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A method for estimating the socioeconomic impact of Earth observations in wildland fire suppression decisions

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Supplemental appendix SA: Resources impacted by the fire

Human

Life/safety. No human lives (firefighter or civilian) were directly lost due to the fire. No serious injuries from the fire have been reported (see Livingston et al. 2011, for a report on a non-serious injury) and no estimate of indirect harm or death from smoke has been made. There were no reported deaths or injuries from the subsequent flooding.

Evacuation. Such costs were not estimated, though both Los Alamos and White Rock were evacuated early in the fire. There were no reported evacuations due to post-fire floods.

Social and cultural. The main cultural-archaeological site burned by and flooded from the fire was the Bandelier National Monument, which reveals the 10,000-year footprint of Native American peoples in

this area. Its social impact on visitors seems impossible to calculate, but we do estimate, as shown below, its multi-year revenue losses from the fire and flooding.

Lost time/productivity. A second type of social loss from Las Conchas can be classified as lost time or productivity. Neither the Los Alamos National Laboratory (LANL) or any other affected organization has reported this type of loss, which would be substantial if calculable.

Natural landscape (Pueblos). A third class of loss cannot be monetized, but obviously matters greatly to the people who value certain forests and valleys for their sacred or spiritual significance. This type of social value should be treated separately from the ecological value that a forest or watershed has to a larger group of people, i.e. naturalists.

LANL. The social value of the Lab to the United States is incalculable. Its possible loss cannot be estimated.

Property and revenue

Acreage. The 2011 Las Conchas wildfire has been reported as burning 156,293 acres, at that time the largest recorded wildfire in New Mexico history.

Private property losses. The extent of private property losses from the fire included 63 homes and 49 outbuildings destroyed (NWCG 2011). Additionally, as noted below, there was the complete loss of the Dixon Apple Orchard due to the fire and the August 2011 flood.

Timber. Direct valuation of lost timber is complicated by the fact of multiple owners over the range of the Las Conchas fire. We discuss the challenges of calculating its economic value in general terms below and then show calculated losses for distinct scenarios. Monetizing its ecological value is more problematic.

Bandelier National Monument. The damages to 20,000+ acres are detailed in their post-fire report (National Park Service, 2011). These losses were probably unavoidable given that the fire burned with high intensity across the park due to high winds during the first few days. Fire control actions were not successful due to the extreme burning conditions. We estimate the likely tourism revenue losses due to the fire from the decline in visitors and include this calculation in Appendix B.

LANL. On the second day of the fire, LANL had a small spot fire on its property along State Road 4 and incurred the loss of one building. According to Fowler et al. (2015), LANL's monetary losses from Las Conchas totaled $15.7 million. Supposing non-factually that this spot fire had not been controlled and had spread further is a key element of our experiment's Scenario 1.

Pueblos. Three Native American Pueblos predating the 16th century Spanish conquest of what is now New Mexico have lands that suffered severe losses from the fire and subsequent floods. Those losses, presented and discussed below, can be monetized when linked to tangible property or business revenues.

Ecological

Timber. Much of the timber lost in the Las Conchas fire was mixed conifer, and how we monetized its value is described in the following section. Though the timber market value in a forest can be readily monetized, a forest's function in the larger natural environment provides essential ecological values such as oxygen production, carbon dioxide absorption, wildlife habitat and other intrinsic values which we emphasize and do not attempt to monetize.

Flora and fauna. Fauna possessing critical value (Springer 2012) due to their threatened/endangered designation are: Jemez Mountains salamander (*Plethodon neomexicanus*), Houston toad (*Bufo houstonensis*), Rio Grande silvery minnow (*Hybognathus amarus),* Mexican spotted owl (*Strix occidentalis lucida*), Apache trout (*Oncorhynchus apache*), Rio Grande cutthroat trout (*Onchorynchus clarki virginalis*) on the ESA candidate list in 2011, but later removed.

Watersheds. Watersheds impacted by the Las Conchas fire drain into the Rio Grande, which supplies water to downstream agriculture in New Mexico and Texas and supports human life for millions of residents in the Rio Grande basin. Within the burn area we also highlight the severely damaged watersheds which nourished local flora and fauna and supported the ancestral lands of the indigenous Pueblos. We did not attempt to monetize these damages.

Supplemental appendix SB: Valuation of assets

We now describe in more detail how the values of the assets and of the fuel in the model cells were determined.

Property. The private property losses were assembled and calculated from county tax records using the most recent cadastral maps provided by each county's GIS manager; see Calkin et al. (2011) for validation of cadastral maps to identify structures in wildfire decision making. Three New Mexico counties were impacted by the Las Conchas fire. After inspecting maps and reviewing news reports of the fire and its aftermath, we determined that only two of the counties--Los Alamos and Sandoval--suffered destruction of physical property during the two-day period beginning 6/29/2011. To ascertain the private property values in or near the fire, we chose to use the assessed values of each parcel as determined by the County Assessor's office.

One of the co-authors (Miller) visited each office (February 2017) and established communication with the individual in charge of mapping and geographical information systems (GIS) for the county. After explaining the purpose of the study and the need for parcel values and GIS coordinates of all properties in the vicinity of the fire, we received electronic files containing the requested data along with offers of further assistance.

Subsequent to receiving these files, the same co-author visited with Patrick Samora, Chief Appraiser of Rio Arriba County, in his office to understand more thoroughly how assessed property values are determined in New Mexico. He stated that per state law county-wide reassessments are conducted periodically and that the assessed values are intended to reflect market or 'expected' values. Therefore, we used the assessed values as proxies for property value losses for those entities impacted by the Las Conchas fire.

One exception to use of county maps for determining property value was the Dixon Apple Orchard, which had been an iconic business operation for decades that residents of Albuquerque and Santa Fe frequented when apples were in season. Its location required customers to traverse Cochiti Pueblo lands to reach it. The orchard was subjected to fire on June 27th and then severe flooding in

August. After lengthy negotiations, the orchard land was returned to the Cochiti Pueblo, and a $2 million settlement was reached with the orchard owners (Brown 2014). In cases of this type we would use the cash settlement as the market value lost for this property.

Forest. Concerning timber values, Ponderosa pine (*Pinus ponderosa* Dougl. Ex Laws) is the dominant tree species in the area of the Las Conchas fire (USDA 2011). Mature Ponderosa pines are low-intensity fire tolerant. Seedlings establish well on burned-over seed beds, but the species does not regenerate well on unburned organic surfaces (Graham and Jain 2005). Clearly, the immediate post-fire conditions for seedlings are critical to the maintenance and recovery of a Ponderosa Pine ecosystem.

Post-fire timber salvage is controversial due to compounding the damage to ecosystems already laid waste by fire, increasing erosion and denying habitat to wildlife which are part of the natural process of post-fire ecosystem restoration. (Evans 2017). Additional timber sales do help mitigate wildfire's other negative economic impacts (Prestemon and Holmes 2008), but salvage logging has been shown to reduce Ponderosa pine regeneration by 75% after the moderate and high severity 2000 Jasper fire in South Dakota. (Keyser et al. 2009).

Part of the Las Conchas fire area was salvage logged, but logging volume and financial data for this area were not found. Comparison of salvaged and un-salvaged areas near Jemez Springs showed that salvage logging destroyed the forest's initial regeneration in New Mexico as well (Duara 2015).

To estimate timber values affected by the fire, we assigned timber harvest values to each of the Anderson fuel categories (Table SB1). The harvest values were based on tables used for California tax valuation of timber producing property (CA BOE 2011). We chose our model's maximum value of $200 per acre from the California BOE table green timber harvest value for Ponderosa pine in southern California. While not arbitrary, this value should be considered nominal.

Table SB1. Estimating timber losses

	Nominal value	Scenario 1 acres	Scenario 2 acres	Scenario 1 Est'd value	Scenario 2 Est'd value

Fuel model	Fuel group	per acre before fire	burned 1st 24 hours	burned 1st 24 hours	burned 1st 24 hours	burned 1st 24 hours
1	Grass	$0	4,218	4,109	$0	$0
2	Grass	$25	2,901	2,901	$72,525	$72,525
3	Grass	$0	5,090	4,327	$0	$0
4	Shrub	$0	5,295	4,492	$0	$0
5	Shrub	$25	1,045	1,045	$26,131	$26,131
6	Shrub	$0	8,950	7,193	$0	$0
7	Shrub	$50	6,546	5,869	$327,291	$293,437
8	Timber	$200	12,202	10,299	$2,440,411	$2,059,869
9	Timber	$200	3,282	2,545	$656,311	$509,037
10	Timber	$100	3,128	2,249	$312,835	$224,866
11	Slash	$50	754	729	$37,684	$36,448
12	Slash	$0	576	534	$0	$0
13	Slash	$0	633	608	$0	$0
	Total		54,620	46,901	$3,873,188	$3,222,313
	Total	rounded			$3,900,000	$3,200,000

Fuel model	Fuel group		Scenario 1 acres burned 1st 48 hours	Scenario 2 acres burned 1st 48 hours	Scenario 1 Est'd value burned 1st 48 hours	Scenario 2 Est'd value burned 1st 48 hours
1	Grass		7,653	6,951	$0	$0
2	Grass		2,901	2,901	$72,525	$72,525
3	Grass		10,682	7,838	$0	$0
4	Shrub		11,337	8,256	$0	$0
5	Shrub		1,045	1,045	$26,131	$26,131
6	Shrub		20,754	14,132	$0	$0
7	Shrub		12,607	9,995	$630,365	$499,770
8	Timber		24,619	19,284	$4,923,817	$3,856,817
9	Timber		7,065	5,753	$1,412,947	$1,150,522
10	Timber		6,459	5,310	$645,933	$531,029
11	Slash		1,156	1,102	$57,823	$55,104
12	Slash		949	885	$0	$0
13	Slash		1,067	998	$0	$0
	Total		108,296	84,451	$7,769,542	$6,191,899
	Total	rounded			$7,800,000	$6,200,000

Tourism. Tourism losses caused during the 48-hour simulation window were zero, but tourism losses due to Bandelier National Monument burning in the initial two days of the Las Conchas may be estimated as shown in Table SB2.

Table SB2. Estimating Bandelier National Monument tourism losses

Year	Annual visits[1]	Est'd visit losses from base	Avg NM day trip expenditure[2]	Annual dollar losses from lost day-trip visits	Midyear (June) CPI-U[3]	Est'd annual losses in 2011 Dollars
Avg. of 2006-2010 base period	224,599					
2011	193,914	30,685	$62.16	$1,907,247	225.672	$1,907,247
2012	150,289	74,310	$65.94	$4,900,214	229.601	$4,816,360
2013	126,682	97,917	$69.83	$6,837,500	233.049	$6,621,063
2014	130,106	94,493	$75.06	$7,092,284	234.812	$6,816,218
2015	174,073	50,526	$77.54	$3,917,836	236.525	$3,738,065
5-year total	775,064	347,931		$24,655,080		$23,898,954

[1]National Park Service Visitor Use Statistics (National Park Service 2019)
[2]Day-trip expenditures from Longwoods International (Tourism Economics 2017). Data for 2011-2013 closely correspond to a 2014 report from the New Mexico Tourism Department (NMTD 2014).
[3]Historical Consumer Price Index (Bureau of Labor Statistics 2019)

Supplemental appendix SC: Other than monetary losses

Human

As noted earlier, there were no reported deaths or serious injuries directly caused by Las Conchas, and no estimations have been made concerning evacuation costs.

Social and cultural

The four social values that we observed to be relevant in Las Conchas were Bandelier National Monument, an archaeological site, lost time/productivity, the natural landscape, and LANL. Out of 1,500 ancient archaeological sites in Bandelier National Monument 1,104 were inside burned areas (National

Park Service 2012a). Unexcavated underground portions of archaeological sites may be protected from fire, but not necessarily. Fire-killed trees may fall later and crush or uproot sites spared by the fire. Where ground cover has been destroyed by fire, increased erosion threatens sites on sloped ground. Post-fire flash flooding further threatens burned sites and unburned sites further downstream (National Park Service 2012b). Therefore, the count of damaged sites may increase for years after the fire. These likelihoods make it difficult to assign a fixed loss to the social/cultural values that Bandelier National Monument represents.

Regarding lost time/productivity, no entity affected by Las Conchas has reported estimates of such losses. Though substantial given the duration of the fire, such invisible losses can be assumed but not calculated.

Researchers in the United Kingdom reviewed and summarized studies in several countries of the psychological impacts of wildfire, especially for those with strong personal connections to the natural landscape (Finlay et al 2012). Findings indicate that psychological distress associated with wildfires includes posttraumatic stress, depression, anxiety, hostility, paranoia, and unexplained physical symptoms. Children are at especially high risk. Experiencing evacuation or perceiving a wildfire as a personal threat or as a threat to their parents were followed for six months and seen to experience continuing emotional distress. As expressed four years after the fire in testimony to the U.S. Congress by Santa Clara Pueblo Governor J. Michael Chavarria, *"eighty percent of our forests and a huge part of our heritage has been destroyed"* and that wildfire and subsequent flooding was a *"devastating emotional impact to our community"* (Chavarria 2015).

LANL is a unique social/cultural value which was threatened by the Las Conchas fire. Its historical significance dating back to World War II and the Cold War cannot be easily dismissed. Its current role in national defense preparedness and research discoveries seems impossible to estimate or monetize. The human knowledge base assembled in Los Alamos cannot be reflected by its budget expenditures. Although controversial, LANL's contribution to the nation and society is irreplaceable.

Calculations of timber salvage value are less meaningful if active logging and salvage did not actually occur. Regardless, this timber clearly had value. If the managers of this land chose not to harvest the forest for its valuable timber, then we may conclude that they valued this forest even more than the potential economic value of logging there. Hence, the lost value of burned timber can serve as a proxy or lower bound of the forest's value.

The Bandelier National Monument archaeological site administered by the National Park Service did incur considerable damage, both from the wildfire and subsequent flooding. In an early report on the Las Conchas impact upon Bandelier National Monument, they detailed property losses totaling $4.5 million (National Park Service 2011, Appendix L). In terms of this experiment, the fire losses occurred in the first days of Las Conchas, prior to our scenarios, and the claim against the property losses was later dropped. Thus, these losses, though substantial, would not be expected to impact outcomes revealed in the scenarios of this study. In addition to the fire-flood losses, Bandelier National Monument also experienced a dramatic downturn in tourist visits. To calculate this loss, we contrast the estimated higher tourism revenues from a five-year period prior to 2011 with the estimated lower revenues from the 2011-2015 period. Using the more conservative estimate of a day-trip tourist expenditure per visit in New Mexico (Tourism Economics 2017), the total revenue losses to Bandelier National Monument for the 2011-2015 period were $24 million. The choice of this five-year period was based on the observation that tourist visits to had more-or-less returned to their pre-fire level.

The Los Alamos National Laboratory also experienced losses, but they seem insignificant relative to its size. As discussed above, there was a single spot fire on LANL property and the loss of a single building. Fowler et al. (2015) pegged the Lab's monetary losses at $15.7 million, but there is no evidence that the resulting damages had an adverse impact on its operations. Implicitly, the lack of damages to LANL underscore its ongoing mitigation efforts to reduce fire risk on its property.

To understand the nature and extent of losses to the Cochiti and Jemez Pueblos, Miller (trial notes unpublished) attended a preliminary hearing in the courtroom of Judge McDonald, Sandoval County, New Mexico. At this hearing (subsequent to the initial 2015 jury trial that established the co-defendants

were liable for damages and losses), Judge McDonald announced that the consolidated lawsuits stemming from the Las Conchas fire/floods would be split and that the Cochiti and Jemez Pueblos' cases would be tried in early 2017 with two phases. The jury trial for determining monetary losses to the two Pueblos began on February 15, 2017 and ended February 22, 2017 after the first phase when confidential settlements were reached between all the opposing parties. During the first phase of the trial for the Cochiti Pueblo, notes were taken to document its property losses, exclusive of timber losses. Post-fire flooding loss claims, totaling $19.7 million, were specified for Peralta, Cochiti, and Bland canyons and their downstream flows. Each canyon's flood-loss value was pro-rated and associated with a string of approximately equally spaced locations in that canyon. The losses claimed by the Jemez Pueblo on the introductory day of the trial were noted as $15 million, primarily due to forest destruction from the fire.

Because the Santa Clara Pueblo sought remedial help from federal agencies, their loss claims were taken from public announcements. For the Santa Clara Pueblo (town and canyon) there were five federal disaster declarations resulting from the Las Conchas fire and subsequent flooding with total infrastructure repair estimates as high as $150 million (McCleery 2014). The same report stated that only $5 million had been spent to this purpose in the first three years following the fire and that the tribe estimated at least $40 million more was needed. In our summary we show a total claim expected value of $45 million.

Ecological

Assigning value to the forest and its timber presents a difficult challenge. As shown above, the timber can be assigned a monetary value if certain assumptions remain acceptable. However, such an assignment does not preclude other values worth noting. First, the forest with its timber undergirds an ecosystem that supports the flora and fauna of the area. It permits these species to exist and to thrive, hopefully, and by allowing them to be it gives them their own innate value. Second, this forested ecosystem also provides value to those humans who derive pleasure or fulfillment from the ecosystem itself. They ascribe value to it whenever they choose to 'spend' time and funds on it instead of another

activity. Third, the ecosystem impacted by Las Conchas nourishes and sustains a watershed(s) that offers a necessary and essential element to life downstream from the wildfire. The fire, depending on its intensity, is a threat to that life. In view of the abundance of that life, assigning it value and then ascribing losses to it from Las Conchas seems impossible to do; nevertheless, the fact that it has value seems undeniable.

Supplemental appendix SD: Timeline for the Las Conchas wildfire

The following including a timeline for the Las Conchas fire provides a chronological justification for our selection of the experiment's two-day time period.

Ignition. On Sunday, 6/26/2011, just after 1pm, the Las Conchas wildfire, ignited by a fallen power line due to high winds and extreme drought, roared into being. Almost immediately, it was believed to threaten LANL, which had already experienced numerous wildfires since its inception in 1941. The fact of 43 thousand acres consumed by fire on the first day, and the proximity of nuclear material at LANL quickly generated attention at the local, state, and national levels.

Growth without IMT management. On Monday, 6/27/2011, the fire grew slower than on Sunday and spread to a total of 60,000+ acres (Gabbert 2011a). Suppression of the fire was managed by local firefighting units, particularly the Los Alamos Fire Department.

Moderate growth with IMT management. By Tuesday, the 28th, the first national IMT assumed responsibility for fighting the fire, and within a few days two more ICTs were brought in to manage suppression of the three-zone wildfire throughout the month of July. Almost 70,000 acres had been burned since Sunday (Gabbert 2011b).

Rapid growth with IMT management. On June 29th, the fire burned eastward from Bandelier National Monument to NM Hwy 501, where it was prevented from entering Los Alamos and held at the western edge of LANL. Winds pushed the fire north into the Santa Clara reservation rapidly burning the Santa Clara Canyon watershed and remained uncontrolled for several more days. Though IMT reporting

remained sketchy (Gabbert 2011c), the las Conchas fire appeared to have consumed some more than 92,000 acres by mid-day on the 30th.

Fire containment by ICTs. During the first part of July the fire expanded from Santa Clara Canyon south toward Los Alamos and was stopped before reaching the city. The fire spread further north from Santa Clara land burning several square miles of Rio Arriba County. The southwestern front continued burning uncontrolled through the Jemez reservation. The Las Conchas fire became the largest fire in the recorded history of New Mexico up to that time, eventually consuming 156,293 acres until the fire was officially contained on August 3rd.

Supplemental appendix SE: Scenario simulation notes

Date	Time	Who	Topic	Description
5/25/2017	9:00 AM		Intros	Brief introductions, including AK by Skype.
5/25/2017	9:15 AM	JM,VM		Description of methods and purpose.
5/25/2017	10:00 AM	VH	maps	Copies to everyone present of Las Conchas Fire Transportation map with some drop points (DP).
5/25/2017	10:00 AM	VH	maps	Copies to everyone present of 6/29 fire perimeter overlaid on 4-color map of geographical regions.
5/25/2017	10:00 AM	VH	maps	Copies to everyone present of 13 fuel models' descriptions from Anderson paper.
5/25/2017	10:04 AM	VH	map	Copies to everyone of 3-color Days 1,2,3 fire progression overlaid on map of geographical regions, and emailed to AK.
5/25/2017	10:15 AM	DO,RM	IMT's perspective	IMT decision making in general. Fluid multi-dimensional situations. Main question: "What's at risk?"
5/25/2017		RM		Complexities include the conflicting objectives of landowners, natural resource advisors, and agencies.
5/25/2017		DO		Recommended book about decision-making: "Blink". Many decisions are made in a blink which shouldn't be.
5/25/2017		DO,RM		Each day's IMT decisions are based on the current situation and on considerations many days ahead.
5/25/2017		VH note		Our model and experimental design are necessarily shorter term than this. We should be prepared to answer in what ways any time-scope mismatch or deferred effects may be captured or not in our results.
5/25/2017	11:20 AM	DO,RM	IAPs	Begin review of LC 2011 Incident Action Plans.
5/25/2017	12:10 PM	DO,RM, VM	IMT strategy	Consultants discuss scenario 1 plan with VM.

5/25/2017	12:50		Lunch	
5/25/2017	2:10 PM	RM	Detailed experience	Experience: incident commander, fire boss for prescribed burns, USFS, Bureau of Indian Affairs, WFA. Very familiar with the Las Conchas area in person.
5/25/2017	2:15 PM	DO	Detailed experience	Experience: incident commander, hot-shot crew, smoke jumper, fire boss for prescribed burns, National Park Service-Glacier N.P., WFA.
5/25/2017	2:20 PM	DO,RM	Scenario 1 strategy	Discuss base case fire suppression strategy.
5/25/2017		DO,RM	Available data	confirmed that fuel maps would be available to IMTs.
5/25/2017		DO,RM	Missing data	Data we are missing which would normally be available to IMTs: IAPs normally include maps indicating location and type of fireline work already accomplished.
5/25/2017	3:10 PM	RM,VH	GoogleEarth	Practice drawing lines in GoogleEarth.
5/25/2017	3:15 PM	all	GoogleEarth	Close-up tour of entire fire perimeter via GoogleEarth.
5/25/2017	3:26 PM	JM	KMZ file	JM emailed June 29 fire perimeter Domain 4 KMZ file to VH.
5/25/2017	3:30 PM	all	Scenario 1 strategy	Full baseline strategy discussion.
5/25/2017	5:00 PM	RM	Scenario 1 strategy	Drew scenario 1 fire lines and observation lines for Divisions A,B,C,D,E.
5/25/2017	5:27 PM	VH	Scenario 1 firebreaks.	Emailed Div A,B,C,D,E lines in KMZ file to AK.
5/25/2017	5:31 PM	VH	Scenario 1 firebreaks.	Emailed Div A,B,C,D,E lines in KMZ file to DO, RM, JM,VM.
5/25/2017	5:34 PM	VH	Scenario 1 firebreaks.	Emailed Div A,C,E fire break lines in 3 KML files to AK.
5/26/2017	9:00 AM	all	IAP	Discuss firefighting resources available 6/29/2011 per IAPs.
5/26/2017	9:10 AM	AK	Scenario 2	Discuss spot fire northeast of Hwy 4, outside the Scenario 1 fire break line, and newly moved fire break line further north.
5/26/2017	9:25 AM	JM	Fire detections	JM showed satellite fire detections overlaid on yesterday's maps and fire lines. He described: polar orbiting satellite, Fire Radiative Power (FRP), detection confidence level. Negative detection data is not present. False detections. Time detail on each detection squares allow squares to be viewed as movie.
5/26/2017	9:55 AM	DO,RM	Scenario 3 Strategy	Discuss strategy revision based on satellite detections data. New safety concerns about safety concerns for SW perimeter (Div A) arise after movie of fire detections showing more heat and fire movement to the SW in the early AM hours of 6/29/2011.
5/26/2017	10:14 AM		Vegetation maps	Landfire.gov has vegetation maps.
5/26/2017	10:20 AM	DO,RM	Fire detections	Discuss IMTs' degree of understanding and degree of confidence of fire detections data.
5/26/2017	10:27 AM	DO,RM	Scenario 3 firebreaks.	Discuss possibly using the same lines as Scenario 1 but shifting resource allocations.

5/26/2017	10:35 AM	DO,RM	Scenario 3 firebreaks.	Safety concerns for Div A in the SW motivate changing Div A to observation only instead of trying to stop the fire's SW advancement. (Change Div A line from red to green.)
5/26/2017	10:55 AM	DO,RM	Modeling tools history	Discuss WFDSS and modeling tools which were available in 2011.
5/26/2017	11:00 AM	DO,RM	Scenario 3 Strategy	Safety concerns for Div A: 1) additional heat and spreading of fire to the SW not anticipated by viewing only the 11:34pm local 6/28/2017 fire perimeter , 2) temperature expected to rise during the day, no rain yet, none in the forecast, 3) no quick in and out of the SW canyons (Peralta).
5/26/2017	11:25 AM	JM		Jan set up the WRF-SFIRE fire model display loop.
5/26/2017	11:35 AM		Modeling tools history	More fire modeling tools history discussion.
5/26/2017	11:42 AM	DO	Scenario 3 summary	Summarized IMT's Scenario 3 analysis.
5/26/2017	11:53 AM	JM	WRF-SFIRE simulation model	WRF-SFIRE simulation video.
5/26/2017	12:03 PM	AK	WRF-SFIRE simulation model	Described fuel breaks built into the Baseline scenario which created the experiment's initial fire boundary to closely match the historical fire boundary of early 6/29/2011. Baseline (pre-Scenario 1) fire breaks: 1) along NM hwy 4 from near the ignition point to NW closely matching the Div E fire line, 2) on the east side between the fire and Los Alamos.
5/26/2017	12:07 PM	DO,RM	WRF-SFIRE simulation model	It is observed that in the simulation model "LasConchas2011 4domain" fire traveled further to the SE and did not stop at the Rio Grande, which did not seem likely.
5/26/2017	12:08 PM	JM	Wind model	Displayed wind model showing powerful downbursts 6/29/2011.
5/26/2017	12:12 PM	JM,AK	Diffusion modeling	Diffusion modeling is turned off in our simulation.
5/26/2017	12:13 PM	JM	Smoke	Displayed the simulation with smoke.
5/26/2017	12:16 PM	AK	Scenario 2	Overnight AK observed that the simulation shows that Div C line protecting Los Alamos did not hold due to small spot fire immediately the other side of Hwy 4 toward LANL. He redrew the Div C line a little further toward LANL to create simulation 2.
5/26/2017	12:21 PM	VH		Displayed in GoogleEarth view, two points along the road where the fire boundary was slightly beyond the original Div C line.
5/26/2017	12:25 PM	JM	WRF-SFIRE simulation model	Viewed online using Scenario 2 revised fire lines, Div C fire break holds.
5/26/2017	12:28 PM	JM	Making model videos	Discussed model post-processing, movie maker. Command "make kmz".
5/26/2017	12:30 PM	AK	2	Discussed Div C break line technical correction in 2 simulation videos.

5/26/2017	12:32 PM	JM	Air temperature	Introduced the simulation's 2-meters-above-ground air temperature video.
5/26/2017	12:33 PM	JM	Fuel moisture	Introduced the simulation's fuel moisture layer graphics.
5/26/2017	12:36 PM	JM	WRF-SFIRE simulation model	GoogleEarth view of simulation 2 video.
5/26/2017	12:42 PM	VH	Cerro Grande Fire 2000	Viewed map of Cerro Grande fire perimeter overlaid on the Las Conchas area.
5/26/2017	12:42 PM	all	Cerro Grande Fire 2000	Discussed the influence of the 2000 Cerro Grande Fire on fuels for the 2011 Las Conchas fire.
5/26/2017	12:42 PM	DO	Return interval	Discussed the return interval of fires.
5/26/2017	12:42 PM	JM	Percolation equilibrium	Discussed the long-term balance of nature in terms of forest density and fuel types.
5/26/2017	12:50 PM		Lunch	
5/26/2017	2:05 PM	JM,VH	Asset values	Displayed, discussed property values Excel file.
5/26/2017	2:12 PM	VH	Asset values	Emailed most current detailed asset values workbook to JM.
5/26/2017	2:15 PM	DO,RM	Timber value	Discussed timber values. The Pueblos have detailed forest inventory data.
5/26/2017	2:25 PM	VM	Settlements	Jemez Pueblo and Cochiti Pueblo cases were split from the rest.
5/26/2017	2:27 PM	DO	Timber value	Discussed aspects of litigation involving timber lost to fire.
5/26/2017	2:52 PM	JM	Burn times	JM loaded baseline burn times into detailed asset values worksheet. Emailed to VH.
5/26/2017	2:52 PM	JM	Burn times	JM loaded Scenario 2 burn times into detailed asset values worksheet. Emailed to VH.
5/26/2017	3:02 PM	JM	Scenarios summary	Summarized baseline scenario, Scenarios 1 and 2 3, and simulation 2.
5/26/2017	3:10 PM	VH	Asset values summary	Value of properties burned, and value of subsequent flood damage settlements under baseline and scenario 2.
5/26/2017	3:20 PM	VH	Fire-fighting costs	Showed total costs and costs/acre for the direct costs of fighting the LC fire.
5/26/2017		VH	Timber value	Group discussed the uncertainty of timber values, and variables affecting it. Vince displayed a table of detailed timber values by type.
5/26/2017		VH note	Timber value	Timber values lost in baseline and other scenarios are not calculated yet.
5/26/2017	3:28 PM	JM	Next Steps	Discussed the considerations involved in identifying the next steps in continuing this research: Study another fire? What type of fire? Which parameters should we use in narrowing down the type of fire?
5/26/2017	3:42 PM	RM	Fire detections	RM said the IMTs in 2011 would have used MODIS data.
5/26/2017	3:45 PM	JM,AK	Fire detections	Discussed how satellite fire detection might be improved. JM mentioned Karl Pennypacker of Berkeley, Fuego project.
5/26/2017	3:48 PM	DO	IMT perspective	Discussed the IMT's overall priorities 1) safety, 2&3) property and infrastructure.

5/26/2017	3:52 PM	JM	Fire suppression direct costs	Discussed Mark Finney writing about fire suppression costs.
5/26/2017	3:54 PM	DO	Research funding	Discussed the politics and logistics of wildland fire research. The trend is increasingly toward research focused on forest fire management.
5/26/2017	3:56 PM	JM,AK	Next Steps	JM and AK will select another fire.
5/26/2017	3:57 PM	VM	Scenario 4	Proposed Scenario 4 questions for the consultants.
5/26/2017	3:58 PM	VM	Next Steps Data Criteria	A major criterion for choosing another fire is data collection. The completeness of existing data, and how readily available it is, especially property coordinates. We need counties with GIS people who will provide properties data with latitude and longitude.
5/26/2017	4:00 PM	JM	Next Steps Data Criteria	Asked how much of the FOIA data did we use?
5/26/2017	4:00 PM	VM	Next Steps Data Criteria	The IAPs were essential. From them we used weather forecasts, lists of fire suppression resources, ...
5/26/2017	4:08 PM	VM,DO	Maps	Las Conchas IAPs came without maps. This is unusual/baffling.
5/26/2017	4:10 PM	VM	FOIA	Discussed 340(?)-page log of records.
5/26/2017	4:11 PM	JM		Asked consultants a question about Div C.
5/26/2017	4:13 PM	AK	Scenario 2	Asked which simulations did we use?
5/26/2017	4:14 PM	JM	Scenario 2	Answer: baseline and Simulation 2.
5/26/2017	4:15 PM	AK	Scenario 1	Discussed result for simulation 1 (original unadjusted Div C line left in place): fire crossing into Los Alamos in a major way.
5/26/2017	4:17 PM	JM	Scenario 2	Three 4-domain simulations run: baseline simulation, simulation 1, and simulation 2. Financial results on baseline and 2 only, so far.
5/26/2017	4:25 PM		Simulation 1	View and analyze spots where fire perimeter crossed highway south of LANL.
5/26/2017	4:31 PM	JM		Emailed animated perimeter file to VH.
5/26/2017	4:41 PM	JM		Asked were back-burns done for the historical fire?
5/26/2017	4:41 PM	RM		IAPs do not say what was done, only their planned objectives.
5/26/2017	4:43 PM	DO,RM		Discussed uncertainties about fire detection squares. It's hard to interpret whether single isolated squares are real spot fires or hot rocks or other false signals.
5/26/2017	4:45 PM	JM	Scenario 3	Questions toward wrapping up. Would you make any changes from Scenario 3 decisions based on the simulation results shown from Scenario 2?
5/26/2017	4:45 PM	DO	Scenario 3	Answer: No.
5/26/2017	4:46 PM	DO	Next steps	Suggests Chimney Top Fire in the Smoky Mtns.
5/26/2017	4:46 PM	VM	Next steps	Discussed 14 deaths, 2000 structures burned. Human caused fire.
5/26/2017	4:47 PM	JM	Next steps	All discussed fire near Gatlinburg, TN.
5/26/2017	4:50 PM	JM,AK	Next steps	Displayed Gatlinburg fire model.
5/26/2017	5:00 PM	JM,VH	Next steps	Displayed Gatlinburg fire detections data.
5/26/2017	5:00 PM			Visited websites to discuss MODIS, VIIRS, AVHRR.

5/26/2017	5:35 PM	End meeting.

Supplemental appendix SF: Modeling setup.

The numerical experiments utilized the WRF-SFIRE model in version 3.4.1, available from: https://github.com/openwfm/wrf-fire.git (accessed 22 Jul 2019). Modeling setup parameters are presented in Table SF1. Meteorological forcing was generated from Climate Forecast Reanalysis data (Saha et al. 2010). Fuel and topography data from LANDFIRE available at 30m horizontal resolution were used to initialize the fire model. The initial dead fuel moisture was estimated based on the data from National Fuel Moisture Database as 1%, 2%, and 5%for 1h, 10h, and 100h fuels respectively. The simulations were initialized on June 29 at 11:00 am. A 30-minute spin-up was used at the beginning of each run. During the spin-up, the fire progression was prescribed based on the artificial fire history generated from the IR fire perimeter observed on June 29 at 11:30 am as described in Kondratenko et al. (2011) and Mandel et al. (2014). The artificial history was generated by reversing the fire progression (shrinking the fire) based on the local rate of spread computed in a preliminary simulation without the fire. This procedure allowed to generate the fire arrival time that was used for the gradual release of the fire heat provided information about the burnt area at the beginning of the simulation, assuring that the atmospheric circulation at the end of the spin-up was consistent with the fire position defined by the fire perimeter observed on June 29th 11:30. The fuel in the grid cells heaving arrival time earlier than the simulation start (June 29th 11:00) was removed to prevent inward fire propagation. After the spin-up, the coupled model carried the simulation forward, allowing the fire to expand. The firebreaks designed by the IMT were drawn in Google Earth, exported as KML files and ingested into the model. They were implemented by modifying the fuel map by setting corresponding model grid cells to fuel category 14 (no fuel). The fuel break lines were in place from the beginning of the simulation and were assumed 100% effective if placed ahead of the approaching fire front. However, any part of the fuel break line located within already burnt area at the end of the spin-up time, was ineffective, as at the fire was already pass

that point at the beginning of the actual simulation. In other words, sections of the division lines defined within the starting fire perimeter created discontinuities in the fuel break lines allowing for fire penetration.

Table SF1. Detailed WRF configuration used in the study.

Domains	**d01**	**d02**	**d03**	**d04**
Horizontal resolution of atmospheric model	12km	4km	1.33km	444m
Horizontal resolution of the fire model	-	-	-	22m
Number of grid points (X×Y×Z)	130×130×41	130×130×41	130×130×41	130×130×41
Initial 1h fuel moisture	-	-	1%	
Initial 10h fuel moisture	-	-	2%	
Initial 100h fuel moisture	-	-	5%	
Initial life fuel moisture	-	-	50%	
Time step	45s	15s	5s	1.25s
Microphysics	Thompson[1]	Thompson[1]	Thompson[1]	Thompson[1]
PBL Physics	MYNN[2]	MYNN[2]	MYNN[2]	MYNN[2]
Surface Model	RUC[3]	RUC[3]	RUC[3]	RUC[3]
Cumulus Parametrization	Kain–Fritsch[4]	-	-	-

[1] Thompson et al. [2008]; [2]Nakashini and Niino [2006]; [3]Benjamin et al. 2004, [4] Kain [2004]

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