Assessing Wildfire Risk in Real Time on the 2017 Frye Fire

LaWen T. Hollingsworth and **Matthew Panunto**, Rocky Mountain Research Station, Forest Service, U.S. Department of Agriculture, Missoula, Montana

Abstract—The Frye Fire started June 7, 2017, in the Pinaleño Mountains of southeast Arizona. The Pinaleños are host to important resources and assets including Mount Graham International Observatory, recreation residences, a church camp, Forest Service infrastructure, spiritual significance to tribes, and 11 endemic fish and wildlife species. This assessment was stimulated by the need to make sense of the numerous resources and assets within the planning area of the Frye Fire in order to enable quality dialog between the Coronado National Forest and the Incident Management Team. The assessment was created to help guide the management of the fire to best meet the desires of the local unit and stakeholders. Highly valued resources and assets (HVRAs) in the fire's planning area were identified and prioritized. The response function to fire for each individual HVRA was identified as positive, neutral, or negative by flame-length class by local staff. The net value change was then calculated to discern the probable effects to an area if it were to burn and isolate which HVRA was driving that response. This assessment allowed us to verify the incident strategies, develop tactics, prioritize actions on the ground, and align the strategy and tactics by providing pertinent information to ground resources.

Keywords: risk assessment, fire management, Frye Fire, incident strategies, incident tactics, intent-based planning

INTRODUCTION

The Frye Fire started June 7, 2017, in the Pinaleño Mountains of southeastern Arizona on the Coronado National Forest (CNF). Since it was a lightning-caused fire, the Forest Plan is flexible on management options but encourages managing lightning-caused fires to promote diverse and resilient ecosystems. Given the direction provided in the Forest Plan, how do you restore or maintain fire as a natural process while protecting the things we care about? As is often the case with any fire, the values and assets identified as important by the CNF and stakeholders created a blurry picture of how to manage the fire as there were often multiple values and assets present in any particular area. Which value or asset is of the highest importance? In addition, if it is likely that the fire will burn into an area that has important values and assets, how do you provide substantive information to guide the desired fire effects? In essence, how do you want the area to look if there is the option?

This assessment was stimulated by the need to make sense of the numerous values and assets within the planning area of the Frye Fire to enable quality dialog between the CNF and the Incident Management Team (IMT). As is often the case within a fire area, there were many competing values and assets that respond differently to fire. The intent of the exploratory analyses was to (1) identify the values and assets within the planning area and then prioritize those values and assets, (2) calculate the net value change to inform fire strategy, and (3) better align strategy and tactics by applying risk assessment methods to an incident.

In: Hood, Sharon; Drury, Stacy; Steelman, Toddi; Steffens, Ron, tech. eds. The fire continuum—preparing for the future of wildland fire: Proceedings of the Fire Continuum Conference. 21-24 May 2018, Missoula, MT. Proc. RMRS-P-78. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 358 p.

METHODS

This assessment draws upon similar methods used by the Forest Service, U.S. Department of Agriculture, in a regional wildfire risk assessment prepared for the Southwestern Region (Southwestern Region Fire and Aviation Management 2017) and described in multiple publications (Finney 2005; Scott et al. 2013). There are three components included in assessing wildfire risk: susceptibility, intensity, and likelihood. The value in this approach is that the process and methods have been defined and the necessary inputs are readily available.

Project Area

The Pinaleño Mountains are an island mountain range with vast ecological diversity including desert shrub and grassland vegetation near the base of the mountain range, forest woodland ecosystems at mid elevation, and cold forest at the upper reaches of Mount Graham. Elevation ranges from 3,000 to 10,700 ft. Approximately 29,000 ac of the project area burned in 2004 in the Nuttall Complex in addition to multiple smaller fires. The Frye Fire had already burned approximately 38,500 acres in 3 weeks when this assessment was completed.

The Pinaleño Mountains provide habitat for the endangered Mount Graham red squirrel, threatened Gila trout, and threatened Mexican spotted owl. In the vicinity of Mount Graham are the Columbine Administrative Site and recreation residences, a Bible camp, and the Mount Graham International Observatory that includes three research telescopes. Situated mid-slope southeast of Heliograph Peak are a couple hundred recreation residences in Turkey Flat.

Susceptibility

What are the effects to the HVRAs at different fire intensity levels? This component takes into account the potential effect of fire on the HVRAs identified by the administrative agency and additional stakeholders. The IMT had numerous discussions with the CNF and stakeholders to identify and map critical values and assets. The initial list was modified to exclude values and assets within the current fire perimeter and those assets that listed a tactical mitigation, such as obtaining approval for ground-disturbing activities. The HVRAs were categorized into three groups and the groups were prioritized by CNF agency representatives. Each group included sub-HVRAs, essentially the individual assets and values that were identified. For each sub-HVRA, resource staff identified the response function to different fire intensity levels (in this case, three flame-length classes including 0-4 ft, 4-8 ft, and > 8 ft) as being positive, neutral, or negative.

Intensity

What are the predicted fire intensities based on the current fuel conditions? Late June is typically the height of the Southwest's fire season as the fuels are dry and available to burn prior to the arrival of adequate monsoonal moisture. A Basic fire behavior simulation was conducted in FlamMap (Finney 2006), which provides a predicted flame length for every pixel within the planning area based on weather and wind inputs. Since approximately 2 weeks remained until the predicted arrival of monsoonal moisture, inputs were representative of conditions in late June 2017. Live herbaceous moisture of 30 percent and live woody fuel moisture of 90 percent were used, representing fully cured and two-thirds cured conditions, respectively. Dead fuel moistures of 3 percent, 3 percent, and 5 percent were used for 1-hr, 10-hr, and 100-hr fuels, respectively. The Scott and Reinhardt (2001) crown fire method was used. Gridded winds were initialized at 270° using WindNinja (Wagenbrenner et al. 2016) in FlamMap, producing wind speeds of 8 to 15 mph with ridgetop winds of approximately 30 mph based on wind speed ranges observed in the fire area the previous week.

Likelihood

How likely is it that any given area will burn? This component includes the likelihood, or probability, for the HVRAs to be affected within a specified timeframe. In this case, a 14-day Fire Spread Probability (FSPro, Noonan-Wright et al. 2011) analysis was used. FSPro simulates thousands of potential fire perimeters using different weather scenarios informed by current conditions and the historical record of the selected Remote Automated Weather Station (RAWS) to produce ensemble burn probabilities. Noon Creek RAWS at an elevation of 4,925 ft was used for weather data as it represented lower elevations within the fire area. Columbine RAWS at an elevation of 9,521 ft was used for wind data as it represented wind speed and direction based on field observations and direction of fire growth. A total of 3,000 fires were simulated in FSPro.

Net Value Change

Net value change is the net change in value of an HVRA when it burns. For the Frye Fire, we explored conditional net value change (cNVC) and expected net value change (eNVC). The cNVC includes susceptibility and intensity; eNVC is the product of cNVC and likelihood. Once the HVRA groups were identified, the relative importance for each HVRA and sub-HVRA were identified. Relative importance scores provide quantitative weights to distinguish the importance of HVRAs and sub-HVRAs in the net value change products and are a key step when there are multiple overlapping values and assets. Both cNVC and eNVC were calculated in ArcGIS using Python scripts.

RESULTS

Susceptibility

The HVRAs were categorized into three prioritized groups, including (1) built assets, (2) natural and cultural resources, and (3) ecosystem function. Built assets included structures, improvements, infrastructure, and private lands (fig. 1). Natural and cultural resources included critical terrestrial and aquatic habitat, range allotment infrastructure, and archaeological sites (fig. 2). Ecosystem function includes 12 fire groups created by combining ecological response units with similar historical fire regimes (fig. 3) and are consistent with the fire groups used in the Regional Wildfire Risk Assessment.

The response functions (table 1) were provided by CNF staff representing wildlife, fisheries, range, and fire in addition to agency representatives. Some of the values for response functions, notably Residentially Developed Populated Areas (RDPA), transmission lines, communication sites, and the fire groups used for ecosystem function were derived from the Regional Wildfire Risk Assessment.

Intensity

The area predicted to burn with flame lengths greater than 8 ft ranges from the mid to higher elevations in forests in rugged terrain (fig. 4). Predicted flame lengths decrease substantially in the foothills and nonforested ecosystems. The remainder of the analysis area was either nonburnable (rock) or had already burned in the preceding weeks.

Likelihood

Average fire size for the 3,000 simulations was 23,800 ac over the 2-week analysis period, not including suppression actions or growth from burnouts, potential rollout, or spotting due to outflow winds (fig. 5).

Conditional Net Value Change (cNVC)

The cNVC includes susceptibility (table 1) and flame lengths (fig. 4). The cNVC is the average net value change for any pixel within the planning area should it burn during the course of the Frye Fire (fig. 6); the sub-HVRAs that are responsible for creating a negative response under conditions analyzed are identified. This product fostered continued dialog between the CNF and the IMT and directed incident tactics aimed at keeping flame lengths less than 4 ft.

Expected Net Value Change (eNVC)

The expected net value change is the product of the cNVC (fig. 6) and burn probabilities (fig. 5) and displays the net value change if a pixel were to burn (fig. 7). The value of the eNVC is that it allows you to focus on the probability footprint for the specified time period rather than the cNVC for the entire analysis area. The eNVC was used to ensure the incident strategies were aligned with potential losses indicated by negative value change and potential benefits captured by positive value change.

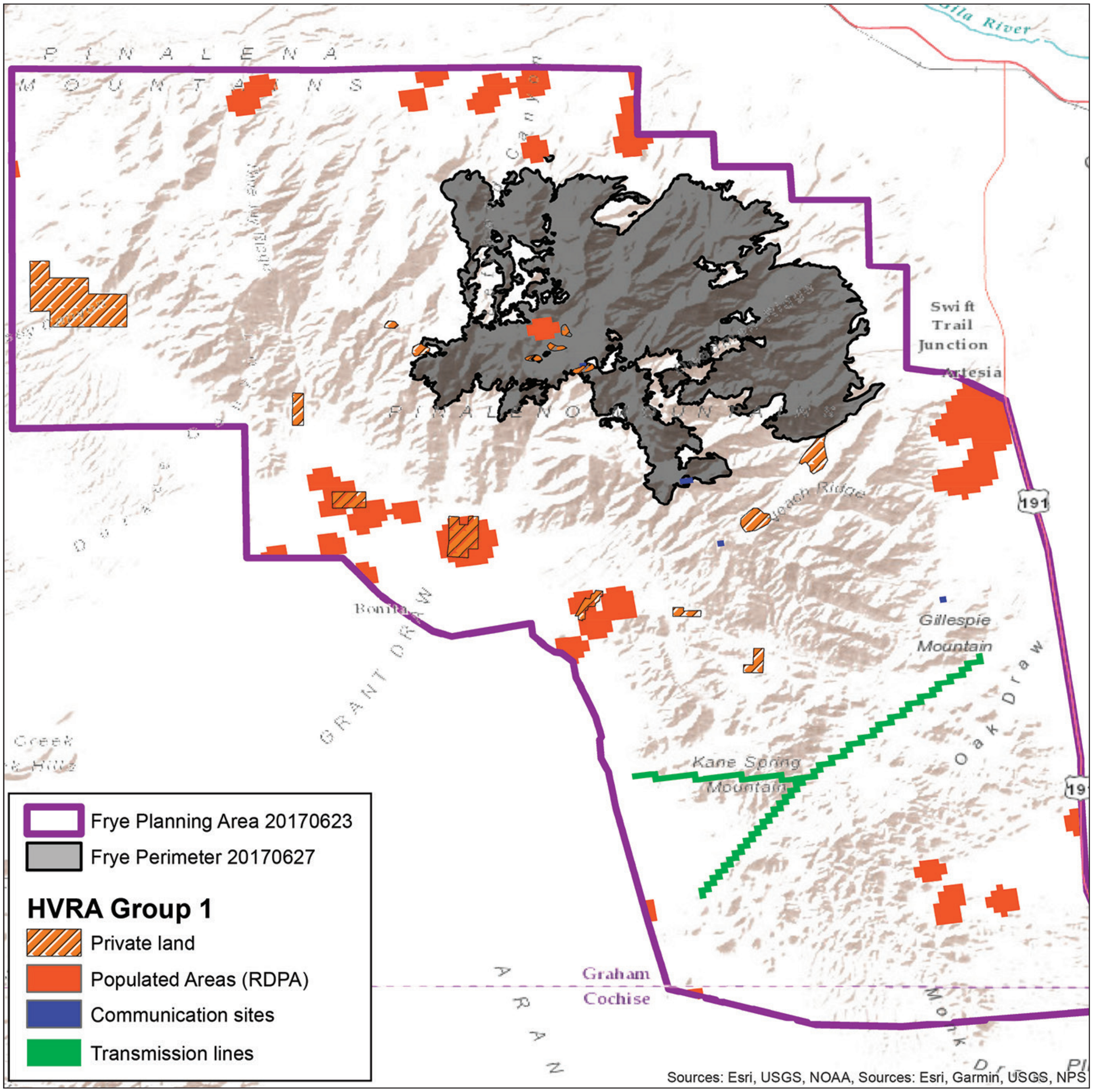

Figure 1—Locations of sub-HVRAs in HVRA Group 1 representing built assets.

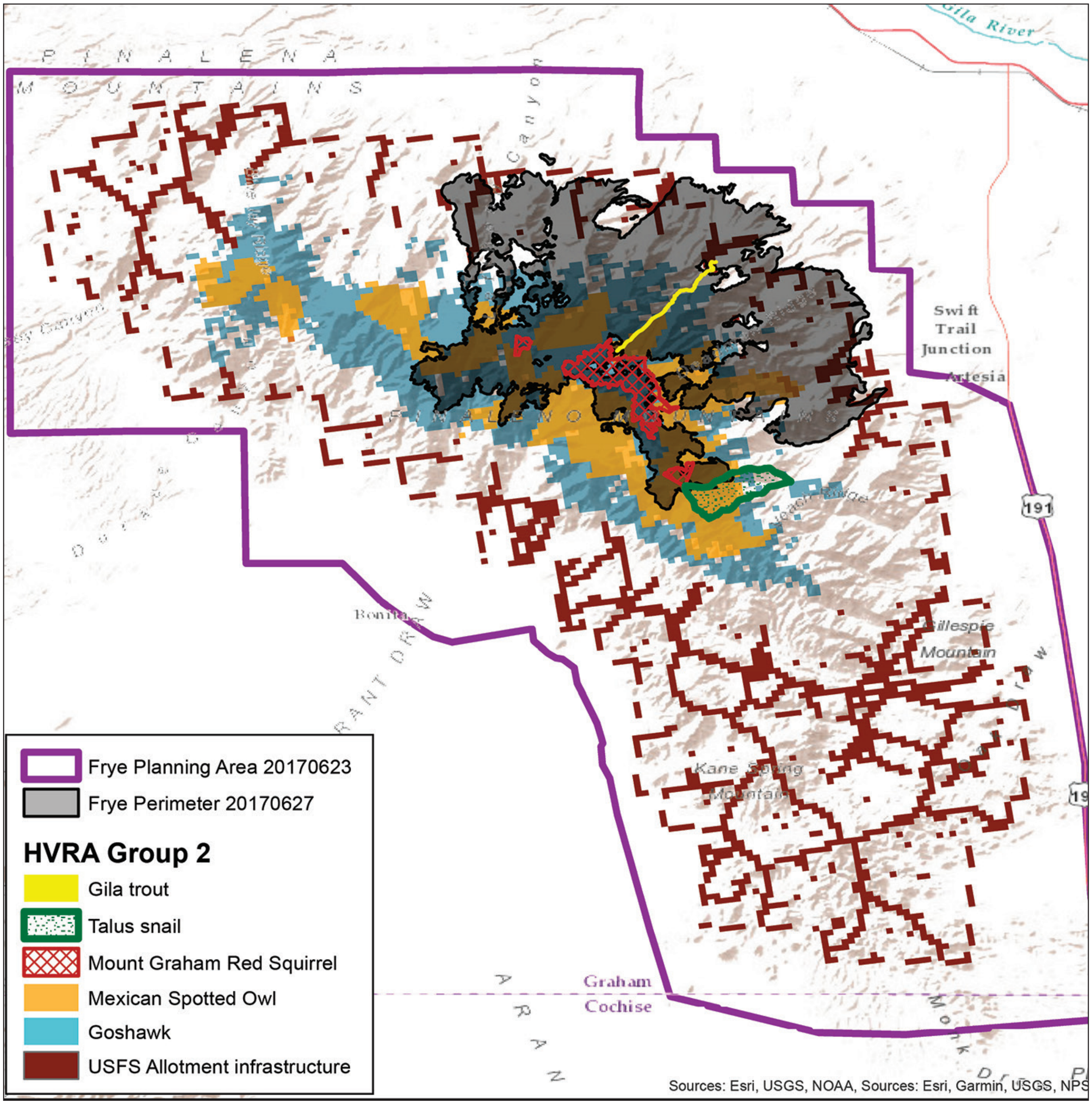

Figure 2—Locations of sub-HVRAs in HVRA Group 2 representing natural and cultural resources. Archaeological sites are not displayed.

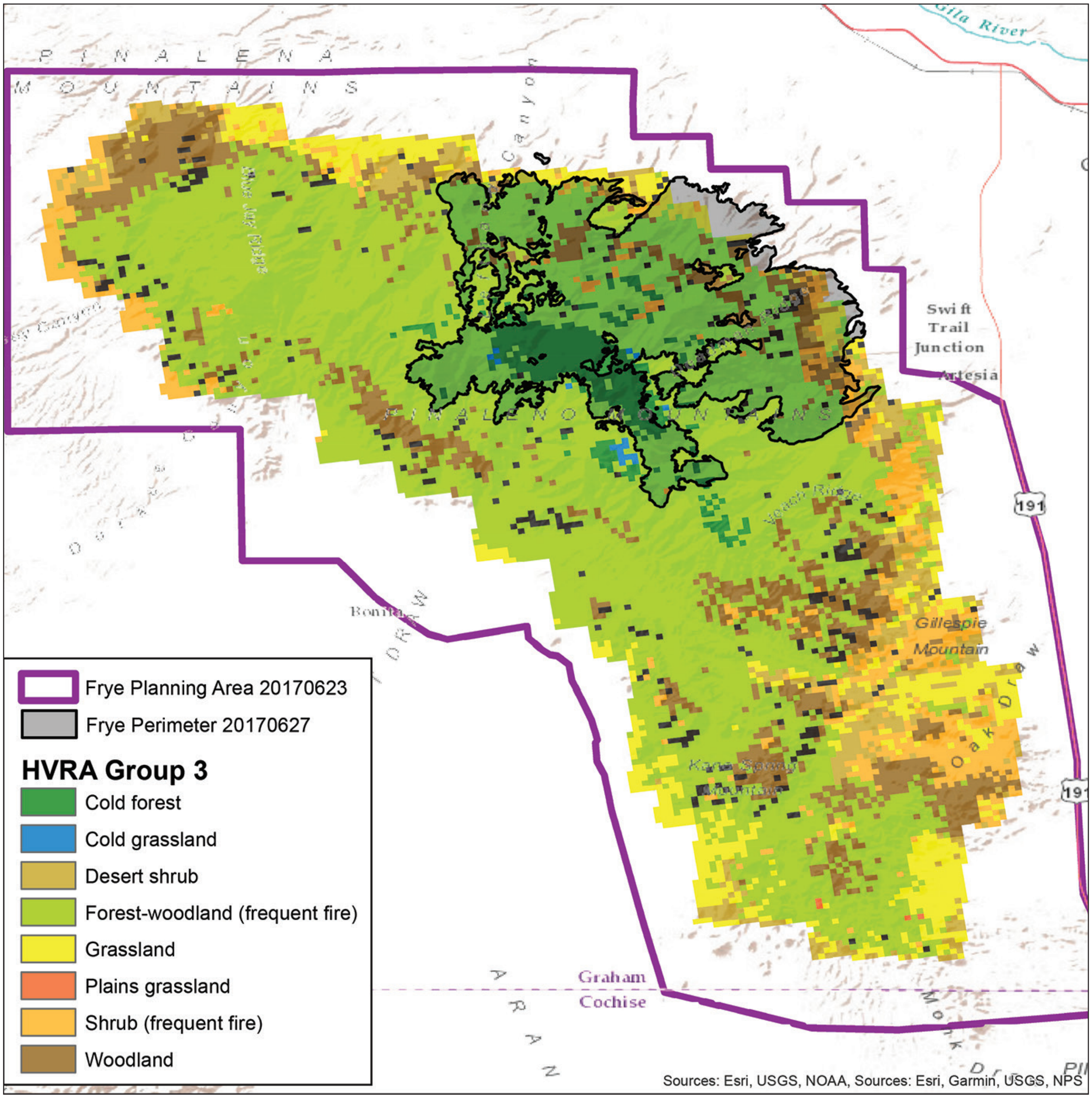

Figure 3—Locations of sub-HVRAs in HVRA Group 3 representing ecosystem function.

Table 1—Response functions of each sub–HVRA to different fire intensities (flame lengths). Negative response functions range from −0.1 (slightly negative) to −1 (fully negative). Neutral response functions are 0. Positive response functions range from 0.1 (slightly positive) to 1 (fully positive).

Group priority	HVRA	Sub–HVRA	Flame length class 1 (0–4 ft)	Flame length class 2 (4–8 ft)	Flame length class 3 (> 8 ft)
1	Built assets	Residentially Developed Populated Areas (RDPA)	−0.4	−1	−1
		Private land and inholdings	−0.4	−1	−1
		Transmission lines	0	−0.4	−1
		Communication sites	0	−0.4	−1
2	Natural and cultural resources	Mexican spotted owl	0.7	−0.2	−1
		Northern goshawk	0.7	−0.2	−1
		Mount Graham red squirrel	0.7	−0.2	−1
		Talus snail	0.6	−0.2	−1
		Gila trout	0.6	−0.2	−1
		USFS allotment infrastructure	0	−0.7	−1
		Archaeological sites	−0.1	−0.2	−1
3	Ecosystem function	Cold forests	1	1	0.8
		Forest-woodland (frequent fire)	1	0.3	−0.6
		Woodlands	1	0.8	0.6
		Grasslands	1	1	1
		Cold grasslands	1	1	1
		Alpine	−1	−1	−1
		Desert shrub	−0.5	−0.7	−0.9
		Salt scrub	−0.5	−0.7	−0.9
		Shrub	1	0.5	−0.4
		Shrub (frequent fire)	0.5	1	1
		Plains shrubland	1	0.8	0.7
		Plains grassland	1	1	1

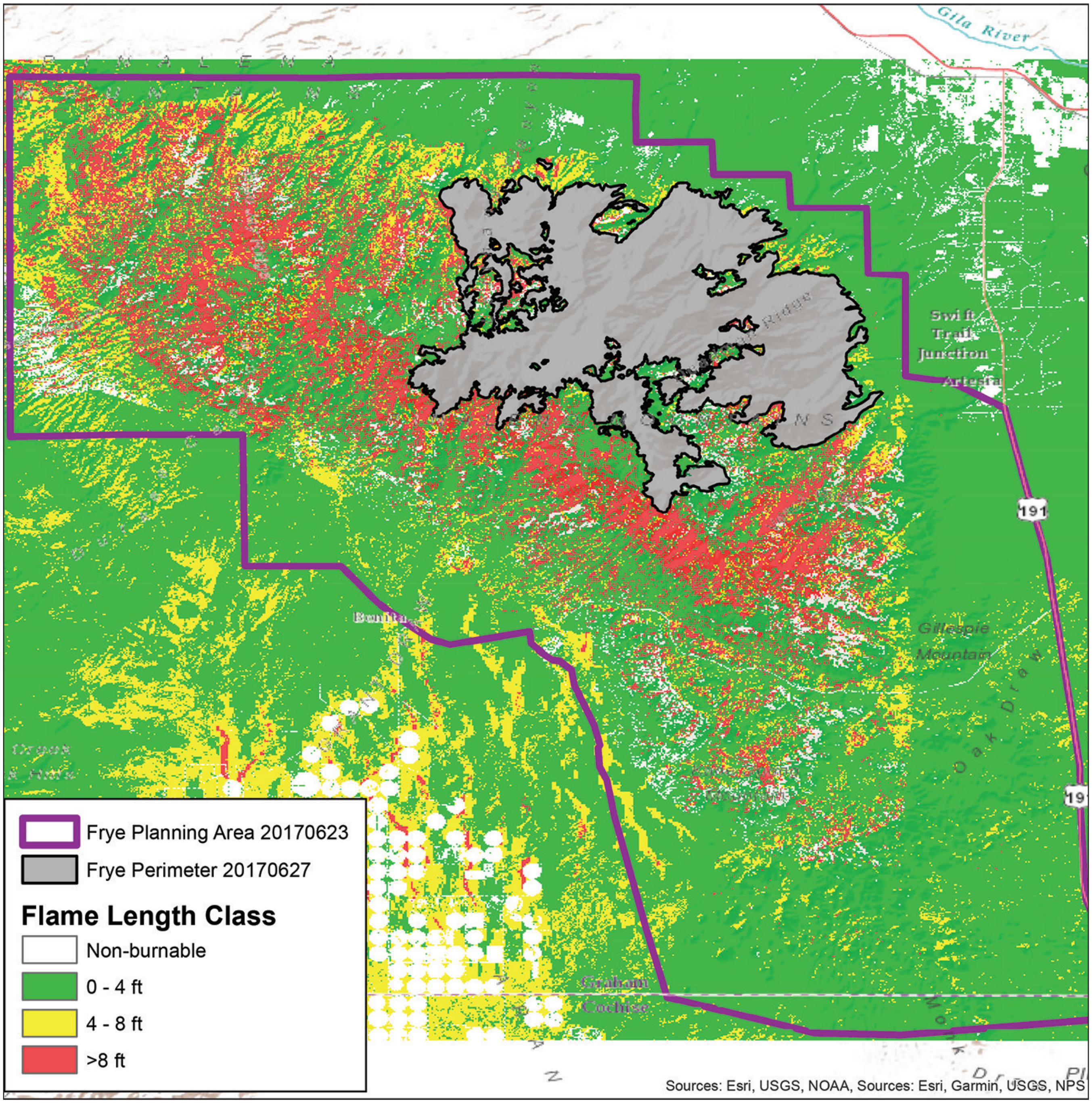

Figure 4—Predicted flame lengths for the Frye Fire for the period representing conditions during the end of June to early July 2017.

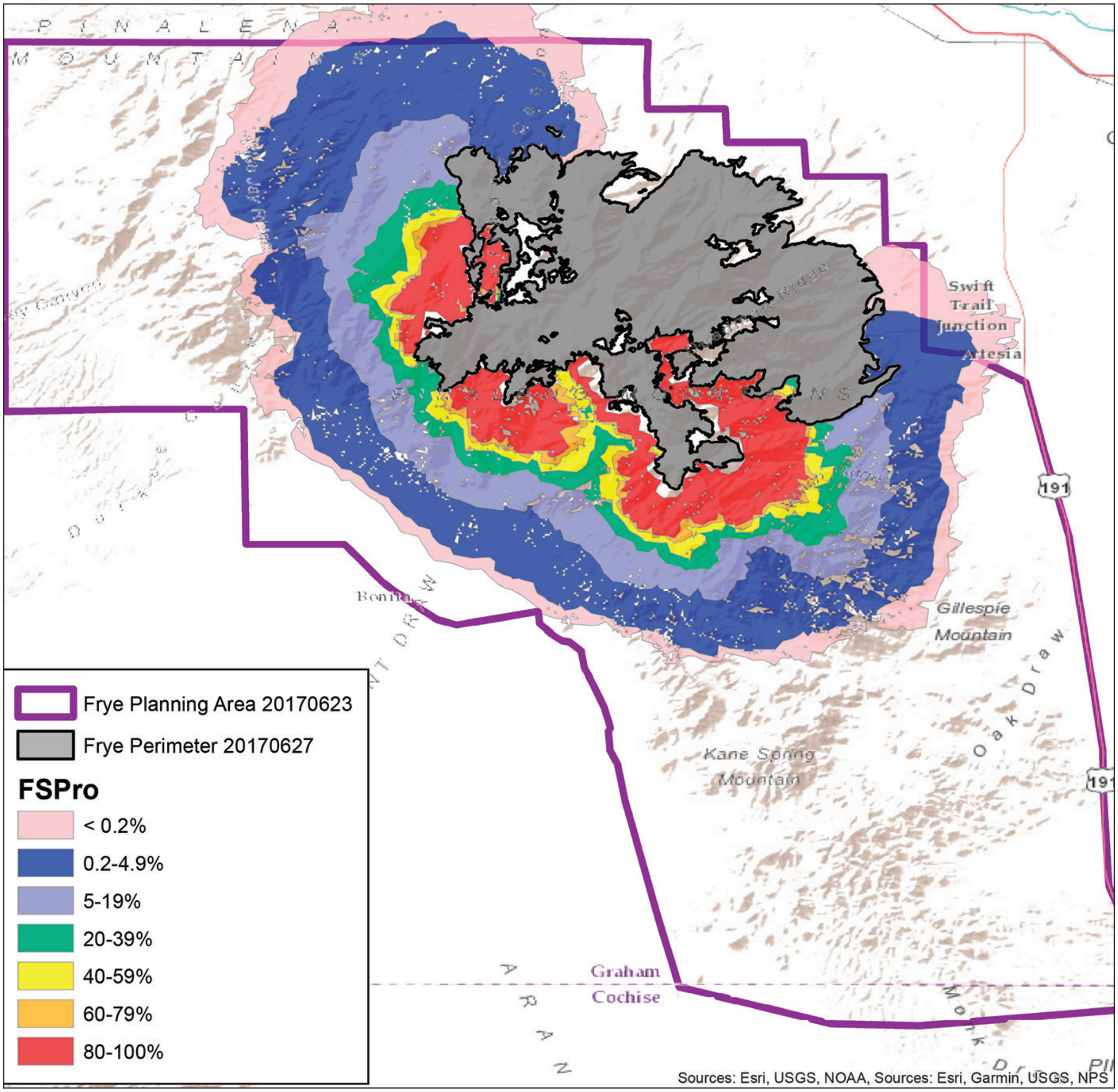

Figure 5—FSPro simulation for the Frye Fire for the period from June 29 until July 12, 2017, displaying burn probabilities for an ensemble of 3,000 individual fires.

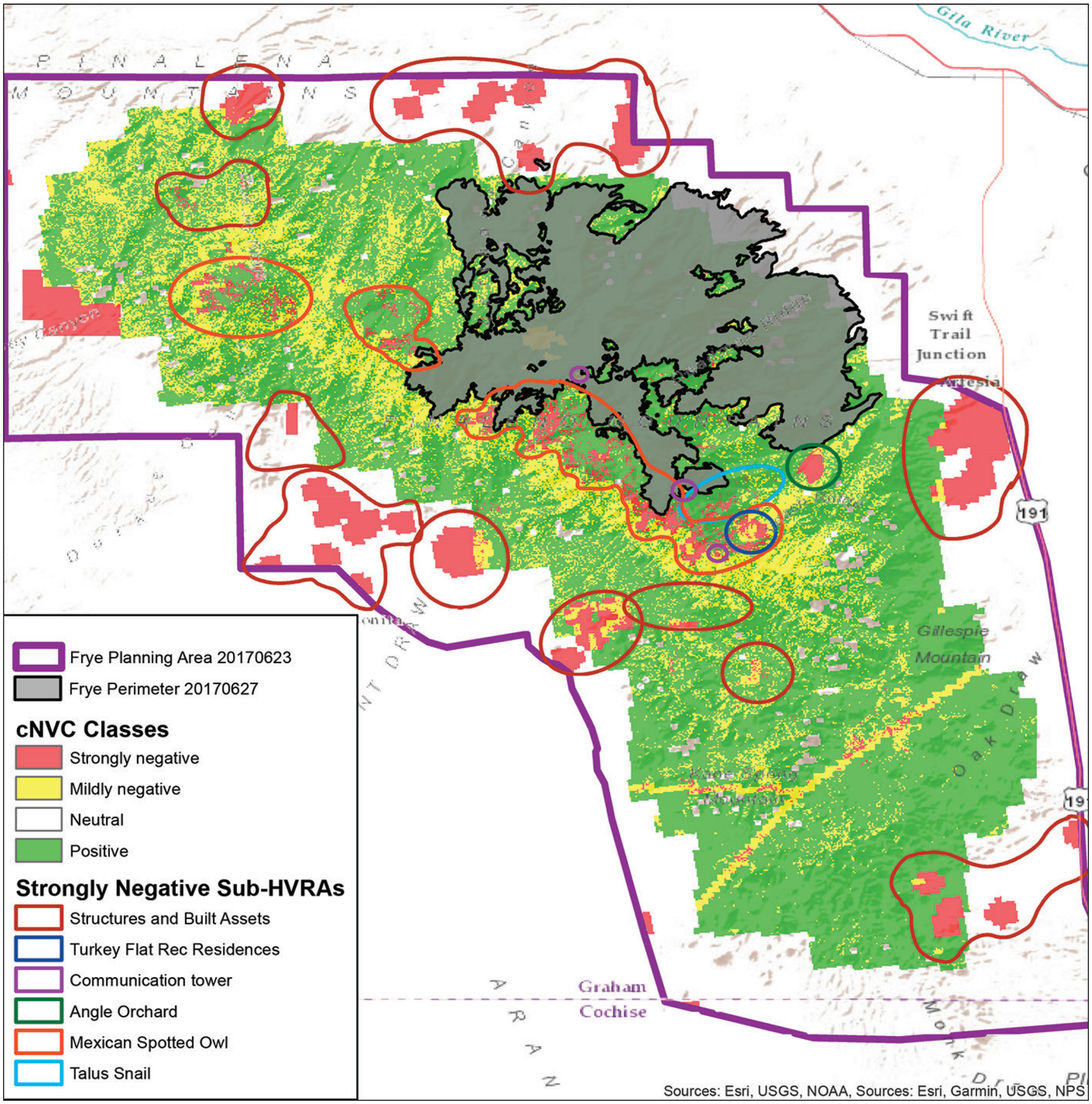

Figure 6—Conditional net value change (cNVC) for the Frye Fire, which combines susceptibility with flame lengths. The sub-HVRAs that showed a strong negative response were identified to provide guidance for incident personnel.

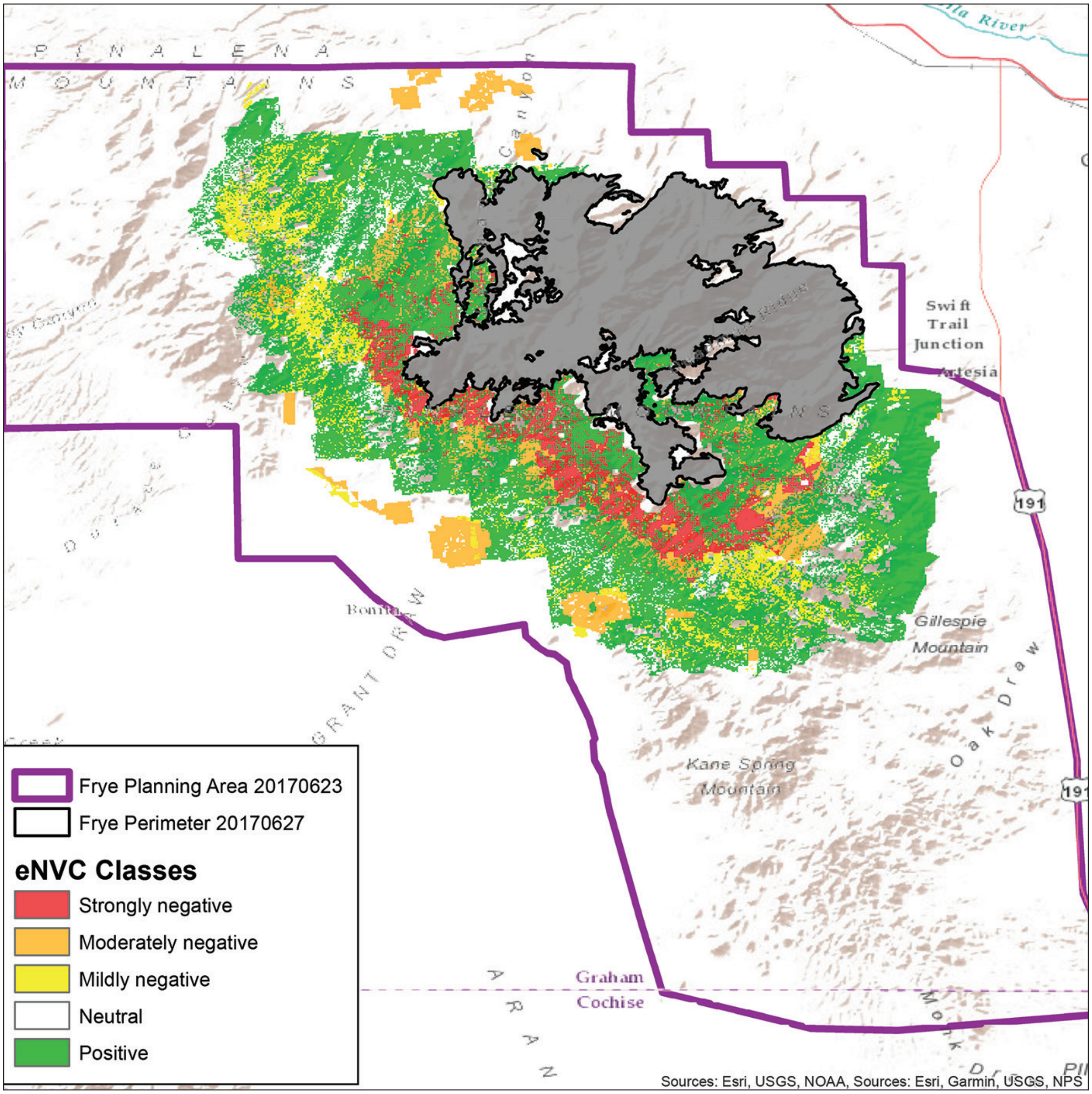

Figure 7—Expected net value change (eNVC) for the Frye Fire. The eNVC combines cNVC with burn probabilities from FSPro.

DISCUSSION

While risk is commonly analyzed during wildfires, the authors are not aware of any other attempts to apply and tailor the wildfire risk assessment methods to an ongoing incident. The Frye Fire cNVC data were compared with the cNVC data from the Southwestern Region Wildfire Risk Assessment (fig. 8). There are some notable differences between the two risk assessments: the Frye Fire used a pixel size of 60 m while the regional assessment used 180 m; the HVRA groups and sub-HVRAs were different as the values and assets for the Frye Fire were locally identified by the CNF and other stakeholders; and the response functions were created by local staff for three flame-

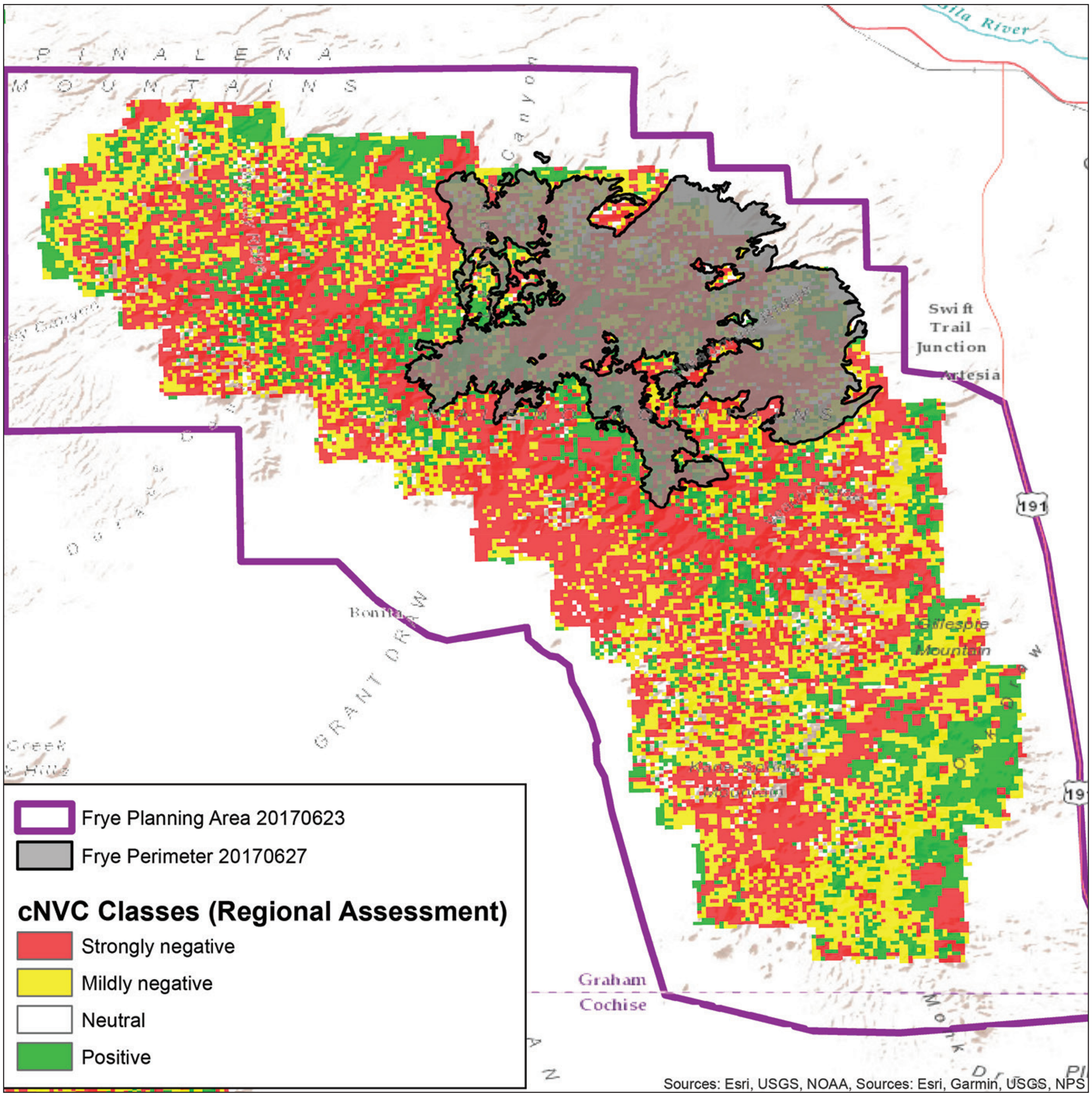

Figure 8—Conditional net value change for the Pinaleño Mountains from the Southwestern Regional Wildfire Risk Assessment (Southwestern Region Fire and Aviation Management 2017).

length classes whereas the regional assessment used conditional flame lengths from the large fire simulator system known as FSim (Finney et al. 2011). The driving reasons to complete this assessment were to guide the management of the fire using incident-specific products rather than the range of weather conditions and regional values and assets used in the regional assessment.

CONCLUSION

What makes an incident a good candidate for an incident-specific cNVC or eNVC? The simplest answer is any incident that has a large number of nested values and assets. Some have made the case that this type of information is most useful for fires that have an incident strategy other than full suppression; however, these products may be applied to a fire with a full suppression strategy that may further guide priorities for operational resources, desired fire effects, and dialog regarding firefighter exposure.

How can this assessment be recreated for another incident? First and foremost, you must find a GIS analyst who has experience using scripts, as that is currently the only way to calculate the products. The GIS analyst could work remotely, but this will create an additional workload for the person at the incident meeting with the local unit and stakeholders and gathering data.

REFERENCES

Finney, M.A. 2005. The challenge of quantitative risk analysis for wildland fire. Forest Ecology and Management. 211: 97–108.

Finney, M.A. 2006. An overview of FlamMap fire modeling capabilities. In: Andrews, P.L.; Butler, B.W., eds. Proceedings, fuels management—how to measure success. 2006 March 28-30, Portland, OR. Proceedings RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 213–220.

Finney, M.A.; McHugh, C.W.; Grenfell, I.C.; Riley, K.L.; Short, K.C. 2011. A simulation of probabilistic wildfire risk components for the continental United States. Stochastic Environmental Research and Risk Assessment. 25(7): 973-1000.

Noonan-Wright, E.K.; Opperman, T.S.; Finney, M.A.; [et al.]. 2011. Developing the U.S. wildland fire decision support system. Journal of Combustion. 2011: 168473. doi:10.1155/2011/168473.

Scott, J.H.; Reinhardt, E.D. 2001. Assessing crown fire potential by linking models of surface and crown fire behavior. Res. Pap. RMRS-RP-29. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 59 p.

Scott, J.H.; Thompson, M.P; Calkin, D.E. 2013. A wildfire risk assessment framework for land and resource management. Gen. Tech. Rep. RMRS-GTR-315. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 83 p.

Southwestern Region Fire and Aviation Management. 2017. Southwestern wildfire risk assessment: 2017 regional wildfire risk assessment results. Unpublished report on file with: U.S. Department of Agriculture, Forest Service, Fire and Aviation Management, Fuels and Fire Ecology, Albuquerque, NM. 41 p.

Wagenbrenner, N.S.; Forthofer, J.M.; Lamb, B.K.; Shannon, K.S.; Butler, B.W. 2016. Downscaling surface wind predictions from numerical weather prediction models in complex terrain with WindNinja. Atmospheric Chemistry and Physics. 16: 5229–5241.