Fire Behavior Analysis
Whitewood Apartments

Prepared for:

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Multi-Family, LLC.

and

Murrieta Fire & Rescue

Prepared By:

firesafe
::PLANNING SOLUTIONS

12/14/21

Table of Contents

Whitewood South
FIRE BEHAVIOR ANALYSIS AND REPORT
City of Murrieta, California

Purpose and Scope of Report

Firesafe Planning Solutions performed an assessment of the wildland fire related risks in order to establish the appropriate criteria for the design of a performance-based fuel modification/defensible space system and maintenance program that will reduce the intensity of a wildfire approaching the Whitewood Apartments (A.P.N. 392-320-014) to an acceptable level. This report provides the results of that assessment and objective defensible space criteria for this community that is equal to or greater than the risk which would be 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 and flame lengths from a worst-case scenario wildfire in both the extreme (Santa Ana/Offshore winds) and the predominant (Onshore wind) wind conditions. The results of fire behavior calculations have been incorporated into the fuel modification designs which can be applied to the interfaces of the 'Whitewood Apartments'.

General Geographic Description and Site Overview

The Whitewood Apartments project is located east of Whitewood Road, south of Lee Lane, north of Greenberg Place and approximately ½ mile west of the eastern boundary of the City of Murrieta, California. The location is shown below in Figure 1 and Figure 2, on the next page.

The majority of the site has been maintained in a low vegetation state. The project site is bifurcated by a protected native vegetation area consisting mostly of streambed trees and shrubs. The riparian area will be conserved and maintained in its native state. The project site is bounded by current or future paved roads on three sides (the east side is not). The project site is situated in a relatively small slope area with the undeveloped site ranging in elevation from approximately 1,470 to just over 1,500 above sea level (asl)

The project will construct approximately 324 residential dwelling units on 18.7 acres. The project will provide a variety of unit configurations consisting of one-, two- and three-story buildings. The project will take its access off of Greenberg Place for the southern portion and Lee Lane for the northern portion. One- and two-story duplex units will be protected with NFPA 13D residential sprinkler systems and the three-story units will have NFPA 13R systems. No buildings will have eaves in excess of 30 feet from the grade plane. All manufactured slope (after grading) will be a maximum of 2:1 slope while some of the natural slopes within the riparian areas may be steeper for short distances.

The 'Whitewood Apartments' is located partially within CalFire Fire Hazard Severity Zones. The project site is within the Local Responsibility Area (LRA). The Fire Severity Zones are geographical areas designated pursuant to California Public Resources Code Sections 4201 through 4204 and are classified as Very High, High, or Moderate in State Responsibility Areas or as Local Agency Very High Fire Hazard Severity Zones designated pursuant to California Government Code sections 51175 through 51189. All areas within Very High Fire Hazard Severity Zones in either SRA or LRA areas are required by state code to comply with the Chapter 7A of the California Building Code, Chapter 49 of the California Fire Code, and Section R337 of the California Residential Code as adopted and amended by the local agency (Riverside County and the City of Murrieta for this project site).

Figure 1 - Vicinity Map

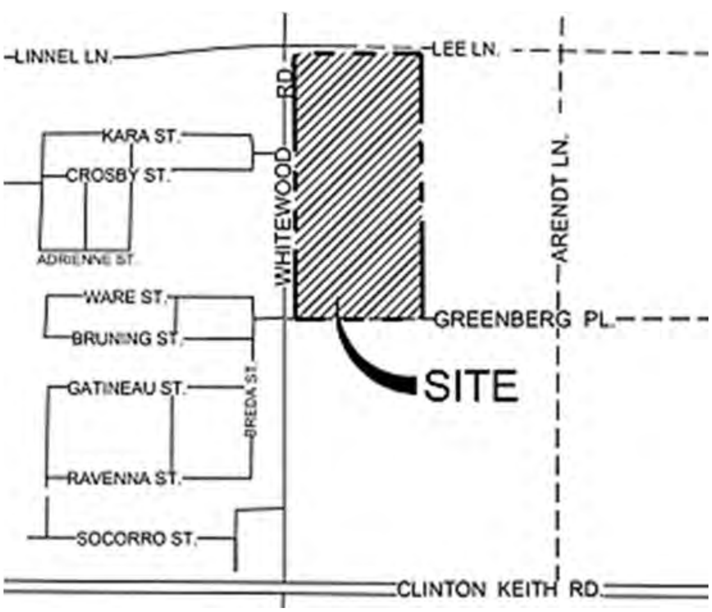

Figure 2 -Location Map

Figure 3 – Development Area and Surrounding Uses/Vegetation

Areas within High and Moderate Zones within SRA areas are also required to comply with the same code sections. These Very High Fire Severity Zones are shown in red areas on the map one the next page (Figure 4). The entire development area is within the Very High Fire Hazard Severity Zones.

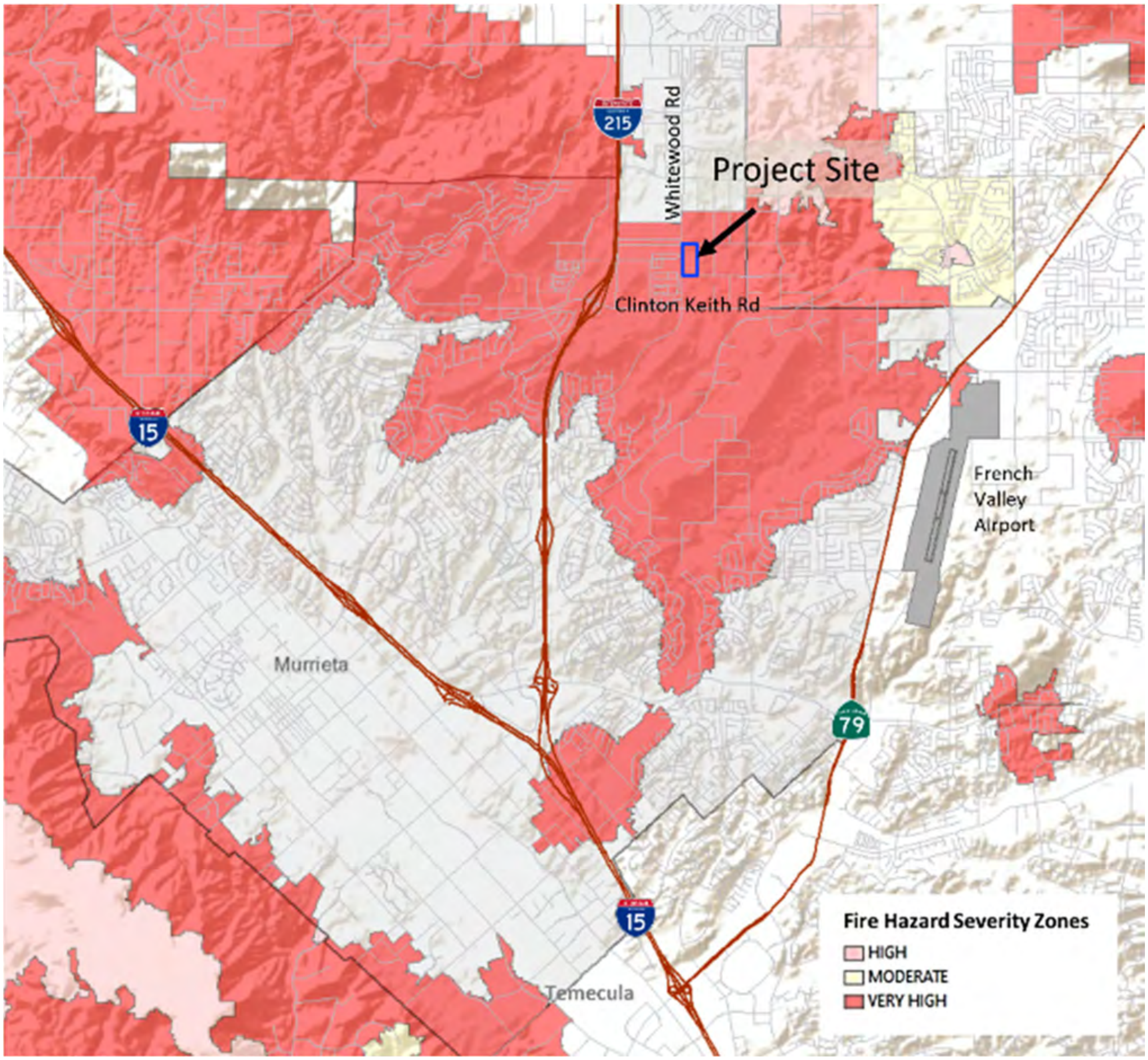

Figure 4 - Fire Hazard Severity Zones Project Site Outline in Blue

Fire Risk Assessment

Fire risk assessment is based on several factors. These include the fire history of the developed area and the surrounding areas; the vegetation (fuel) that surrounds the community; the weather history for the general area and the specific site; the topography of the project site (slope and aspect); and the placement of structures relative to the factors listed above.

The fire behavior analysis for this project site was completed to develop a performance-based fire protection system from the modeling results (based on a worst-case scenario) for the 'Whitewood Apartments'. By using the worst-case scenario fire conditions, it is expected that any future fires will be equal to or less extreme than those modeled here and would produce fire behavior spread/intensity at was within the risks analyzed and therefore be safe.

Fire History

A review of the CalFire database (FRAP), which maintains a 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 since 1980, is shown on the next page (Figures 5). 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 collection criteria for CAL FIRE fires eliminated the monetary criterion and redefined the definition of structures.

Whitewood Apartments is outlined in blue in the figure below (Figure 5). The fire perimeters are shown in red with a shading effect that allows the overlap between fire perimeters to be seen. The overlap areas are more highly shaded so that it is possible to see the areas that with more fire activity and the extent of each of the perimeters without having to provide separate graphics for each.

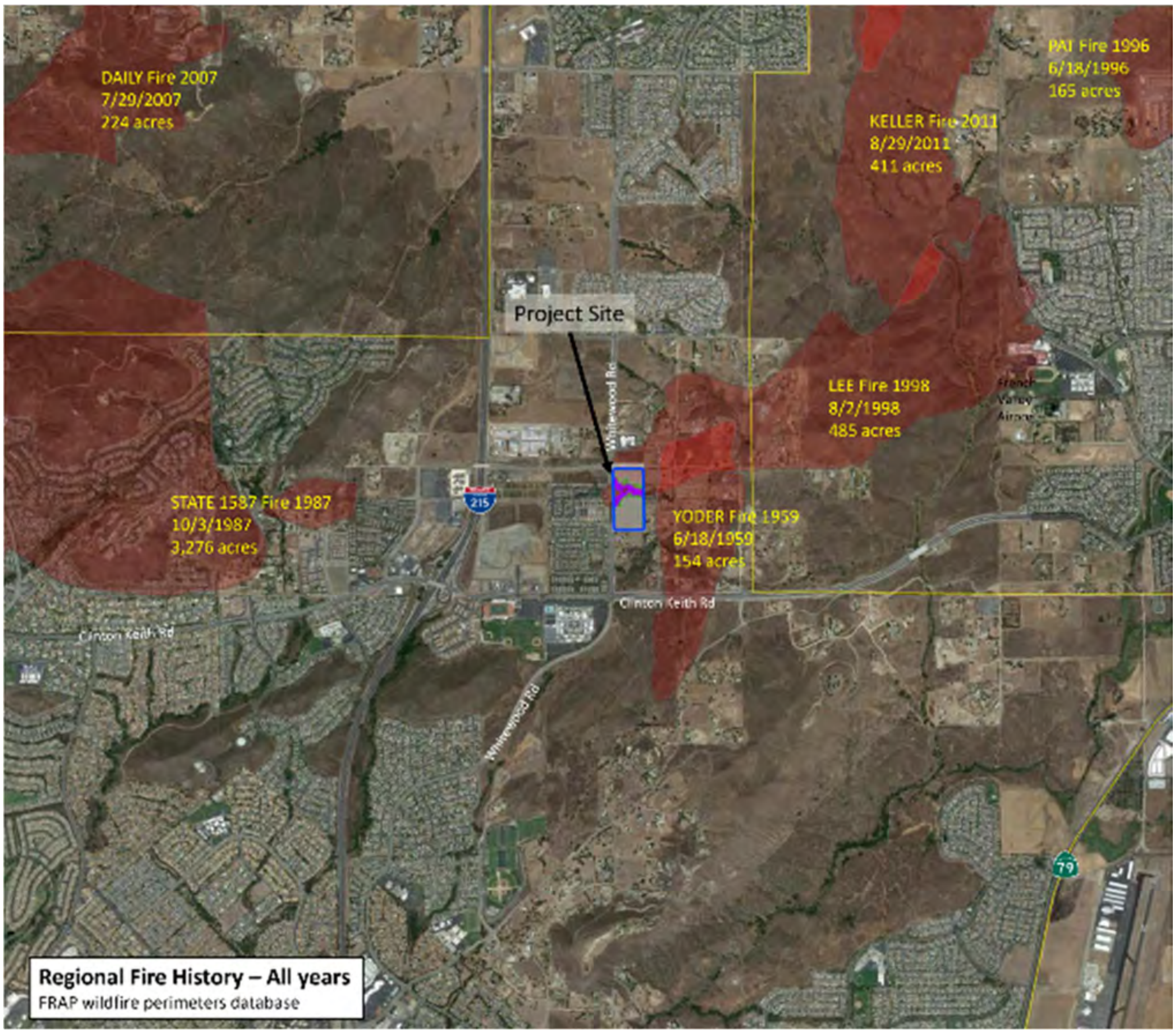

Figure 5 – Fire History Map (All years)

As shown in Figure 5, there have been several fires near the project site in the time that records have been kept (100 years) but only one fire burned onto or through the project site. The perimeter of that fire (Lee Fire 1998) is provided in Figure 6, below on an aerial from that period of time to show the native of the vegetation and state development at that time. The regional area (within three miles of the project site) has had a fire approximately once every decade with a few exceptions. In the past sixty years, six fires have burned in this area. The Yoder Fire in 1959 was close to the project site but did not burn onto it. Most of the fire burned in the direction of the onshore/offshore winds (SW/NE). Most are longer and thinner which indicates that they were influenced by the wind. The State Fire 1587 in 1987 and Daily Fire in 2007 appear to have some slope influence on the fire direction with more limited wind impacts. Smaller fires have likely occurred within the project site and surrounding area in the past 50 years but have not met the criteria for the record keeping at the state and federal level. FPS could find no records of homes in the project site area which have been destroyed by a wildland fire in the past 60 years.

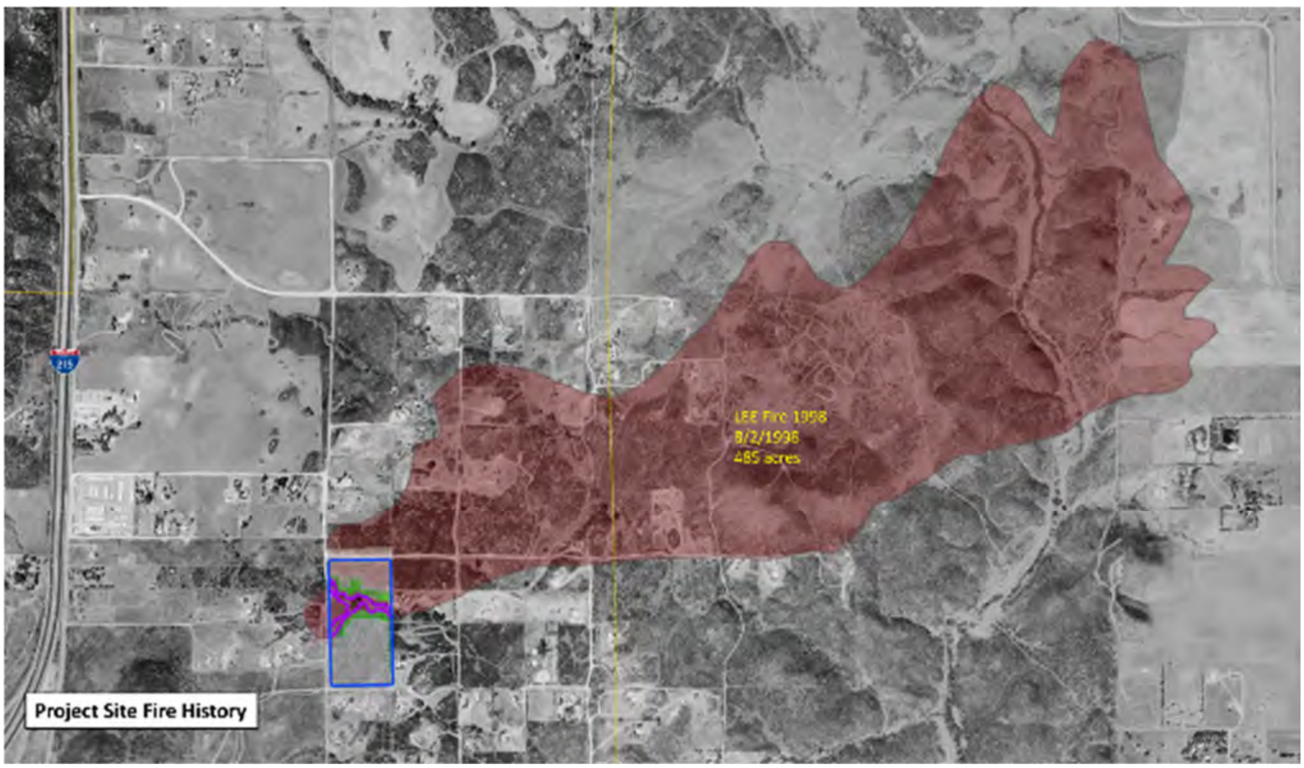

Figure 6 – Site Fire History

Fire Behavior Analysis (BehavePlus/FlamMap)

The BehavePlus, Fire Behavior Prediction and Fuel Modeling System is the most popular and accurate method for predicting wildland fire behavior in prefire defense planning. The BehavePlus fire behavior computer modeling system is utilized by wildland fire experts nationwide. Because the model was designed to predict the spread of a fire, the fire model describes the fire behavior only within the flaming front. The primary driving force in the fire behavior calculations is the dead fuel less than ¼" in diameter; these are the fine fuels that carry the fire. Fuels larger than ¼" contribute to fire intensity, but not necessarily to fire spread. The BehavePlus fire model describes a wildfire spreading through surface fuels, which are the burnable materials within 6' of the ground and contiguous to the ground. This type of modeling demonstrates the potential of a wind-driven fire that could potentially enter the fuel modification zones from the adjacent wildland areas.

Weather Inputs and Wind Patterns

After a review of the weather data, the most extreme wind patterns and speeds relating to wildfires were entered into the modeling programs (BehavePlus and Wind Ninja which is a computational fluid dynamics wind model software funded by the US Forest Service, Joint Fire Science Program and the Center for Environmental Management of Military Lands at Colorado State University). All other lesser wind patterns and wind speeds normally produce less fire intensity based on a fire in wildland fuels and have not been analyzed for this report. The SCE224 RAWS (Remote Access Weather Station) is located approximately 1.15 miles south of the project site (Figure 7, below) and approximately 2.5 miles to the SE, French Valley Airport has an AWOS (Automated Weather Observation System) which collects data in a similar manner to a RAWS.

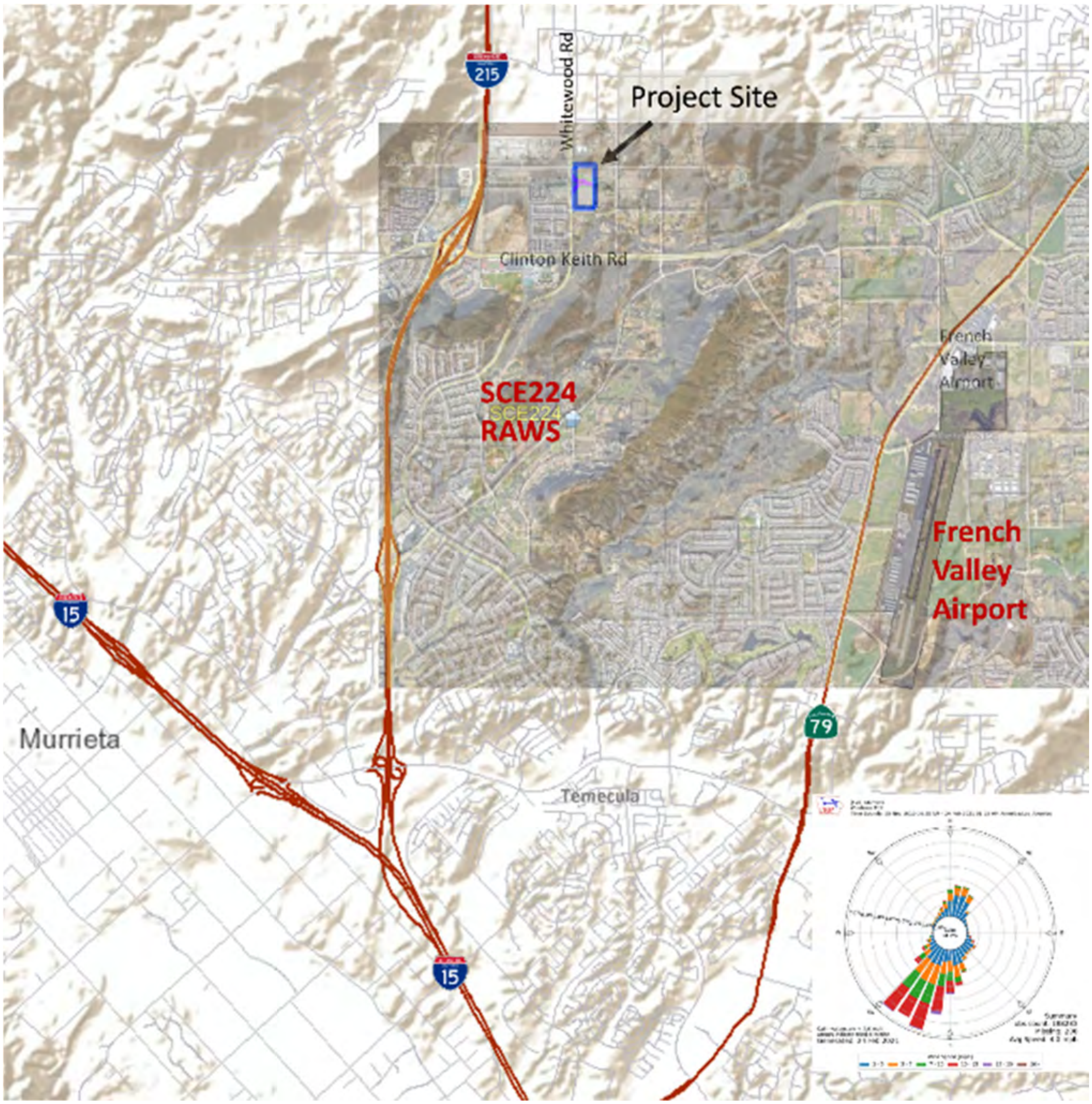

Figure 7 – Weather Data Locations

The results of the AWOS data are shown on the wind rose graph in Figure 8, below. The graphic clearly shows the predominant winds are the onshore (SSW) and offshore flow (NNE). These winds align with the runway configuration (Runways 18 and 36 oriented to magnetic north which is 13 degrees different from geographic north). The volume of wind from the onshore is significantly more than the offshore and winds from other directions are relatively infrequent. Offshore winds tend to be stronger but the real surprise in the data is that 41.6% of the time wind are less than 2 miles per hour at this airport.

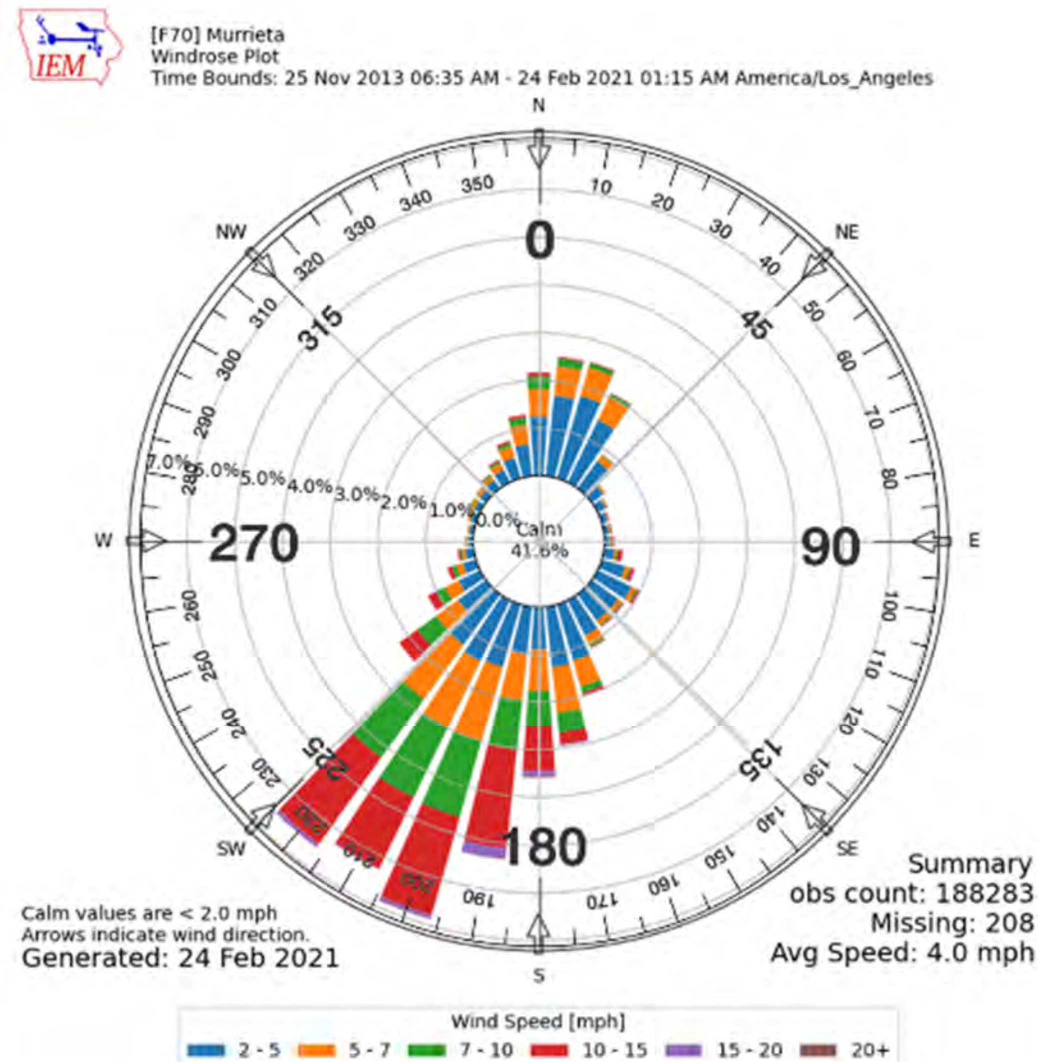

Figure 8 – AWOS Output for French Valley Airport (8 years)

The SCE RAWS site has only been in place since 4/26/2019. SCE has been installing these units in high hazards areas for several years and will eventually have a very robust network of sensors capable of being used in real-time analysis and fire weather prediction. The tables in Figure 9, on the next page, provide a different look at the weather data. This data is for maximum wind gusts and RH (relative humidity). These graphics clearly show the prevailing wind direction is from the South-Southwest (daytime onshore) and from the NE (Santa Ana winds and nightly offshore wind). Strong onshore winds account for 43.6% of the wind and strong offshore winds another 31.5%. This means that over 75% of the wind is in one of these two general directions.

The Maximum Wind Gust table, below, indicates that a strong wind (25-30 mph) can come from almost any direction. Still, the stronger winds are essentially from the offshore Santa Ana wind events and the heat generated onshore flow created by heating (rising) in the interior and air from over the ocean moving in to fill that low-pressure area. The table with the three tabulation of temperature, RH, Wind speed, wind direction and wind gust speed provide the average, minimum and maximum values and values for the 97.5th percentile and the 2.75th percentile.

Wind Gust Direction										
	2021		2020		2019 Partial		Average		
N	1,223	2.5%	1,532	2.9%	718	2.0%	2.5%		
NNE	3,076	6.3%	3,561	6.8%	1,951	5.4%	6.2%		
NE	9,002	18.4%	11,603	22.2%	6,620	18.4%	19.7%	31.5%	Offshore
ENE	2,577	5.3%	3,185	6.1%	1,986	5.5%	5.6%		
E	1,447	3.0%	1,509	2.9%	977	2.7%	2.9%		
ESE	1,570	3.2%	1,444	2.8%	946	2.6%	2.9%		
SE	1,576	3.2%	1,399	2.7%	1,124	3.1%	3.0%		
SSE	2,007	4.1%	1,856	3.5%	1,305	3.6%	3.8%		
S	5,069	10.4%	4,672	8.9%	3,795	10.6%	10.0%		
SSW	10,031	20.5%	9,719	18.6%	8,638	24.1%	21.1%	43.6%	Onshore
SW	6,051	12.4%	6,471	12.4%	4,679	13.0%	12.6%		
WSW	1,924	3.9%	1,944	3.7%	1,177	3.3%	3.6%		
W	706	1.4%	775	1.5%	399	1.1%	1.3%		
WNW	488	1.0%	489	0.9%	283	0.8%	0.9%		
NW	624	1.3%	663	1.3%	316	0.9%	1.1%		
NNW	905	1.9%	1,011	1.9%	434	1.2%	1.7%		
BLANK	583	1.2%	515	1.0%	560	1.6%	1.2%		
	48,859	100.0%	54,368	100.0%	35,908	100.0%	100.0%		

2021						
		Temp	RH	Wind	Dir	Gust
48,860	Average	64	59.0	3.4	151	7
observations	Min	33	6.3	-	0	-
	Max	106	100.0	19.9	360	38
Percentile	97.50%	92	98.0	9.3	333	17
	2.75%	42	12.7	0.1	20	1
2020						
		Temp	RH	Wind	Dir	Gust
52348	Average	64	58.7	3.2	144	6
observations	Min	28	5.5	-	0	-
	Max	114	100.0	15.2	360	29
Percentile	97.50%	94	98.6	8.9	337	16
	2.75%	41	12.1	0.1	18	1
2019 Partial						
		Temp	RH	Wind	Dir	Gust
35908	Average	65	60.5	3.4	151	7
observations	Min	34	2.9	-	0	-
	Max	102	99.9	18.0	360	33
Percentile	97.50%	93	97.6	9.2	317	17
	2.75%	44	10.9	0.1	23	1

Maximim Wind Gust			
	2021	2020	2019
E	31.1	23.5	32.66
ENE	28.8	23.7	29.24
ESE	26.3	24.3	24.85
N	20.1	26.2	16.06
NE	38.2	28.2	28.27
NNE	21.8	23.0	26.96
NNW	22.4	24.9	16.73
NW	17.4	19.8	15.21
S	26.3	28.9	27.98
SE	21.9	20.4	18.57
SSE	19.4	18.6	18.92
SSW	32.4	25.5	30.53
SW	26.5	29.2	23.44
W	23.8	22.6	17.02
WNW	16.9	17.6	12.57
WSW	25.1	24.4	23.24
Max	38.2	29.2	32.66

RH						
	2021		2020		2019 Partial	
<15	2,125	4.3%	2,622	5.0%	1,802	5.0%
<10	532	1.1%	767	1.5%	763	2.1%
	3	0.0%	2	0.004%	110	0.3%
	<6.4		<5.6		<5	

Figure 9 – RAWS data (2.6 years)

Values outside of the 2.75th and 97.5th percentile are normally considered to be anomaly or outliers which are not statistically significant. For the purposes of this report, all data will be used in its maximum impact condition.

Below, a wind rose is superimposed onto the project site so that the orientation of the wind and its relationship to the project boundaries can be illustrated. These same compass heading will be used to reference the aspect and fire spread direction during the fire behavior discussion.

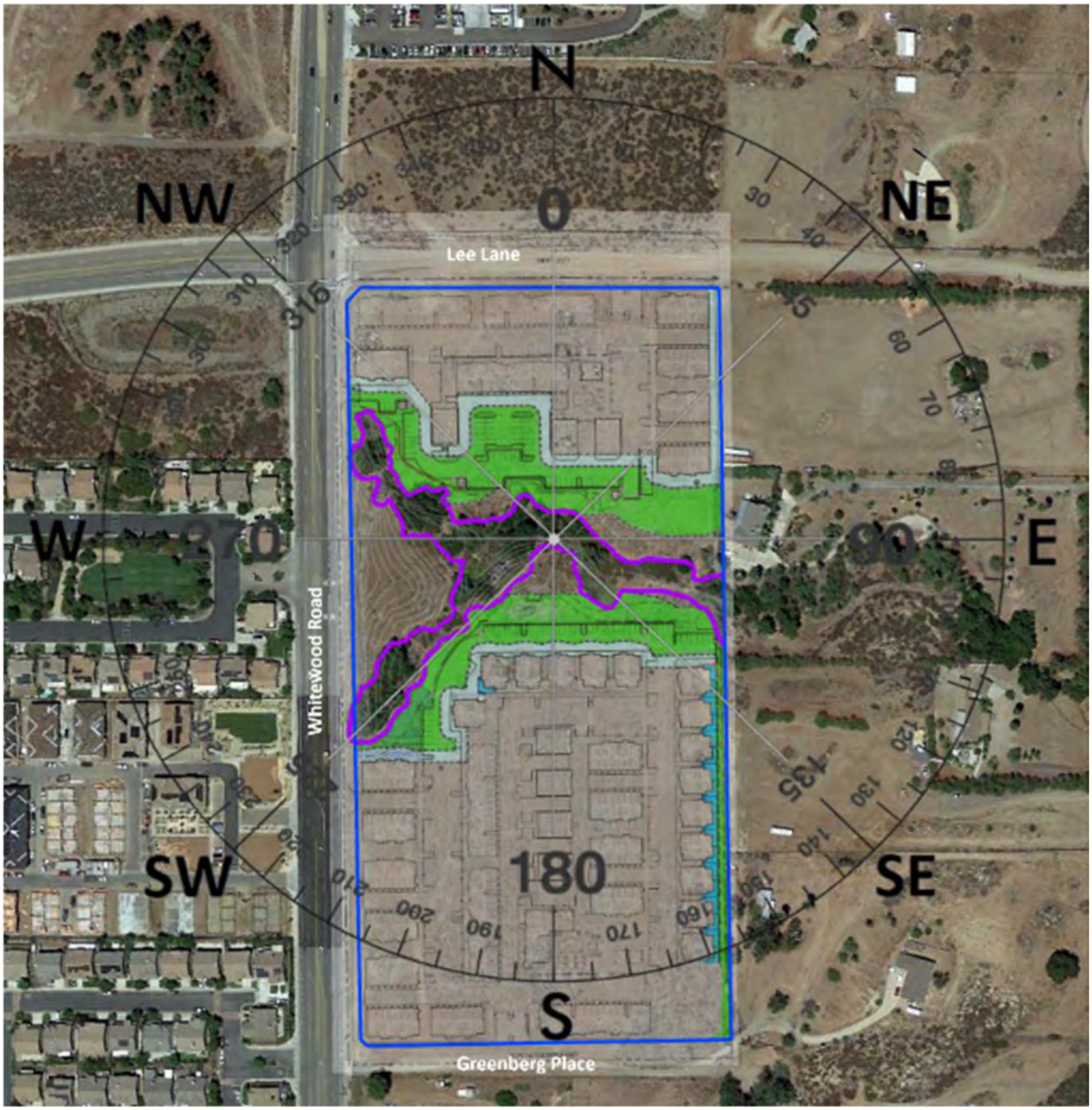

Figure 10 – Project Site with Compass Overlay

The graphic below (Figure 11) provides an indication of how the predominant wind (red arrows) run in the onshore and offshore flow. Additionally, north, and east winds are shown in the gray arrows. The east winds do not move fire in the direction of any of the structures from the riparian areas within the project site. The north wind does align with some limited fuels on the west side of the project site on the south side of the riparian area.

Figure 11 – Project Site Wind Directions

In addition to the direction of the wind, the wind flow through and around the topography must also be considered. The project site was modeled in Wind Ninja to provide an illustration of the wind flow as the wind travels across the region and onto the interface areas of the project site for the onshore wind and for the offshore wind. Figures 12 and 13, on the next page, illustrates the outputs in plan view for offshore wind (N and NE winds). In all of these wind scenarios, the west interface has winds that are at or below (blue, green or yellow) the modeled wind speed for the domain average. Wind acceleration (red or orange) are present on the ridgetops north of the project site and downwind past the west interface but not in large contineous fuelbeds in the upwind side of the interface. Of specific note is the small differences in the wind values (approximately 4 mph) amongst the middle 60% of the values (each color represents 1/5th the total wind values). In all cases at the interface, the values are within 10% of the domain average. The topography has little effect on the winds speed and no wind channeling (direction change) occurs in this modeling. The onshore winds are the exact opposite of the offshore with similar values in the same locations.

The area of concern with the current configuration is the riparian area which will be maintained in a native state in perpetuity. No fuel reduction, thinning or other modifications will be allowed in these areas. This analysis will provide objective findings determine what distances, configuration and additional fire protection measures will be needed to prevent a fire in this area from becoming a threat to the adjacent structures.

Figure 12 – Wind Ninja Output for Offshore NE Winds

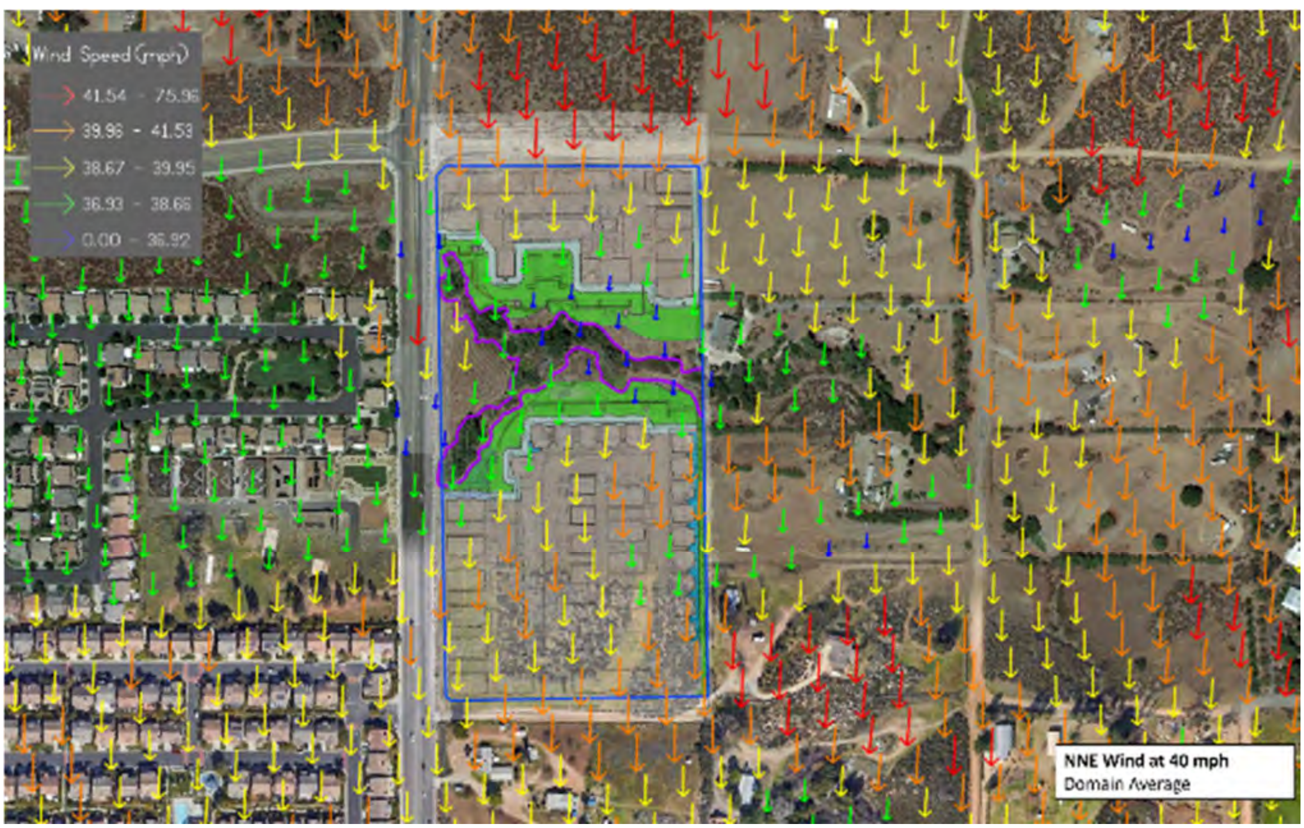

Figure 13– Wind Ninja Output for Offshore N Winds

Wildland Interface Fuel Types

For the purposes of the BehavePlus modeling the standardized fuel models were used as provided by the National LANDFIRE Database maintained by U.S. Department of the Interior | U.S. Geological Survey. Figure 14, on the next page, provides an illustration of the wildland fuels adjacent to Whitewood Apartments project site. The parameter of each fuel type shown in the Landfire Database and those identified on the site survey are as follows:

Fuel **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.

Fuel **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.

Fuel **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.

Fuel **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 TL2** (182) Fuelbed not recently burned. Fuelbed composed of broadleaf (hardwood) litter. Low load, compact. Spread rate very low; flame length very low. Moisture of extinction is 25%. Fuel bed depth is 0.2 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.

Fuel **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.

Fuel **Model TL9** (189) Fuelbed not recently burned. Fuelbed does not include coarse fuels. Fuelbed composed of broadleaf (hardwood) litter. Very high load, heavy needle-drape in otherwise sparse shrub layer. Spread rate moderate; flame length moderate. Moisture of extinction is 35%. Fuel bed depth is 0.6 feet.

In addition to the fuels found in the Landscape database, a site visit found the following fuel model to be present.:

Fuel **Model SCAL18** is a southern California specific model for coastal sage scrub and Buckwheat OR dominated by coastal sage scrub AND greater than 15 years maturity OR dominated by northern mixed chaparral AND greater than or equal to 3 years maturity AND less than or equal to 12 years maturity. The vegetation has an average fuel depth of 3 feet and a moisture of extinction of 25%.

Not all of the fuel models listed above are represented within the interface area. In addition to the fuel models, the Landfire database provides a data layer that indicates the vegetation class as well. This information is provided in Figure 15 on the next page).

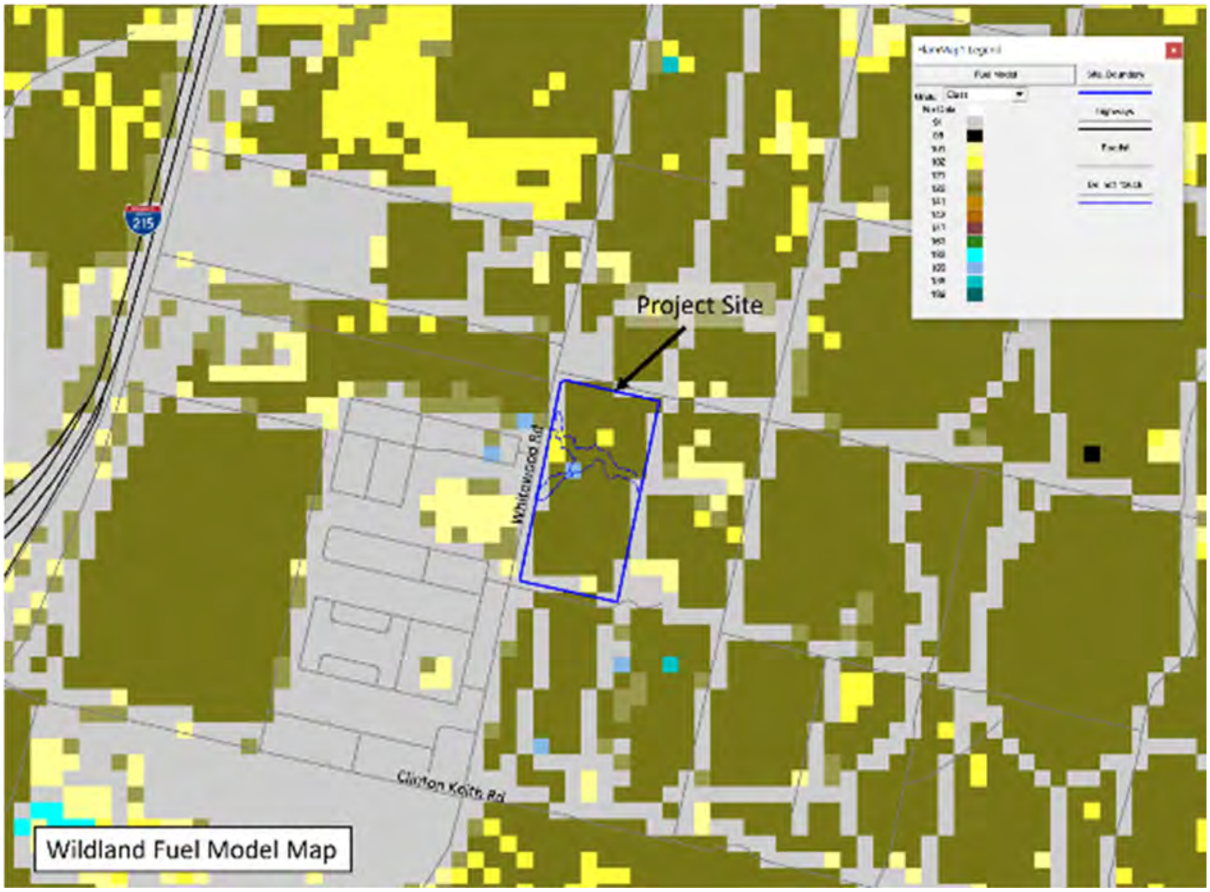

Figure 14 – Wildland Fuels (Landfire Database – Scott and Burgan 40) Project site outline in blue

Figure 15 – Vegetation Classes for project site interfaces. Project site outlined in blue.

The predominant fuels on and near the project site are grasses, grass/scrub mixtures, and riparian areas as shown on the next four photos and in a series of photos in Appendix B of this report. Each of the grids in the graphics (Figures 14/15 and all other Landfire database graphics) is a 30 meters square (just under ¼ acre). Fuel parameters for each grid are determined by the predominant fuel types. This does mean that other fuels are not present in each grid but from a fire modeling perspective, they are not impactful enough to change the predominate fuel type shown. The riparian area is shown below (outlined in purple/project site outlined in blue). The riparian area is a ribbon of fuel that bisects the project site. Fuels are limited in quantity as shown in the site photos on the next two pages.

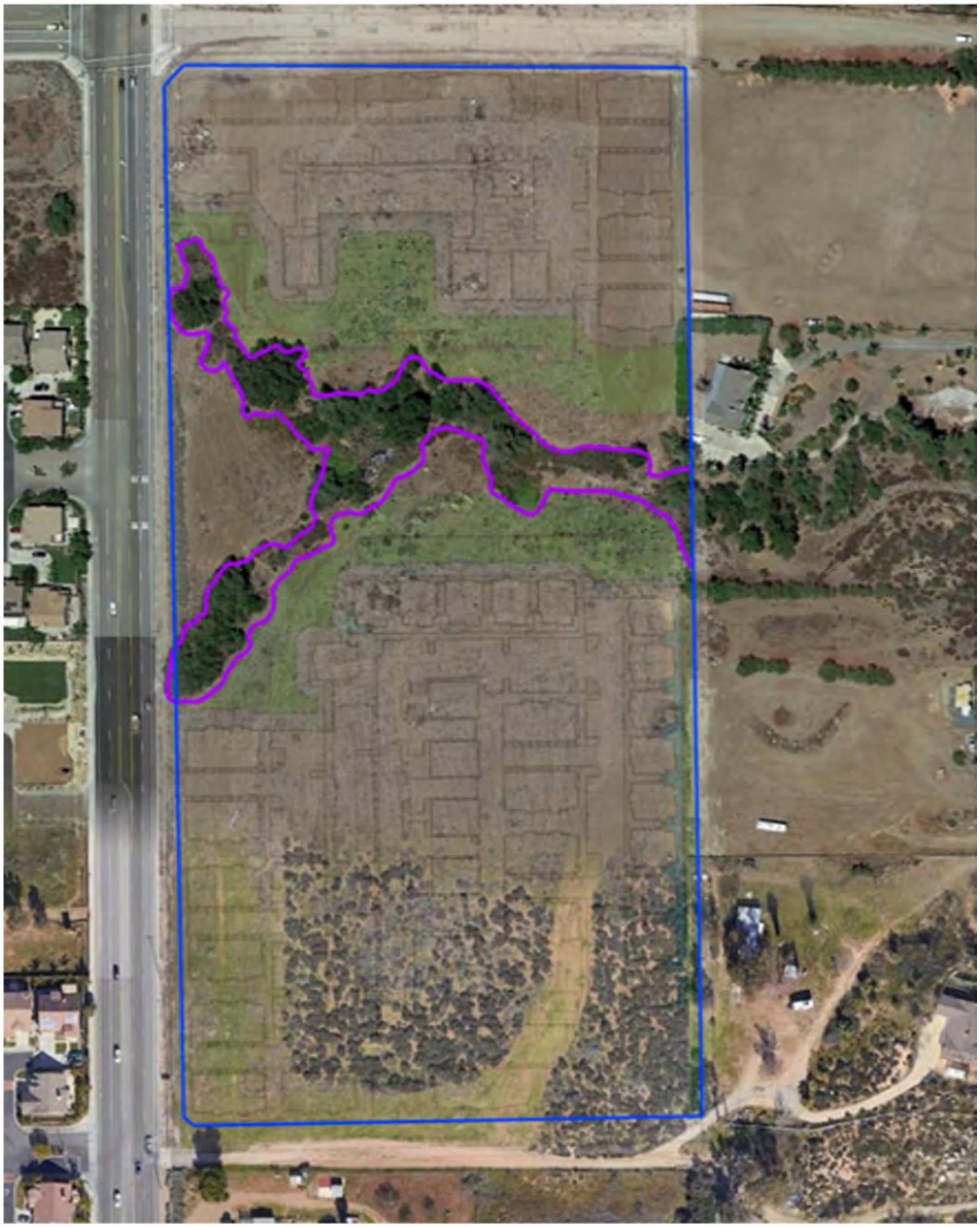

Figure 16

Photo 1

Photo 2

Photo 3

Photo 4

Fuels Discussion

The project site is surrounded on three sides by developed land. Onsite, the project area will be transformed to development and fuel modification zones in all areas except the riparian area and the open space between the two riparian area branches. In accordance with the project site biological assessment for CEQA, (*Initial Study/Mitigated Negative Declaration, Whitewood Apartment Project, dated 12/2021, prepared by DUDEK, 605 Third Street, Encinitas, California 92024*), the remaining undeveloped areas will contain Coastal sage–chaparral scrub, Non-native grasslands, Riparian Forest and Mulefat scrub areas.

- Coastal sage–chaparral scrub is disturbed and confined to boulder and rock outcrops, and the manufactured slope along Whitewood Road. Isolated pockets of native shrubs mixed with landscaping materials are scattered around the project site; most of which will be developed.

- Non-native grasslands encompass a majority of the project site and supports some spring annuals and wildflowers, most of which will be developed.

- The Riparian Forest is associated with the drainage that bisects the property and is characterized by a mix of mature black willow (Salix gooddingii), red willow (Salix laevigata), western cottonwood (Populus fremontii subsp. fremontii), and coast live oak trees. The understory is a mixture of riparian and upland species. The habitat shows a moderate variability in patch size and bush height. Some areas are dense while other areas are sparce.

- Mulefat scrub on the project site, is a small portion of the drainage near the eastern property boundary.

Small areas of the riparian have dense fuels with a significant dead component. Ladder fuels exist capable of moving fire from the surface to the tree canopies if the foliar moisture level is low enough. Since the canopy fuels are not continuous in the direction of the structures (for most wind directions) only torching or canopies from a small number of trees could possibly be involved at any point in time. The large gaps between groups of trees also prevent the possibility of a canopy fire run in the direction of the proposed structures due to the lack of available fuel. The trees within the riparian (oaks, willows and cottonwood trees) are not as inclined to crown fires as the pine, fir and mixed conifer on which the crown fire modeling is based.

Elevation Slope and Terrain

The project site is relatively flat from a fire behavior perspective. Figure 17, on the next page, provides a representation of how the site and general area rise up from the east to the west. There are no significant topographic features on or near the project site which will have an immediate impact on fire behavior at the interface.

The slope is an important input to the BehavePlus modeling software. For this reason, a slope analysis was completed using the Landfire database for this area. Figure 18, on the next page, is a graphic representation of the average slope within each of the 30-meter grids in the dataset. The maximum slope in any grid within the immediate areas is <10 degrees (16%). The project site is relatively flat with the slopes being the transition to the adjacent riparian areas or the site boundary. All interface areas which will be regraded will be reestablished with a slope not to exceed 50% (2:1 slope).

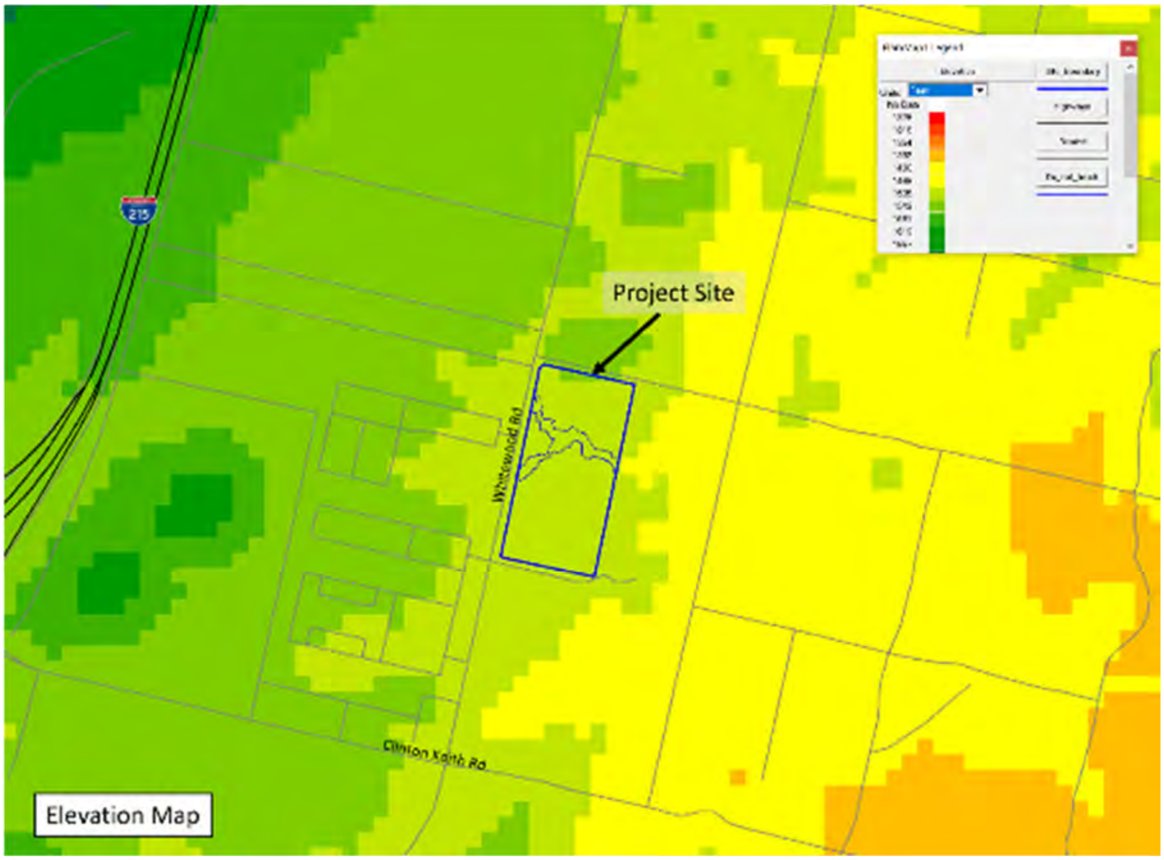

Figure 17 – Elevation Map

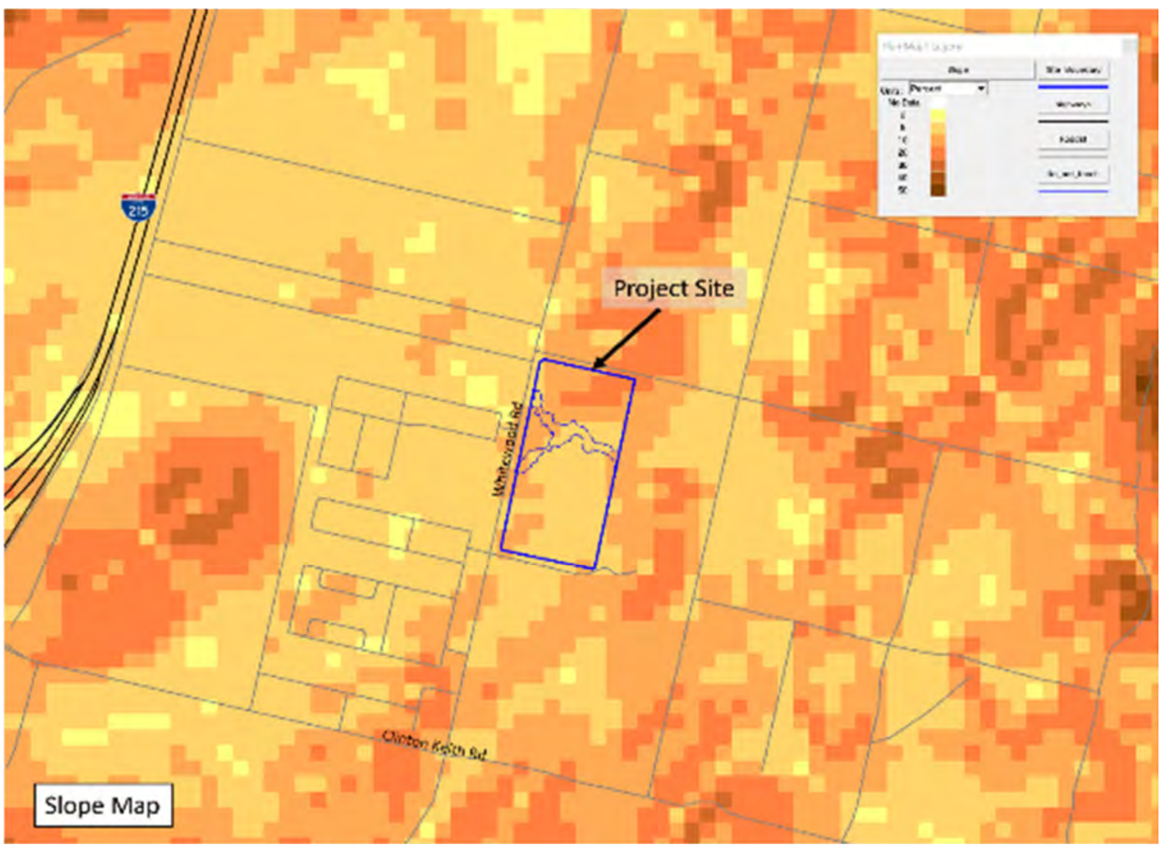

Figure 18 – Slope Map

Due to the lack of slope, the aspect of the difference does not play a significant role in fire behavior, and due to the grading and other changes within the development areas, the overall site conditions will be flat or modeled as a south aspect (sunlight most of the day and lowest fuel moistures). Current site aspects are provided below (Figure 19) for the pre-graded site conditions. Most of the site is already considered to be a south aspect (yellow).

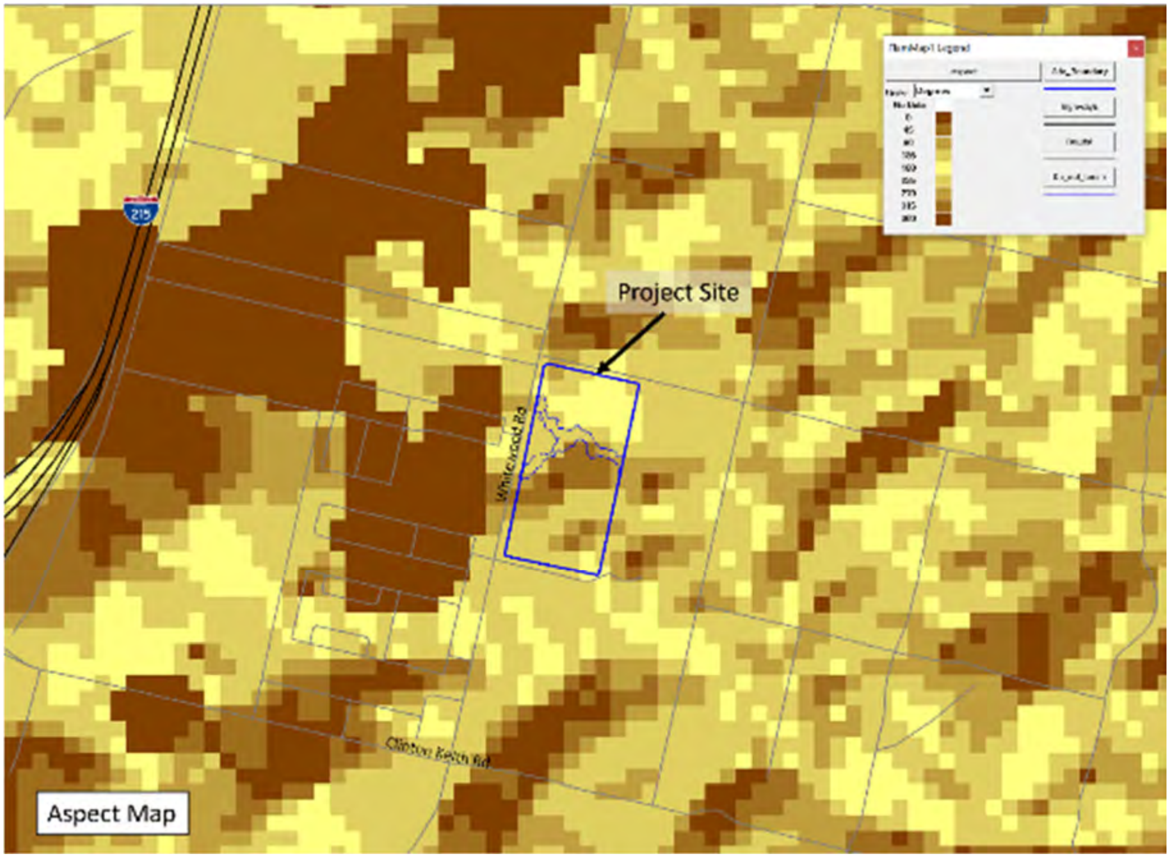

Figure 19 – Aspect Map

The worst-case fire conditions exist when topography, fuels and wind are in alignment. Full alignment (homes are up slope from the fuel modification zones and are in alignment with the extreme winds–Santa Ana or the normal onshore flow) of all three factors does not occur in the project site for the predominant wind patterns.

BehavePlus Plus Fire Behavior Inputs and Results:

Worst case National Wildfire Coordinating Group Fireline Handbook models have been used for analysis; specifically, all dry climate fuel models have been used. Worst case fire weather was used as well. Inputs for the BehavePlus Fire Behavior Model are as follows:

- One-hour dead fuel moistures were calculated at 5%; ten-hour at 6% and 100-hour at 10%.
- Live Herbaceous fuels were calculated at 30% in the wildland.
- Live Woody fuels were calculated at 60% in wildland.
- Temperatures were assumed to be over 100 degrees.
- Worst-case scenarios assumed a 16% slope (< 10 degrees) in the wildland interface.
- Winds are calculated at 40 mph (20-foot wind speed).

- Aspect of the slope is assumed to be in alignment with the wind (directly upslope as worst-case).
- Spread direction is shown at the direction of greatest spread per Behave outputs.
- Wind adjustment factor of 0.5 was used under the worst-case scenario.

The inputs to the fire modeling are shown in Figures 20 and 21, below. Fuel Descriptions from the outputs have been added for readability.

Fuel Model		
102	gr2	Low load, dry climate grass (D)
122	gs2	Moderate load, dry climate grass-shrub (D)
165	tu5	Very high load, dry climate timber-shrub (S)

Figure 20 – Fuel Model Descriptions

Full details for each model run are available in the appendixes. Version 6.0.0 of the BehavePlus modeling program was used for this analysis. The modeling inputs/outputs are attached in the appendixes but have been summarized here in the next few figures for discussion purposes.

Inputs: SURFACE		
Description		Whitewood Apartments Murietta
Fuel/Vegetation, Surface/Understory		
Fuel Model		gr2, gs2, tu5
Fuel Moisture		
1-h Fuel Moisture	%	5
10-h Fuel Moisture	%	6
100-h Fuel Moisture	%	10
Live Herbaceous Fuel Moisture	%	30
Live Woody Fuel Moisture	%	60
Weather		
20-ft Wind Speed	mi/h	40
Wind Adjustment Factor		0.5
Wind Direction (from north)	deg	45
Terrain		
Slope Steepness	%	0, 10, 20, 30
Site Aspect	deg	45

Figure 21 – BehavePlus Inputs

Modeling Assumptions

Shrub and SCAL fuels are certainly present in the riparian area of the project site. The timber understory (tu5) is the worst-case condition for the riparian forest areas that occupy the bottom of drainages. The Landfire database indicates that the project in general is predominately gs2 fuel with small area of timber litter models in the bottom of the drainages. The majority of the drainages, when averaged with the adjacent vegetation are shown as grass/shrub mixtures. Modeling has used the seasonal grass model (gr2), the grass/shrub mixture (gs2) and the timber understory (tu5) as the appropriate fuel models for the project site interfaces.

It is important to view the fuel parameters of the fuel models to be used for the worst-case scenario. They must be applicable to the fuel beds adjacent to the project site since they will be the locations that are pushed to the most extreme fire behavior. First to be examined is the average fuel bed depth. The graphic below (Figure 22) provides an illustration of how this value is calculated. It is not based on the highest fuel but rather an average of the entire fuel bed area to produce a value that represents a continuous fuel bed at a constant rate for the model.

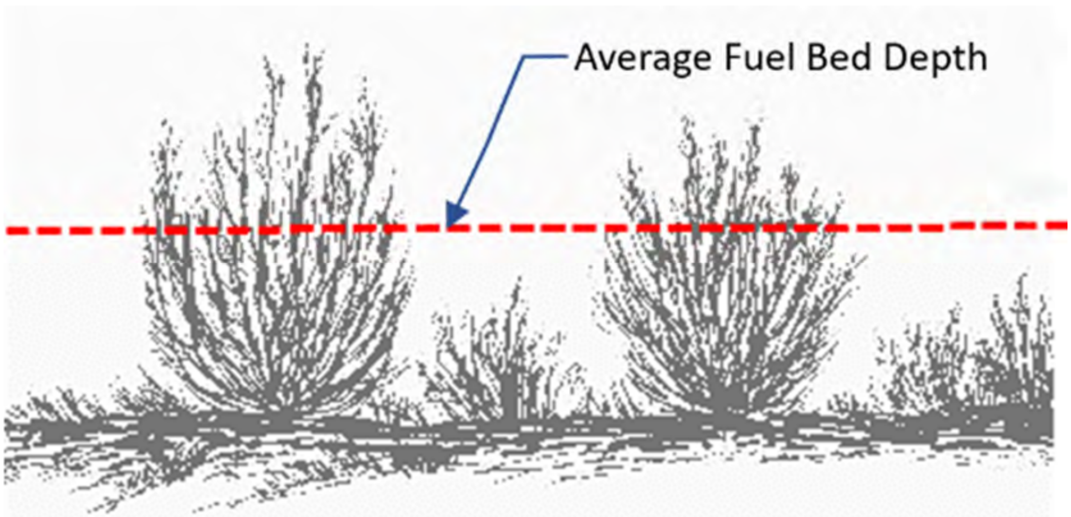

Figure 22 – Average Fuel Bed Depth

Below and on the next page (Figure 23 and 24), are the specific parameters for each of the dry fuel models which could be used for the project site. All of the four-foot or larger fuel bed models can be eliminated as there is simply not enough continuous fuel on the site to drive this level of fire behavior. It should be noted that these are surface fuel models which only consider the fuel within six feet of the ground. Canopy fuels (above six feet) are considered in a different calculation.

Fuel Model Parameters												Fuel
Fuel	Fuel		Fuel load (t/ac)					Fuel	SAV ratio (1/ft)			bed
Model	Model					Live	Live	model	Dead	Live	Live	depth
Code	Number	Climate	1-hr	10-hr	100-hr	herb	woody	type	1-hr	herb	woody	(ft)
GR1	101	Dry	0.10	0.00	0.00	0.30	0.00	dynamic	2200	2000	9999	0.4
GR2	102	Dry	0.10	0.00	0.00	1.00	0.00	dynamic	2000	1800	9999	1.0
GS1	121	Dry	0.20	0.00	0.00	0.50	0.65	dynamic	2000	1800	1800	0.9
GS2	122	Dry	0.50	0.50	0.00	0.60	1.00	dynamic	2000	1800	1800	1.5
SH1	141	Dry	0.25	0.25	0.00	0.15	1.30	dynamic	2000	1800	1600	1.0
SH2	142	Dry	1.35	2.40	0.75	0.00	3.85	static	2000	9999	1600	1.0
TU5	165	Dry	4.00	4.00	3.00	0.00	3.00	static	1500	9999	750	1.0
SCAL14	Manzanita	SCAL	3.00	4.50	1.05	1.45	5.00	static	350	1500	250	3.0
SCAL15	Chamise 1	SCAL	2.00	3.00	1.00	0.50	2.00	static	640	220	640	3.0
SCAL17	Chamise 2	SCAL	1.30	1.00	1.00	2.00	2.00	static	640	2200	640	4.0
SCAL18	Sage/Buckwheat	SCAL	5.50	0.80	0.10	0.75	2.50	static	640	1500	640	3.0

Figure 23 – Fuel Parameters Part 1

The SCAL fuels are species specific, and the biologist report indicates that the amount of fuels represented by these unique fuels is not great enough to be the predominant fuel within the 30-meter grid. For this reason, they were not used here.

	Dead fuel		Dead Component Calculation				
Fuel Model Code	extinction moisture (percent)	Heat content BTU/lb)c	Dead	100% Transfer Herb	Dead load	Total Load	Percentage Dead Component
GR1	15	8000	0.10	0.30	0.40	0.40	100%
GR2	15	8000	0.10	1.00	1.10	1.10	100%
GS1	15	8000	0.20	0.50	0.70	1.35	52%
GS2	15	8000	1.00	0.60	1.60	2.60	62%
SH1	15	8000	0.50	0.15	0.65	1.95	33%
SH2	15	8000	4.50	no transfer	4.50	8.35	54%
TU5	25	8000	11.0	no transfer	11.00	14.00	79%
SCAL14	15	9211	8.55	no transfer	8.55	15.00	57%
SCAL15	13	10000	6.00	no transfer	6.00	8.50	71%
SCAL17	20	8000	3.30	no transfer	3.30	7.30	45%
SCAL18	25	9200	6.40	no transfer	6.40	9.65	66%

Figure 24 – Fuel Parameters Part 2

The fuel used represent the highest risk for the project site interface given the amount of fuel that currently and historically exists at the interface.

The first Behave output to examine is flame length. A maximum flame length for the tu5 fuel model is 17.7 feet in a 40-mph wind at 30% slope in the wildland. This level of fire activity would produce a fireline intensity of 10,194 kW/m^2. This fire model is for fire burning at the head (leading edge) in direct alignment with the slope, fuel and wind (full alignment) and represents the worst-case scenario for the project site interface. Flanking fire (90 degree off the head fire) is 1/3 the length and intensity.

Whitewood Apartments Murietta
Head Fire
Surface Fire Flame Length (ft)

Slope	Fuel Model		
%	gr2	gs2	tu5
0	9.0	15.9	17.5
10	9.0	15.9	17.5
20	9.0	16.0	17.6
30	9.0	16.1	17.7

Whitewood Apartments Murietta
Head Fire
Surface Fireline Intensity (kW/m)

Slope	Fuel Model		
%	gr2	gs2	tu5
0	2338	8062	9870
10	2338	8079	9906
20	2338	8129	10014
30	2338	8213	10194

Figure 25 – BehavePlus Outputs – Head Fire Flame Length and Fireline Intensity

Whitewood Apartments Murietta
Flanking Fire
Surface Fire Flame Length (ft)

Slope	Fuel Model		
%	gr2	gs2	tu5
0	3.6	5.1	5.6
10	3.6	5.1	5.6
20	3.6	5.1	5.6
30	3.6	5.1	5.6

Whitewood Apartments Murietta
Flanking Fire
Surface Fireline Intensity (kW/m)

Slope	Fuel Model		
%	gr2	gs2	tu5
0	317	677	828
10	317	677	829
20	317	679	831
30	317	682	835

Figure 26 – BehavePlus Outputs – – Flanking Fire Flame Length and Fireline Intensity

If the project site structures are protected from a direct hit, any other fire scenario will be less risky.

The risk analysis needs to examine the potential for a fire within the adjacent native fuel 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 17.7 feet under any scenario. Any distance greater than this will keep the flames off of the structure.

The 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 (Figure 27, below).

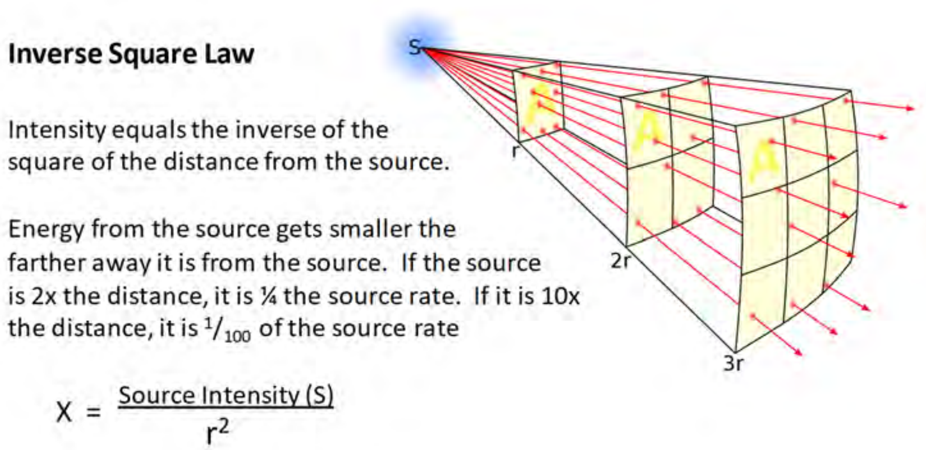

Figure 27 – Inverse Square Law

While this is simplified, it is overall accurate at a conceptual level. Several models exist for the calculation of the Radiant Heat Flux on a structure from various fire sources. Most are complicated and have a set of complex assumptions that must be made. The Inverse Square Law does not specify a unit of measure. The formula is relational between the distance and the source. The drop in heat from the source to distance r is relational to distant 2r and 3r. Firesafe uses a simple formula as a "yardstick" for generalized assumptions about radiant heat from fire. This formula is the FI (Fireline Intensity) from the Behave outputs over the distance in feet squared. Because Newton's Law is relational, it does not specify a unit of measure. Firesafe has derived its "rule of thumb" from the research done by Qiong Liu, using the formula shown below.

Radiative heat transfer from multiple discrete fires

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SAGE

Qiong Liu[1], Naian Liu[2] and Xinyan Huang[3]

Date received: 17 May 2017; accepted: 8 June 2017

For a single pool fire, it is generally assumed that the flame radiation energy is released from the point source located at the center of the flame, based on the point-source model. Then, the incident radiative heat flux $\dot{q}''$ that a target receives in the horizontal distance L from the center of pool fire is given by[14]

$$\dot{q}''_0 = \frac{\dot{Q}_r}{4\pi R^2}\cos\theta \qquad (3)$$

where $\dot{Q}_r$ refers to the total radiative energy output of the fire; θ represents the view angle if the target horizontally faces the fire; $R=\sqrt{L^2+H_T{}^2}$ (here, H_T denotes the height from the point source to the target) is the distance from the point source to the target, as illustrated in

[14] Beyler CL. Fire hazard calculations for large, open hydrocarbon fires. In: Hurley MJ, Gottuk DT, Hall JR, et al. (eds) SFPE handbook of fire protection engineering. 3rd ed. Bethesda, MD: National Fire Protection Association, 1999, pp. 3-268-3-314.

Figure 28 – Source of Radiant Heat Formula

In nearly all cases, two times the maximum flame length will provide a radiant heat flux value of about 10 kW/m^2. This stands to reason as flame length (LF) is a function of fireline intensity (I) in Byram's formula LF=0.0775*$I^{0.46}$ which most closely approximates the interchanges between these two values (fireline intensity and flame length) in the Behave program.

We should be very clear here; this is not the only factor of the amount of heat that might be subject to a specific structure. The real world is much more complicated than a simple formula. Most literature indicates that a hardened structure should be able to withstand 20 to 30 kW/m^2 for a period of 5 minutes or less and not ignite. Using the two times the maximum flame length on the worst-case fire should place the actual value much less than the ones calculated here when a fire actually burns in the interface.

Jack Cohen's SIAM (Structural Ignition Assessment Model) uses a radiant heat flux threshold of 20 kW/m^2 for 5.5 minutes as the baseline for structure ignition (Cohen, J.D., 1995. Structure Ignition Assessment Model (SIAM), USDA Forest Service Gen. Tech. Rep. PSW-GTR- 158). The residence time for a fire within the adjacent drainage would have a residence time of less than one minute under the worst-case scenario; far below the 5.5 minutes needed and would not have sufficient heat beyond the fuel medication zone to ignite any structures. The adjacent wildland areas simply lack the quantity of fuel necessary to burn at a high rate for a time period long enough to create a radiant heat issue at the distances provided at two times the maximum flame length.

Radiant heat flux (energy/time/area reaching a surface) is the amount of radiant heat energy a wall could receive from flames, depends on its distance from the fire. Fire 29, on the next page is from live fire experiments conducted by Jack Cohen showing the relationship between radiant heat energy and distance to a structure. The test-fire is 20 meters in height and 50 meters wide. The graphic shows how energy dissipates over distance. At 40 meters (2x the flame height), the ignition time is over ten minutes whereas at 30 meters, it is 90 seconds. The ignition time is inverse to the heat flux in terms of energy vs distance. The heat energy drops exponentially, and the ignition time increases exponentially as well.

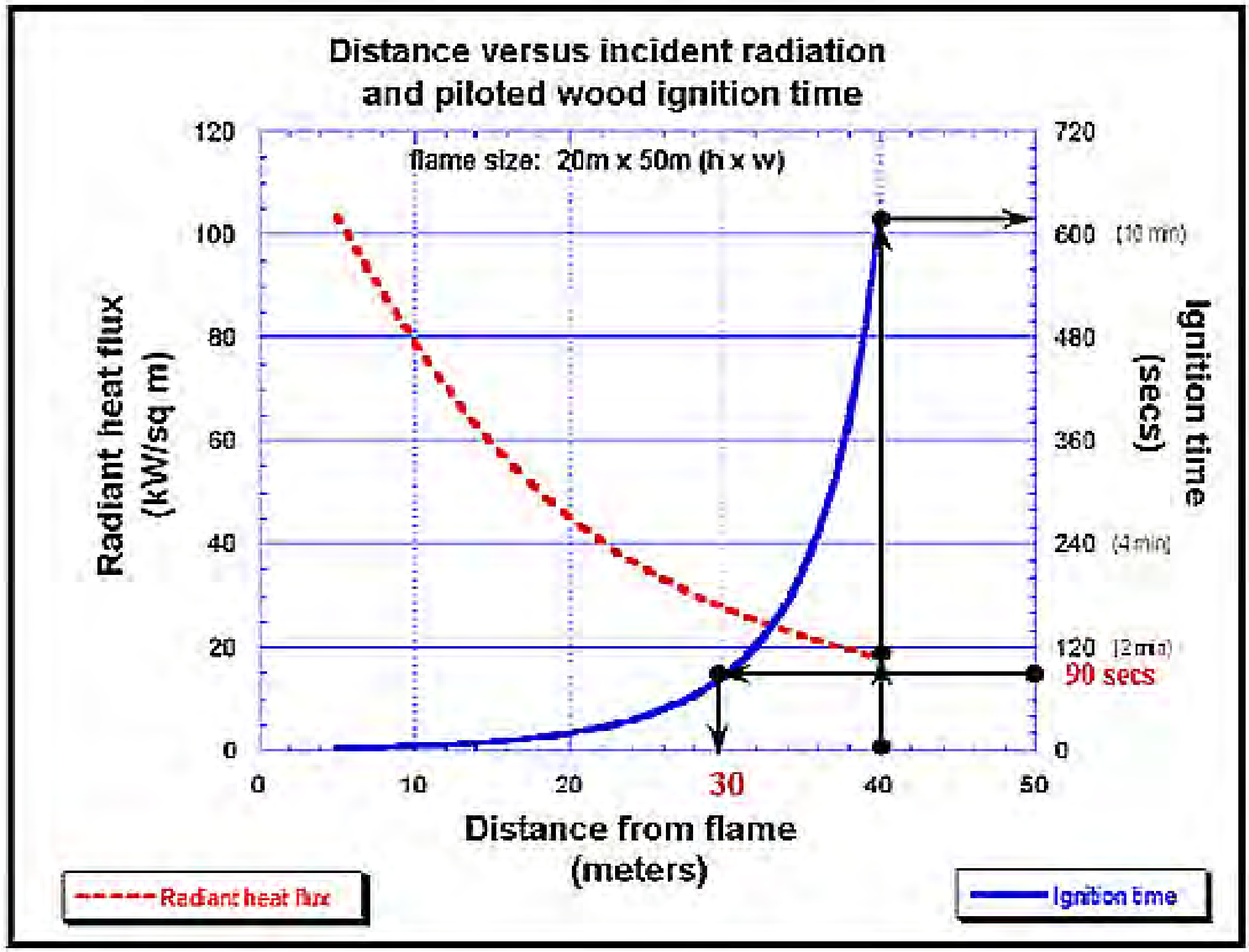

Figure 29 - Radiant Heat Exposure *(Jack D. Cohen, What is the Wildland Fire Threat to Homes?,April 10, 2000, School of Forestry, Northern Arizona University, Flagstaff, AZ)*

The design of the fuel modification zones will ensure that the structures within the project site will not have heat energy exposures of 20 kW/m^2 (this level will kill half of the victims exposed to it in 30 seconds but requires 5.5 minutes of exposure to ignite a wood wall). Figure 30, on the next page, provides a guide to radiant heat levels and their effect on structures and the human body.

Per the Behave outputs, the 17.7-foot flame lengths will produce 10, 194 kW/m^2. At 30 feet, the maximum energy generated has fallen to under 12 kW/m^2 using the simplified formula.

$$10{,}1943/30^2 = 11.326$$

This is not a level of safety for residents or firefighters (exposed skin would burn in eight seconds) but is low enough to protect the hardened structures (20 minutes to piloted ignition on wood structures).

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.

The final method of fire encroachment would be embers and brands. These can and will travel great distances. The project site will be protected from this threat by compliance with California Residential Code Section R337.

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 – Calculation of Radiant Heat Exposure

Fire Behavior Summary

The modeling indicates that flame lengths of just under 18 feet are possible under perfect conditions, in the worst-case scenario that does not currently exist at or near the project site. The design criteria for the project site must properly protect the structures from a wildland fire under these conditions. Most of the fuels are not aligned with the slope and wind as little slope exists on or near the project site. Most of the interface fuels are not continuous enough to drive fire behavior to the level of the equilibrium spread rates used in the modeling. Fire driven by the onshore or offshore winds will not align fuels to create continuous fuel beds that will lead directly to proposed structures where the distances are not enough to mitigate the energy. Winds which take fire across the riparian areas will simply run out of fuel in a short about of time.

At 17.7-foot flame lengths and 10,194 kWm², the worst-case fire must consumer 68.3 feet of linear fuel per minute. At the absolute worst location possible, only 120 feet if fuel exists running diagonally across the riparian area. A "line of fire" cannot burn into the project site. Except for the east interface, the fire must cross a road. In all cases, the fire must enter the property as an ember or small fire and accelerate to the worst-case scenario. From an ember, this acceleration burns up fuel.

Using the 120 feet worst-case run and the tu5 fuel model, a surface fire would need to ignite, then as it grows, we can assume that it will increase by 150% every sixty seconds consuming fuel as it burns. The fire will run out of fuel before it reaches the maximum rate of spread/flame length. It will reach the maximum in less than five minutes, but it will run out of fuel prior to achieving equilibrium. This scenario assumes the fire starts at the farthest point and runs through all of the available fuel. It should also be noted that at its maximum consumption, the residence time for the flaming front will be less than one minute.

Interval (min)	Flame Length	ROS	Accumulated Distance
1	4.6	3.3	3.3
2	7.1	8.6	11.9
3	11	22.5	34.4
4	16.6	55	89.4
5	17.7	63.8	153.2

The combination of limited fuels, lack of slope, alignment of the wind and the nature of the fuelbed, the project site risk is not significant. Where possible, the project site will provide the prescriptive 100-foot fuel modification zones, but where this distance is problematic, shorter distances are safe when the correct factors are in place. These specific details are discussed in the next section.

A FlamMap run was produced to review the issue of Crown Fire potential. Using the Landfire database LCP file for this area, the following outputs were obtained. The output indicates surface only (Figure 31below) and flame lengths for the project are generally the same (Figure 32, on next page). While some torching of single trees is possible, a canopy run (crown fire) is not indicated.

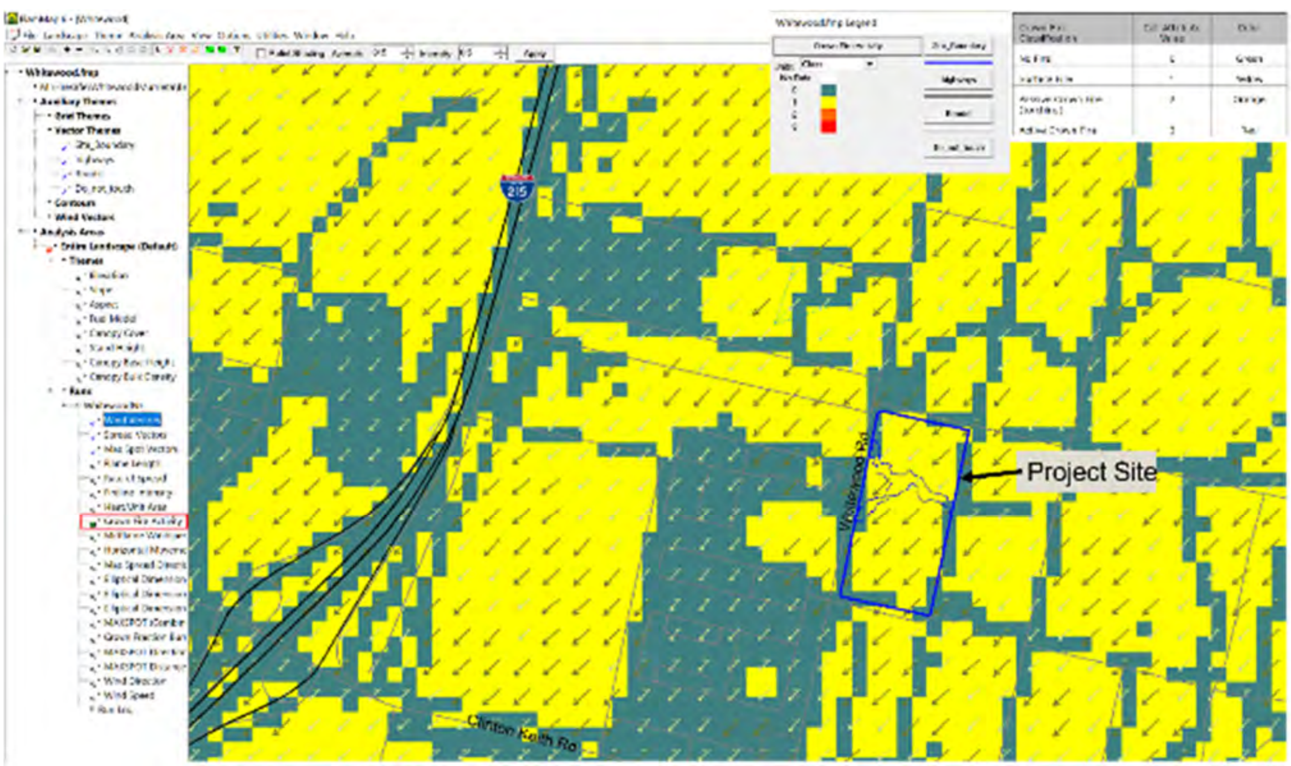

Figure 31- FlamMap Crown Fire Output

Figure 32 -FlamMap Flame Length Output

The technical results provided as part of the Fire Behavior Analysis within this report were obtained using BehavePlus Plus version 6.0.0. and Wind Ninja software.

Gene F. Begnell
Fire Protection Analyst

Fuel Modification Plan Design Guidelines

The rationale for the proposed fuel modification zones configuration is based on the outputs from the BehavePlus modeling. According to the modeling, under the worst-case scenario, a maximum flame length of 17.7 feet could be present in the native fuels within the riparian areas. Fuels in the native areas are considered to be unmanaged in calculations for the design of the fuel modification zones in this project.

This performance-based design of the fuel modification zones modifies the distances and configurations from the standard fuel modification plan based on specific analysis of the wind, topography, wildland fuels and the location of the structures. The thinning zones (C Zones) are not used to reduce fire intensity in specific areas of the project site. Only A and B zones are used.

The first 20 feet of the of the prescriptive fuel modification zones (100 feet) will use only approved fire resistive vegetation from the approved plant palette in the fuel modification areas. Planting within the A and B will be encouraged to use succulent material (such as cactus and agave) and the designs use rock or non-combustible materials to reduce the water impacts of the fuel modification zones. Still, irrigated zones with an approved plant palette are acceptable from a fire modeling point of view. Specific plant species will be provided on the Final Fuel Modification Plan which accompanies the Landscaping Plans for the project site. The approved fuel modification plant configuration shall be maintained as such in perpetuity and remain unchanged unless modifications to the plan have been approved in advance by Murrieta Fire & Rescue.

Interfaces to adjacent undeveloped residential parcels where vegetation is managed to keep the perimeter in a low fuel condition will need only perimeter a wall to provide protection. Where indicated on the Fuel Modification Plan, radiant heat walls shall be provided as shown below and on the next page.

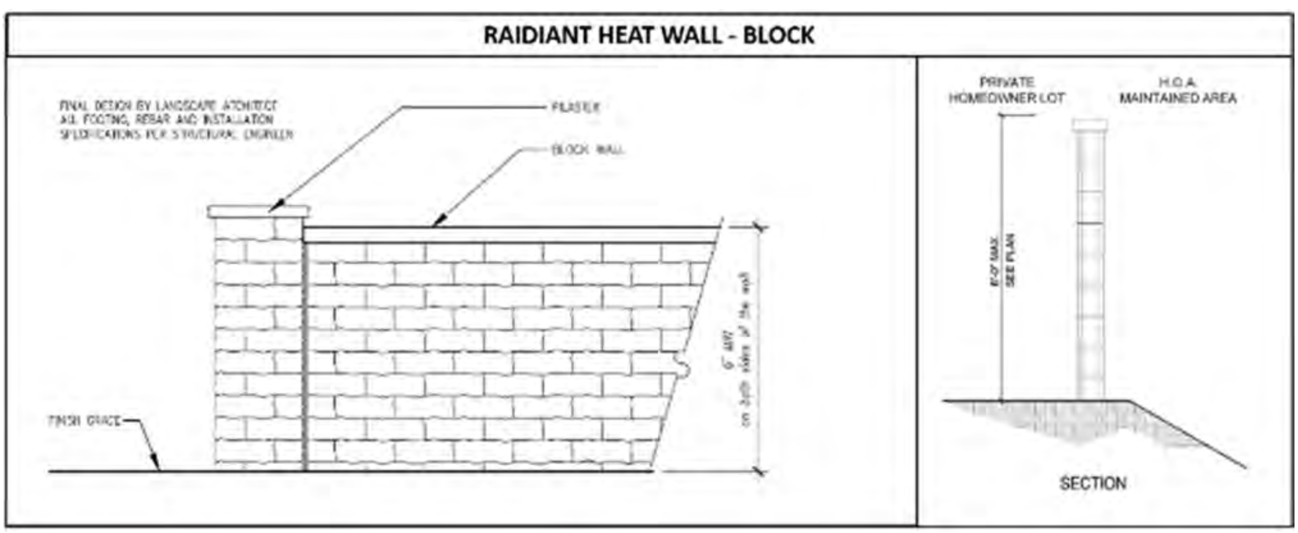

Figure 33 – Radiant Heat Wall Detail - Block

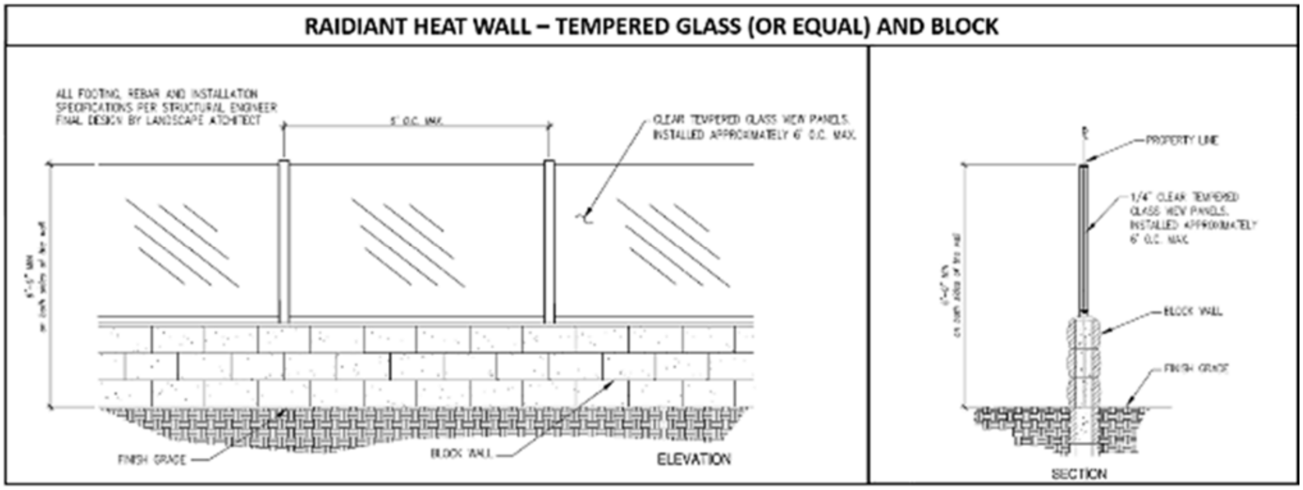

Figure 34 - Radiant Heat Wall Detail – Glass over Block

Fuel Modification Design Criteria (Performance Based)

The prescriptive fuel modification areas are 100 feet in *flat plane* distance and will protect from flame length up to 50 feet. Below is an illustration of this configuration.

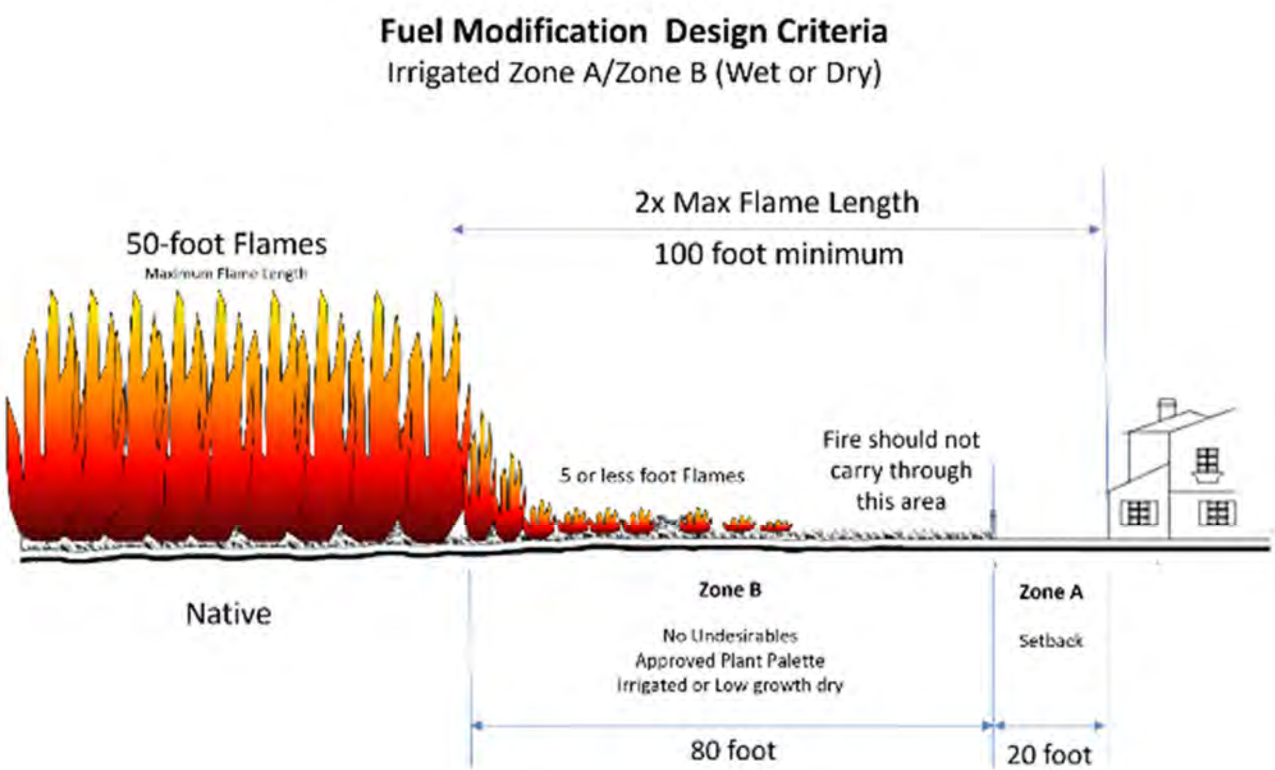

Figure 35 – Prescriptive Fuel Modification Zones

The minimum design conditions for the fuel modification zones within the ‘Whitewood Apartments’ project are as follows:

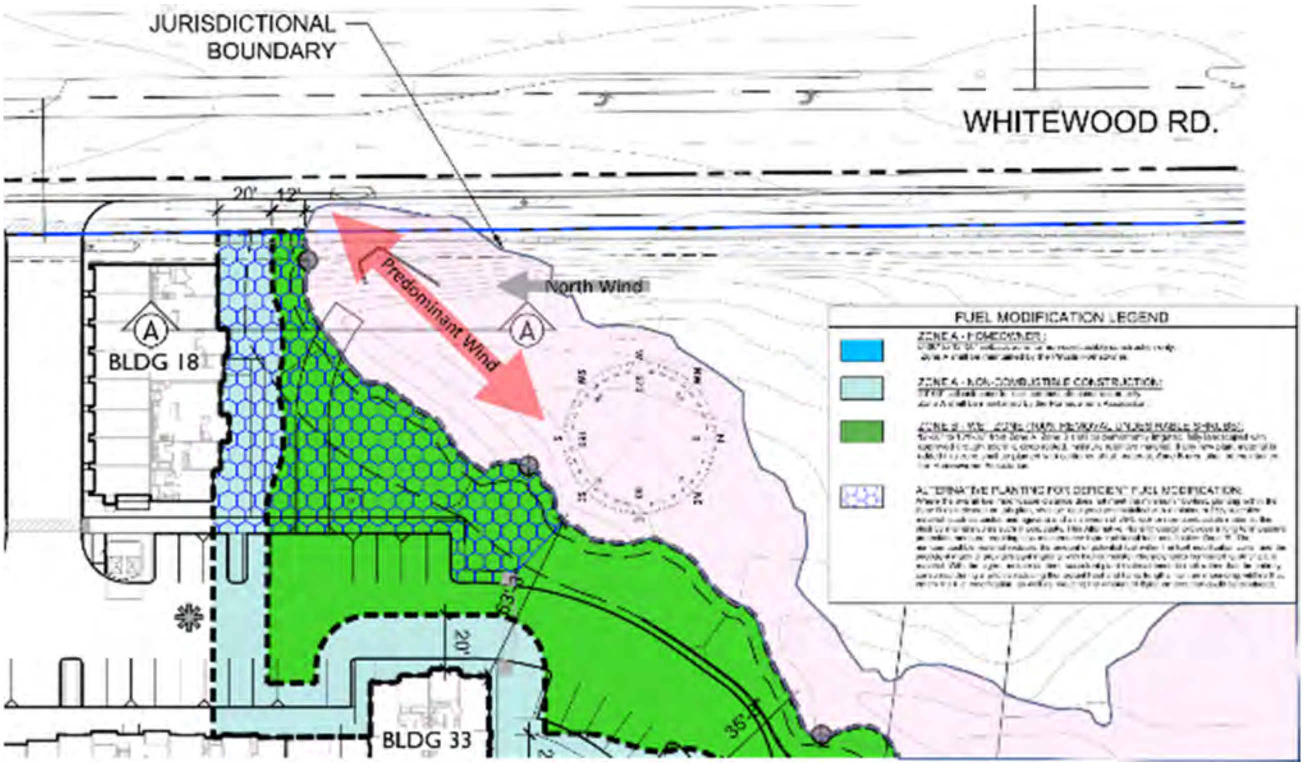

Figure 36 – Performance-Based Condition Site A:A

A small area at the southwest end of the riparian area has only 32 feet from the jurisdictional boundary to the structure.

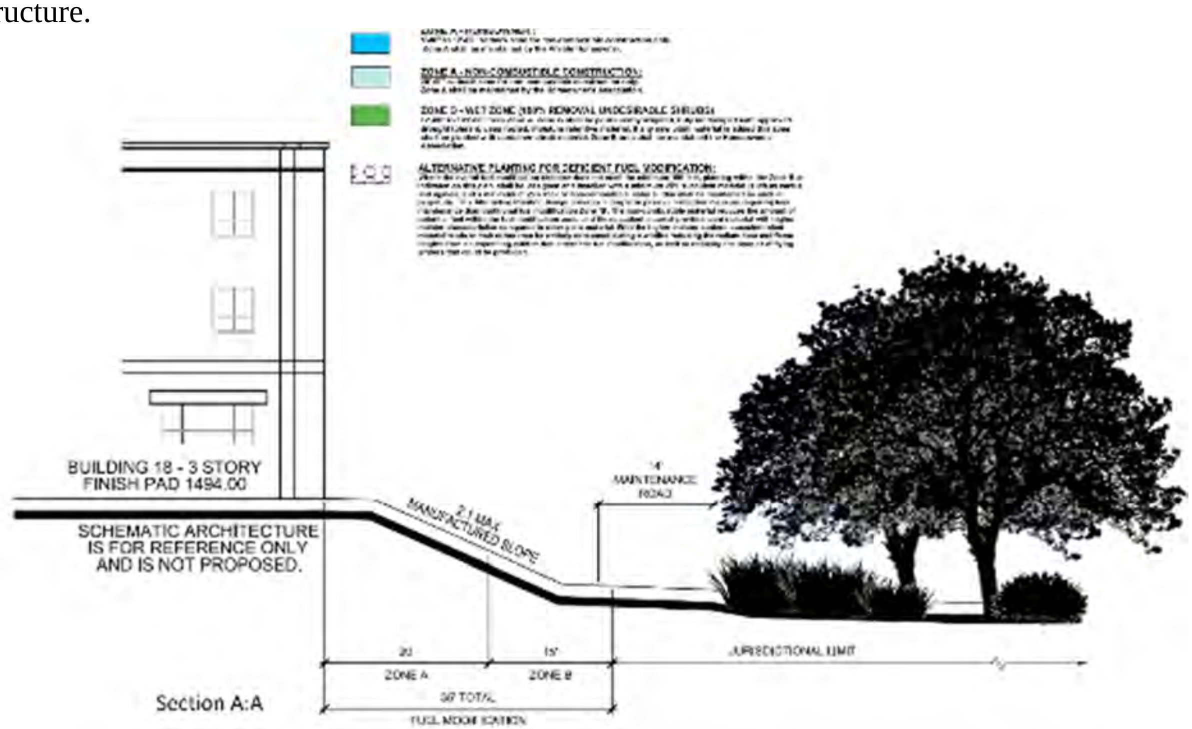

Figure 37 – Section of Site A:A

Riparian areas are protected by various state and federal laws and regulations. No fuel modification can occur within these boundaries. They are, for the most part, ribbons of vegetation at the bottom of the drainages. Without the ability to reduce the fuel, we are left with protecting the structure.

The maximum flame length of 17.7 will not impinge on the structure; the radiant heat value calculation provides a value of under 12 kWm^2, on the face of the structure and prevailing winds do not align with the fire travel in this area. To provide additional safety margins in this area:

1. The exterior of the structure (Building 18) will be rated to one hour in accordance with the requirement of the Murietta Building Code standard for rated constructions;
2. Both panes of glass in all windows for the adjacent building will be tempered glass
3. The fire sprinkler system design criteria (flow density) will be increased to a level acceptable to the Murietta Fire and Recuse Department, and
4. The area between the riparian and the structure will be devoid of trees and planted in accordance with the Alternative Planting for Deficient Fuel Modification specifications of the Fuel Modification Plan as approved by Murietta Fire and Rescue.

Zone A will need to be irrigated if vegetation is present. This area, often identified as the "Green Zone", is the most critical to the safety of the structure. Ignition of any material in this zone is a direct threat to the structure. Vegetation should not be placed below or in front of windows or opening as these are the most vulnerable portions of the hardened structure.

Low maintenance and reduced water requirements must be considered in the evaluation of the project perimeter fire protection needs. While lush, irrigated fuel modification zones look nice, they are expensive to maintain and require regular maintenance to be 100% effective in their design. Lower amounts of fuel within the fuel modification zone are always better from a fire defense perspective. Succulents are a good choice for fuel modification zones; noncombustible materials are even better.

In Areas B and C (Figures 38 and 39), the shielding to be used is the radiant heat fence described earlier in this report. The area to installed are indicated by the red lines on the graphics and on the Fuel Modification Plan. These walls are used to provide a solid stop for fire progression and as a shield against radiant and convected heat. They are provided in areas where the prescriptive 100-foot distance is not provided as an additional safety measure.

Figure 38 – Area B Radiant Heat Locations

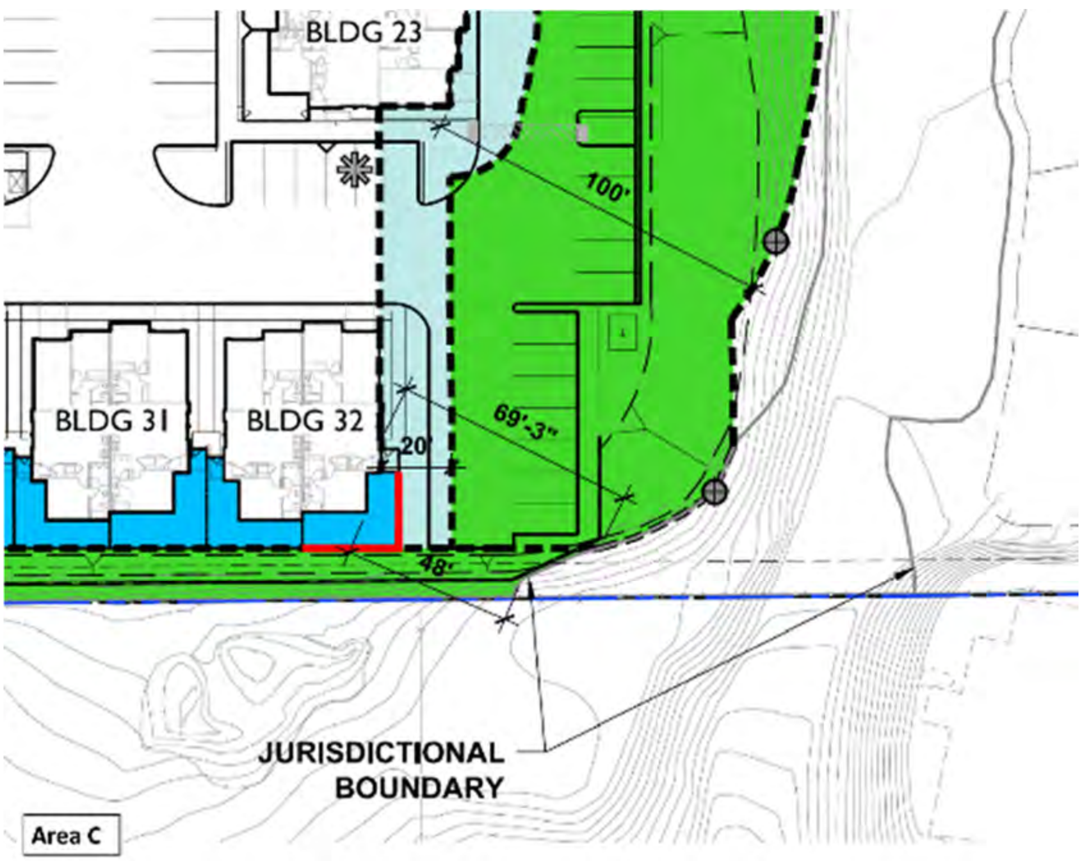

Figure 39 Area C Radiant Heat Locations

Fire Behavior Analysis Summary

Based on the scientific fire behavior analysis, exterior portions of structures within the 'Whitewood Apartments' will not ignite from the exposure of fire from a wildland vegetation fire with distances and configuration provided in this report. This is primarily because the greatest fire energy is too far away from the structures due to lack of wildland fuels and fire intensity as it approaches the community from the easterly direction; all of other interfaces within the project site are residentially developed. This does not account for windows or doors which are left open or other factors not under the control of this analysis.

Modeling has shown that the performance based design offered for the project site provides the necessary protection to keep the structures safe during a wildland fire incident within the adjacent native fuels and that additional distance would not necessarily increase the safety of these structures beyond the point that is already provided.

The codes enforced by Murrieta Fire & Rescue for Fuel Modification and Hazard Reduction were developed to handle the exact type of fuels that are interfacing with development areas. The proposed fuel modification plan provides fuel modification distances and configurations which are equal to or greater than the risk threat from the wildland fire fuel in the adjacent areas. The performance-based justifications for areas less than 100 feet indicate that these areas will be adequately protected. Additional fire protection features have been added to the standard interface requirement where it was considered beneficial to the exposed structures. These are enhancements and are not utilized as the primary protection for the structures. The modeling indicates that the structures are safe with the distance and configurations are shown.

We recommend approval of this Fire Behavior Analysis as an accurate and acceptable assessment of the hazard and risk factors for the 'Whitewood Apartments' as they relate to wildland fire protection and the Fuel Modification Zone design. The Firesafe team is available for any additional analysis or additional supplemental support materials for our position on this matter. This report is submitted in support of the Fuel Modification Plan which has the specific details on the location, configuration and site-specific distances used in each interface for the project site.

Respectfully;

Gene F. Begnell
Fire Protection Analyst

Concurrence;

David Oatis
Principal, Firesafe 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 are shown above.

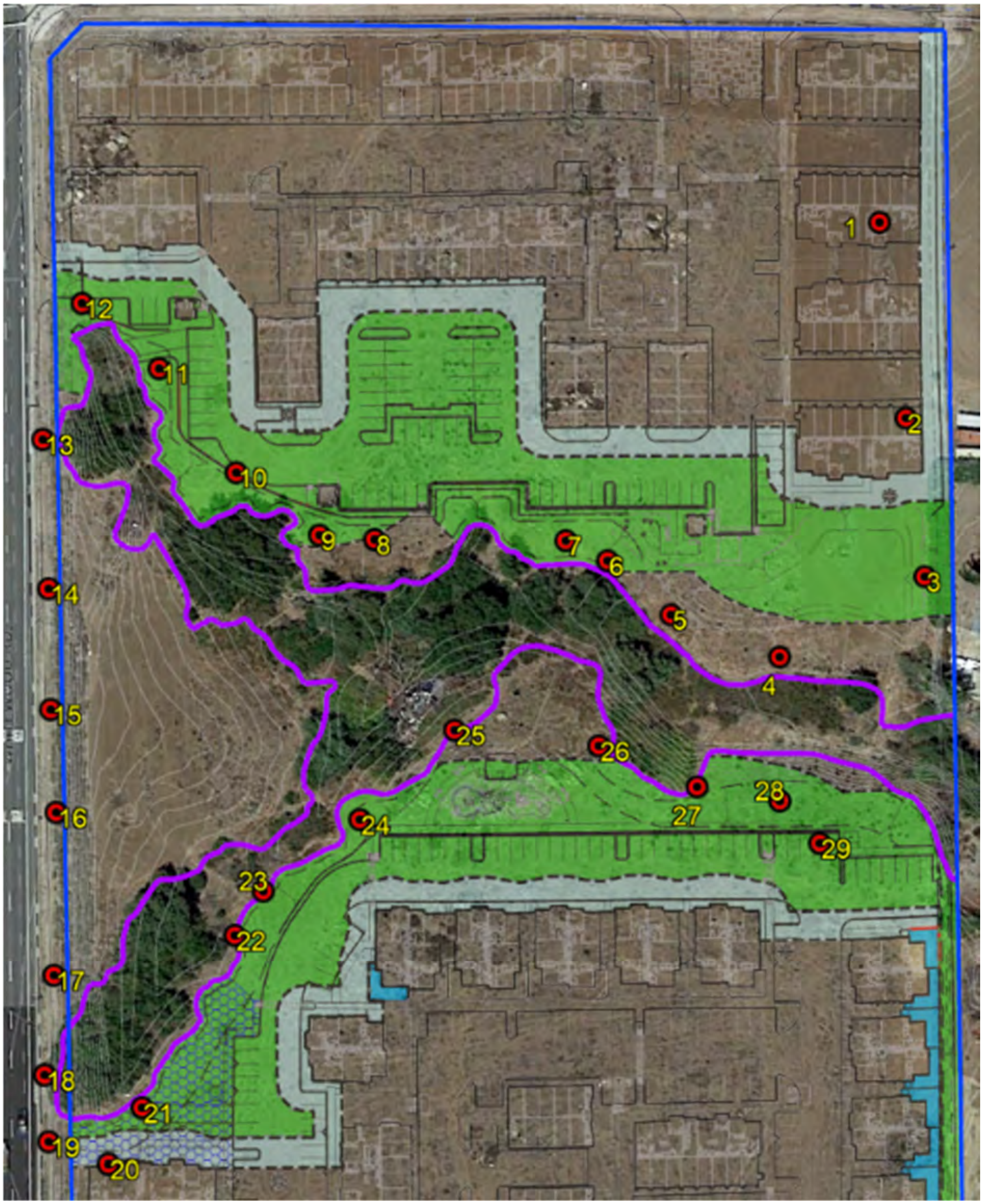

Photo Site 1 – Looking South

Looking Southwest

Photo Site 2 – Looking South

Photo Site 3 – Looking South

Looking West

Zoomed to the West

Zoomed farther to the West

Photo Site 4 – Looking Southwest

Looking West

Photo Site 5 – Looking West

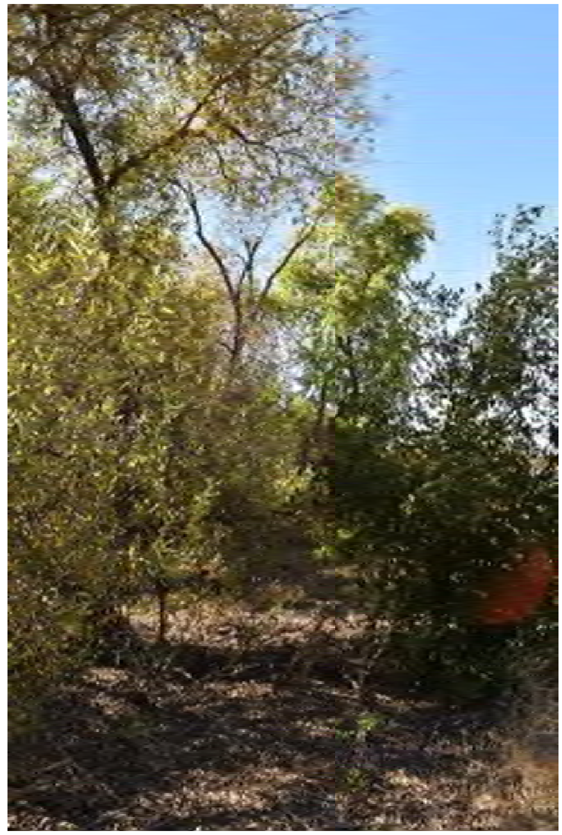

Photo Site 6 – Looking West Northwest

Photo Site 7 – Looking West

Looking at specific vegetation

Photo Site 8 –Looking South

Looking West

Photo Site 9 – Looking West

Looking West Northwest

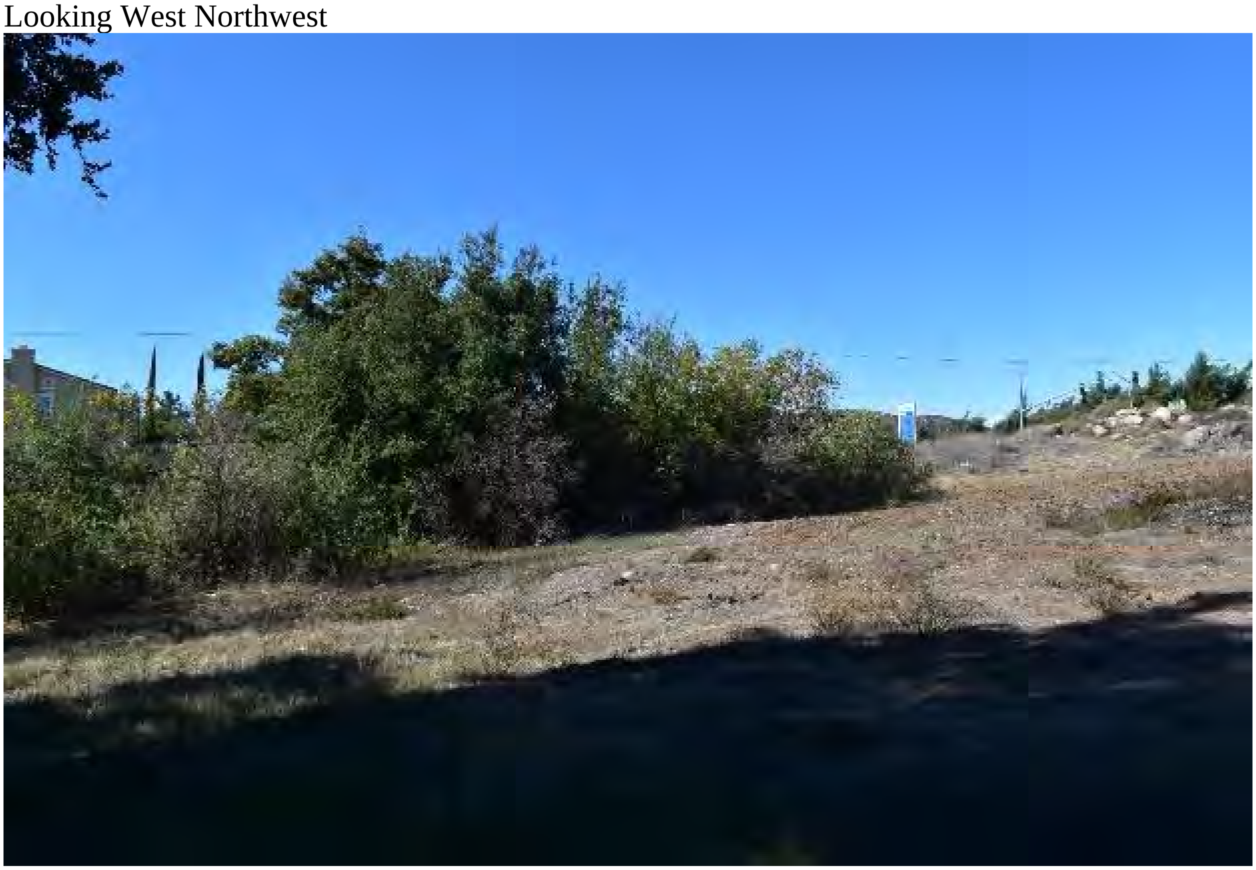

Photo Site 10 – Looking West Southwest

Looking West

Photo Site 11 – Looking Southeast

Looking East

Photo Site 11 (cont.) Looking Northwest

Photo Site 12 – Looking at riparian headwall

Photo Site 12 – Looking North

Looking South

Photo Site 13 – Looking Southeast

Photo Site 14 – Looking North

Photo Site 14 – Looking South

Photo Site 15 – Looking North

Photo Site 15 – Looking South Southeast

Photo Site 16 – Looking North

Photo Site 16 – Looking South

Photo Site 17 – Looking North

Photo Site 17 – Looking South

Photo Site 18 –Looking at specific vegetation

Photo Site 19 – Looking North

Photo Site 20 – Looking Northeast

Photo Site 21 – Looking West

Looking Northeast

Photo Site 22 – Looking Northwest

Looking North Northwest

Photo Site 23 – Looking Northeast

Zoomed to the Northeast

Photo Site 24 – Looking Southwest

Looking Northeast

Photo Site 25 – Looking East

Looking West

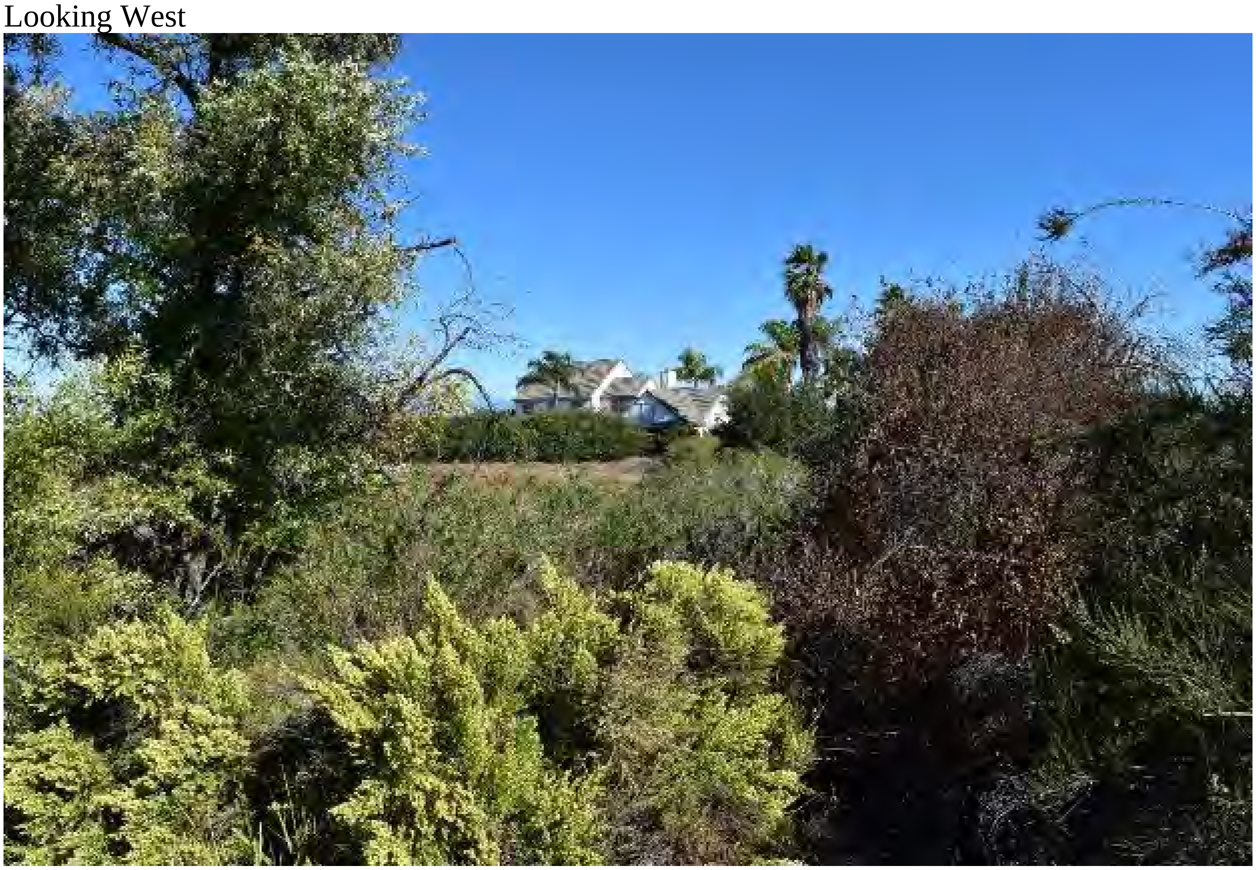

Photo Site 26 – Looking Northeast

Looking East

Photo Site 27 – Looking Northeast

Photo Site 28 – Looking North

Photo Site 28 – Looking West

Photo Site 29 – Looking North Northwest

Photo Site 29 – Looking North

Looking West

Photo Site 29 – Looking West

Appendix B
BehavePlus Reports

Inputs: SURFACE

Description		Whitewood Apartments Murietta

Fuel/Vegetation, Surface/Understory

Fuel Model		gr2, gs2, tu5

Fuel Moisture

1-h Fuel Moisture	%	5
10-h Fuel Moisture	%	6
100-h Fuel Moisture	%	10
Live Herbaceous Fuel Moisture	%	30
Live Woody Fuel Moisture	%	60

Weather

20-ft Wind Speed	mi/h	40
Wind Adjustment Factor		0.5
Wind Direction (from north)	deg	45

Terrain

Slope Steepness	%	0, 10, 20, 30
Site Aspect	deg	45

Run Option Notes

Maximum effective wind speed limit IS imposed [SURFACE].

Fire spread is in the HEADING direction only [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]

Notes

Whitewood Apartments Murietta

Head Fire

Surface Fire Rate of Spread (ft/min)

Slope	Fuel Model		
%	gr2	gs2	tu5
0	178.5	275.4	61.8
10	178.5	276.0	62.0
20	178.5	277.7	62.7
30	178.5	280.6	63.8

Whitewood Apartments Murietta

Head Fire

Surface Fireline Intensity (kW/m)

Slope	Fuel Model		
%	gr2	gs2	tu5
0	2338	8062	9870
10	2338	8079	9906
20	2338	8129	10014
30	2338	8213	10194

Whitewood Apartments Murietta

Head Fire

Surface Fire Flame Length (ft)

Slope	Fuel Model		
%	gr2	gs2	tu5
0	9.0	15.9	17.5
10	9.0	15.9	17.5
20	9.0	16.0	17.6
30	9.0	16.1	17.7

Discrete Variable Codes Used
Whitewood Apartments Murietta

Fuel Model

102	gr2	Low load, dry climate grass (D)
122	gs2	Moderate load, dry climate grass-shrub (D)
165	tu5	Very high load, dry climate timber-shrub (S)

Inputs: SURFACE

Description		Whitewood Apartments Murietta

Fuel/Vegetation, Surface/Understory

Fuel Model		gr2, gs2, tu5

Fuel Moisture

1-h Fuel Moisture	%	5
10-h Fuel Moisture	%	6
100-h Fuel Moisture	%	10
Live Herbaceous Fuel Moisture	%	30
Live Woody Fuel Moisture	%	60

Weather

20-ft Wind Speed	mi/h	40
Wind Adjustment Factor		0.5
Wind Direction (from north)	deg	45

Terrain

Slope Steepness	%	0, 10, 20, 30
Site Aspect	deg	45

Run Option Notes

Maximum effective wind speed limit IS imposed [SURFACE].

Fire spread is in the FLANKING direction only [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]

Notes

Whitewood Apartments Murietta

Flanking Fire

Surface Fireline Intensity (kW/m)

Slope	Fuel Model		
%	gr2	gs2	tu5
0	317	677	828
10	317	677	829
20	317	679	831
30	317	682	835

Whitewood Apartments Murietta

Flanking Fire

Surface Fire Flame Length (ft)

Slope	Fuel Model		
%	gr2	gs2	tu5
0	3.6	5.1	5.6
10	3.6	5.1	5.6
20	3.6	5.1	5.6
30	3.6	5.1	5.6

Discrete Variable Codes Used
Whitewood Apartments Murietta

Fuel Model

102	gr2	Low load, dry climate grass (D)
122	gs2	Moderate load, dry climate grass-shrub (D)
165	tu5	Very high load, dry climate timber-shrub (S)