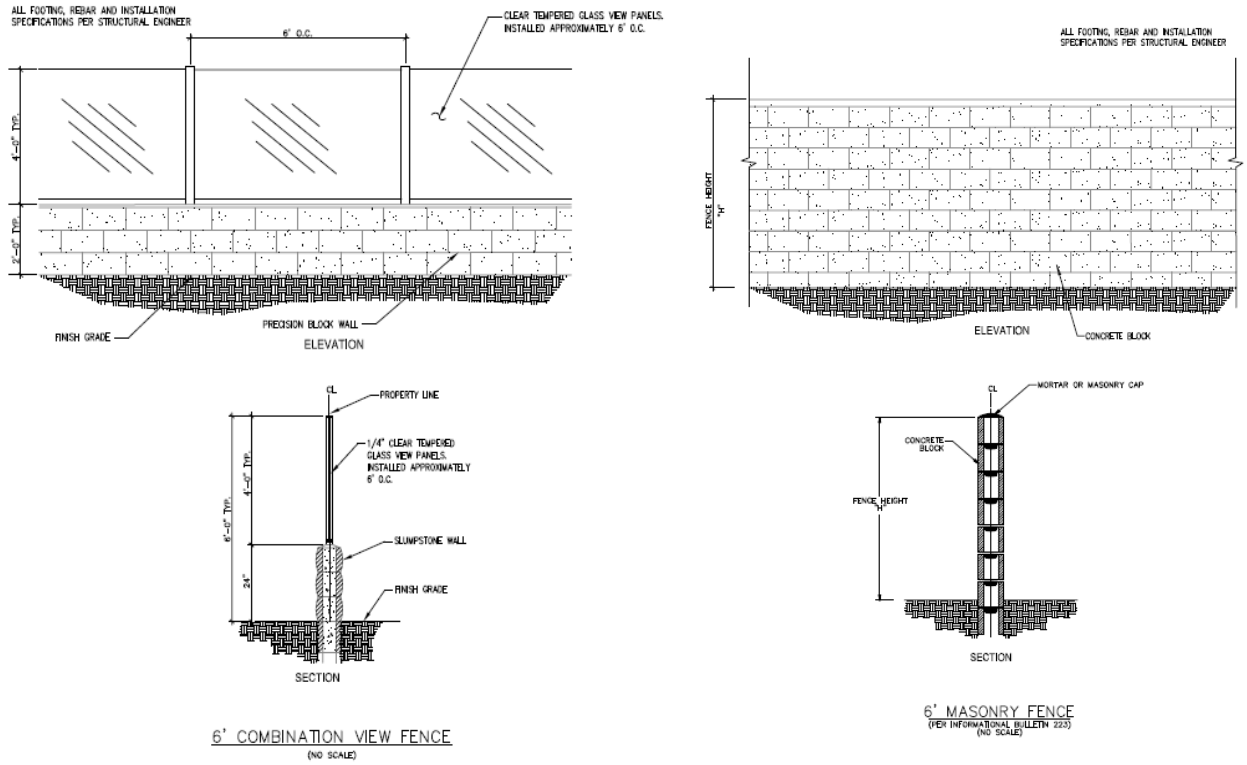


Figure 40 – Radiant Heat Wall Detail

The area adjacent to Lot 105 requires a 100' fuel modification zone to the east and 40' to the north. This will require either a change to the riparian boundary or a redesign of the lot configuration to provide for this distance. The NE wind (strong Santa Ana wind potential) aligns with the slope, aspect and fuels to create an interface which does not allow for other mitigations.

The 40' buffer on the top of this row of lots works because the fuel loading is much less (GS2) and does not produce a flame length greater than 20 feet. (19.2 in GS2 running upslope with the wind). The requirements for this interface are provided in Figure 41, on the next page.



Figure 41 – Lot 105 Requirements

The final interface discussion is for the southeast interface with the proposed development to the south and east of the project site (Figure 42.

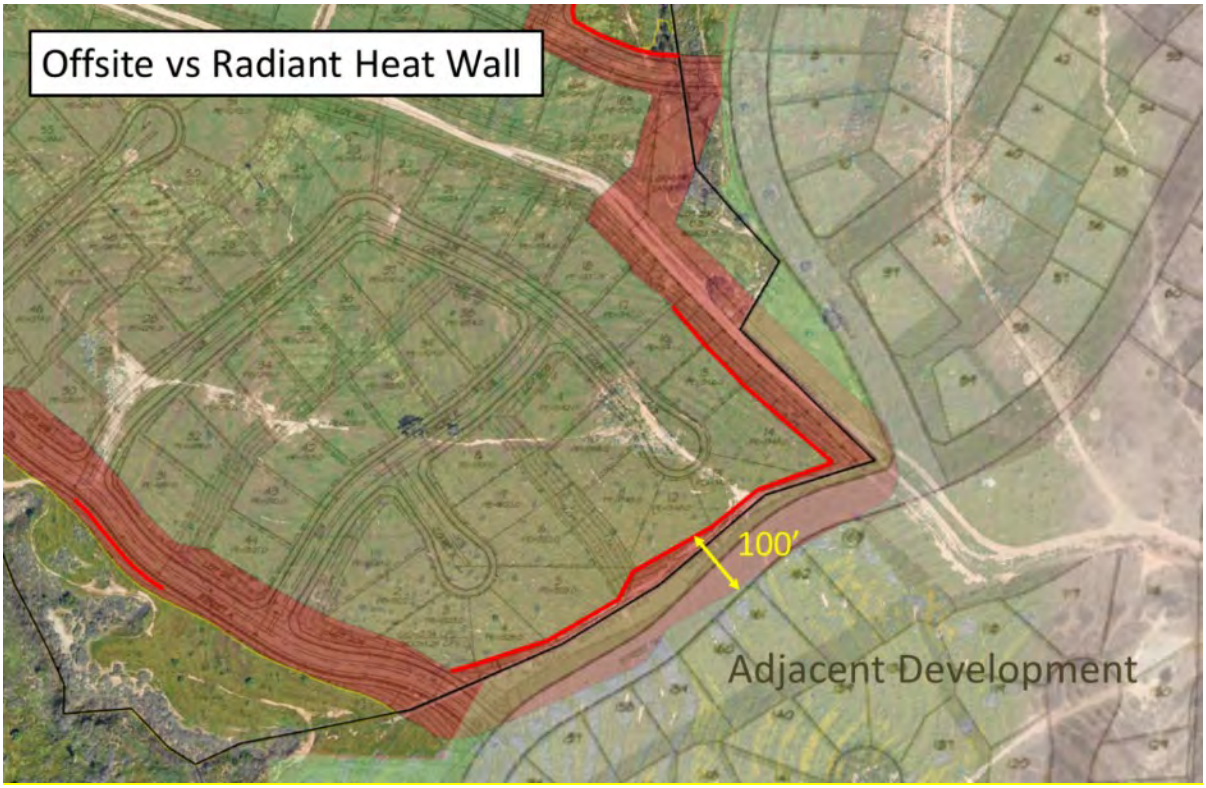


Figure 42 – Southeast Interface Options

Two possible scenarios exist here. First is that the adjacent development occurs before the project site is completed. The interface between the two projects would be fuel modification for both sides. It would ensure that each completed the required installation and maintenance which would overlap and provide the needed safeguards. The second scenario is that Willow Creek needs to provide its fuel modification before the adjacent development has completed its grubbing or grading.

In this second scenario, two options are available, the first would be providing offsite fuel modification via an easement or the second would be the use of a radiant heat wall at this location and cleaning of the area beyond the wall to provide for a level of protection that is acceptable to the specific location(s). It may require a combination of the two approaches if a full offsite easement is not possible.

Report Summary

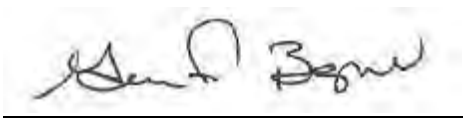
Firesafe has used the Behave model to measure the intensity of a fire, moving towards this development to design a protection system to ensure that the project will be safe from wildland fires even without fire department suppression activities . Flame lengths and fire intensity are ultimately reduced by the installation and maintenance of the fuel modification plan through the use of the irrigated Zone 1 and thinning Zone 2 and the possible use of radiant head walls surrounding the homes on the perimeter.

Based on the scientific fire behavior analysis, exterior portions of future structures or attic spaces have a reduced risk of ignition from the exterior fire exposure from a wildland vegetation fire when proper construction and defensible space are applied. This is primarily because the most significant fire energy is too far away from the structures due to the low plant densities within the defensible space zones and the fire-resistant construction feature requirements.

The codes enforced by the Riverside County Fire Department for defensible space were developed to handle the exact type of fuels that are interfacing with this future development. We recommend approval of this Fire Behavior Report as a design criterion for the Fuel Modification Zones in the Willow Creek project.



Principal
Fire Safe Planning Solutions



Fire Protection Analyst
Fire Safe Planning Solutions

Appendix A
Site Photos Locations



Photo locations are shown on the map above as reference points. Several photos were taken from each general location and are within a few feet of each other. For simplicity, these photo sites have been grouped in the locations shown above.

Photo Site 1 – Looking Northwest



Looking Northeast



Photo Site 2 – Looking North



Looking Southeast



Photo Site 3 – Looking Southeast



Looking East



Photo Site 4 – Looking Southeast



Looking North



Photo Site 5 – Looking East Northeast



Looking Southeast



Photo Site 6 – Looking East



Looking South



Photo Site 7 –Looking South



Looking North



Photo Site 8 –Looking North



Looking Southeast



Photo Site 9 –Looking North



Looking Southeast



Photo Site 10 – Northwest



Looking North



Photo Site 11 –Looking North



Looking South



Photo Site 12 – Looking North



Looking East



Photo Site 13 –Looking West



Looking Northwest



Photo Site 14 – Looking Southeast



Looking North



Photo Site 15 –Looking West



Looking Northwest



Photo Site 16 – Looking Northeast



Looking West



Photo Site 17 –Looking Southwest



Looking Northeast



Photo Site 18 –Looking Southwest



Looking Northeast



Photo Site 19 – Looking East



Looking Southwest



Photo Site 20 –Looking Northwest



Looking South Southeast



Photo Site 21 –Looking Northwest



Looking Southeast



Photo Site 22 –Looking North Northwest



Looking South



Photo Site 23 – Looking Southwest



Looking Southeast



Photo Site 24 –Looking Northwest



Looking Southeast



Photo Site 25 –Looking Northwest



Looking West Southwest



Photo Site 26 –Looking West Northwest



Looking Southwest



Photo Site 27 – Looking North Northeast



Looking South



Photo Site 28 –Looking North



Looking Northwest



Photo Site 29 –Looking Northwest



Looking Southwest



Photo Site 30 –Looking Northeast (bottom of drainage)



Looking Southwest (bottom of drainage)



Photo Site 31 – Looking West



Looking Southeast



Photo Site 32 –Looking East



Looking Northeast



Photo Site 33 –Looking North



Looking Southeast



Photo Site 34 –Looking Northeast



Looking East Northeast



Photo Site 35 – Looking South Southeast



Looking North



Photo Site 36 –Looking Northwest



Looking West



Photo Site 37 –Looking West



Looking South Southeast



Photo Site 38 –Looking Northeast



Looking Southeast



Photo Site 39 –Looking North



Looking East



Photo Site 40 – Looking East



Looking West



Photo Site 41 –Looking West



Looking East



Photo Site 42 – Looking South



Looking North Northwest



Photo Site 43 –Looking South



Looking North



Photo Site 44 –Looking South



Looking West



Photo Site 45 –Looking South



Looking East



Photo Site 46 – Looking South



Looking Southeast



Photo Site 47 –Looking Southeast



Looking South Southeast



Photo Site 48 –Looking Northwest



Looking South



Photo Site 49 –Looking South



Looking North



Photo Site 50 –Looking East



Looking Northeast



Photo Site 51 – Looking Northeast



Looking East



Photo Site 52 –Looking West



Looking North



Photo Site 53 –Looking East



Looking West



Photo Site 54 –Looking West



Looking North Northeast



Photo Site 55 – Looking



Looking North Northeast



Photo Site 56 –Looking East



Looking North



Photo Site 57 –Looking South



Looking Northeast



Photo Site 58 –Looking Southeast



Looking North



Photo Site 59 –Looking Northwest



Looking North



Photo Site 60 –Looking South



Looking North



Photo Site 61 – Looking West



Looking Southwest



Photo Site 62 –Looking Northwest



Looking Southwest



Photo Site 63 –Looking Northwest



Looking Southwest



Appendix B
Behave Reports

Inputs: SURFACE

Description		Willow Creek NE 50 mph

Fuel/Vegetation, Surface/Understory

Fuel Model		gr2, gs2, sh5, scal18, tl6

Fuel Moisture

1-h Fuel Moisture	%	3
10-h Fuel Moisture	%	4
100-h Fuel Moisture	%	5
Live Herbaceous Fuel Moisture	%	30
Live Woody Fuel Moisture	%	50

Weather

20-ft Wind Speed	mi/h	50
Wind Adjustment Factor		0.4
Wind Direction (from north)	deg	45

Terrain

Slope Steepness	%	50
Site Aspect	deg	45

Fire

Surface Fire Spread Direction (from north)	deg	0, 15, 30, 45, 60, 75, 90,

---

Run Option Notes

Maximum effective wind speed limit IS imposed [SURFACE].

Fire spread is in the specified directions from the FIRE PERIMETER [SURFACE].

Wind is in specified directions [SURFACE].

Wind and spread directions are degrees clockwise from north [SURFACE].

Wind direction is the direction from which the wind is blowing [SURFACE].

Output Variables

Surface Fire Rate of Spread (ft/min) [SURFACE]

Surface Fireline Intensity (kW/m) [SURFACE]

Surface Fire Flame Length (ft) [SURFACE]

Flame Residence Time (min) [SURFACE]

(continued on next page)

Input Worksheet (continued)

Notes

Fuel model parameters

Fuel Model Code	Fuel Model Number	Climate	Fuel load (t/ac) 1-hr	10-hr	100-hr	Live herb	Live woody	Fuel model type[a]	SAV ratio (1/ft)[b] Dead 1-hr	Live herb	Live woody	Fuel bed depth (ft)	Dead fuel extinction moisture (percent)	Heat content BTU/lb[c]
GR1	101	Dry	0.10	0.00	0.00	0.30	0.00	dynamic	2200	2000	9999	0.4	15	8000
GR2	102	Dry	0.10	0.00	0.00	1.00	0.00	dynamic	2000	1800	9999	1.0	15	8000
GS1	121	Dry	0.20	0.00	0.00	0.50	0.65	dynamic	2000	1800	1800	0.9	15	8000
GS2	122	Dry	0.50	0.50	0.00	0.60	1.00	dynamic	2000	1800	1800	1.5	15	8000
SH5	145	Dry	3.60	2.10	0.00	0.00	2.90	static	750	9999	1600	6.0	15	8000
TL3	183	N/A	0.50	2.20	2.80	0.00	0.00	static	2000	9999	9999	0.3	20	8000
TL6	186	N/A	2.40	1.20	1.20	0.00	0.00	static	2000	9999	9999	0.3	25	8000
SCAL18	N/A	N/A	5.50	0.80	0.10	0.75	2.50	static	640	1500	640	3.0	25	9200

Note: Dynamic fuels calculated at 100% herbaceous live fuel load transfer due to extreme low fuel moisture in the worse case scenario

Dead Component Calculation

Fuel Model Code	Fuel Model	100% Transfer Dead	Herb	Dead load	Total Load	Percentage Dead Component
GR1	GR1	0.10	0.30	0.40	0.40	100%
GR2	GR2	0.10	1.00	1.10	1.10	100%
GS1	GS1	0.20	0.50	0.70	1.35	52%
GS2	GS2	1.00	0.60	1.60	2.60	62%
SH5	SH5	5.70	no transfer	5.70	8.60	66%
TL3	TL3	5.50	no transfer	5.50	5.50	100%
TL6	TL6	4.80	no transfer	4.80	4.80	100%
SCAL18	SCAL18	6.40	no transfer	6.40	9.65	66%

[a] Fuel model type does not apply to fuel models without live herbaceous load.
[b] The value 9999 was assigned in cases where there is no load in a particular fuel class or category
[c] The same heat content value was applied to both live and dead fuel categories.

Willow Creek NE 50 mph

Spread from Fire Perimeter

Surface Fire Rate of Spread (ft/min)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh5	SCAL18	tl6
0	5.6	3.4	5.5	2.1	0.6
15	4.6	2.8	4.5	1.7	0.5
30	4.1	2.5	4.1	1.5	0.5
45	4.0	2.4	3.9	1.5	0.5
60	4.1	2.5	4.1	1.5	0.5
75	4.6	2.8	4.5	1.7	0.5
90	5.6	3.4	5.5	2.1	0.6
105	7.7	4.8	7.7	2.9	0.9
120	13.2	8.7	14.1	5.3	1.6
135	32.8	29.9	49.2	19.1	5.6
150	81.7	103.1	171.6	68.5	19.4
165	140.0	187.1	312.0	124.9	35.2
180	192.8	261.3	435.8	174.6	49.2
195	233.8	318.6	531.5	213.0	60.0
210	259.8	354.7	591.8	237.2	66.8
225	268.7	367.1	612.4	245.5	69.1
240	259.8	354.7	591.8	237.2	66.8
255	233.8	318.6	531.5	213.0	60.0
270	192.8	261.3	435.8	174.6	49.2
285	140.0	187.1	312.0	124.9	35.2
300	81.7	103.1	171.6	68.5	19.4
315	32.8	29.9	49.2	19.1	5.6
330	13.2	8.7	14.1	5.3	1.6
345	7.7	4.8	7.7	2.9	0.9
360	5.6	3.4	5.5	2.1	0.6

Willow Creek NE 50 mph

Spread from Fire Perimeter

Surface Fireline Intensity (kW/m)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh5	SCAL18	tl6
0	84	113	618	492	20
15	69	93	507	403	16
30	62	83	455	362	15
45	60	81	440	350	14
60	62	83	455	362	15
75	69	93	507	403	16
90	84	113	618	492	20
105	116	158	863	687	28
120	198	287	1570	1254	50
135	493	989	5478	4502	173
150	1227	3410	19116	16165	597
165	2104	6190	34760	29493	1084
180	2896	8644	48555	41229	1514
195	3513	10541	59217	50296	1846
210	3903	11737	65938	56011	2055
225	4037	12145	68233	57962	2127
240	3903	11737	65938	56011	2055
255	3513	10541	59217	50296	1846
270	2896	8644	48555	41229	1514
285	2104	6190	34760	29493	1084
300	1227	3410	19116	16165	597
315	493	989	5478	4502	173
330	198	287	1570	1254	50
345	116	158	863	687	28
360	84	113	618	492	20

Willow Creek NE 50 mph

Spread from Fire Perimeter

Surface Fire Flame Length (ft)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh5	SCAL18	tl6
0	2.0	2.2	4.9	4.4	1.0
15	1.8	2.0	4.5	4.0	0.9
30	1.7	1.9	4.2	3.8	0.9
45	1.7	1.9	4.2	3.8	0.9
60	1.7	1.9	4.2	3.8	0.9
75	1.8	2.0	4.5	4.0	0.9
90	2.0	2.2	4.9	4.4	1.0
105	2.3	2.6	5.7	5.1	1.2
120	2.9	3.4	7.5	6.8	1.5
135	4.4	6.1	13.3	12.2	2.7
150	6.7	10.7	23.7	21.9	4.8
165	8.6	14.1	31.2	28.9	6.3
180	9.9	16.4	36.4	33.7	7.4
195	10.9	18.0	39.8	37.0	8.1
210	11.4	18.9	41.9	38.8	8.5
225	11.6	19.2	42.5	39.4	8.6
240	11.4	18.9	41.9	38.8	8.5
255	10.9	18.0	39.8	37.0	8.1
270	9.9	16.4	36.4	33.7	7.4
285	8.6	14.1	31.2	28.9	6.3
300	6.7	10.7	23.7	21.9	4.8
315	4.4	6.1	13.3	12.2	2.7
330	2.9	3.4	7.5	6.8	1.5
345	2.3	2.6	5.7	5.1	1.2
360	2.0	2.2	4.9	4.4	1.0

Willow Creek NE 50 mph

Spread from Fire Perimeter

Flame Residence Time (min)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh5	SCAL18	tl6
0	0.21	0.21	0.31	0.49	0.20
15	0.21	0.21	0.31	0.49	0.20
30	0.21	0.21	0.31	0.49	0.20
45	0.21	0.21	0.31	0.49	0.20
60	0.21	0.21	0.31	0.49	0.20
75	0.21	0.21	0.31	0.49	0.20
90	0.21	0.21	0.31	0.49	0.20
105	0.21	0.21	0.31	0.49	0.20
120	0.21	0.21	0.31	0.49	0.20
135	0.21	0.21	0.31	0.49	0.20
150	0.21	0.21	0.31	0.49	0.20
165	0.21	0.21	0.31	0.49	0.20
180	0.21	0.21	0.31	0.49	0.20
195	0.21	0.21	0.31	0.49	0.20
210	0.21	0.21	0.31	0.49	0.20
225	0.21	0.21	0.31	0.49	0.20
240	0.21	0.21	0.31	0.49	0.20
255	0.21	0.21	0.31	0.49	0.20
270	0.21	0.21	0.31	0.49	0.20
285	0.21	0.21	0.31	0.49	0.20
300	0.21	0.21	0.31	0.49	0.20
315	0.21	0.21	0.31	0.49	0.20
330	0.21	0.21	0.31	0.49	0.20
345	0.21	0.21	0.31	0.49	0.20
360	0.21	0.21	0.31	0.49	0.20

Discrete Variable Codes Used
Willow Creek NE 50 mph

Fuel Model		
102	gr2	Low load, dry climate grass (D)
122	gs2	Moderate load, dry climate grass-shrub (D)
145	sh5	High load, dry climate shrub (S)
18	SCAL18	Sage / Buckwheat
186	tl6	High load broadleaf litter (S)

Inputs: SURFACE

Description		Willow Creek SW 30 mph

Fuel/Vegetation, Surface/Understory

Fuel Model		gr2, gs2, sh5, scal18, tl6

Fuel Moisture

1-h Fuel Moisture	%	3
10-h Fuel Moisture	%	4
100-h Fuel Moisture	%	5
Live Herbaceous Fuel Moisture	%	30
Live Woody Fuel Moisture	%	50

Weather

20-ft Wind Speed	mi/h	30
Wind Adjustment Factor		0.4
Wind Direction (from north)	deg	225

Terrain

Slope Steepness	%	50
Site Aspect	deg	225

Fire

Surface Fire Spread Direction (from north)	deg	0, 15, 30, 45, 60, 75, 90,

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Run Option Notes

Maximum effective wind speed limit IS imposed [SURFACE].

Fire spread is in the specified directions from the FIRE PERIMETER [SURFACE].

Wind is in specified directions [SURFACE].

Wind and spread directions are degrees clockwise from north [SURFACE].

Wind direction is the direction from which the wind is blowing [SURFACE].

Output Variables

Surface Fire Rate of Spread (ft/min) [SURFACE]

Surface Fireline Intensity (kW/m) [SURFACE]

Surface Fire Flame Length (ft) [SURFACE]

Flame Residence Time (min) [SURFACE]

(continued on next page)

Input Worksheet (continued)

Notes

Fuel model parameters

Fuel Model Code	Fuel Model Number	Climate	Fuel load (t/ac) 1-hr	10-hr	100-hr	Live herb	Live woody	Fuel model type[a]	SAV ratio (1/ft)[b] Dead 1-hr	Live herb	Live woody	Fuel bed depth (ft)	Dead fuel extinction moisture (percent)	Heat content BTU/lb[c]	Fuel Model Code
GR1	101	Dry	0.10	0.00	0.00	0.30	0.00	dynamic	2200	2000	9999	0.4	15	8000	GR1
GR2	102	Dry	0.10	0.00	0.00	1.00	0.00	dynamic	2000	1800	9999	1.0	15	8000	GR2
GS1	121	Dry	0.20	0.00	0.00	0.50	0.65	dynamic	2000	1800	1800	0.9	15	8000	GS1
GS2	122	Dry	0.50	0.50	0.00	0.60	1.00	dynamic	2000	1800	1800	1.5	15	8000	GS2
SH5	145	Dry	3.60	2.10	0.00	0.00	2.90	static	750	9999	9999	6.0	15	8000	SH5
TL3	183	N/A	0.50	2.20	2.80	0.00	0.00	static	2000	9999	9999	0.3	20	8000	TL3
TL6	186	N/A	2.40	1.20	1.20	0.00	0.00	static	2000	9999	9999	0.3	25	8000	TL6
SCAL18	N/A	N/A	5.50	0.80	0.10	0.75	2.50	static	640	1500	640	3.0	25	9200	SCAL18

Note: Dynamic fuels calculated at 100% herbaceous live fuel load transfer due to extreme low fuel moisture in the worse case scenario

Dead Component Calculation

Fuel Model Code	100% Transfer Dead	Herb	Dead load	Total Load	Percentage Dead Component
GR1	0.10	0.30	0.40	0.40	100%
GR2	0.10	1.00	1.10	1.10	100%
GS1	0.20	0.50	0.70	1.35	52%
GS2	1.00	0.60	1.60	2.60	62%
SH5	5.70	no transfer	5.70	8.60	66%
TL3	5.50	no transfer	5.50	5.50	100%
TL6	4.80	no transfer	4.80	4.80	100%
SCAL18	6.40	no transfer	6.40	9.65	66%

[a] Fuel model type does not apply to fuel models without live herbaceous load.
[b] The value 9999 was assigned in cases where there is no load in a particular fuel class or category
[c] The same heat content value was applied to both live and dead fuel categories.

Willow Creek SW 30 mph

Spread from Fire Perimeter

Surface Fire Rate of Spread (ft/min)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh5	SCAL18	tl6
0	192.8	132.7	252.5	115.7	24.7
15	233.8	161.0	306.5	140.5	30.0
30	259.8	178.9	340.6	156.2	33.3
45	268.7	185.0	352.3	161.6	34.5
60	259.8	178.9	340.6	156.2	33.3
75	233.8	161.0	306.5	140.5	30.0
90	192.8	132.7	252.5	115.7	24.7
105	140.0	96.3	183.1	83.8	17.9
120	81.7	56.0	106.2	48.3	10.4
135	32.8	22.2	41.6	18.4	4.1
150	13.2	8.8	16.3	7.0	1.6
165	7.7	5.1	9.4	4.0	0.9
180	5.6	3.7	6.9	2.9	0.7
195	4.6	3.1	5.6	2.4	0.6
210	4.1	2.8	5.1	2.2	0.5
225	4.0	2.7	4.9	2.1	0.5
240	4.1	2.8	5.1	2.2	0.5
255	4.6	3.1	5.6	2.4	0.6
270	5.6	3.7	6.9	2.9	0.7
285	7.7	5.1	9.4	4.0	0.9
300	13.2	8.8	16.3	7.0	1.6
315	32.8	22.2	41.6	18.4	4.1
330	81.7	56.0	106.2	48.3	10.4
345	140.0	96.3	183.1	83.8	17.9
360	192.8	132.7	252.5	115.7	24.7

Willow Creek SW 30 mph

Spread from Fire Perimeter

Surface Fireline Intensity (kW/m)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh5	SCAL18	tl6
0	2896	4390	28131	27317	761
15	3513	5327	34148	33180	924
30	3903	5920	37951	36886	1027
45	4037	6122	39251	38152	1062
60	3903	5920	37951	36886	1027
75	3513	5327	34148	33180	924
90	2896	4390	28131	27317	761
105	2104	3187	20405	19779	552
120	1227	1853	11833	11395	321
135	493	735	4635	4333	127
150	198	292	1815	1648	50
165	116	170	1053	949	29
180	84	123	764	687	21
195	69	101	629	566	17
210	62	91	566	509	16
225	60	88	547	492	15
240	62	91	566	509	16
255	69	101	629	566	17
270	84	123	764	687	21
285	116	170	1053	949	29
300	198	292	1815	1648	50
315	493	735	4635	4333	127
330	1227	1853	11833	11395	321
345	2104	3187	20405	19779	552
360	2896	4390	28131	27317	761

Willow Creek SW 30 mph

Spread from Fire Perimeter

Surface Fire Flame Length (ft)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh5	SCAL18	tl6
0	9.9	12.0	28.3	27.9	5.4
15	10.9	13.2	30.9	30.5	5.9
30	11.4	13.8	32.5	32.0	6.2
45	11.6	14.0	33.0	32.5	6.3
60	11.4	13.8	32.5	32.0	6.2
75	10.9	13.2	30.9	30.5	5.9
90	9.9	12.0	28.3	27.9	5.4
105	8.6	10.4	24.4	24.1	4.6
120	6.7	8.1	19.0	18.7	3.6
135	4.4	5.3	12.3	12.0	2.4
150	2.9	3.5	8.0	7.7	1.5
165	2.3	2.7	6.2	6.0	1.2
180	2.0	2.3	5.4	5.1	1.0
195	1.8	2.1	4.9	4.7	0.9
210	1.7	2.0	4.7	4.5	0.9
225	1.7	2.0	4.6	4.4	0.9
240	1.7	2.0	4.7	4.5	0.9
255	1.8	2.1	4.9	4.7	0.9
270	2.0	2.3	5.4	5.1	1.0
285	2.3	2.7	6.2	6.0	1.2
300	2.9	3.5	8.0	7.7	1.5
315	4.4	5.3	12.3	12.0	2.4
330	6.7	8.1	19.0	18.7	3.6
345	8.6	10.4	24.4	24.1	4.6
360	9.9	12.0	28.3	27.9	5.4

Willow Creek SW 30 mph

Spread from Fire Perimeter

Flame Residence Time (min)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh5	SCAL18	tl6
0	0.21	0.21	0.31	0.49	0.20
15	0.21	0.21	0.31	0.49	0.20
30	0.21	0.21	0.31	0.49	0.20
45	0.21	0.21	0.31	0.49	0.20
60	0.21	0.21	0.31	0.49	0.20
75	0.21	0.21	0.31	0.49	0.20
90	0.21	0.21	0.31	0.49	0.20
105	0.21	0.21	0.31	0.49	0.20
120	0.21	0.21	0.31	0.49	0.20
135	0.21	0.21	0.31	0.49	0.20
150	0.21	0.21	0.31	0.49	0.20
165	0.21	0.21	0.31	0.49	0.20
180	0.21	0.21	0.31	0.49	0.20
195	0.21	0.21	0.31	0.49	0.20
210	0.21	0.21	0.31	0.49	0.20
225	0.21	0.21	0.31	0.49	0.20
240	0.21	0.21	0.31	0.49	0.20
255	0.21	0.21	0.31	0.49	0.20
270	0.21	0.21	0.31	0.49	0.20
285	0.21	0.21	0.31	0.49	0.20
300	0.21	0.21	0.31	0.49	0.20
315	0.21	0.21	0.31	0.49	0.20
330	0.21	0.21	0.31	0.49	0.20
345	0.21	0.21	0.31	0.49	0.20
360	0.21	0.21	0.31	0.49	0.20

Discrete Variable Codes Used
Willow Creek SW 30 mph

Fuel Model		
102	gr2	Low load, dry climate grass (D)
122	gs2	Moderate load, dry climate grass-shrub (D)
145	sh5	High load, dry climate shrub (S)
18	SCAL18	Sage / Buckwheat
186	tl6	High load broadleaf litter (S)