Yarnell Hill Fire

June 30, 2013

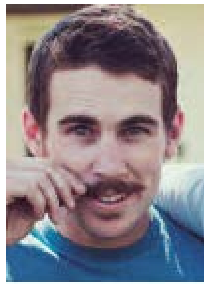
Serious Accident Investigation Report

September 23, 2013

Cover Photo: Raising the United States and State of Arizona flags at the Granite Mountain crew's deployment site. Courtesy of the Southwest Area Type 1 Incident Management Team.

In Memory Of

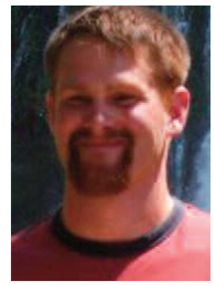
Andrew Sterling Ashcraft



Robert E. Caldwell

Travis Clay Carter

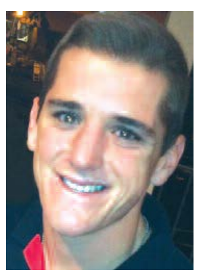
Dustin James DeFord



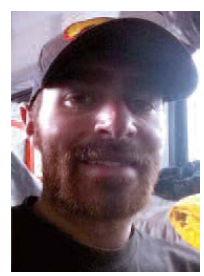
Christopher A. MacKenzie

Eric S. Marsh

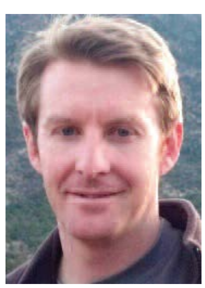
Grant Quinn McKee



Sean M. Misner

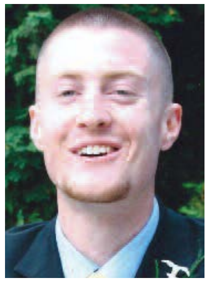


Scott Daniel Norris



Wade S. Parker

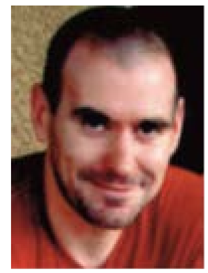
John J. Percin, Jr.



Anthony M. Rose

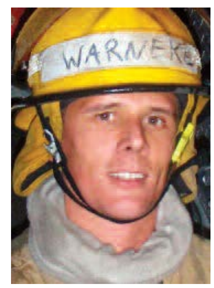
Jesse James Steed

Joe B. Thurston



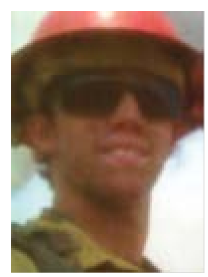
Travis Turbyfill

William Howard 'Billy' Warneke

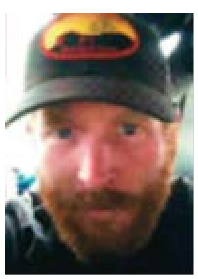


Clayton Thomas Whitted

Kevin J. Woyjeck

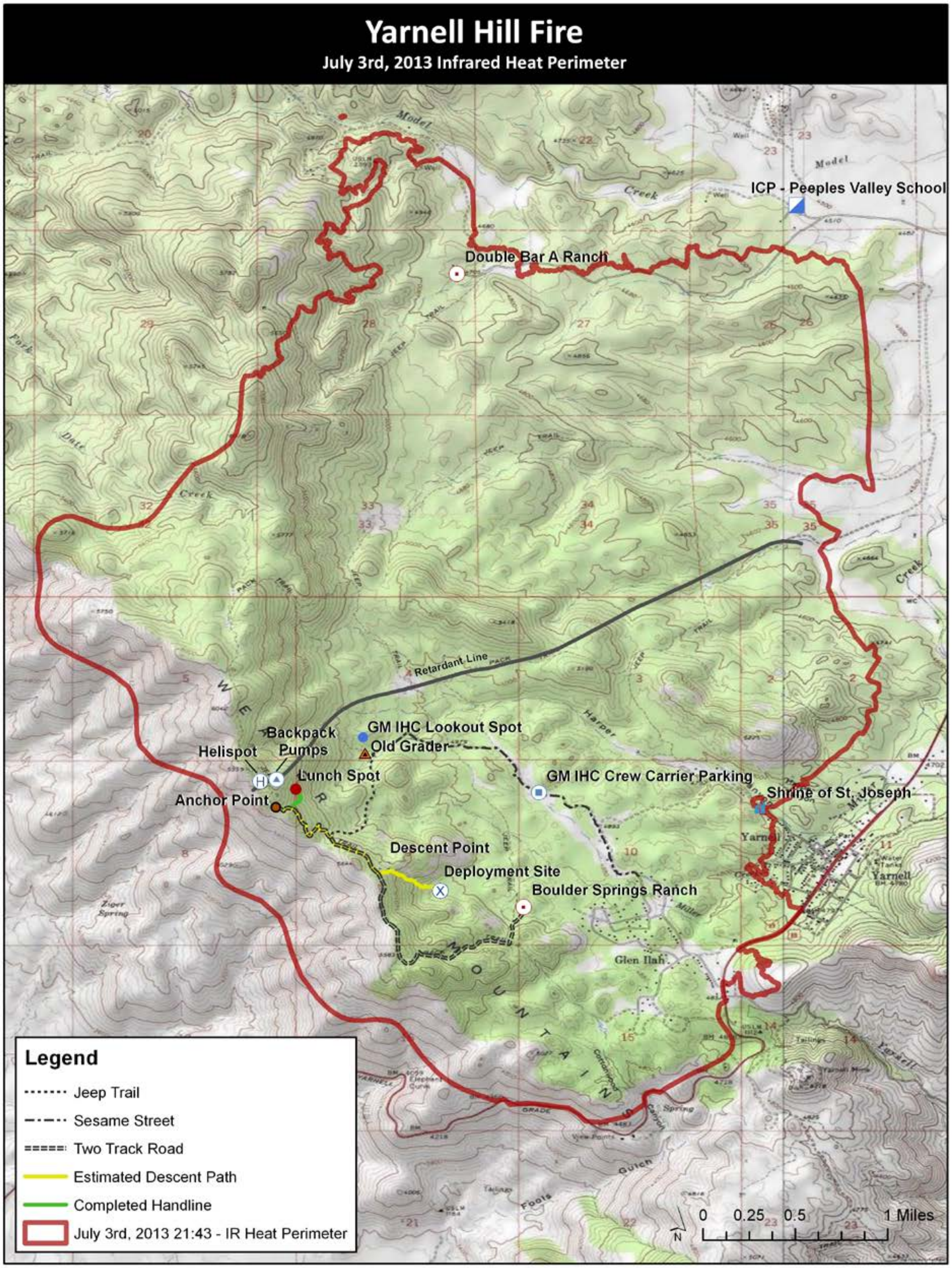


Garret Zuppiger



Granite Mountain
R-3
Prescott Fire
Interagency Hot Shot Crew
"Esse Quam Videri"

Contents



Yarnell Hill Fire
July 3rd, 2013 Infrared Heat Perimeter
ICP - Peeples Valley School
Double Bar A Ranch
Retardant Line
GM IHC Lookout Spot
Old Grader
Backpack Pumps
Helispot
Lunch Spot
Anchor Point
GM IHC Crew Carrier Parking
Shrine of St. Joseph
Descent Point
Deployment Site
Boulder Springs Ranch
Glen Ilah
Legend
Jeep Trail
Sesame Street
Two Track Road
Estimated Descent Path
Completed Handline
July 3rd, 2013 21:43 - IR Heat Perimeter
0 0.25 0.5 1 Miles
N

Executive Summary

Nineteen firefighters died on the Yarnell Hill Fire in central Arizona on June 30, 2013 after deploying fire shelters. They were members of the Granite Mountain Interagency Hotshot Crew (IHC), hosted by the Prescott Fire Department. One crewmember was separated from the crew earlier that day and was not at the deployment site.

* * * * *

Late afternoon on June 28, the Yarnell Hill Fire started high on a ridge west of Yarnell, Arizona when lightning ignited multiple fires. The fire, which was under the jurisdiction of the Arizona State Forestry Division, started in a boulder field in steep terrain with no vehicle access; it was about one-half acre in size. Responders saw minimal fire activity or spread potential, and they had several safety concerns with putting firefighters on the hill overnight. In consideration of these and other factors, the Incident Commander prepared for full suppression on the following morning.

On June 29, resources held the fire in check until around 1600, when winds increased and the fire spotted outside containment lines. That evening, the Type 4 Incident Commander ordered a Type 2 Incident Management Team (IMT) and additional resources for the next morning. The fire grew throughout the night, to an estimated 300 to 500 acres by morning.

Early on June 30, members of the Type 2 IMT began arriving. In a briefing at 0700, the incoming Granite Mountain IHC Superintendent accepted the role of Division Alpha Supervisor. His assignment was to establish an anchor point at the heel of the fire with the Granite Mountain IHC. The Type 2 IMT assumed command, an action formally announced by radio at 1022.

For most of the day, the fire spread to the northeast, threatening structures in Model Creek and Peeples Valley. Around 1550, the wind shifted and the fire started pushing aggressively to the southeast, toward Yarnell. Fire resources shifted to resident evacuation and structure protection in town. Only the Granite Mountain IHC remained out on the ridge, on the southwest perimeter of the fire. Personnel who communicated with the Granite Mountain IHC knew the crew was in the black at that time and assumed they would stay there. No one realized that the crew left the black and headed southeast, sometime after 1604. At 1630, thunderstorm outflows reached the southern perimeter of the fire. Winds increased substantially; the fire turned south and overran the Granite Mountain IHC at about 1642.

* * * * *

There is a gap of over 30 minutes in the information available for the Granite Mountain IHC. From 1604 until 1637, the Team cannot verify communications from the crew, and we have almost no direct information for them. *There is much that cannot be known about the crew's decisions and actions prior to their entrapment and fire shelter deployment at around 1642.*

It is known that the Granite Mountain IHC left the black sometime after 1604 and traveled through an unburned area toward a safety zone at the Boulder Springs Ranch. Thunderstorm outflows changed the intensity and direction of fire spread, and the rapidly advancing fire eliminated the crew's options of reaching the safety zone or returning to the canyon rim. They had less than two minutes to improve a deployment site. They were deploying fire shelters when the fire overtook them. Temperatures exceeded 2000^{o}F, and the deployment site was not survivable. The nineteen crewmembers were found approximately one mile south-southeast of their last known location, approximately 600 yards west of the Ranch.

* * * * *

The State of Arizona convened a Serious Accident Investigation Team. A delegation of authority letter, signed by the State Forester on July 3, 2013, charged the Team with reviewing and reporting on the circumstances leading to entrapment of the Granite Mountain IHC. The Team used a variety of data sources and methods to reconstruct events and analyze them. In deliberations, the Team drew from their knowledge of wildland fire operations and culture, as well as the perspectives of Subject Matter Experts. Through these processes, the Team generated the following conclusions:

- The Granite Mountain IHC was a fully qualified, staffed, and trained hotshot crew. They were current with the required training and met work/rest guidelines. The crew followed all standards and guidelines as stated in the Standards for Interagency Hotshot Crew Operations and the Arizona State Forestry Division's Standard Operational Guideline 804.

- The Yarnell Hill area had not experienced wildfire in over 45 years. It was primed to burn because of extreme drought, decadent chaparral, and above average cured grass loadings.

- Although Yavapai County had a Community Wildfire Protection Plan, many structures were not defendable by firefighters responding to the Yarnell Hill Fire. The fire destroyed over one hundred structures.

- Radio communications were challenging throughout the incident. Some radios were not programmed with appropriate tone guards. Crews identified the problem, engaged in troubleshooting, and developed workarounds so they could communicate using their radios. Radio traffic was heavy during critical times on the fire.

- The fire's complexity increased in a very short time, challenging all firefighting resources to keep pace with the rapidly expanding incident. As complexity dramatically increased starting Saturday evening, fire management went through multiple transitions from a Type 4 through a Type 1 incident in fewer than 20 hours.

- The Granite Mountain IHC had been watching the active fire burn away from their position all day but their observations did not lead them to anticipate the approaching outflow boundary or the accompanying significant fire behavior changes. These changes included a doubling of fire intensity and flame lengths, a second 90-degree directional change, and a dramatically accelerated rate of spread.

- The Granite Mountain IHC left the lunch spot and traveled southeast on the two-track road near the ridge top. Then, they descended from the two-track road and took the most direct route towards Boulder Springs Ranch. The Team believes the crew was attempting to reposition so they could reengage.

- The Granite Mountain IHC did not perceive excessive risk in repositioning to Boulder Springs Ranch.

- The Team found no indication that the Granite Mountain IHC doubted the black was a valid safety zone, or that they moved towards the Boulder Springs Ranch because they feared for their safety if they stayed in the black.

- Although much communication occurred among crews throughout the day, few people understood Granite Mountain's intentions, movements, and location, once they left the black. The Team believes this is due to brief, informal, and vague radio transmissions and talkarounds that can occur during wildland fire communications. Based on radio conversations, Operations and other resources had concluded the Granite Mountain IHC was located in the black, near the ridge top where they had started that morning. This resulted in confusion about the crew's actual location at the time of search and rescue.

- In retrospect, the importance of the 1526 weather update is clear. However, the update appears to have carried less relevance in the crew's decision-making process, perhaps due to the wind shift (starting at about 1550) that preceded the outflow boundary, or perhaps because of the time it took the outflow boundary to reach the south end of the fire (at 1630). It is possible they may have interpreted the early wind shift as the anticipated wind event.

- An Air Attack and/or an Aerial Supervision Module provided aerial supervision coverage throughout the day including at the time of the accident.

- The Aerial Supervision Module working the fire was very busy fulfilling leadplane duties, which limited their ability to perform full Air Attack responsibilities over the fire at the same time.

- During some limited times, aircraft were not available due to adverse weather and refueling needs.

- At the time of the shelter deployment, a Very Large Airtanker was on station over the fire waiting to drop retardant as soon as the crew's location was determined.

- The judgments and decisions of the incident management organizations managing this fire were reasonable. Firefighters performed within their scope of duty, as defined by their respective organizations. The Team found no indication of negligence, reckless actions, or violations of policy or protocol.

This report has two parts. Part One includes the fact-based Narrative of the incident and offers the Team's Analysis, Conclusions, and Recommendations. Part Two, the Discussion section, is meant to prompt discussion and facilitate learning. It explores multiples concepts and perspectives, in order to support the broader community seeking to make sense of the accident and to improve safety and resilience. Appendices provide technical details and other supplemental information.

The Investigation Process

Following the tragic loss of 19 lives on the Yarnell Hill Fire, the State of Arizona convened a Serious Accident Investigation Team. A delegation of authority letter, signed by the State Forester on July 3, 2013, charged the Team with reviewing and reporting on the circumstances leading to entrapment of the Granite Mountain Interagency Hotshot Crew (IHC).

The Team included representatives from local (Missoula Fire Department, Kern County Fire Department, Boise Fire Department), State (Florida), and Federal (US Forest Service, National Weather Service) governments, as well as independent experts from across the country. Appendix H includes a list of Team members.

Approach and Philosophy

The primary goal of this report is to facilitate learning from this tragedy, in order to reduce the likelihood of future accidents. To this end, the Team retained some of the most effective techniques of past investigations while integrating current theory and practices. The intent of this blending is to offer to the wildland fire community the highest-quality learning product possible, in a timely manner.

This report does not identify causes in the traditional sense of pointing out errors, mistakes, and violations but approaches the accident from the perspective that risk is inherent in firefighting. Leaders are responsible for guiding firefighters in consideration of the tradeoffs between safety, risk management, and other organizational goals. In this report, the Team tries to minimize the common human trait of hindsight bias, which is often associated with traditional accident reviews and investigations.

Hindsight Bias

The term "hindsight bias" refers to the tendency people have to view past events as more predictable than they really were before the events took place. After an event occurs, people often believe they could have predicted the outcome of the event before it actually happened.

The Team based its approach on the philosophy that firefighters are expected and empowered to be resourceful and decisive, to exercise initiative and accept responsibility, and to use their training, experience and judgment in their decision-making. The wildland fire community uses a doctrine approach to fire suppression, which requires the use of judgment. An individual's judgment in a given situation depends upon their unique training and experiences. The 10 Standard Firefighting Orders and 18 Watch Out Situations (10 and 18) are the foundation of training in fire suppression operations, but they require judgment in application. These principles, as stated below, outline the Team's perspective regarding the use and consideration of the 10 and 18 in this report:

Principles of Suppression Operations

> "The primary means by which we implement command decisions and maintain unity of action is through the use of common principles of suppression operations. These principles guide our fundamental fire suppression practices, behaviors, and customs, and are mutually understood at every level of command. They include Risk Management, Standard Firefighting Orders and Watch Out Situations, LCES [Lookouts, Communications, Escape Routes, and Safety Zones], and the Downhill Line Construction Checklist. These principles are fundamental to how we perform fire suppression operations and are intended to improve decision making and firefighter safety. They are not absolute rules. They require judgment in application."[1]

In light of this doctrine, the Team attempted to use foresight rather than hindsight in this discussion. That is, the Team tried to stand with the crew to try to understand, as best they could, what crewmembers were seeing and how they were making sense of unfolding conditions, *when it was time to act*. The Team also looked at broader cultural factors that may have influenced the crew. This helps set the stage for ongoing learning, which began with the Team's efforts and which will continue over time in the greater wildland fire community.

Methodology

The Team reconstructed events through a variety of methods and data sources. They conducted over 65 interviews with firefighters, fire support personnel, leadership personnel, and the public. The Team also gathered photos, videos, audio fragments, maps, dispatch logs, incident documentation, weather station records, and training records. They conducted site visits, equipment analysis, and wind and fire behavior modeling.

Different individuals can perceive the same event differently. This account acknowledges interpretations may vary from one person to the next, and there can be apparent inconsistencies between individual perspectives. However, in most cases, two or more data sources corroborated key details. Team members shared portions of the narrative with key interviewees to correct and clarify important details.

The Team held two sessions with Subject Matter Experts (SMEs) to review the draft investigation report. Each session included current IHC Superintendents, Type 3 Incident Commanders and Operations personnel representing local, state, and federal agencies. Each participant had the opportunity to ground-truth and refine a draft report, as well as to help generate recommendations. Appendix I lists the SME session participants.

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[1] *Interagency Standards for Fire and Fire Aviation Operations,* NFES 2724 (Boise, ID: Federal Fire and Aviation Task Group, National Interagency Fire Center, January 2013), p. 07-1. See http://www.nifc.gov/PUBLICATIONS/redbook/2013/2013RedBook.pdf.

Report Structure

This report is in two parts, plus appendices.

Part One includes the fact-based **Narrative**, the **Analysis, Conclusions**, and **Recommendations**. The primary purpose of the Analysis is to provide context for key action points associated with the entrapment and fire shelter deployment. This supports the Conclusions section, which represents the Team's impressions and conclusions about these events. Recommendations presented to management are opportunities for improving safety.

Part Two, the **Learning Discussion** section, explores multiple concepts and perspectives that may help readers to understand and learn from this accident. The intent is to prompt the wildland fire organization to think about and discuss how they can improve at the individual, team, and organizational levels, thereby improving both safety and resilience in their organizations.

Background

The Yarnell Hill Fire occurred in west-central Arizona, west of the town of Yarnell along a north-south mountainous ridge with elevations of 4,500 to 6,000 feet. Within the fire area, the terrain varies from steep ridges to nearly flat valley bottoms with numerous rock outcroppings and boulder piles. The dominant vegetation type, chaparral brush, ranged in height from one to ten feet and, in some places, was nearly impenetrable. The Yarnell Hill Fire area had not experienced wildland fire since 1966.

Conditions leading up to the Yarnell Hill Fire consisted of very high to extreme fire danger and extreme drought during a transition to the Southwest's summer monsoon season. During this seasonal transition, temperatures are typically very hot. Relative humidity values remain low but fluctuate as storms become more numerous and cloud cover more prevalent. Winds are highly variable with the highest wind speeds occurring during thunderstorms. These storms can generate strong downdrafts, micro-bursts, outflows, and gust fronts, all of which can affect fire behavior.

Granite Mountain Hotshots

The Prescott Fire Department created a Wildland Division in 2001 to conduct a risk assessment and develop a Vegetation Management Plan for the City. The risk assessment found Prescott to be at risk of catastrophic wildfire. As a result, the Division formed a Fuels Management Crew to create defensible space on private and City-owned property. The 2002 Indian Fire led to an expansion of the crew's duties. In 2004, the Fuels Management Crew evolved into Crew 7, a Type 2 Initial Attack crew that, while continuing with fuels reduction work, responded to wildfires both regionally and nationally. Just before the 2007 season, Crew 7 gained IHC trainee status and became known as the Granite Mountain Hotshots. Following the IHC certification process, Granite Mountain became a certified IHC in 2008.

The Southwest Coordination Center's Predictive Services issued a Fire Behavior Advisory on June 16, 2013 that discussed critically low fuel moistures and increased fuel loading. On June 25, the National Weather Service (NWS) office in Flagstaff issued an excessive heat watch for Yavapai and northern Gila counties below 4000 feet.

Multiple lightning ignitions occurred from thunderstorm activity on lands southwest of Prescott at about 1700 Phoenix Standard Time (PNT) on Friday, June 28. Of the seven lightning fires discovered, four were on State, private, and adjacent Bureau of Land Management (BLM) lands. The Yarnell Hill Fire was one of these four. Statewide, 37 active fires—four ongoing and 33 new fires—were under management that day. Figure 1, Yarnell Hill Fire Land Ownership Map depicts the boundary of the Yarnell Hill fire and displays the land ownership within the fire boundary.

The Southwest Area was in Preparedness Level 4 and had eight uncontained large fires, Types 2 and 3 in complexity. These were the Silver, Jaroso, Creek, Doce, Sycamore, Thompson Ridge, Tres Lagunas, and Rock Creek fires. Some precipitation and higher humidity had begun to enter the Southwest in certain places, which assisted agencies in nearing containment on five of the eight fires. Figure 2, Arizona Wildland Fire Activity, shows locations, estimated sizes, percentage contained, and land ownership for the fires burning across the state on June 29.

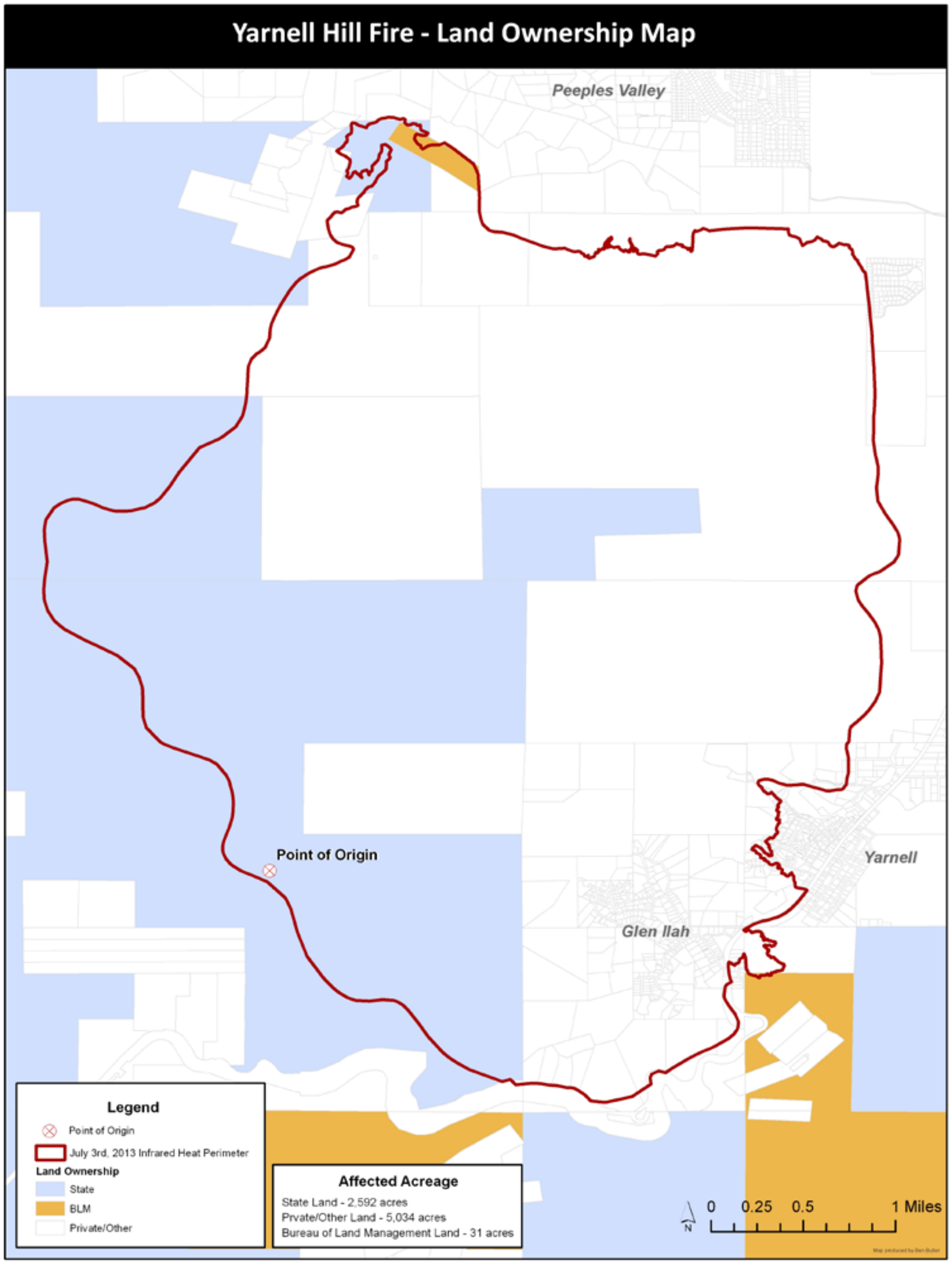
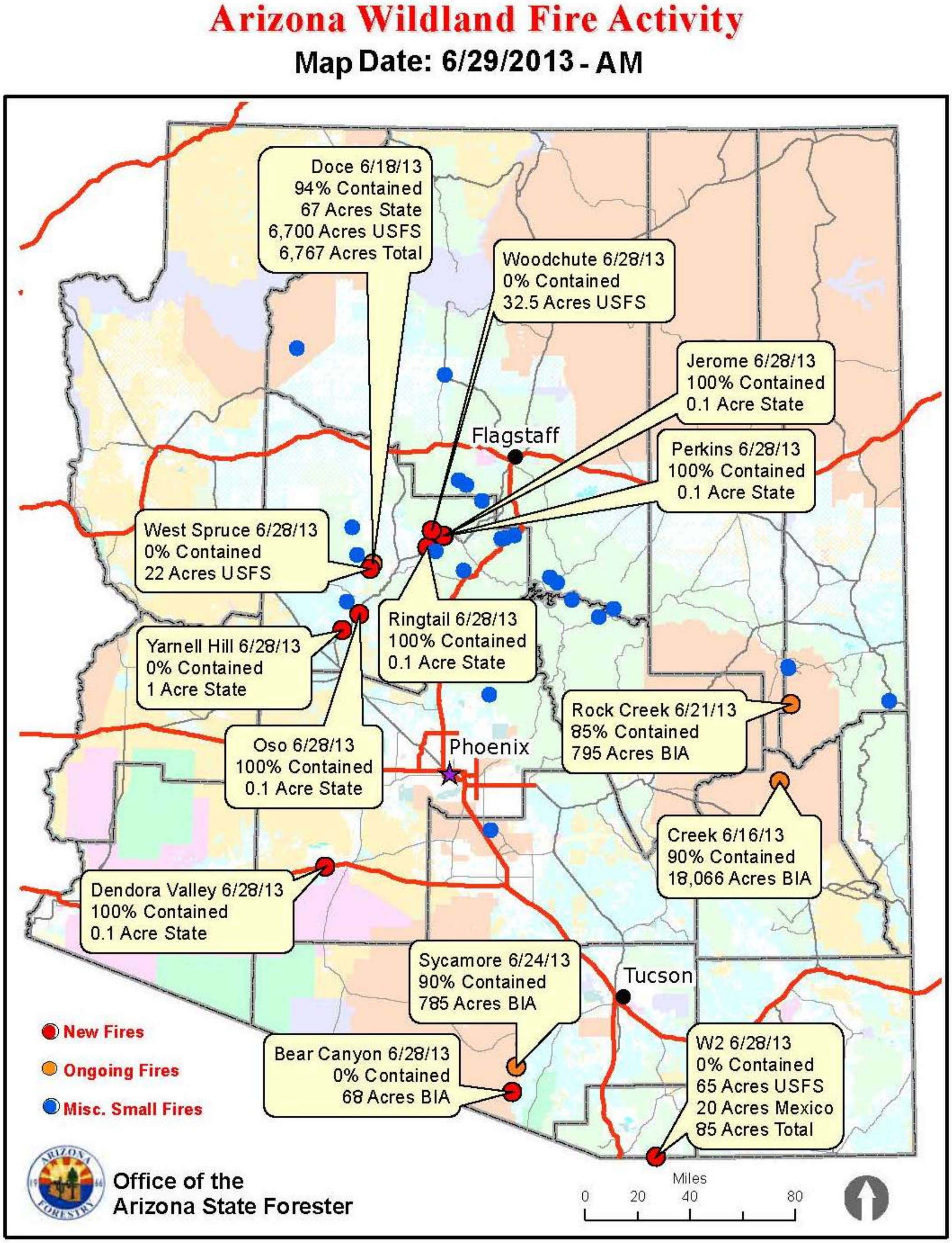


Figure 1. Land within the fire perimeter is a mixture of privately owned, State of Arizona, and BLM-managed land.

Resource availability was average for that time of year and planning level. Resources available on June 28 were two Type 1 Incident Management Teams (IMTs), four Type 2 IMTs, three Type 3 IMTs, two Type 1 airtankers, two smokejumper aircraft (2+ loads), approximately ten Single Engine Airtankers (SEATs), two Type 1 helicopters, two Type 2 helicopters, eight Type 1 IHCs, and Type 2 crew capability. Some of these resources, along with other ordered resources, would eventually be committed to both the Yarnell Hill incident and to the Dean Peak incident a couple of days later.



Fire acreage may be based on estimates from overnight information (Infrared flights and other data sources) and may not have been verified. For official fire acreage and other information refer to http://inciweb.org or http://gacc.nifc.gov/swcc/.

Figure 2. Wildland fire activity in Arizona the morning of June 29.

Part One: Factual & Management Report

Narrative

The purpose of this narrative is to help readers understand the events occurring around the Granite Mountain IHC on the day of the accident. It is impossible to construct a complete account of the crew's movement and entrapment because they cannot give their perspectives. Instead, the Team relied on others involved with the fire and with the crew, as well as on data gathered during the investigation, to reconstruct the most accurate account possible.

Different individuals can perceive the same event differently. This account acknowledges interpretations may vary from one person to the next, and there can be apparent inconsistencies between individual perspectives. However, in most cases, the Team corroborated key details with two or more data sources. Team members also shared portions of the narrative with key interviewees to correct and clarify important details.

The narrative is in present tense to help readers place themselves in the boots of the people involved. Instead of personal names, the Team uses Incident Command System (ICS) or other acronyms to protect the privacy of personnel involved in the incident (see Appendix F for fire terminology and acronyms). Parts of the narrative occasionally backtrack to capture a variety of perspectives and simultaneous events on different areas of the fire.

Friday, 28 June 2013

Several parties notify the Arizona Dispatch Center (Dispatch) of a lightning-ignited fire on State of Arizona land west of Yarnell at about 1730 on June 28. It is one of four fires on state lands in the vicinity caused by significant lightning activity. Dispatch begins documenting the incident at 1736 as the Yarnell Hill Fire.

An Arizona State Forestry Division (AZSF) firefighter, a qualified Type 3 Incident Commander (ICT3) who has worked in the local area since 1995, coordinates responses to the lightning strikes. He and the BLM Duty Officer on scene anticipate multiple new lightning-caused fires in the morning. The AZSF firefighter asks Air Attack to fly the general area around Yarnell to confirm there are no additional fires. The Air Attack assigned to the Doce Fire flies over Yarnell Hill and initially has difficulty finding the fire due to lack of smoke. Once he spots it, he reports the fire is in a boulder field, has no vehicular access, and shows very little smoke. He spots no additional fires. They schedule another reconnaissance flight for the following morning.

At 1940, the AZSF firefighter becomes the Type 4 Incident Commander (ICT4) for the Yarnell Hill Fire. On initial assessment, ICT4 notes the fire is less than a half-acre in size, 80 percent out, active only in one corner, with low spread potential and no structures or people at risk. He notes the fire is in a steep, rocky area on a west-facing slope. ICT4 is concerned about firefighters moving across the rugged terrain at night, and he knows he cannot provide logistical support for them overnight. He is also concerned about potentially exposing firefighters to lightning on the ridge. In consideration of these factors, the relatively low fire behavior and the attention required by other fire starts, he prepares to begin full suppression efforts on Yarnell Hill the following morning. He requests two Type 2 Department of Corrections crews, a light helicopter, and an AZSF engine for the morning.

Saturday, 29 June 2013

ICT4, the BLM Duty Officer, and an ICT3-qualified BLM Representative together coordinate tactical response on the fire the morning of June 29. They had been planning to address new fires in multiple jurisdictions that morning but the Yarnell Hill Fire is now the area's only active fire resulting from the June 28 lightning ignitions. ICT4 asks the BLM Representative to remain engaged with him that day.

ICT4 assesses the fire then reports to Dispatch that little smoke is showing and they will drop retardant to hold the fire until crews arrive. At 0651, he requests two Single Engine Airtankers (SEATs). They arrive mid-morning and drop fire retardant on the south and west flanks until about noon, each making two retardant drops. These SEATs initially work out of the Prescott Airtanker Base while the closer Wickenburg Base, being a Call When Needed (CWN) operation, takes the necessary four to six hours to prepare for operations.

Just before 1100, a BLM helicopter transports seven firefighters to within ¼ mile of the ridge. The one helitack and six Department of Corrections firefighters hike in the rest of the way to construct handline.

Air Attack and the SEATs return to Prescott by 1225, after Air Attack reports retardant is securing the south and west flanks of the fire, the north flank is a ridge, and a two-track road is securing the east flank. The fire size is about two acres. While on the ground at Prescott, Air Attack and the SEATs refuel.

The fire is holding on all four sides and none of the other starts from the day before shows smoke. At 1442, ICT4 advises Dispatch he is releasing Air Attack. At 1540, he releases the BLM brush engine and a local Peeples Valley fire engine, because the multiple fire starts he had expected do not materialize. ICT4 releases the two SEATs for new assignments and the State of Arizona Aviation Officer orders them to reposition to the Wickenburg SEAT Base.

Weather conditions are hot and dry, and increasing west-southwest winds elevate fire activity at around 1600. ICT4 responds at 1610 by requesting the two SEATs and Air Attack to return to the Yarnell Hill Fire. One SEAT and Air Attack launch from Wickenburg but the second SEAT stands by for potential new fire starts from active lightning across central Arizona.

The fire eventually jumps the two-track road on the east flank and grows to about six acres by late afternoon. ICT4 tells Dispatch they are having problems catching the fire, and he orders a Type 1 Heavy Helitanker and Large Airtanker (LAT). At around 1730, ICT4 requests an ICT3 and a State of Arizona Incident Management Team (IMT) to take the fire in the morning, voicing concerns about potential threats to Peeples Valley and Yarnell if the fire burns to the northeast in the next 24 to 48 hours.

Arizona Incident Management Team (IMT)

The Arizona IMT can be configured to meet the requirements of almost any all-risk incident up to and including a Type 2 level. The team can respond as a Type 3 IMT, as a Type 2 Short IMT, as a Type 2 Long IMT, or as ordered depending on the needs and desires of the Agency Administrators responsible for the incident. The Type 2 team that arrived on the fire was a Type 2 Short IMT.

Source: 2013 Southwest Area Mobilization Guide, p. 60-10.

Dispatch informs ICT4 at 1742 that the Heavy Helitanker and the LAT declined the resource orders because of high winds and severe weather en route from their locations. A few minutes later, Dispatch tells him a Very Large Air Tanker (VLAT), a DC-10 with an 11,400-gallon capacity, is available and can take off from an airport unaffected by the weather. ICT4 discusses the option with Air Attack over the fire and with the BLM Representative. ICT4 declines the VLAT offer at 1750 based on fire conditions. ICT4 continues to use the SEATs to drop retardant.

* * * * *

The operational tempo and complexity continue to escalate. The fire grows throughout the evening to an estimated 100 acres, prompting ICT4 to change his request for an ICT3 to a Type 2 IMT. Dispatch fills the order with the Arizona Type 2 short IMT. ICT4 also notifies the Yavapai County Sheriff's Office (YCSO) to prepare for reverse 911 calls in case evacuations become necessary, and he requests additional resources for the next day including 14 engines, six water tenders, two Type 2 crews, two bulldozers, and numerous aircraft. ICT4 also asks for two structure group specialists, one for the north end (Model Creek, Peeples Valley) and one for the south end (Yarnell, Glen Ilah), and he requests three IHCs. Dispatch orders the IHCs through the Southwest Coordination Center (SWCC), one of the nation's interagency Geographic Area Coordination Centers. SWCC fills two of the orders with the Blue Ridge IHC and the Arroyo Grande IHC but advises Dispatch to rescind their order for the third crew and fill it internally with the local Granite Mountain IHC.[2]

By 1924, the fire is spreading actively in chaparral to the north-northeast (Figure 3). The Stanton Remote Automated Weather Station (RAWS) indicates a temperature of 101^{O}F and relative humidity of 12 percent with sustained winds of 10 miles per hour (mph) gusting to 20

[2] Arroyo Grande IHC has mechanical problems that cause the crew to miss this assignment.

Figure 3. Air Attack's reconnaissance photo looking to the northeast, June 29 at 1924.

mph out of the south-southwest. Assessing the fire behavior from the air is difficult but flame lengths appear to be 10 to 20 feet with rates of spread of 5 to 10 chains per hour.[3]

The Structure Protection Group 1 Supervisor (SPGS1) arrives at about 2340 and is assigned structure protection for Yarnell. He drives the roads to learn the town, heading into the hills on backcountry roads, tying in with personnel on the fire, and looking for strategic options for protecting Yarnell. He sees overgrown yards and indefensible houses, and he recognizes there are limited options for a protection strategy. Although the fire appears in check, he thinks it could come down the hill during the next burn period. He spends the night building his situational awareness and developing contingency plans. As one contingency, he considers how to tie roads together to burn off vegetation if needed to protect Yarnell.

That night, 13 firefighters remain on the hill while other resources (ICT4, BLM Representative, BLM Duty Officer, two structure group specialists, and four engines) remain in the Yarnell and Peeples Valley areas.

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[3] A chain is a unit of measure commonly used in firefighting. 1 chain = 66 feet.

Sunday, 30 June 2013

At the 0700 briefing on June 30, ICT4 and others from the previous shift meet at the Yarnell Fire Station with incoming personnel including ICT2, two Operations Section Chiefs (OPS1 and OPS2), SPGS1, a fire behavior analyst (FBAN), YCSO deputies, and the Granite Mountain IHC Superintendent.[4] The briefing covers strategy and tactics, the previous night's spot weather forecast (Figure 4), and radio frequencies. They review the area using Google Maps on an iPad, and they note Boulder Springs Ranch as an excellent safety zone. They establish the command channel setup and communications plan for the incident. As part of the leader's intent, they also discuss strategies for the north side of the fire and for keeping the fire, now estimated at 300 to 500 acres, out of Yarnell by improving old roads, taking advantage of previous fuel mitigation work, and constructing some new dozer line to backfire if necessary. They lay out a strategy to establish an anchor on the south end. They also agree the Granite Mountain Superintendent will become Division Supervisor Alpha (DIVS A) and his Assistant Superintendent (Granite Mountain Captain or GM Capt) will run the crew. DIVS A's assignment is to establish an anchor point at the heel of the fire, using direct or indirect tactics as appropriate.

FORECAST:

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DISCUSSION...STRONG HIGH PRESSURE OVER THE SOUTHWEST WILL
MAINTAIN THE HEAT SPELL THROUGH THE WEEKEND. LIMITED MOISTURE
WILL RESULT IN ISOLATED THUNDERSTORM ACTIVITY SUNDAY AFTERNOON
AND EARLY EVENING. THESE STORMS WILL PRODUCE LIGHTNING AND
GUSTY WINDS...BUT LITTLE OR NO MEASURABLE PRECIPITATION.

SUNDAY NIGHT WEATHER WILL BE VERY SIMILAR TO TONIGHT'S
CONDITIONS.

.TONIGHT...

SKY/WEATHER......PARTLY CLOUDY.
MIN TEMPERATURE..75 TO 78.
MAX HUMIDITY.....30 TO 33 PCT.
WINDS (20 FT)....SOUTHWEST WINDS AROUND 10 MPH. GUSTS UP TO 20
                    MPH EARLY IN THE EVENING.
LAL..............2.
HAINES INDEX.....5 MODERATE.
MIN VENT RATE....POOR (2900 KNOT-FT).

.SUNDAY...

SKY/WEATHER......PARTLY CLOUDY. A SLIGHT CHANCE OF SHOWERS AND
                    THUNDERSTORMS IN THE AFTERNOON.
MAX TEMPERATURE..101 TO 104.
MIN HUMIDITY.....12 TO 15 PCT.
WINDS (20 FT)....LIGHT WINDS...BECOMING SOUTHWEST AROUND 10
MPH WITH GUSTS UP TO 25 MPH IN THE AFTERNOON.
LAL..............2.
HAINES INDEX.....5 MODERATE.
MAX VENT RATE....VERY GOOD (95600 KNOT-FT).
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Figure 4. Excerpt of the spot forecast taken at 2033 on June 29 and shared at the 0700 briefing on June 30.

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[4] Operations sections carry two operations chiefs. Usually one oversees field operations while the other works a planning function.

As additional resources arrive, they assemble at the Model Creek School in Peeples Valley, designated as the Incident Command Post (ICP). Incoming resources receive a communications plan, have their radios cloned, and receive operational assignments. ICT4 and the incoming Type 2 Incident Commander (ICT2) conduct a briefing starting around 0930 at the ICP. The formal transfer of command is announced by radio at 1022.

Radio Frequencies

The Yarnell Hill Fire was assigned Group 1 A1S PHX District channels on June 28. On June 30 at 1022, the communications plan was as follows:

Channel No.	Channel Name	Assignment
1	AZSF1	Command
5	VFIRE21	Optional Tactical, Unassigned
6	AZSFTAC1	Tactical 1, Div A and Div Z
7	AZSFTAC2	Tactical 3, Structure Protection Group 1
8	AZSFTAC3	Tactical 2, Structure Protection Group 2
10	AZSFTAC5	Air-Ground
16	AIRGUARD	AIRGUARD

Early in the day on June 30, there was limited use of AZSFTAC3 Tactical 3 by Granite Mountain IHC, Blue Ridge IHC, and heavy equipment boss. Tactical 3 was assigned to Structure Protection Group 1 at 1200 that day.

During this time, the fire continues to escalate, threatening structures in the Model Creek subdivision north of the fire. Radio traffic increases as the fire moves into this area, particularly among Structure Protection Group 2. The YCSO issues evacuation notices to residents of Model Creek and the Double Bar A Ranch around 1045. Immediately after the 0930 briefing, ICT2 assigns several resources to Structure Protection Group 2 in an attempt to keep homes from burning. After the briefing, Structure Protection Group 1, under the direction of SPGS1, starts structure assessment in the Yarnell area and affirms the majority of the homes are not easily defendable with available resources.

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ICT2 talks with the State Fire Management Officer (FMO) at 1100 about the need for a full Type 2 IMT, based on the fire's continuing escalation and complexity. At 1107, he contacts the Incident Commander from the Southwest Area Central West Zone (SWCWZ) IMT and asks her to prepare her logistics and operations people to respond as soon as possible because he is sure they will order her team. ICT2 assumes SWCWZ will be the long team taking over the fire since most of its members are within the Prescott area and can respond quickly.

The AZSF's District Forester requests a complexity analysis, which he and ICT2 develop at 1300. With this information, ICT2 recommends ordering the SWCWZ Type 2 IMT. The District Forester and State FMO, seeing that the complexity places the fire between a Type 2 and Type 1 IMT, decide to order a Type 1 IMT instead. In less than 20 hours, the fire has transitioned from a Type 4 incident to a Type 1 incident. ICT4 requests a Type 1 IMT at 1402.[5]

Concurrently, the fire is advancing toward the ICP by 1330, forcing personnel to re-position vehicles. The fire also flanks the Double Bar A Ranch, causing responding resources from the north end's structure protection group to retreat at about 1420. The fire approaches the ICP at approximately 1510, holding short of reaching the buildings.

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After the 0700 briefing, SPGS1 and the Granite Mountain IHC drive through Yarnell, stopping at a property on Sesame Street. While there, SPGS1 gestures to the southwest and reminds DIVS A about the "bomb-proof" safety zone, the Boulder Springs Ranch. SPGS1 follows up by saying, "Of course, you also have the black [as a safety zone]."

The Granite Mountain IHC parks their crew carriers in a clearing about three-quarters of the way down Sesame Street. DIVS A scouts further up to a point where the road is impassable with vehicles, then parks his truck. The crew hikes to DIVS A at his truck for a briefing that the Granite Mountain Lookout later recounts: the weather would be "superhot and windy," structures are threatened, and escape routes will be into the black or back to the carriers. The lookout also recalls the crew's assignment is to establish an anchor point, then determine whether to go direct along the black or to go indirect and burn off a two-track road.

Figure 5. Hikers took this photo of the Granite Mountain IHC the morning of June 30. Photo courtesy of Joy Collura.

DIVS A scouts ahead of the crew as they hike about 45 minutes along the two-track road to a potential anchor point just below a saddle. From there, DIVS A scouts out the west side of the

[5] The formal transfer of command to the ICT1 occurred July 1 at 1800.

ridge. A short squad of a few crewmembers follows him, working along the fire's edge toward a cold part of the fire to establish the anchor point. On the east side, fire activity picks up a bit and the rest of the crew slowly burns off adjacent to the two-track road, keeping pace with the fire. At approximately 0930, DIVS A is near the top of the ridge by a helispot where a BLM helicopter had dropped backpack pumps the night before. DIVS A has a short radio briefing with the helitack crewmember who served as night division on the ridge and who is heading back to camp on the last helicopter load. The helitack relays the weather and fire behavior he has seen, and he estimates the fire at around 500 acres.

Fire activity increases throughout the morning as the weather gets warmer and drier. Fire personnel observe distinct cloud build-ups well to the north by late morning. One particular cell building to the north concerns OPS1 and he contacts DIVS A on the radio. He confirms that DIVS A can see it through the smoke; DIVS A says he will keep an eye on the cloud movement.

As the Granite Mountain IHC continues its burnout, DIVS A and Air Attack discuss options. Air Attack directs two SEAT drops at 1136 and 1145 directly onto the burnout. DIVS A is frustrated. This is not what he wanted but he has Granite Mountain IHC shift tactics and go direct along the fire's edge.

During this same period, the short squad on the west side of the ridge ties into the cold black and into the steep rocky terrain. DIVS A considers this a good anchor and, around noon, the short squad rejoins the crew on the east side of the ridge near the anchor point.

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Earlier that day, at 0800, the Blue Ridge IHC arrives at the ICP where they clone their radios to frequencies for the fire and stage in their crew carriers. At about 0845, they head south to the Yarnell Fire Station for staging. OPS1 calls about 45 minutes later and tells them to drive into the fire area and to tie in with SPGS1 on their way in. Using tactical frequency 3 (Tac 3), DIVS A calls Blue Ridge while they are en route and they discuss the fire.

The Blue Ridge IHC parks their crew carriers next to the Granite Mountain IHC carriers. The Superintendent (BR Supt) and Captain (BR Capt) unload their utility task vehicle (UTV) and continue along Sesame Street. They encounter SPGS1 who requests a Heavy Equipment Boss (HEQB) to manage a dozer and clear out the two-track road on both sides as far as possible to provide access and to prepare for possible backfire. Blue Ridge assigns one of their squad leaders, who is qualified as an HEQB, to help.

As BR Supt and BR Capt continue to scout, HEQB takes the dozer as far as an old abandoned grader to push a clear area around it. He then heads in the direction of the saddle near Granite Mountain's anchor point. Following this, his plan is to turn around and clear out the two-track road (an old fuel break) between Sesame Street and Shrine Road. Meanwhile, the rest of the Blue Ridge IHC stays with the crew carriers where they have "good eyes on the fire."

Figure 6. Estimated fire perimeter (418 acres) at 1000 hours on June 30.

BR Supt and BR Capt reach the old grader around 1100. From there, they can see Granite Mountain IHC working on the east side of the ridge, slowly burning off the two-track road. Over the radio, BR Supt and BR Capt can hear the Granite Mountain IHC is trying to get the fire squared up with the two-track road so it cannot come back up at them. BR Supt and BR Capt continue scouting before heading up toward the saddle near the anchor point.

A little before noon, on the two-track road just below the saddle, BR Supt and BR Capt meet DIVS A and GM Capt at the anchor point. Over the next half hour, they discuss tactics and agree to use a Granite Mountain crewmember as a lookout (GM Lookout). GM Lookout identifies a lookout spot down near the old grader at the bottom of the slope, and GM Capt agrees it will be a good vantage point. BR Supt, BR Capt, DIVS A, and GM Capt also discuss problems

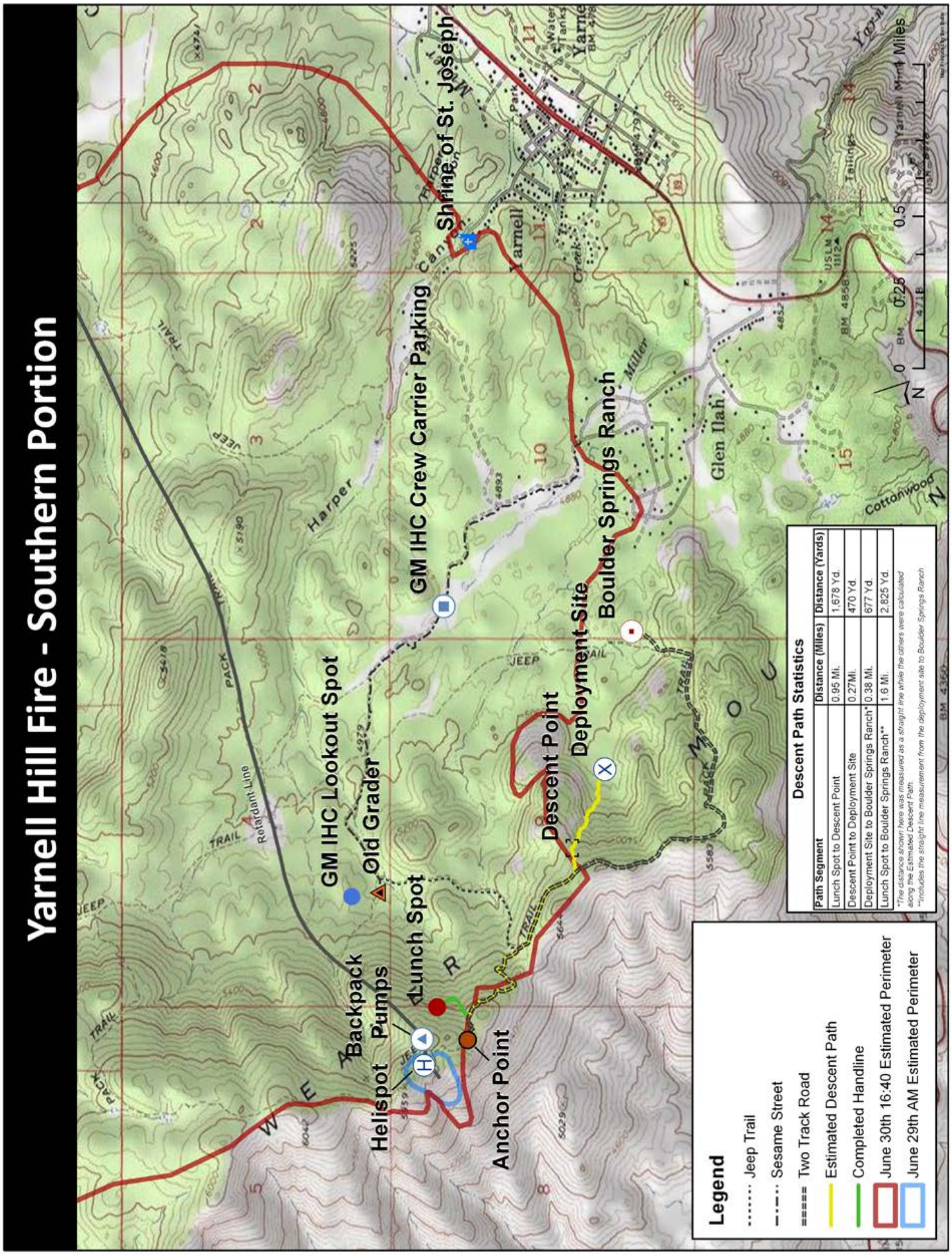

Figure 7. Southern portion of the Yarnell Hill Fire.

with radios on the incident, noting some radios do not have appropriate tone guards and communication is adversely affected.

Division Supervisor Zulu (DIVS Z), a single resource ordered for the Type 3 team, arrives at the Blue Ridge crew carriers around 1210 and calls DIVS A to discuss a division break and resource assignments. DIVS Z is having radio problems, so he uses a Blue Ridge crew radio to talk with DIVS A over the Blue Ridge intra-crew frequency. DIVS A and DIVS Z cannot agree on the break location or associated supervisory responsibilities, resulting in uncertainty among some personnel about the physical break between Divisions Alpha and Zulu.[6]

BR Supt and BR Capt depart and drive GM Lookout down to the old grader, dropping him off at 1239. They feel comfortable leaving him at this spot, and BR Supt tells the lookout, "If you need me, call, and I'll come get you."

After dropping off GM Lookout, BR Supt and BR Capt scout for opportunities to engage the fire. The HEQB continues to work the dozer to open the line between Sesame Street and Shrine Road. The Blue Ridge IHC move their crew carriers toward the Shrine of St. Joseph (the Shrine) and a youth camp area around 1500 and then start preparing for burnout along the dozer line.

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After BR Supt drops him off at the old grader at 1239, GM Lookout hikes about 120 yards north to the lookout spot and calls DIVS A to tell him he has "good eyes" on the Granite Mountain crew. The crew also has a good view of him and of the fire. The Granite Mountain IHC has good black, and is now going direct along the fire's edge. Although the head of the fire is pushing north toward structures in Peeples Valley, it is backing to the Granite Mountain IHC's location. Some dry drainages are out ahead of the crew. The crew anticipates the fire will become more active around mid-afternoon, and they expect no additional support will arrive since the focus of aircraft and firefighters is up north on the head of the fire. Given these conditions, Granite Mountain IHC's plan is to construct line direct along the fire's edge, but they do not want to overextend or overcommit themselves. They plan to take a little piece at a time, then go back and secure the line to make sure it holds.

The Granite Mountain IHC reaches a rock face and takes lunch. After eating, the crew works their way back, reinforcing their line as they go. They make sure their line is solid and they have a good anchor point. For lookouts, they have DIVS A on a knob, GM Lookout down by the grader and GM Capt near the anchor or in the immediate vicinity of the crew. Each is looking out for the other two lookouts, the crew, and the fire. GM Lookout has trigger points for the crew and for himself in case the fire changes direction. The crew has ongoing contact with the

[6] DIVS A and OPS1 communicate later about the division break being at the grader.

Blue Ridge IHC, SPGS1, and OPS1. They also contact air resources and adjoining forces as needed.

GM Capt, GM Lookout, and others talk over the radio about thunderstorms coming in. GM Capt mentions he might have seen a few lightning strikes.

* * * * *

At 1402, FBAN receives a call with a weather update from the NWS office in Flagstaff. The NWS informs him of thunderstorms east of the fire that may produce wind gusts of 35 to 45 mph out of the northeast. FBAN relays the update to OPS1 and OPS2 via radio on state tactical frequency 1 (Tac 1).

At 1526, NWS-Flagstaff calls FBAN with a second weather update about expected thunderstorm outflow winds from the north-northeast with speeds between 40 and 50 mph. This update does not meet the NWS criteria for a Red Flag Warning for this area. FBAN radios this second update to OPS1 and OPS2 on Tac 1.

National Weather Service

The NWS office in Flagstaff used social media and received several fire chat room messages from the Predictive Services staff at SWCC on the afternoon of June 30. This close coordination helped increase situational awareness and better prepared them for monitoring the weather.

* * * * *

At about 1540, DIVS A calls BR Supt and asks him to meet face-to-face. BR Supt starts heading back towards DIVS A's location in his UTV. BR Supt hears the second weather announcement as he drives the UTV out Sesame Street to meet DIVS A.

OPS1 is listening on the radio to make sure everyone received the most recent weather announcement. At about 1550, he radios DIVS A directly to ask if he got the weather update and if he is "in a good spot." DIVS A affirms that he received the update, and he tells OPS1 the winds are starting to get "squirrely" up on the ridge. He says he is working his way off the top and OPS1 closes by advising DIVS A to hunker and be safe.

At about 1550, Air Attack tells DIVS A the fire is heading quickly toward Yarnell and could reach the town in one to two hours. He also says the Granite Mountain IHC's crew carriers may be in the path of the fire. DIVS A acknowledges and tells Air Attack he has a plan to address this issue. Shortly after this, Air Attack leaves the fire because of duty time limitations.[7]

[7] Pilots on Forest Service and Department of the Interior contracts may only fly a total of 8 hours and be on duty 14 hours each day.

Also, at about 1550, GM Lookout is taking weather observations when GM Capt calls him to relay the weather update. DIVS A hears the transmission and copies. GM Lookout copies and continues taking weather observations. He looks at the fire to the north and notes it is moving slowly toward his location. He scans back up to where the crew is working, to the thermometer, back to the crew, and then back to the fire. In that short time, the fire has started building and the wind is already beginning to shift. GM Lookout is not *worried*, but he recognizes it is time for him to move. He calls GM Capt and says the fire has hit his trigger point and he is moving towards the open area at the old grader. GM Capt calmly replies, "Okay, cool."

Outflow Winds

When thunderstorms produce rain, hail, or virga (rain that evaporates before reaching the ground), strong downdraft winds develop under the storm cloud. The downdrafts turn horizontal when they reach the earth's surface and become "outflow winds." These winds can reach speeds in excess of 50 miles per hour. An outflow boundary, also called a gust front, is the leading edge of the outflow winds as they move away from the thunderstorms.

GM Lookout hikes toward the grader. As he hikes, he identifies options including an alternative lookout spot further up the road, a possible shelter deployment site near the grader, and a little clearing just down from his original lookout spot where he could deploy his fire shelter if the fire caught him. At this same time, BR Supt is driving back in his UTV to meet DIVS A for a face-to-face meeting. As GM Lookout reaches the grader, he reaches for his radio to call BR Supt and ask for a ride, when he sees BR Supt driving around the corner. About then, GM Capt calls GM Lookout and says, "I've got eyes on you and the fire, and it's making a good push."

Figure 8. Christopher MacKenzie took this photo at 1550 on June 30.

GM Lookout loads his gear into the UTV and hands his radio to BR Supt so BR Supt can contact the Granite Mountain IHC on the Granite Mountain intra-crew frequency. BR Supt tells them GM Lookout is with him and is safe, and they will probably need to move the Granite Mountain trucks. The Granite Mountain IHC says they have "good eyes," they are "in the black," and they will assess from there. As GM Lookout departs, he believes the crew is in the black and watching the fire, and DIVS A is scouting.

Figure 9. Wade Parker texted this photo at 1604 on June 30.

BR Supt drops GM Lookout off at the Granite Mountain IHC Supt truck at about 1555 and then heads around the corner to get some of his crew to help move the Granite Mountain crew carriers. On the Granite Mountain intra-crew frequency, GM Lookout hears DIVS A and GM Capt talking about their options, whether to stay in the black or to come up with a plan to move.

Around this time, some crewmembers take photos and send text messages to family members. At 1554, one crewmember texts, "This fire is running at Yarnell!!!" Another texts a photo at 1604 and writes, "This thing is runnin straight for yarnel jus starting evac. You can see fire on left town on the right."

* * * * *

As BR Supt is en route to pick up drivers to move the Granite Mountain crew carriers, SPGS1 contacts him to ask if they still have the option to burn out from the dozer line. BR Supt tells him no. DIVS A, hearing the transmission, agrees and says he believes the fire is almost as far as the Granite Mountain vehicles. A moment later, DIVS A says, "I want to pass on that we're going to make our way to our escape route." BR Supt attempts to clarify, "You guys are in the black, correct?" DIVS A responds, "Yeah, we're picking our way through the black." DIVS A then mentions a road in the bottom and "going out toward the ranch." BR Supt thinks DIVS A is talking about heading northeast, through the black, to one of the ranches in that direction. BR Supt says, "DIVS A, to confirm, you're talking about the road you saw me on with the UTV earlier, in the bottom." DIVS A replies, "Yes, the road I saw you on with the Ranger [the UTV]."

* * * * *

Earlier that day, the YCSO issues pre-evacuation notices to area residents. In Northern Yarnell and the Shrine area, SPGS1 has three trigger points for evacuation. The first is on a ridge one mile north of town. Resources in the area anticipate a one-hour window to evacuate the residents when the fire reaches this trigger point. SPGS1 establishes a closer, second trigger point for the firefighters themselves to start leaving the area. He has a third trigger point for making sure everyone is out.

A task force with Structure Protection Group 1 is working in the area. They are cutting a piece of indirect line from the area near the youth camp on Shrine Road eastward to a boulder pile, expecting that they may need to burn off this line overnight. This piece of indirect line connects to the dozer line between Shrine Road and Sesame Street, which the Blue Ridge IHC have been prepping since about 1500.

Between 1530 and 1545, winds pick up and gradually shift direction from the southwest to the west-northwest, and the fire becomes very active. There is some spotting, and heavy ash is falling onto fire personnel working in the youth camp area. By this time, the two-mile flanking fire looks more like a head fire and is starting to move southeasterly.

Summary of Wind Shifts in the Afternoon

Until about 1550, winds have been pushing the fire generally northeast. At about this time, pressure changes start happening ahead of the outflow boundary. These pressure changes cause the air to become more erratic, even before the outflow boundary itself reaches the fire.

Personnel on the fire see significant changes in wind and fire spread direction, even before the outflow boundary arrives and brings its full increase in wind speed. These pressure changes caused wind shifts on different parts of the fire at different times. Then, the outflow boundary itself arrived at different parts of the fire at different times. This is why there are a number of conflicting accounts of when "the wind shift" occurred. Also, personnel at various locations saw the early wind shifts and may have interpreted them to mean the anticipated wind event was fully manifested.

At the Granite Mountain IHC's location near the anchor point, wind shifts began at approximately 1550. Before that, the fire was moving generally northeast. Around 1550, the fire shifted to moving southeast and aggressively pushing toward Yarnell. The outflow boundary itself had not arrived yet. It did not hit the southern perimeter of the fire until 1630. When the outflow boundary hits, winds drastically increase and drive the fire south.

Fire reaches SPGS1's first trigger point, and he requests YCSO to order an immediate resident evacuation for Yarnell. Around this time, drivers arrive at the Shrine area with the Granite Mountain crew carriers, and soon they are loading the Blue Ridge crewmembers and leaving the area. The fire hits the second trigger point five to seven minutes later so SPGS1 directs all resources at the youth camp to leave. The fire then spots a half mile beyond that and reaches the third trigger point—a ridge on the edge of town—covering about one mile in 15 minutes. SPGS1 reconfirms that crews are getting out.

By 1622, the firefighters in the Shrine area recognize the fire has reached the second trigger point and they start moving out toward Highway 89. Blue Ridge has left and they try several times to contact SPGS1 about getting the rest of the firefighters out of the area. Some of the firefighters do not share their sense of urgency, so BR Supt and BR Capt drive back in to hurry them, urging them out of the Shrine area. As they follow the last firefighters out, the smoke column above brings darkness. Embers fall and ignite numerous spot fires, which quickly burn together. By 1630, the fire is bearing down on them. The last firefighters reach Highway 89 at 1640 and they call SPGS1 on Tac 1 to confirm they are out. They drive south a few minutes, to the Ranch House Restaurant to regroup and to determine if it is a safe area or if they need to continue further south.

SPGS1 gives direction for Air Attack to "drop at will" to keep the fire out of town. Later, he would say he felt they stayed too long. The fire outperformed their expectations even with many knowledgeable people there, and their trigger points were not valid, not even "by one half," given the push by the weather.

Figure 10. One of the VLATs, a DC-10, drops retardant on the Yarnell Hill Fire on June 30. Photo courtesy of Rick Tham.

* * * * *

Earlier, an Aerial Supervision Module (ASM2) arrives above the fire at 1447 to relieve the first ASM (ASM1), which had been on the fire since about noon.[8] The two ASMs have a 10-minute briefing about the strategy and priorities for the fire then ASM1 departs for refueling

[8] An Aerial Supervision Module is a fixed wing aircraft with two crewmembers who perform the functions of traditional air attack and low-level leadplane operations.

with the stated intent of being back on scene at 1715. Air Attack's pilot is getting short on duty time so he departs about 1600 after a brief handoff with ASM2.

ASM2 is busy dealing with an arriving VLAT and with structure protection on the north end when the fire begins shifting, turning priorities to Yarnell. Radio traffic is heavy in the cockpit with the pilot giving directions to incoming airtankers on the air-to-air frequency, and with the air attack member of ASM2 talking to OPS1 and ground personnel on the air-to-ground frequency. He is also repositioning aircraft, planning a sequence of tanker drops for Yarnell, and coordinating helicopter operations.

At approximately 1600, ASM2 overhears a comment on the radio referencing a crew and a safety zone. ASM2 calls OPS1 and clarifies, "I heard a crew in a safety zone, do we need to call a time out?" OPS1 replies, "No, they're in a good place. They're safe and it's Granite Mountain." They talk about flying over to check on the crew, but for now, they think the crew is safe in the black.

Following this conversation, ASM2 hears DIVS A announce on the radio, "We're going down our escape route to our safety zone." ASM2 asks, "Is everything okay?" to which DIVS A replies, "Yes, we're just moving."

At 1637, ASM2 flies a drop path for a VLAT north of Yarnell west to east and apparently over DIVS A, turning northward to avoid high ground at the end of Yarnell. DIVS A, seeing the flight, calls and calmly says, "[ASM2], Division Alpha, That's exactly what we're looking for. That's where we want the retardant." ASM2 again circles the south end of the fire above Yarnell to line up a final flight path for a tanker drop. The aircraft crew is in the middle of a discussion with OPS1 on the air-to-ground frequency and the pilot is talking to the VLAT on the air-to-air frequency when an overmodulated and static-filled transmission comes over the air-to-ground frequency at 1639:

"Breaking in on Arizona 16, Granite Mountain Hotshots, we are in front of the flaming front." [9]

Following this is a very broken, with wind in the microphone, transmission: *"Air-to-ground 16, Granite Mountain, Air Attack, how do you read?"*

Due to poor reception, ASM2 can only understand fragments of these communications. The fire's rapid advance toward Yarnell is generating a lot of radio traffic about structure protection so ASM2 assumes the broken and unclear transmission is one of the structure protection units calling to request a retardant drop. He does not suspect it's Granite Mountain since they were safe when he talked to them earlier.

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[9] Arizona 16 is the Airguard frequency, an emergency frequency that all aircraft have programmed into their radios and monitor. It appears the Granite Mountain crewmember thinks he is breaking in on Arizona 16 but he is on the air-to-ground frequency.

OPS1 tries to reach Granite Mountain: *"Granite Mountain, Operations on air-to-ground."*

Seconds later, Granite Mountain calls: *"Air Attack, Granite Mountain 7, how do you copy me?"*

Some of the firefighters near the highway overhear this radio traffic. Hearing chainsaws in the background and the Granite Mountain crewmember's increasing urgency, they are confused—the last they had heard, Granite Mountain was in the black.

Less than a minute later, they hear: *"Air Attack, Granite Mountain 7!"* [10]

At the same time, ASM2 is talking to OPS1 about how to use aircraft orbiting overhead to stop the fire heading for Yarnell. The Granite Mountain IHC transmissions are unclear to him. He tells the unit calling on air-to-ground frequency to stop yelling. OPS1 believes the unit may be in trouble, so he tells ASM2:

"Okay, Granite Mountain 7 sounds like they got some trouble, uh, go ahead and get that, he's trying to get you on the radio, let's go ahead and see what we've got going on."

ASM2: *"Okay copy that, uh, I'll get with Granite Mountain 7 then."*

Just seconds later, a call from DIVS A (sounding calm): *"[ASM2], Division Alpha with Granite Mountain."*

ASM2: *"Okay uh Division Alpha, [ASM2]."*

DIVS A (now more urgent): *"Yeah, I'm here with Granite Mountain Hotshots, our escape route has been cut off. We are preparing a deployment site and we are burning out around ourselves in the brush and I'll give you a call when we are under the sh— the shelters."*

ASM2: *"Okay copy that. So you're on the south side of the fire then?"*

At about 1642, DIVS A yells: *"Affirm!"*

ASM2: *"K, we're gonna bring you the VLAT okay."*

ASM2 then tells the VLAT to orbit to the southeast until ASM2 locates the Granite Mountain crew. The VLAT Captain replies he will keep full eyes on ASM2 and be ready for an immediate drop.

Over the next four minutes, ASM2 makes seven attempts to reach the Granite Mountain IHC to determine their location but he is unable to establish contact. Helicopter 215KA (a Type 2 Medium) is preparing to lift off the heliport to go refuel elsewhere when he hears the radio

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[10] Some interviewees believe this is a reference to the crew as a whole; it may come from their earlier designation as Crew 7 before they became an IHC.

traffic. He contacts ASM2 and assists with searching. They can't see the ground through the heavy smoke. ASM2 continues calling the Granite Mountain IHC, asking them to listen for the helicopter and let him know when it sounds close. There is no further contact with the Granite Mountain IHC. ASM2 reminds the pilot of 215KA about his fuel situation and 215KA departs the area.

* * * * *

During the Granite Mountain IHC's movement and deployment, an outflow boundary moves southward toward the fire area and the atmosphere becomes more erratic ahead of this boundary. Even before the outflow boundary arrives, the wind direction shifts to west-northwest and the fire responds with stronger movement toward the east-southeast. The outflow boundary reaches the northern portion of the fire around 1618, having covered 13.5 miles in 50 minutes (16 mph). As it initially crosses into the fire area, several things occur: the smoke plume rises to over 31,500 feet; two fingers of concentrated smoke begin to develop from two main heads of fire moving southward; and southward fire rates of spread begin to quickly escalate. The boundary drives the fire southeast and south at increasing speeds with rapidly increasing intensity. Thunder rumbles and spritzes of rain or mist mixed with ash fall over portions of the fire area. The outflow boundary reaches the southern perimeter of the fire at 1630, and pushes the fire to the main ridgeline to the south and into Glen Ilah and Yarnell. By 1648, the smoke plume top grows to 40,000 feet mean sea level (MSL).

Several fire resources, beginning with firefighters on the north end, notice the "spritzes" of rain. The mist reduces ASM2's visibility as it mixes with ash on the windows. Thunder heard with the smattering of rain and a very short period of calm wind conditions cause several firefighters in Yarnell to think about the 1990 Dude Fire in Arizona and the six fatalities that occurred on that fire.

* * * * *

The fire reaches the Glen Ilah community at the south end of Yarnell during Granite Mountain IHC's communications with ASM2. The owner of the Boulder Springs Ranch, on the town's west edge, happens to go outside to check on her dog. As she gets to the door, she realizes the fire has advanced significantly toward her house. She and her husband run outside, put all of their livestock into the barn, and then return to their house just as the fire sweeps over their property. The owners, their animals, and their property are unharmed thanks to fire-resistant construction and defensible space around their buildings.

> "The fire way outperformed our expectations and surpassed any thoughts we had about our trigger points."
>
> **— SPGS1**

In town, the smoke gets thicker. Security cameras switch from day mode to night mode, and driving requires headlights. As the fire and smoke run through Yarnell, YCSO deputies and firefighters quickly evacuate residents. Some residents are overwhelmed, not knowing where to go. Some they load into ambulances, others they pick up and drive to safety.

* * * * *

Upon hearing of the deployment, Dispatch and resources on the fire immediately initiate a medical response using the ICS for multiple casualties including triage, treatment, and transport leaders. They assign OPS1 as IC for the Incident within an Incident (IWI). They notify burn centers; mobilize medical personnel, ambulances, and five medevac helicopters; and set up a triage center. Blue Ridge IHC and other firefighters begin a ground search for the Granite Mountain IHC.

The crew of Ranger 58, an Arizona Department of Public Safety (DPS) helicopter assigned to the fire, loads medical gear when they overhear the Granite Mountain IHC's transmissions on the air-to-ground frequency.[11] Ranger 58 launches at 1716 and ties in with ASM2 to help aircraft and ground resources search for the crew. They begin looking over the last reported location of the crew but heavy smoke limits their search area. They see backpack pumps left at the helispot by the initial attack crew and assume they are the Granite Mountain IHC's backpacks, adding to the confusion about the crew's location.

As the smoke clears, Ranger 58 sees the Boulder Springs Ranch and, recalling the Granite Mountain IHC's earlier communication about heading toward a ranch, flies in that direction. At approximately 1810, nearly an

Granite Mountain Crew Movement, 1605-1642

During this period, the Granite Mountain IHC's motivation and path were unknown to other resources on the fire. The best available information (interviews, times, evidence of probable route, and best possible routes) suggests the following:

Around 1605 to 1610, the crew began moving from the flank of the fire where they had been working (the lunch spot area). They traversed the two-track road near the top of the ridge and proceeded southeast along the ridge until they reached a saddle.

As they traveled along the ridge, they had a good view of the fire. When they reached the saddle at the logical spot to descend, they had a direct and clear view of the Boulder Springs Ranch but they rapidly lost their view of the fire. The Ranch appears to be very close and readily accessible. The view is deceptive, however, because after an initial descent, the slope quickly drops off. The route to the Ranch is arduous, strewn with boulders and covered with thick chaparral brush. According to one local, the terrain in the area is not difficult but it is time consuming.

Granite Mountain IHC worked their way down the slope through the boulders and brush until the flaming front cut them off.

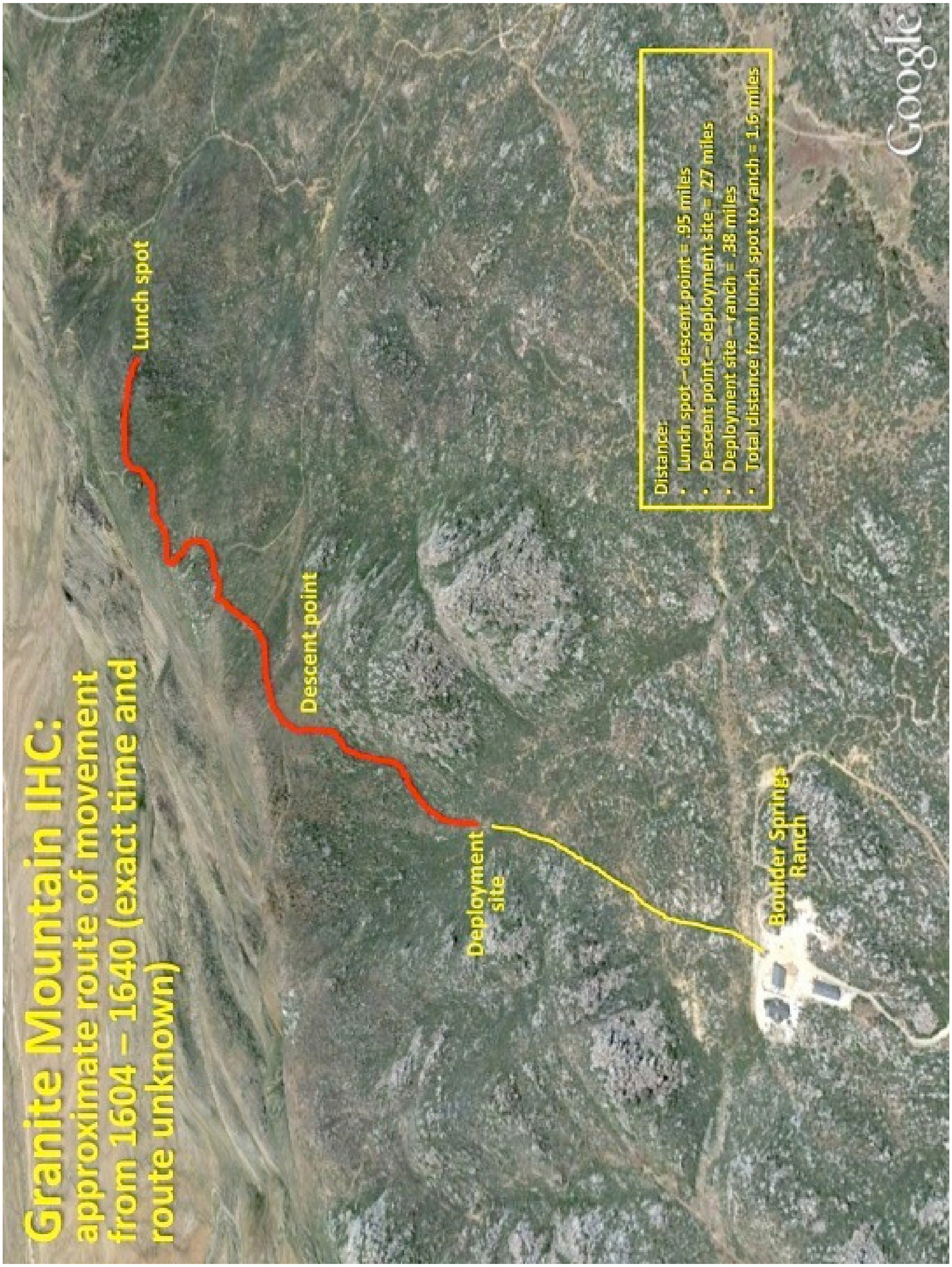
[11] Ranger 58 flew two reconnaissance flights with members of the IMT earlier that day and was on standby for medical, search and rescue, and additional reconnaissance flights.

hour after launching, they spot the shelters approximately one mile south-southeast of the firefighters' last known location. People involved with the fire and the search effort express surprise at the location.

The pilot lands about 500 yards from the shelters. A DPS officer/paramedic hikes to the deployment site and confirms at 1835 that none of the men survived. He notes the nineteen Granite Mountain IHC crewmembers were in various stages of deploying fire shelters about 600 yards west of the Boulder Springs Ranch when the fire overtook them.

Summary

This tragedy occurred when the Granite Mountain IHC was traveling through an unburned area toward a safety zone when a rapidly advancing fire of great intensity overtook them. The fire's extreme speed of 10 to 12 miles per hour eliminated any opportunity for the crew to reach the safety zone or return up to the canyon rim. The crew had less than two minutes to improve a shelter deployment site by using chain saws and burning out. The crew was deploying their fire shelters close together in a small area when the fire overtook them. The deployment site in the box canyon was not survivable because heavy brush caused direct flame contact, and temperatures exceeded 2000^{o}F as the fire swept through the site.


Granite Mountain IHC:
approximate route of movement from 1604 – 1640 (exact time and route unknown)
Lunch spot
Descent point
Deployment site
Boulder Springs Ranch
Distance:
• Lunch spot – descent point = .95 miles
• Descent point – deployment site = .27 miles
• Deployment site – ranch = .38 miles
• Total distance from lunch spot to ranch = 1.6 miles
Google

Analysis

There is a gap of over 30 minutes in the information available for the Granite Mountain IHC. From 1604 until 1637, the Team cannot verify any communications from the crew, and we have almost no direct information from them. We cannot fully know how they made their decisions prior to their entrapment and fire shelter deployment around 1642. No crewmembers from the deployment site survived to tell why the crew took the actions they took.

However, for the sake of creating a learning tool, the Team has developed an understanding of what the Granite Mountain IHC likely knew and saw during this period. The Team based this on information from various sources, including accounts from others on the fire, information from dispatch logs, photographs, radio conversations, and fire modeling. The Team conducted site visits to retrace events, drew from their understanding of wildland fire operations and culture, and considered the perspectives and experience of SMEs.

This Analysis helps reconstruct the context in which the crew was operating. The Team attempts to avoid oversimplifying and judging the crew's actions in hindsight. Instead, we aim to understand how the Granite Mountain IHC and others on the fire made sense of their situation at the times when they took the critical actions.

Three key actions this section focuses on are A) The Granite Mountain IHC's movement to the southeast along the two-track road sometime after 1604; B) Their descent from the two-track road sometime around 1620; and C) Their shelter deployment around 1642.

This is the Team's interpretation and reconstruction of these moments. The Team may be assuming a more deliberative thought process than what the Granite Mountain IHC actually used at the time. Nobody will ever know how the crew actually saw their situation, the options they considered, or what motivated their actions. The purpose of this section is to provide a tool that others can use for learning and prevention.

Foresight vs. Hindsight

After an accident, investigators learn information that participants may not have known at the time, such as the actual rate and direction of fire spread, the outcomes of various events, and other relevant details. This information can be very clear in "hindsight," but it may not have been so clear at the time.

To understand key actions more fully, it is necessary to set aside the information that we only know in hindsight, and try to understand what they knew in "foresight." The purpose is to try to put ourselves in their shoes and minimize "hindsight bias."

Key Action A: The Granite Mountain IHC's movement to the southeast along the two-track road, sometime after 1604.

WHAT THEY LIKELY KNEW AT POINT A, AROUND 1604:

Prior to 1604, the Granite Mountain IHC likely knew or perceived the following:

- A spot weather forecast generated the evening before, and given to the Granite Mountain IHC early on June 30, indicated a slight chance of showers and thunderstorms in the afternoon.
- A weather update received shortly after 1402 advised of thunderstorms to the east that could produce winds of 35 to 45 mph out of the northeast. These winds never materialized; the crew could have perceived this as a false alarm.
- FBAN provided a second weather update sometime after 1526 on State Tac 1. The radio transmission passed on a NWS weather update about an outflow boundary north of the fire that may produce north or northeast winds of 40 to 50 mph.
- Over the radio, OPS1 asked DIVS A if he received the later weather update, and if they were in a good spot. DIVS A affirmed they received the update.
- GM Capt relayed the update to GM Lookout around 1550, advising of possible wind direction shifts and thunderstorms.
- The flanking fire in the area below the Granite Mountain IHC had started to become more active with west winds at 10 to 12 mph.
- GM Lookout left his lookout spot in response to the fire crossing a defined trigger point. At about 1555, BR Supt picked up GM Lookout and contacted the Granite Mountain IHC, who tells BR Supt they have "good eyes" and they are "in the black."
- GM Lookout rode with BR Supt on the UTV to the Granite Mountain IHC trucks, which were then moved to a safer location.
- DIVS A had been scouting ahead of the Granite Mountain IHC to the north and northeast to monitor fire activity, watch over GM Lookout, and check on possible line construction areas. This kept him physically separated from the Granite Mountain IHC, but still within radio contact for much of the morning and early afternoon. The Team does not know whether he was with the Granite Mountain IHC when they started moving after 1604.
- While scouting, DIVS A encountered two local residents, avid hikers who are familiar with the area. The hikers took a path down the two-track road along the ridge to the southeast toward the Boulder Springs Ranch. They discussed their route with DIVS A prior to leaving.

- Fire behavior observed by the Granite Mountain IHC all day was in pulses and variable, not a consistent fire spread direction.
- The Granite Mountain IHC's original assignment to establish an anchor point and construct fireline was no longer valid based on the fire's movement.
- The Granite Mountain IHC knew they were the only resource left on the fireline. The Blue Ridge IHC was pulling back to Yarnell.
- The primary focus of operational activity on the fire that day was on structure protection to the north and northeast. However, by this time, the fire was moving southeast and was beginning to threaten Yarnell. A Granite Mountain IHC member sent a text message at 1555: "Fire is running at Yarnell!"
- General radio traffic markedly increased with the fire heading into Yarnell, the evacuation order and its immediate initiation.
- A Granite Mountain IHC member sent a photo text message at 1604: "This thing is runnin straight for yarnel jus starting evac. You can see fire on left town on the right."
- The Granite Mountain IHC heard the Boulder Springs Ranch was a "bomb proof safety zone" that morning. Using Google Maps and an iPad, they had seen the Ranch, as well as potential trails and roads leading to it.

COURSES OF ACTION AVAILABLE AT POINT A, AT ABOUT 1604:

Course of Action A1: Stay in the black

- An active weather update called for north-northeast winds with gusts up to 50 mph. Fire spread direction was likely to change during the afternoon. The fire was actively running to the east-southeast, exhibiting extreme fire behavior, which exposes a very long flank. If the north wind materialized, it could drive the open flank south (i.e., the flank could turn into a head fire).
- The cold, black area adjacent to them was over 400 acres and extended over the lee side of the ridge.
- The Granite Mountain IHC was on foot, separated from their trucks with limited overall mobility.
- The Granite Mountain IHC and DIVS A were the only resources remaining on the fireline; the others had withdrawn to Yarnell.
- The Granite Mountain IHC's original assignment to establish an anchor point and construct fireline was no longer valid based on fire movement, so there was no tactical reason to remain at this location.

- Radio traffic indicated a distinct threat to the community of Yarnell so there was a tactical reason to move from this location.
- The threat to GM Lookout and the Granite Mountain IHC's trucks had been mitigated by moving them to a safer location.
- Staying in the black required less arduous action.

Course of Action A2: Hike to the north staying in the black

- Could move through recently burned, black areas.
- Could remain behind the fire front and eventually tie in with other resources.
- Could reposition for further engagement.
- Could move to the northeast or east and tie back in with the two-track road. Then, if conditions allowed, could be picked up by trucks and eventually get to Yarnell.
- Limited operational or tactical effectiveness – would be some time before they could re-unite with vehicles and be prepared to re-engage in tactical operations.
- Cross-country travel not on trails or roads would be time consuming and arduous.

Course of Action A3: Move southwest off the back side of ridge toward Hwy 89

- Lighter fuels on the backside of the ridge.
- Moving away from the fire and from fire alignment with terrain.
- Consistent with mental model in that part of country: "down and out" is a way to get away from the hazard; bailing off a ridge to a highway is a typical route off the fire.
- Current position not under imminent threat from fire.
- No tactical reason to move along this route.
- Would require transportation by others to return to Yarnell.
- Would be a lengthy time before being able to re-engage in tactical operations.
- Could be stranded in a remote location, further away from being relevant to the ongoing threat to Yarnell.

Course of Action A4: Move southeast along the two-track road toward the Boulder Springs Ranch

- Clearest need for firefighting resources is in Yarnell, not near the black area.

- Moving to Yarnell provides the fastest opportunity to re-engage tactically.
- Had not yet observed wind direction shift as described in most recent weather update–fire was still moving east-southeast, it had not started moving south.
- The Boulder Springs Ranch, identified as a "bomb proof safety zone," is between them and Yarnell.
- Fire still appeared to be moving away from them, or at worst, parallel.
- There was a very rocky ridge between the fire and where they wanted to be. They could have perceived this as a natural barrier to fire movement.
- They perceived this southeast pathway as an escape route.
- If they take this route, it appeared they would still have alternate escape routes southwest over the ridge or back to the black the way they came.
- While traveling along the ridge, they would have a comfortable view of the fire and could see it headed to the east-southeast; they could serve as their own lookouts.

COURSE OF ACTION TAKEN: A4

At some time after 1604, the Granite Mountain IHC moved from the area where they had been working throughout the day. The Team has no indication that anyone asked them to move, and does not know for certain why they moved. The crew started traveling southeast to the Boulder Springs Ranch along the two-track road. It is not clear whether they planned to follow the two-track road all the way to the Ranch, or whether they were already planning to descend from the two-track road and take the more direct route through the box canyon.

Key Action B: The Granite Mountain IHC's descent from the two-track road sometime around 1620.

WHAT THEY LIKELY KNEW AT POINT B:

As the Granite Mountain IHC was travelling southeast along the two-track road, they likely knew or perceived:

- They had attempted to communicate their movement to other resources on the fire.
- They could see and confirm the size of the cleared area around the Boulder Springs Ranch and could conclude that it appeared to be a valid, "bomb-proof" safety zone.
- The Ranch appeared very close. Several Team members, looking at the Ranch from the road during site visits, agreed that it "seems so close, almost as if you could reach out and touch it." This is due to a number of perceptual factors.

- If they descended from the ridge, they would maintain sight of the Ranch.
- Fire was still heading east-southeast toward Yarnell.
- Smoke column was predominantly going east-southeast with clear air south of the fire.

As the crew reached the descent point at about 1620, they likely knew or perceived:

- Below the two-track road, they could see the following:
  - A box canyon
  - Pockets of heavy brush mixed with rock-strewn hillsides with some large boulders
  - Washes and game trails and areas of lesser vegetation they could tie together and make a path
  - Steep descent initially and then flattening terrain
- The direct path to the Ranch appeared shorter, and potentially faster, than continuing to follow the two-track road around the rim of the box canyon.
- The weather in the update had not materialized at their location and the update was about 50 minutes old.

WHAT THEY LIKELY DID NOT KNOW AT POINT B:

- A large thunderstorm over 15 miles to the north and northeast was creating an outflow boundary that was going to cause a wind direction shift and increase in velocity, resulting in an increase in fire spread rates and a directional change to the south.
- This outflow boundary had reached the north end of the fire at 1618 according to Federal Aviation Administration (FAA) radar.
- The crew's possible rate of travel would be less than half of what it had been to this point due to lack of a defined trail, heavy vegetation, and rocky terrain between the crew and the Ranch.
- Boulder Springs Ranch was further away than it appeared.
- Other resources did not understand fully when the Granite Mountain IHC attempted to communicate their movement.

FOUR COURSES OF ACTION AVAILABLE AT POINT B, AROUND 1620:

Course of Action B1: Descend here; move toward the Ranch through the box canyon

- Appeared to be the most direct, shortest, and fastest path to the Ranch.
- The fastest route was desirable because of the perceived threat to the community of Yarnell.

- The fire was not below them. They last saw it continuing parallel and away from them.
- Taking this action would cause them to change their travel direction more to the east then southeast.
- The Boulder Springs Ranch seemed close.
- They could see their destination and they would continue to see it as they descend. This would give a sense of security that the destination seemed reachable.
- They would lose sight of the fire quickly as they descended toward the Ranch. However, they would see the smoke and keep some idea what the fire is doing.
- They lost the option to head off the backside of the ridge southwest toward Highway 89.

Course of Action B2: Continue along the two-track road

- The road would permit easier travel than hiking through the brush.
- Would keep them higher on the ridge and may provide better visibility of the fire and smoke column.
- Could keep open the option to move over the ridge, southwest toward Highway 89 allowing for a secondary escape route.
- Not the most direct route of travel to the Ranch.
- A longer route with longer hiking time would increase the time before they could reengage on the fire, reunite with their other crewmember and vehicles, and resupply.

Course of Action B3: Go off the back side of the ridge, southwest toward Hwy 89

- Since this option had been available all along, there would need to be a compelling reason to take this option now as opposed to doing it earlier.
- Current position was not under imminent threat from fire.
- Lighter fuels on the backside of the ridge.
- Moving away from the fire and from fire alignment with terrain.
- Consistent with normal practice in that part of country. Heading down and out is a typical path away from fire.
- Might become stranded in a remote location, further from being relevant to an ongoing threat.
- Would require transportation by others to return to Yarnell.

- Would face a lengthy time before being able to re-engage in tactical operations.
- There was no tactical reason to move along this route.

Course of Action B4: Return to the black

- Since this option was available all along, there would need to be a compelling reason to take this option now as opposed to doing it earlier.
- Current position not under imminent threat from fire.
- If the black was a desired location and appropriate course of action, they could have just stayed there.

COURSE OF ACTION TAKEN: B1

At this point, the Granite Mountain IHC descended from the two-track road, taking the most direct route toward the Boulder Springs Ranch.

Key Action C: The Granite Mountain IHC's shelter deployment around 1642

WHAT THEY LIKELY KNEW

While they were descending the slope after about 1620, the Granite Mountain IHC likely knew or perceived:

- The ridge, boulders, and brush sheltered them, so:
  - They could no longer see the fire, including its direction and rate of spread.
  - They lost the ability to feel or see wind changes
  - They had a limited view of the smoke column, a lagging indicator of fire location and fire behavior.
- The smoke is heading parallel to them and as an indicator of fire spread likely means that the fire is not headed toward them.

As they reached a small opening in the brush and the terrain begins to flatten, at about 1639, the Granite Mountain IHC likely knew or perceived:

- They suddenly had a view of smoke in front of them and coming over the ridge behind them.
- The smoke was blowing southward. Within minutes, flames were visible ahead of them and were coming over the ridge behind them.
- Winds were coming out of the north and had pushed the flaming front into the mouth of the canyon, and the fire was spreading directly towards them.

- They could not escape the box canyon before the fire reached them.
- They had limited time until the fire reached their location.
- They had very few options.

COURSES OF ACTION AVAILABLE AT POINT C, AT 1639:

Course of Action C1: Run away from this location, seek a safer location or move to another site to deploy fire shelters**:**

- No obvious safe locations were visible.
- Nearby rock piles appeared to have less vegetation.
- Rocky areas were about 120 yards uphill through heavy brush and there would not have been enough time to reach them.
- Uneven terrain and rock piles are not preferred fire shelter deployment locations.

Course of Action C2: Prepare current location and deploy fire shelters here:

- Certainty that survival from advancing fire was not possible outside shelters.
- Uncertainty of whether survival from advancing fire was possible inside shelters.
- Remaining together rather than scattering best maintained crew cohesion.
- Very little time for any other course of action.

COURSE OF ACTION TAKEN: C2

By 1639, the Granite Mountain IHC was preparing the site for fire shelter deployment. Within minutes, they were deploying fire shelters.

Summary

In this Analysis, we attempted to put key actions in context. Key actions included A) Leaving the black and heading along the two-track road for the Boulder Springs Ranch after 1604; B) Descending from the two-track road at about 1620, taking the most direct route to the Boulder Springs Ranch; and C) Deploying fire shelters at about 1642. This is the Team's interpretation and reconstruction of these moments. We may be presenting a more deliberative thought process than what the Granite Mountain IHC actually used at the time. Nobody will ever know how the crew actually saw their situation, which options they considered or what motivated their actions. The purpose of this section is to provide a tool that others can use for learning and prevention.

Conclusions

The Team developed these conclusions through deliberation. The process considered information from a number of sources, including accounts from personnel on the fire, records and logs, physical evidence, knowledge of the firefighting culture, Team observations, and SME sessions.

- The Granite Mountain IHC was a fully qualified, staffed, and trained hotshot crew. They were current with the required training and met work/rest guidelines. The crew followed all standards and guidelines as stated in the Standards for Interagency Hotshot Crew Operations and the Arizona State Forestry Division's Standard Operational Guideline 804.
- The Yarnell Hill area had not experienced wildfire in over 45 years. It was primed to burn because of extreme drought, decadent chaparral, and above average cured grass loadings.
- Although Yavapai County had a Community Wildfire Protection Plan, many structures were not defendable by firefighters responding to the Yarnell Hill Fire. The fire destroyed over one hundred structures.
- Radio communications were challenging throughout the incident. Some radios were not programmed with appropriate tone guards. Crews identified the problem, engaged in troubleshooting, and developed workarounds so they could communicate using their radios. Radio traffic was heavy during critical times on the fire.
- The fire's complexity increased in a very short time, challenging all firefighting resources to keep pace with the rapidly expanding incident. As complexity dramatically increased starting Saturday evening, fire management went through multiple transitions from a Type 4 through a Type 1 incident in fewer than 20 hours.
- The Granite Mountain IHC had been watching the active fire burn away from their position all day but their observations did not lead them to anticipate the approaching outflow boundary or the accompanying significant fire behavior changes. These changes included a doubling of fire intensity and flame lengths, a second 90-degree directional change, and a dramatically accelerated rate of spread.
- The Granite Mountain IHC left the lunch spot and traveled southeast on the two-track road near the ridge top. Then, they descended from the two-track road and took the most direct route towards Boulder Springs Ranch. The Team believes the crew was attempting to reposition so they could reengage.
- The Granite Mountain IHC did not perceive excessive risk in repositioning to Boulder Springs Ranch.

- The Team found no indication that the Granite Mountain IHC doubted the black was a valid safety zone, or that they moved towards the Boulder Springs Ranch because they feared for their safety if they stayed in the black.

- Although much communication occurred among crews throughout the day, few people understood Granite Mountain's intentions, movements, and location, once they left the black. The Team believes this is due to brief, informal, and vague radio transmissions and talkarounds that can occur during wildland fire communications. Based on radio conversations, Operations and other resources had concluded the Granite Mountain IHC was located in the black, near the ridge top where they had started that morning. This resulted in confusion about the crew's actual location at the time of search and rescue.

- In retrospect, the importance of the 1526 weather update is clear. However, the update appears to have carried less relevance in the crew's decision-making process, perhaps due to the wind shift (starting at about 1550) that preceded the outflow boundary, or perhaps because of the time it took the outflow boundary to reach the south end of the fire (at 1630). It is possible they may have interpreted the early wind shift as the anticipated wind event.

- An Air Attack and/or an ASM provided aerial supervision coverage throughout the day including at the time of the accident.

- The ASM working the fire was very busy fulfilling leadplane duties, which limited their ability to perform full Air Attack responsibilities over the fire at the same time.

- During some limited times, aircraft were not available due to adverse weather and refueling needs.

- At the time of the shelter deployment, a VLAT was on station over the fire waiting to drop retardant as soon as the crew's location was determined.

- The judgments and decisions of the incident management organizations managing this fire were reasonable. Firefighters performed within their scope of duty, as defined by their respective organizations. The Team found no indication of negligence, reckless actions, or violations of policy or protocol.

Recommendations

1. The Team recommends that the State of Arizona review and possibly update its approach to mitigating wildfire threat to Arizona life and property. This could be modeled after communities such as Prescott, AZ; Santa Fe, NM; or communities in other states. This process could be a cooperative effort to reduce hazardous fuels and improve overall suppression efforts for communities that are at a high risk from wildfire.

2. The Team recommends that the State of Arizona review the statewide wildfire communications plan and program, as well as similar programs and plans in other states, for possible improvements.

3. The Team recommends that the State of Arizona work cooperatively with its fire cooperators to develop a wildland fire staff ride for the Yarnell Hill Fire incident. The staff ride is a process of conveying the lessons learned from this incident for future fire leaders.

4. The Team recommends that the State of Arizona request the National Wildfire Coordination Group (NWCG) to review current technology that could increase resource tracking, communications, real time weather, etc. For example, this may include GPS units and weather applications.

5. The Team recommends that the State of Arizona request the NWCG and/or Wildland Fire Leadership Council (WFLC) to charter a team of interagency wildland fire and human factors experts to conduct further analysis of this event and the wildland fire communications environment.

6. The Team recommends that the State of Arizona request the NWCG to develop guidance to identify at what point is it necessary to separate the ASM and Air Attack roles to carry out required responsibilities for each platform.

7. The Team recommends that the State of Arizona request the WFLC/NWCG to develop a brief technical tip for fire supervisors/agency administrators on the effective use of VLATs. These are new, emerging fire suppression tools that the ground-based fire supervisors may be utilizing regularly in the future.

Part Two: Learning Discussion

Discussion

The Yarnell Hill Fire was a significant event to those personally affected and to the interagency wildland fire community at large. Because we do not know, and will never know, many of the precise details surrounding the final movements and motivations of the Granite Mountain IHC, we considered many aspects of wildland fire operations in our discussions. This accident prompted us to think about the many unknowns and to explore multiple concepts and perspectives as we tried to reconstruct the incident, to understand it, and to analyze it.

The intent of this Discussion is to inspire readers to think about and to discuss how the wildland fire community can improve at the individual, team, and organizational levels. We do not intend that this Discussion provide readers with finished, concrete answers; instead, we mean it to be a springboard that will prompt readers to think about these issues, to try to understand and learn from the accident, and to find opportunities for improving safety and resilience in their organizations.

Rapidly expanding fires in the urban interface are chaotic by nature. Because lives and property are threatened, emergency response organizations rapidly escalate their actions commensurate with the threat. Members of different organizations attempt to work together under extremely challenging and constantly changing circumstances.

The military term “fog and friction” describes challenges these organizations face as they try to communicate, understand, and respond at the right place and time with the right resources. The Oxford Dictionary defines the fog of war as the “confusion caused by the chaos of war or battle.” “Friction” is the process of coping with ambiguous information, fatigue, and unexpected events. It explains the difference between planned and actual events. “Fog and friction” are as common to wildland fire operations as they are to military operations. The Yarnell Hill Fire had plenty of fog and friction, as does any other fire that quadruples in size in a few hours, threatens people and homes, and requires the integration of many different types of air and ground resources.

This Discussion explores issues and questions that the Yarnell Hill Fire brings to the forefront for all wildland fire operations. Various team members and SMEs raised these issues and questions throughout the investigation. Although we list these issues one after another, they are interdependent and may overlap. We included sample questions to facilitate discussion at different levels of the fire organization, from crews and aviation resources to incident management to agency administration to interagency coordination including research and development.

We present these issues as discussion starters, recognizing that this is not a definitive list of issues raised by this fire, and that these are not the only questions to ask about wildland fire organizations and operations. We challenge every wildland fire organization to identify issues and questions raised in this report that resonate within their organizations, and to initiate and facilitate ongoing discussions.

Sensemaking Frame

Sensemaking refers to how people select what seems important to attend to, and how this influences their actions. According to organizational theorist Karl Weick, who popularized the phrase “sensemaking in organizations,” people cannot possibly cope with all of the raw data and information coming at them at a given moment. Instead, what a person pays attention to is a function of identity, past experience, their understanding of their purpose, and other factors. Sensemaking is a very active process whereby people literally “make sense” of the world around them at each moment.

People engage in sensemaking both individually and collectively. In fire, the term situational awareness describes sensemaking: how comprehensively and how accurately are you making sense of the actual fire environment you are working in? Collective sensemaking is about communication: it is about how crews, IMTs, and host agencies determine potential strategies and tactics, and how they convey and update these during planning meetings, briefings, operations, debriefings, and in after action reviews. Effective risk management communication involves more than simply reporting and transmitting messages. It requires developing effective shared meaning together through dialogue and inquiry. This discussion will frequently return to the concept of collective sensemaking and the role of inquiry in that process.

In a rapidly escalating transition fire, all personnel are simultaneously making sense of two environments at once: the rapidly changing fire environment and the changing organizational environment. At around 1600, an outflow boundary was approaching the Yarnell Hill Fire area with high winds that would hit the fire from a new direction. The sensemaking part comes in terms of the interpretation that people make of that change in the environment, of indicators that change might occur, and of the organization’s changing response.

It is far easier for us to know how we would make sense of the situation in hindsight than it is to know how the Granite Mountain IHC made sense of it. We know that the Granite Mountain IHC was actively making sense of their situation, but we also know that their sensemaking and that of others on the Yarnell Hill Fire did not prevent this tragedy. Because other wildland firefighters have similar training, knowledge, and experience to the Granite Mountain IHC, it is likely that others could “make sense” in a similar manner and suffer a similar outcome. The lessons of the Yarnell Hill Fire are not found in second guessing crew actions in hindsight but in understanding through foresight how things may have made sense at the time. Issues worth discussing for the safety of firefighters on future fires include situational awareness, fireline safety, communications, and incident organization.

Situational Awareness

Wildland fire training emphasizes the importance of situational awareness, or comprehensively and accurately perceiving the environment. It is not possible to "lose" situational awareness except by falling asleep or being knocked unconscious. The important questions are "What are people paying attention to and why?" And, "What are people *not* paying attention to and why?" For the second question, although it is easy to see in hindsight those things that turned out to be important, it is important not to engage in the counterfactual by assuming a reality that did not exist for the crew. It is better to ask, "Why might it have made sense to focus on or not to focus on those things at the time?" because others may find themselves in the same situation in the future.

We do not have the benefit of asking questions of the people whose situational awareness we are trying to understand. Nevertheless, using the information available, coupled with the Team's and the SMEs' understanding of wildland fire culture, we developed two conclusions that may point to the focus of the Granite Mountain IHC:

- The Granite Mountain IHC left the lunch spot and traveled southeast on the two-track road near the ridge top. Then, they descended from the two-track road and took the most direct route towards Boulder Springs Ranch. We believe the crew was attempting to reposition so they could reengage.
- The Granite Mountain IHC had been watching the active fire burn away from their position all day but their observations did not lead them to anticipate the approaching outflow boundary or the accompanying significant fire behavior changes. These changes included a doubling of fire intensity and flame lengths, a second 90-degree directional change, and a dramatically accelerated rate of spread.

The wildland fire community recognizes that hotshots are capable of handling difficult assignments. One Team member identified hotshots as "engagement experts," known to be persistent, flexible, and improvisational. This makes them valuable on many types of fires, including transition fires. As the day developed, action moved to the north end of the fire. With the fire reaching trigger points near Yarnell and with evacuations beginning, firefighters probably realized the time it would take to evacuate a town of that size. Although we will never know for sure, we considered how the Granite Mountain IHC might have reasoned: If they stay in the black, they do no good. If they move, they might do some good even if they do not know what that good will look like. They think they can move without it being especially risky.

We have no indication that Operations or anyone else asked the Granite Mountain IHC to move to a new location but we assume they decided this on their own, believing they could reengage and help defend Yarnell. A culture of engagement and a bias for action is part of wildland firefighter identity and a factor in their success, and in this case, a bias for engagement may have prompted them to move.

What were they not focused on? Using available information coupled with understanding of wildland fire culture, we reached the following conclusion:

- In retrospect, the importance of the 1526 weather update is clear. However, the update appears to have carried less relevance in the crew's decision-making process, perhaps due to the wind shift (starting at about 1550) that preceded the outflow boundary, or perhaps because of the time it took the outflow boundary to reach the south end of the fire (at 1630). It is possible that they may have interpreted the early wind shift as the anticipated wind event.

The outflow boundary update that the NWS communicated to FBAN at 1526 seems to have been relayed efficiently throughout the incident organization. FBAN radioed the update to Operations, and Operations checked in with the crews to make sure they received the update. The Granite Mountain IHC affirmed and passed along the information to their lookout. We considered why this weather update might have carried less relevance with the Granite Mountain IHC, leading to discussions of desensitization, false alarms, and aging of information.

People in the desert southwest may become desensitized to high temperatures and low relative humidity during certain times of year. As two SMEs figured, crews in the area likely received messages over the preceding two months similarly predicting conditions such as hot weather, dry fuels, and thunderstorms. In other parts of the country, these kinds of predictions are rare; when they do occur, they constitute "strong signals." Like car alarms in an urban neighborhood, repetition of strong signals resets the cognitive baseline for what is "normal." People desensitized after repeated warnings start to rely on other cues to identify new and relevant conditions.

There is also danger that a firefighter may become desensitized to extreme fire behavior, based on an old mental model that extreme fire behavior is rare. One SME said, "The unusual is now usual – the scale of fires today is extreme. That's what's normal now." Another said, "This fire went from wildland to WUI (Wildland-Urban Interface) within a burn period. This is part of the new reality. The new normal is extreme fire behavior."

Consider the role of false alarms. If weather conditions described in one update do not occur, or occur at a diminished level as happened in this case, what will be the level of confidence in the next weather update? Does that decrease the confidence in future weather updates originating from the same source? Although we will never know the answer to this question, it is worth asking: In the absence of observed cloud and column conditions, to what extent did the Granite Mountain IHC think the weather in the second update was not going to materialize because weather in the first update occurred on a diminished level?

Regarding aging of information, people process information based on a variety of factors including perceived timeliness, reliability, and observations. Weather personnel often issue forecasts covering a set timeframe. If the forecaster considers the update reliable for a finite period, the recipient may draw conclusions about its window of relevance. The older a weather forecast or update is, the lower the receiver's confidence in the update. If predicted conditions have not materialized in an otherwise dynamic atmosphere, this could further decrease a firefighter's confidence in aging weather updates.

That the original forecast required updating twice during the afternoon of June 30 indicates how rapidly conditions were changing on this fire. As an update ages, firefighters might base their fire behavior estimates on their observations more than on other inputs.

While we do not know exactly what time the Granite Mountain IHC headed southeast from their fire line, it is clear that they were in a place where they observed fire behavior for at least 30 minutes after receiving the last update. We also know the crew would lose awareness of the fire's location and rate of spread for a short time when they descended from the ridge. We believe it is worth considering that the Granite Mountain IHC might have assumed that the transitioning wind shift that caused their lookout to move *was* the strong wind shift that the weather update anticipated. It is also possible that they discounted the update because too much time had passed.

While discussing desensitization, false alarms, and aging of information, the SMEs posed the following questions for consideration and discussion:

- How long does a forecast keep you on the edge of your seat?
- How long do weather bulletins remain fresh in your mind?
- How long do you wait before you decide a forecasted condition is not going to materialize?
- How does this make you think about planning for the worst-case scenario?

The Team and the SMEs also discussed what might improve the signal detection capability of individual resources. Could moving conversations from simple reports to inquiries provide an opportunity for collective sensemaking about the meaning of a weather update? All day, firefighters get information about what *might* happen. Could a crew discuss what *would* happen if the weather were to materialize? Or, could Operations ask the crews, "We've got this weather coming. What's your plan? What have you been doing and what do you need?"

Cell phones and iPads are not available to all fire personnel in many firefighting organizations. Some incidents also prohibit personal use of such items except on designated breaks. Should some crews, working under certain conditions, be able to access their own weather intelligence to increase the accuracy and timeliness of information that affects their own safety? Acknowledging that there are tradeoffs involved in introducing new technologies, this question merits consideration.

We developed the following additional questions for discussion by various fire resources:

Some Questions for Ground Crews and Aviation Resources

- As a way to test your engagement and action orientation, how might your unit react to the instructions, "don't just do something, sit there."
- When working in day after day of extremely hot weather with low humidity, when thunderstorms are predicted, what do you do to stay alert to changing conditions?
- When weather updates come in over the radio, what kinds of conversations typically take place to process the information as a group?
- What kinds of signals in the fire environment make the hair on the back of your neck stand up, and why?
- When was the last time you were surprised by fire behavior? What clues, in hindsight, were there to help you see that things were changing more rapidly than you knew?

Some Questions for Incident Managers

- How do you as a manager transfer your and your staff's thoughts about the special concerns on this fire to the incoming resources?
- How do you ensure that all resources assigned to your fire receive and understand weather forecasts and updates?

Some Questions for Agency Managers/Interagency Coordinators

- In situations where the system is unavoidably dependent on an individual resource, what could we do differently to give firefighters on the ground better information to make decisions?
- What are the benefits and drawbacks of equipping firefighters with handheld technology intended to increase their situational awareness?

Some Questions for Researchers in Human Factors, Organizations, Fire Behavior, etc.

- How might emotion trigger "automatic" movement, and how can we interrupt this circuit to engage in reflection that leads to more purposeful action?
- How might firefighters stay alert to changing conditions when message repetition might encourage desensitization (e.g., working in day after day of extremely hot weather and low humidity with thunderstorms predicted)?

Fireline Safety

The Yarnell Hill Fire also points to issues of fireline safety and risk management while on the move. As noted in the Conclusions section:

- We found no indication that the Granite Mountain IHC doubted that the black was a valid safety zone, or that they moved towards the Boulder Springs Ranch because they feared for their safety if they stayed in the black.
- The Granite Mountain IHC did not perceive excessive risk in repositioning to Boulder Springs Ranch.

The intent of discussing fireline safety is not to second-guess the crew's actions on this incident. Rather, the intent is to point to issues regarding fireline safety that this fire leads us to contemplate regarding *all* fires.

Safety Zones

The Yarnell Hill Fire calls attention to how the phrase "good black" conveys a measure of one crew's safety to other resources on the fire. In generally chaotic conditions when a fire is expanding rapidly and organizational complexity is increasing, if an experienced crew like an IHC reports that they are "good" and "in the black," this relieves Operations from having to attend to another detail on an already busy fire. Anyone hearing such a report from a crew would automatically consider that they are about as safe as it is possible to be in such a situation.

In terms of collective sensemaking and inquiry, one aspect of the crew's communication stands out. The crew communicated that they were moving along their escape route to a safety zone, yet others on the fire believed their location was in a safety zone (the black). Personnel in a safety zone do not need an escape route. Others on the fire inquired with the Granite Mountain IHC about their status and location, yet that inquiry did not lead to mutually accurate understanding.

One communication exchange illustrates how inquiry might lead to collective reassessment. At about 1600 after hearing about "a crew in a safety zone," the ASM asked if they needed to call a time out. Operations replied that it was the Granite Mountain IHC and that they were safe. Then, sometime later, DIVS A followed up and said they were traveling along their escape route to a safety zone. The ASM's question about pausing operations is a good example of one resource updating situational awareness about another resource's location and relative safety, and even recommending an action that could have helped update everyone's collective sense of the crew's status and location. Nevertheless, we might consider how Operations and the Granite Mountain IHC's subsequent radio conversation may have led many on the fire to mentally file the crew back in the "safe" category.

The Yarnell Hill Fire also calls attention to firefighter sensemaking about the "green," including whether there is such a thing as "good green." Firefighters know that being "in the green" on a fire, surrounded by unburned vegetation, can be unsafe. During indirect attack, there is always unburned fuel between the firefighter and the fire. But consider that prior to 1604 on this incident, all ground personnel assigned to the Yarnell Hill Fire *except for the Granite Mountain*

IHC were in the green. Only the Granite Mountain crew was in the black, normally considered a "safe" location, potentially leading others on the fire to have greater concern for people working in the green than for the Granite Mountain IHC.

We considered what provided for the safety of all the other personnel: possibly distance from the fire, mobility, ability to make sense of what the fire was doing and react appropriately, or a combination of these factors. Members of the Blue Ridge IHC moved through the green all day in areas that subsequently burned. It is conjecture, but possible, that their actions may have assisted in saving the life of GM Lookout as well as preventing the Granite Mountain IHC's trucks from burning. Obviously, decisions to operate in the green are laden with a variety of assessments of the relative risk of doing so.

We will never know for sure, but we wondered whether the Granite Mountain IHC's decision to hike through the green might have seemed to them to be a decision to operate in the green just like everyone else. For the crew, this would have meant moving away from a safe location at the time of day when the fire would be most active. Decision makers base such decisions on what they know at the time and their assessment of the risks associated with various courses of action.

Regarding their intended destination, the 0700 briefing on June 30 included identification of the Boulder Springs Ranch as a safety zone. SPGS1 (who had just arrived the evening before) described it as "bomb proof," a label indicating the Ranch was not only a safety zone, but that it seemed to be an especially good safety zone that could withstand extreme fire behavior.

Because identifying a safety zone requires judgment and is therefore subjective, firefighters often know the actual effectiveness of a safety zone only in retrospect. If a fire never affects a safety zone with firefighters in it, firefighters may never know whether it would have proven safe. In this case, fire progression maps and aerial photos taken after the fact demonstrate that the large Ranch was well prepared to act as a fuel break in the hills above Yarnell. Inside the perimeter of the Ranch, the preparation and arrangement of the buildings proved effective to minimize damage to the home, livestock, and other values on the property. For these reasons, the label "bomb proof safety zone" seems to have accurately described the Boulder Springs Ranch.

Escape Routes

Continuing from this previous point, the Yarnell Hill Fire also prompts us to think about the connections that firefighters make between escape routes and safety zones. As noted above, we believe the Granite Mountain IHC did not perceive their route as overly risky, or they would not have taken it. Wildland firefighters should consider to what extent a strong vote of confidence about the effectiveness of a safety zone might be interpreted as a strong vote of confidence about potential escape routes for getting there. Conversely, is there some implied measure of the safety along an escape route *because* it leads to a safety zone?

One might view traveling through an escape route to a safety zone as making educated guesses as to the route and anticipated travel speed while running to a specific point. The educated guess is that the crew can reach the safety zone before the fire reaches them. There are many variables involved in this equation but perhaps the most important one is speed. If the fire can travel at a faster rate than the firefighters, they will lose the race. If they can travel faster than the fire, they will win the race. In order for the educated guess to prove out, the firefighters must predict three things with some degree of accuracy: how fast the fire will travel, which direction the fire will travel, and how fast they will travel. It is possible to misestimate all these factors and suffer no consequences, for example if the firefighters misestimate the fire's direction of travel but it moves away from their position. However, misestimating any of these variables could cause serious trouble and firefighters misestimating them all may pay the ultimate price.

Unfortunately, all three of these variables are difficult to estimate accurately. Estimating how fast a fire will travel, along with its direction of travel, involves making an accurate fire behavior prediction while also doing a number of other things. Even in hindsight, knowing what the fire actually did and using the best available hardware and software, fire behavior analysts can still only approximate how a fire behaved in a blowup situation. Firefighters in the field must use available information and their own sensemaking to estimate both what the fire is likely to do, and what it *could* do under a worst-case scenario. Estimates of how fast firefighters can travel can also be problematic. A crew can only move as fast as its slowest member, and unexpected barriers in the route of travel such as rocks, thick vegetation or cliffs, can significantly change the amount of time required to cover a piece of ground.

This points to a key dilemma of wildland firefighting: firefighters on a fire are one educated guess away from potential entrapment. Increased mobility increases the tolerable margin of error; decreased mobility decreases it in terms of how fast a person can travel versus how fast the fire can travel. Firefighters on foot are perhaps the most vulnerable, but many firefighters have become entrapped in vehicles as well.

Wildland firefighters often discuss the need to have multiple safety zones; many firefighters also identify multiple escape routes to the same safety zone, if they exist, although this can require extensive scouting. In hindsight, we know that the Granite Mountain IHC might have arrived at the Boulder Springs Ranch if they had stayed on the two-track road, although it is unclear whether the crew knew that, or how long it might have taken to get there. This highlights another problem posed by limited mobility: because the Granite Mountain IHC was on foot, their ability to scout potential escape routes was limited.

Lookouts

Lookouts, Communications, Escape Routes, and Safety Zones (LCES) is an interconnected system approach to fireline safety, so it is difficult to discuss safety zones and escape routes without also addressing lookouts. The Granite Mountain IHC had a designated lookout for most of the day, until the advancing fire threatened the lookout's location and forced him to withdraw. This points to one paradox of firefighting: Crews post lookouts to increase safety, but there is no guarantee of the lookout's own safety. The Granite Mountain IHC never took explicit action to replace this lookout after he was forced to withdraw, but it is likely that DIVS A was serving as a lookout for the crew and that the crew was also exercising their own vigilance. In all the photos of the crew at the lunch spot, they appear focused on the active fire.

Ground resources can also use aviation resources to gather information, but crews are cautioned not to rely on them because aircraft move around, have to land to refuel, and are diverted to other missions. When both airtankers and helicopters are conducting operations in the same airspace, the complexity of the air operations and the communications necessary to accomplish this may preclude routine requests by ground resources for situation updates. While aircraft *might* have provided situation updates to the Granite Mountain IHC during the time they were hiking and prior to their shelter deployment, there is no evidence that communication occurred. In the current system, ground resources would have to request such an update.

We contemplated a key question arising from the Yarnell Hill Fire that also likely applies to many other fires: Is it necessary to post a lookout when a crew is moving? In some situations, it may not be feasible to post a lookout while a crew is moving due to time and distance considerations. This raises the question of whether a crew can perform its own lookout functions without designating and posting a lookout in a separate location. It is likely that the Granite Mountain IHC was very vigilant to their surrounding environment as they hiked southeast along the two-track road. Because the crew was moving quickly between two safety zones, it was likely not feasible to post a lookout from the crew at another location. Given previous events that day, the crew was likely very aware that posting a lookout in such a dynamic fire environment can pose challenges to the lookout's own safety and may serve only to separate a crewmember from the rest of the crew.

Whether the crew recognized it or not, their decision to go down the hillside from the Descent Point was a decision to sacrifice some of their effectiveness in serving as their own lookouts. Taking a more direct escape route to minimize exposure in the green generally means traveling a shorter distance and potentially reaching the safety zone more quickly. Moving down the slope into the box canyon meant the Granite Mountain IHC would no longer be able to see the fire. We wondered: Is it possible that they relied on the rock outcropping as a barrier to fire spread? But is it also possible that the outcropping blocked their view of the fire? We will never know if the crew understood that this route of travel required that they sacrifice some of their capacity to serve as their own lookouts. We will also never know if they understood the calculated risk involved in traversing the final distance to the Ranch without the level of situational awareness that a different vantage point might have afforded.

With the help of our SMEs, we developed the following questions for discussion by various fire resources regarding fireline safety.

Some Questions for Ground Crews and Aviation Resources

- How do you and your crew define “good black”? Firefighters identify and discuss good black, but is there also such a thing as “good green”?
- How do you assess the risk of hiking into a fire in the green? What differs about your risk assessment when hiking out through the green?
- When others point out a safety zone to you, what questions do you ask about how they assessed the viability of the site and the safety of the route(s) for getting there?
- Since all escape routes are necessarily “through the green” or through black that is not very “good,” what characteristics make one escape route better than another?
- When you identify an escape route, do you also discuss trigger conditions that would prompt reassessment?
- What assumptions do you make about the safety of other resources? How often do you update that information?
- Other than at a required annual refresher, how many times per season do you and your crew simulate or play out what you would do during an entrapment, including practicing fire shelter deployments?

Some Questions for Incident Managers

- When resources leave the black, do you think of it as a move from safety to danger? Should a decision to leave the black, or any other area deemed safe, be considered a decision to accept more risk? Under what circumstances does this require notification to others?
- What are your own judgments about crews falling back and disengaging? How do you convey this on an incident?

Communications

Communications issues on wildland fires are common. Firefighters usually associate communications problems with technology issues, but communication challenges can occur even when radio systems are working well. Two team conclusions were:

- Radio communications were challenging throughout the incident. Some radios were not programmed with appropriate tone guards. Crews identified the problem, engaged in troubleshooting, and developed workarounds so they could communicate using their radios. Radio traffic was heavy during critical times on the fire.
- Although much communication occurred among crews throughout the day, few people understood Granite Mountain’s intentions, movements, and location, once they left the black. The Team believes this is due to brief, informal, and vague radio transmissions and talkarounds that can occur during wildland fire communications. Based on radio

conversations, Operations and other resources had concluded that the Granite Mountain IHC was located in the black, near the ridge top where they had started that morning. This resulted in confusion about the crew's actual location at the time of search and rescue.

The benefit of radio communication is that when the system is working properly everyone can hear the same messages from multiple sources on the fire. Firefighters commonly experience radio issues on fires but they are used to adapting to problems and developing workarounds. There were problems on the Yarnell Hill Fire with tone guards and "dead spots," or areas where handheld radios could not reach repeaters to transmit messages to other ground resources. To overcome these issues, individuals and crews used time to troubleshoot problems, to reset or reconfigure radios, or to travel to face-to-face meetings. Physical workarounds included lending or sharing radios among crews and using cell phones (text messages and voice calls) as alternatives to radios. Although these alternatives demonstrate initiative and creativity and may permit lengthier, more detailed conversations and interactions, it is worth considering the potential tradeoffs.

Moreover, most firefighters constantly monitor more than one radio channel. They might simultaneously scan three or four channels including the tactical channel for their Division or Group, the Command frequency for the incident, the air-to-ground frequency, and their intra-crew channel. They always designate one channel as a "priority" so that traffic on it will preempt traffic on other scanned channels. This makes it is easy to miss partial or entire transmissions when all channels are busy, even on a channel that the radio is set to monitor.

Rapidly emerging initial or extended attack actions are hectic, resulting in increased radio communication, competition for radio time, and limited time to convey information. As one Team member said, firefighters have "normalized" overloaded radio traffic when operational tempo increases. During busy times, this can cause a firefighter to feel an increased reluctance to get on the radio. Radio traffic was heavy on the afternoon of June 30 on the Yarnell Hill Fire. The situation compounded in one operational period as the fire moved from wildland fire-focused activity to a fire with concurrent actions in multiple wildland and urban areas. Ground crews, aviation resources, and structure protection resources were all vying for radio airtime. We believe it is worth considering whether early radio problems and heavy radio traffic caused the Granite Mountain IHC to hesitate to add to the radio traffic early in the day, when they might have otherwise relayed periodic updates of their crew's location.

Firefighters learn in their training to speak in "clear text" (plain English, no codes) during radio conversations and to keep their conversations brief. The reason for clear text is that some users may not understand numeric codes, and asking for clarifications uses airtime. Clear text works well for sharing straightforward information and it works very well when both parties are of a common understanding. However, clear text has limitations when reaching a mutual understanding requires longer interactions. Shortened messages may not fully explain a point, situation, or request; may send an incomplete message; or may lead the recipient to act upon something they thought they heard. Recipients may carry on with a misunderstood message or assumption rather than asking for clarification. While these misunderstandings likely had no direct impact on the Granite Mountain IHC's fire shelter deployment, confusion over the location of the break between Divisions Alpha and Zulu, and over SEAT drops on the Granite Mountain IHC's burnout that morning are two examples of communication disconnects that emerged during reliance on radio communications.

Some people knew the Granite Mountain IHC was on the move, but only the Granite Mountain IHC knew their location and intended destination. An early miscommunication caused confusion later about which two-track road the crew was on and which ranch they were heading towards. When DIVS A told BR Supt that they were "picking our way through the black" toward the road at the bottom then to a ranch, BR Supt thought Granite Mountain was going out the two-track road to the northeast. After leaving the lunch spot, the Granite Mountain IHC traveled in a different direction toward the Boulder Springs Ranch. It is clear now, in hindsight, that the message BR Supt perceived was not the message DIVS A believed he relayed. All day, the Granite Mountain IHC and BR Supt were in frequent contact with one another and mutually believed they had a clear understanding between them, so neither noted this miscommunication at the time of occurrence. Unbeknownst to them, they were not communicating in the sense of actually understanding one another's movements.

The Incident Response Pocket Guide sets out five communication responsibilities for wildland firefighting, including 1) Brief others as needed; 2) Debrief your actions; 3) Communicate hazards to others; 4) Acknowledge messages; and 5) Ask if you don't know. These responsibilities emphasize the importance of communication content in the overall system, reminding firefighters to share information that others might need and acknowledge information communicated to them. Point 5 reminds firefighters to make an effort to clarify things they do not understand. The guide does not currently capture the need for firefighters to inquire to ensure they have the *right* understanding. We considered that perhaps point 5 be phrased "Ask questions until you know and you are sure you understand."

Some Questions for Ground Crews and Aviation Resources

- When you communicate your assessment of your location, how much detail do you provide to also help others "picture" what you are seeing?
- Can people who are in other locations help you to assess the risks where you are?

Some Questions for Incident Managers

- In what ways do WUI fires make already-challenging radio issues more complex?
- When checking in with your resources, what is the best way to ask for an update to ensure that you receive a report that allows you to visualize what the resources see and know what factors they consider in their assessment?

Incident Organization

Rapidly expanding fires in the WUI are chaotic by nature. Because lives and property are threatened, emergency response organizations escalate their response commensurate with the escalating threat. Our conclusions included:

- The fire's complexity increased in a very short time, challenging all firefighting resources to keep pace with the rapidly expanding incident. As complexity dramatically increased starting Saturday evening, fire management went through multiple transitions from a Type 4 through a Type 1 incident in fewer than 20 hours.

Like many high complexity wildland fires, the Yarnell Hill Fire passed through a series of "modes."[12] In this case, we considered **Mode 1** to be the initial sizing up and engagement of the fire, characterized first by direct attack at the heel and flanks of the fire. A transition to **Mode 2** happened when firefighters largely abandoned efforts to contain the fire through direct perimeter control and shifted to point protection around structures. Mode 2 centered on taking actions to protect values at risk, while anticipating the fire spread and recognizing the inadequacy of attempts at perimeter control. **Mode 3** was largely about survival of incident responders and the public, about disengaging and running away from the fire and helping civilians evacuate. Later, firefighters were able to shift back into Modes 1 and 2.

The Yarnell Hill Fire incident management organization had a dynamic organizational strategy, scaling up within 20 hours with two fronts of structure protection. In a rapidly escalating fire environment, firefighters simultaneously try to make sense of what the fire is doing and how the incident organization is changing. This prompted us to consider whether some fire personnel might remain focused on one mode while others have moved on to another mode, and we considered the potential implications of this disconnect.

This characterization helps illustrate collective sensemaking because it highlights the importance of all resources mutually understanding which mode the fire is in and whether they are all making the same sense of being in that mode. This ties into the operational strategy, and how different people working on the fire understand and interpret that strategy.

Response to transition fires normally starts with in-briefings and good orientation to individual and collective sensemaking. Mode 1 response is strategic leading to tactical, formulating a plan and initial implementation. In Mode 1, the initial briefings and assignments show that the Yarnell Hill incident started the day well organized. However, as complexity increases and the situation changes, the initial response plan requires adjustment, or actions revert to individual sensemaking. Mode 2 is more of a tactical orientation and on this fire involved a shift from a

[12] The Team numbered these modes for illustration only. Different fires may go through different modes.

wildland and WUI focus to primarily a WUI/point protection focus. Mode 3 involves immediate, reactive actions and movement to survival: moving, disengaging, retreating, evacuating.

The Granite Mountain IHC's initial actions at the heel of the fire could be interpreted as the crew being engaged in Mode 1. Moving toward the Ranch would be a movement toward Mode 2. In the analysis, the Team noted that the Granite Mountain IHC likely thought it was safe to move to the Ranch, first on the two-track road and later by dropping down at the Descent Point. As a consequence, the Granite Mountain IHC would not have transitioned into Mode 3 until after reaching the deployment site, when they had little time and limited options.

We wondered: How might personnel ensure that they are individually and collectively oriented to the same Mode? In discussing this issue, we contemplated several questions:

- How might formally giving up on "Mode 1" make it more likely for a crew to disengage?
- Could formally acknowledging a shift in mode on the fire help individual crews reassess their place in the collective effort?
- But is it also possible that recognizing a shift to "Mode 2" might pull people toward the structures?
- Signal strength is a potential factor in an individual's interpretation of mode. During the worst time of day for burnovers to occur, if conditions are all lining up, is it possible to deliver a strong signal about mode that prompts everyone to change their behaviors, including communication behaviors?

We developed additional questions that others should consider.

Some Questions for Incident Managers

- When incident complexity and operational tempo escalate rapidly, what are some of the things you can do to minimize resultant confusion? Who can help you in managing all the incoming information?
- Do you think it is important to update resources on your fire as to what strategic and tactical mode the incident organization is in? What ideas do you have on how best to accomplish such an update?
- What are some ways that you can encourage collective sensemaking among the resources assigned to you?

Some Questions for Agency Managers/Interagency Coordinators

- Organizational culture on transitioning fires tends to make sense of things individually or in small groups or individual crews. How can we increase our ability to make sense of and share what is happening at the incident scale?

Some Questions for Researchers in Human Factors, Organizations, Fire Behavior, etc.

- What are some communication strategies to cultivate inquiry that firefighters and incident managers can use to create more effective collective sensemaking?

Improving Resilience

On rapidly escalating transition fires like the Yarnell Hill Fire, complexity can outpace organizational attempts to respond. In other words, collective sensemaking can fall behind the curve, particularly when a fire simultaneously affects multiple fronts. Collective sensemaking often starts strong early in the operational period with face-to-face briefings and agreement on plans. The Yarnell Hill Fire prompts us to consider how, as complexity increases, as resources are adapting to the fire environment, and as operations slide into and out of different modes, it is necessary to develop a new kind of collective plan. This evolution could occur several times in a single day.

Time pressures, radio limitations, crew familiarity, and other issues can hamper efforts to check in and contribute to sensemaking. For example, the need for communication from multiple resources that are focused on direct actions at the same time crowds the airwaves. As a result, the organization designed during initial attack tends to erode and revert to sensemaking by individual resources until announcement of the next operational period's strategies, tactics, and assignments. This means that collective sensemaking is particularly necessary and difficult at the very moments when autonomous crews most need it: during high tempo situations with escalating complexity.

We considered whether routine use of "inquiry" in communication might increase ground crew capabilities by connecting them to information and expertise available in the larger system. If so, the wildland fire community should consider what it could do to cultivate inquiry, to move wildland fire communications beyond "reporting" and "debriefing," and to help everyone make sense together, for everyone's benefit.

Charge to the Wildland Fire Community

This discussion identifies some issues that the Yarnell Hill Fire prompts the wildland fire community to consider. We introduced issues and questions that readers may find useful as they try to understand this accident and learn from it, but this is only a start. Because sensemaking is ongoing and social, we challenge every wildland fire organization to identify and discuss issues and questions raised in this report that resonate within their organizations, to continue the ongoing process of sensemaking.

Appendices

Appendix A: Sequence of Events

Note to reader: This timeline provides as accurate a sequence of events as possible. This reconstructed sequence of events draws from multiple sources including dispatch records and personal interviews. These sources of information are subject to some variability. Times are approximate. For acronyms, see Appendix F.

TIME	EVENT
June 28, 2013	
1736	Dispatch opens a WildCAD incident card upon receiving reports of a lightning-ignited fire on Yarnell Hill.
1841	Request is made for an Air Attack to fly the area.
1905	Lat, Long 34^{o} 13.7',-112^{o} 47.5'. Fire is reported to be on State-owned land, is 1/4 to 1/2 acre with 80% of fire out, only active on one corner, and has low spread potential with no structures or people at risk.
1919	ICT4 elects to take no action on the fire this evening but plans full suppression strategy the next morning.
2053	Discussion occurs regarding pre-positioning a fire crew in Prescott, utilization of the SEATs, and logistics.

June 29, 2013	
TIME	**EVENT**
0649	First person on scene reports a few smokes showing.
0651	ICT4 requests 2 SEATS to drop on the fire before the crews arrive.
1011	Air Attack reports the fire is showing a few smokes and he plans to have the SEATS drop retardant to hold the fire perimeter. ICT4 requests a helicopter to shuttle crews.
1048	Helicopter H-4HX arrives and drops off 7 firefighters.
1222	ICT4 reports the fire is 2 acres, the south and west flanks were "hit" with retardant and the east flank is an old road.
1442	ICT4 releases Air Attack.
1540	ICT4 releases the BLM and Peeples Valley engines.
1555	ICT4 requests the launch of an Air Attack for a reconnaissance flight.
1610	ICT4 requests two SEATs and an Air Attack be launched.

TIME	EVENT
1613	Dispatch reports only one SEAT is available as they are holding the other one for a new start near Kingman.
1615	ICT4 reports they are still having problems catching it and they'll use more retardant on it if needed but will wait until Air Attack gets over the fire to confirm.
1655	ICT4 orders the closest heavy helitanker, which is located at Prescott.
1718	ICT4 reports the fire has jumped the two-track road on the east side and gained about 2 acres but has started to quiet down and a helitanker and SEAT should be effective.
1729	ICT4 orders a heavy airtanker
1730	ICT4 orders an Arizona IMT
1742	Dispatch is notified the heavy airtanker (Tanker 06) and the Heavy Helicopter in Prescott both declined the mission due to unsafe weather conditions.
1743	Dispatch offers the VLAT from Albuquerque in place of the heavy airtanker that could not respond.
1750	Based on conditions over the fire ICT4 elects not to order the VLAT.
1801	ICT4 requests the second SEAT if it is available, Dispatch responds they will check with the Dean Peak incident and check availability.
1803	SWCC tells Dispatch who advises ICT4 they would not be able to support the Yarnell Hill incident with heavy airtankers (LAT) due to weather concerns and other priority fire commitments.
1821	ICT4 places 2 orders for Type 1 Interagency Hotshot Crews to be at Yarnell at 0600.
2010	Dispatch places order for Type 1 Crew to be filled by the Granite Mountain IHC.
2010	ICT4 reports fire is running to the north lateral of topography, 1 1/2 mile from the closest structure and 2½ miles from a subdivision, about 100 acres in brush operations. Tactics are to anchor and flank the southeast corner to the north.
2033	NWS Flagstaff issues a spot weather forecast for Yarnell Hill
2105	ADC advised by SWCC to assign the Granite Mountain IHC internally to Yarnell Hill incident and to retrieve their order from SWCC.
2155	IMT Type 2 ordered
~2340	SPGS1 arrives at fire, starts assessing structures, and building strategy and contingency plans

TIME	EVENT
June 30, 2013	
~0700	Briefing at Yarnell Fire Station includes SPGS1, OPS1, OPS2, ICT2, Granite Mountain IHC, FBAN, and YCSO deputies. SPGS1 and Granite Mountain IHC drive out to the fire together.
0800	Blue Ridge IHC arrives at ICP, stage in trucks
~0845	Blue Ridge IHC drives to Yarnell Fire Station and stages there.
~0930	OPS1 directs Blue Ridge IHC to drive into fire area and tie in with SPGS1
~0930	Team briefing begins at ICP In Model Creek School in Peeples Valley
0945	Spot weather forecast is received and relayed during the 0930 briefing
1022	Formal transfer of command to ICT2 is announced on Command frequency
1045	YCSO issues evacuation notices to residents of Model Creek and Double Bar A Ranch
1153-1239	Blue Ridge Supt and Capt drive UTV up to the anchor point just below saddle; meet Granite Mountain IHC there; leave with the Granite Mountain Lookout in the UTV and drop him off at lookout location
1402	NWS-Flagstaff calls FBAN with weather update; FBAN relays the update to OPS1 and OPS2 using Tac 1. ICT4 requests a Type 1 IMT
~1447	ASM2 arrives over fire
~1510	Fire reaches ICP Model Creek/Peeples Valley
1526	NWS-Flagstaff calls FBAN with weather update; FBAN relays the update to OPS1 and OPS2
1530	Shifts in wind direction begin, in advance of the outflow boundary. Fire spread begins shifting from NE to SE.
~1550	Granite Mountain Capt hears weather update, relays to Granite Mountain Lookout.
1552	Granite Mountain Lookout sees slight wind shift and increase in fire behavior. He tells Granite Mountain Capt he is leaving lookout location due to fire reaching his trigger point. He then heads to the end of Sesame Street where Blue Ridge Supt picks him up
1555	Granite Mountain Lookout and Blue Ridge IHC start moving Granite Mountain IHC trucks to Shrine area
1558	Air Attack leaves fire, heads to Deer Valley
1600	Evacuation of Yarnell ASM2 and OPS1 discuss Granite Mountain’s comment about a safety zone
1618	Outflow boundary reaches northern perimeter of fire
1622	Fire reaches the trigger point for firefighters to start pulling out of Yarnell

TIME	EVENT
1630	Outflow boundary reaches southern perimeter of fire, brings drastic increase in wind speed and drives the fire south. Winds of 50 mph+ funnel west and southwest into the box canyon which will become the future deployment site.
1637	ASM2 flies a drop path for a VLAT north of Yarnell west to east. DIVS A acknowledges the drop.
~1639	Granite Mountain IHC attempts to contact Air Attack; ASM2 attempts to contact Granite Mountain
1640	Last firefighters leave the northern subdivision of Yarnell and reach Hwy 89
~1641:30	Division A tells Air Attack their escape route has been cut off and they're deploying shelters. ASM2 asks if they are on the south end of the fire. Division A says "Affirm!"
1643	Fire resources regroup at the Ranch House Restaurant in southern Yarnell
1653	Electricity goes off at Boulder Springs Ranch
1716	DPS helicopter Ranger 58 is requested to assist with search and rescue; they begin near the anchor point. Ground resources work their way in.
1829	OPS2 reports to the IC the fire has crossed Hwy 89
1835	DPS officer/medic on scene confirms 19 fatalities

Appendix B: Fire Environment & Behavior Analysis

ENVIRONMENT

Topography: The Yarnell Hill Fire occurred on a plateau in west central Arizona with elevations ranging from 4,500 to 6,052 feet above sea level. The fire area is characterized by a mountainous ridge that runs north-south through the western third of the fire area with more rolling terrain to the east (Figure 1). A one-mile long spur-ridge projects WNW-ESE from the main ridge at about the mid-point of the fire. Slopes vary from flat on the east side to 50%, with isolated steeper sites in the mountains on the west side. Numerous rocks and rock outcroppings are scattered through the fire area (Figure 2).

Figure 1. Typical topography of the Yarnell Hill Fire area

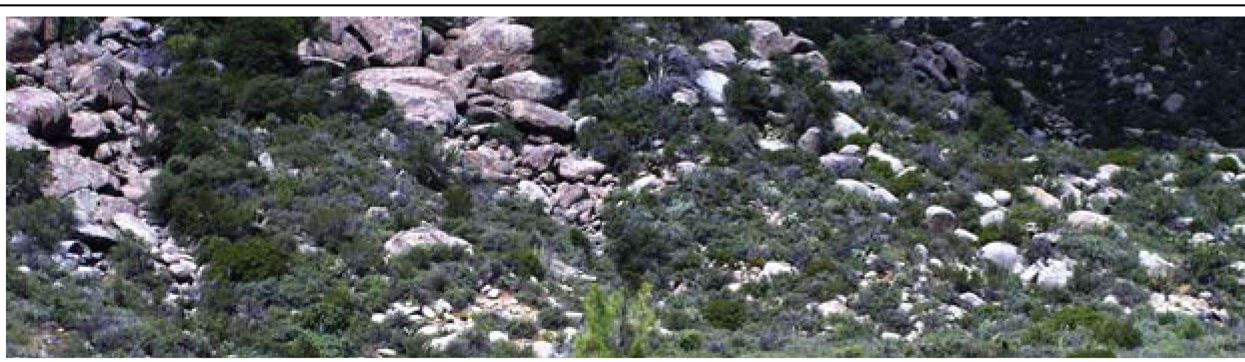


Figure 2. Frequent rock outcrops are scattered throughout the Yarnell Hill Fire area

Fuels: The fire area was characterized by chaparral type brush (Figure 3) consisting primarily of turbinella oak (Quercus turbinella), catclaw acacia (Acacia greggii), manzanita (genus Arctostaphylos), and scattered juniper (Juniperus deppeana). The brush varied in height from three to eight feet depending on site conditions. The drainages on the site tended to have better soil conditions and higher soil moisture than the surrounding soils, and had thicker and taller vegetation than the surrounding areas. The last documented fire in the area was 1966. All of these conditions combined to produce very dense stands of chaparral, characterized by substantial fuel continuity, both horizontally and vertically, which supported increased potential fire rate of spread and intensity, and introduced increased challenges to firefighter mobility. There was also a heavier than average cured grass component in the fuel complex due to abundant rain during the 2012 monsoon season.

Figure 3. Fuel complex typical of the Yarnell Hill Fire area

On June 30, fine dead fuel moistures were 6% for shaded fuels and 3% for non-shaded fuels. The calculated probability of ignition was 60% in the shade and 90% in non-shaded areas.

Live fuel moisture measurements taken five miles from the fire location indicated varying levels of deviation from average. Ceanothus and mahogany had much lower than average moisture contents while juniper and oak were at or slightly above average.

Climate: No weather stations in Yarnell have current and long-term weather data, so two sources of weather data were used. These weather stations are the Stanton Remote Automated Weather Station (RAWS) and the weather station at Prescott's Love Field. Stanton RAWS is approximately 4 miles south-southeast and 1,200 feet lower than the town of Yarnell. Love Field is 40 miles northeast of and 245 feet higher than the town of Yarnell.

Precipitation	Previous 12 Months			April, May and June Total		
	Average	7/12-6/13	% of Normal	Average	2013	Percent of Normal
Stanton	10.35	11.91	115%	0.73	0.12	16%
Prescott	13.97	10.41	75%	1.35	0.13	10%

Table 1. Average annual precipitation for the general Yarnell Hill Fire area (Source: Stanton RAWS and Prescott Love Field)

Climate data indicates a non-typical drying trend that began in the Spring of 2012 (Table 1).

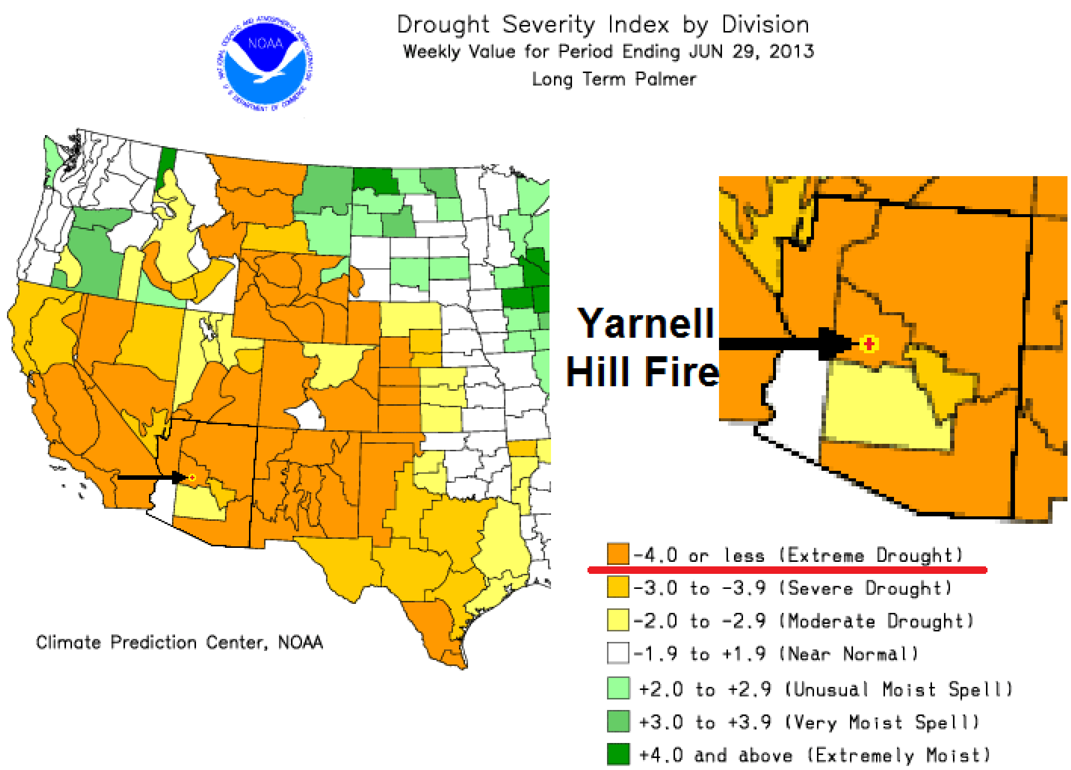


Figure 4. Drought severity on June 29, 2013.

The Drought Severity Index showed the fire area as being in "extreme drought" on June 29, 2013, one day before the entrapment (Figure 4).

By mid-June, fuel conditions had become enough of a concern that the Predictive Services Section of the Southwest Coordination Center issued a Fuels and Fire Behavior Advisory concerning fire behavior potential. It included a section titled "Concerns to Firefighters and the Public":

- Surface fire will quickly transition to crown fire and only requires low to moderate surface fire intensity to transition.
- Active/running crown fire has produced long range spotting up to one mile under the influence of an unstable atmosphere.
- Active fire behavior can extend well into night and early morning hours even with moderate RH recovery.
- Thunderstorm activity will create a mosaic pattern of surface fuel moistures. Surface fire intensity and fire behavior may change abruptly when fires cross these boundaries of moist and dry surface fuels.

Weather: The Southwest region of the United States experiences a weather phenomenon known as the Summer Monsoon. The monsoon period represents a switch in wind patterns from a drier westerly flow to a moist southerly or easterly flow. This typically occurs from mid-June through mid-July and generally lasts into September. During the initial stages of the monsoon, drier thunderstorms are dominant but generally give way to larger footprints of wetter storms. Gusty outflow winds dominate the drier thunderstorm period. Storms typically form over the higher terrain such as the Mogollon Rim and then try to move off the higher terrain as the day progresses. Terrain features pertinent to thunderstorm formation include the Bradshaw Mountains and Mogollon Rim. There is typically a one to two-week period when the moisture shift is dynamic and provides highly variable weather.

Temperatures are typically hot just prior to and during this transition. Relative humidity values will start out low and then fluctuate widely as storms and cloud cover become more numerous. Winds are highly variable during this period with highest wind speeds tied to thunderstorms. These winds, known as downdrafts, micro-bursts, outflows, and gust fronts, generally deliver erratic wind shifts and short bursts of strong speeds.

The dynamic monsoonal transition started the last week of June. On June 28, widely scattered thunderstorms formed over the Mogollon Rim. The cells tracked southwestward bringing cloud-to-ground lightning to the Yarnell area (Figure 5). The region was in its initial stages of a significant heat wave prior to the thunderstorm. The Phoenix airport, about 110 miles southeast of Yarnell, reported a high of 110^{o}F, 4^{o} above normal. The fire area reported high temperatures between 101^{o} to 107^{o}F. Humidity was low, ranging between 8 to 10 percent.

During the thunderstorm on June 28, temperatures fell and humidity values rose. The Peeples Valley weather-observing site seven miles north of Yarnell reported measurable rain (0.04"). Storms generally were drier and produced gusty outflow winds. The RAWS reported gusts between 38 to 43 mph during the thunderstorm passage.

Figure 5. Cloud-to-ground lightning observed between 0900 to 1800 MST, June 28, 2013. Graphic courtesy of BLM.

Temperatures increased on June 29. The Phoenix airport reported a high temperature of 116^{o}F, 10^{o} above normal and 1^{o} away from tying the record for that day. Storm coverage was lighter with less intensity than the 28. Storms did not directly affect the fire area although they did affect an area near Prescott, 27 miles northeast of Yarnell, during the late afternoon to early evening. Humidity values were again low, generally ranging from 9 to 10 percent that afternoon. Winds took on a typical south-southwest orientation turning more west-southwest during the afternoon. Sustained values generally ranged between 10 to 15 mph with gusts in the 20s at times.

Figure 6. Doppler radar image from June 30 at 1200 MST. Graphic courtesy of NWS-Albuquerque

The morning of June 30 was warm and dry. Maximum relative humidity usually occurs at night when the temperatures are the coolest but overnight relative humidity recoveries were poor, ranging from 25 to 35 percent. Minimum temperatures across the broader fire area ranged between the mid 70s to mid 80s. The Phoenix airport recorded a low temperature that was 10^{o} above normal. Warm overnight temperatures and poor humidity recoveries are two critical fire weather indicators for daytime significant fire growth across the Southwest. Wind speeds were low overnight.

The Phoenix and Flagstaff National Weather Service (NWS) offices released routine weather balloons to capture atmospheric profiles of temperature-humidity and winds at 0400 MST. These balloons reported increased moisture and instability across the middle portion of the atmosphere, indicating potential for thunderstorm development and a high likelihood for strong downdraft winds and subsequent outflows.

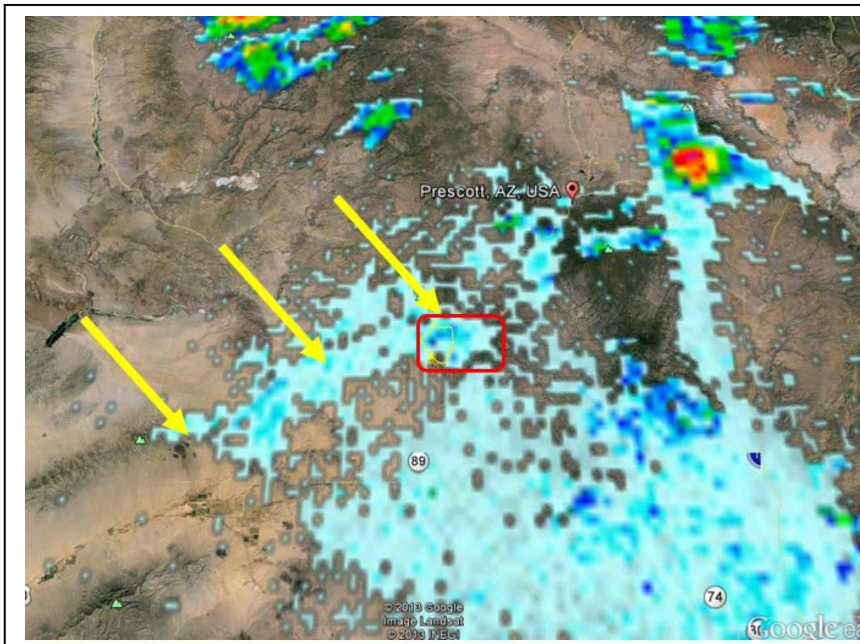


Figure 7. Desert thermal boundary detected by FAA radar at 1332 MST.

As the morning progressed, temperatures increased and humidity values dropped. The observed southerly wind flow was typical for the area. By late morning, field personnel noted cloud buildups to the north. By 1200, temperatures were in the mid to upper 90s under full sun conditions with humidity values ranging from the upper teens to around 20%. The Flagstaff Doppler radar indicated a broken line of thunderstorms extending from near Flagstaff southeast to Forest Lakes along the Mogollon Rim (Figure 6). These storms were moving towards the west-southwest. Red colors indicate the most intense storms.

Between 1200 to 1300 MST, Federal Aviation Administration (FAA) radar detected the formation of a weak but discernible boundary west of the fire location. Boundaries indicate changes or discontinuities in the atmosphere that can include changes in temperature, humidity, or wind. The boundary was orientated southwest to northeast. The boundary may have formed due to the intense heat coming off the surface, terrain interactions, and significant mid-level wind shear found above. The Flagstaff Doppler radar did not detect the boundary, indicating it was shallow.

The boundary sharpened and slowly progressed over the fire area between 1300 to 1330 MST. The yellow arrows on Figure 7 show the boundary in relation to the fire area (yellow line) at 1332 MST. The boundary appeared to create instability above the fire and it caused a slight decline in humidity and a slight rise in temperature. The winds increased and flow fluctuated, becoming westerly, especially near the north end of the fire area. Table 2, a synopsis of Peeples Valley weather observations between 1209 to 1509 MST, shows the boundary-induced changes in temperature, humidity, wind speed, and direction over time. The boundary coincided with an increase in fire behavior according to fire personnel interviewed. The red box in Figure 7 shows a weak smoke signature and a strong thunderstorm to the east of Prescott with weaker cells developing over the Bradshaw Mountains.

Table 2: Peeples Valley Observations Between 1209 to 1509 MST, June 30, 2013

Peeples Valley	Temperature (˚F)	Relative Humidity (%)	Wind speed (mph)	Wind direction
1209	97	18	6	SSW
1224	98	18	6	SW
1239	97	18	6	WSW
1254	97	17	11	SSW
1309	98	17	4	SW
1324	99	15	10	WNW
1339	98	16	7	WSW
1354	99	17	17	W
1409	99	15	12	W
1424	98	16	14	W
1439	98	17	17	SW
1454	96	15	15	W
1509	96	15	11	WSW

At 1500 MST, the FAA radar showed a slight shift in the Desert Thermal boundary towards the east and south with some weakening based on radar returns. A line of thunderstorms over the Bradshaw Mountains to the north and northeast moved towards the fire area, darkening the skies. Temperatures remained around 100° with humidity values between 14 and 20%. West-southwest winds continued, but were somewhat variable based on field reports. Figure 8 shows the lightning between 1300 and 1530 as the storms were tracking west-southwest. It was during this time that a fire official, responding to the Yarnell Hill fire from Prescott, recalled driving through an intense thunder cell between Prescott to Skull Valley along Highway 89. Intense rain significantly lowered his visibility. This person also observed strong winds from the pass into Skull Valley below.

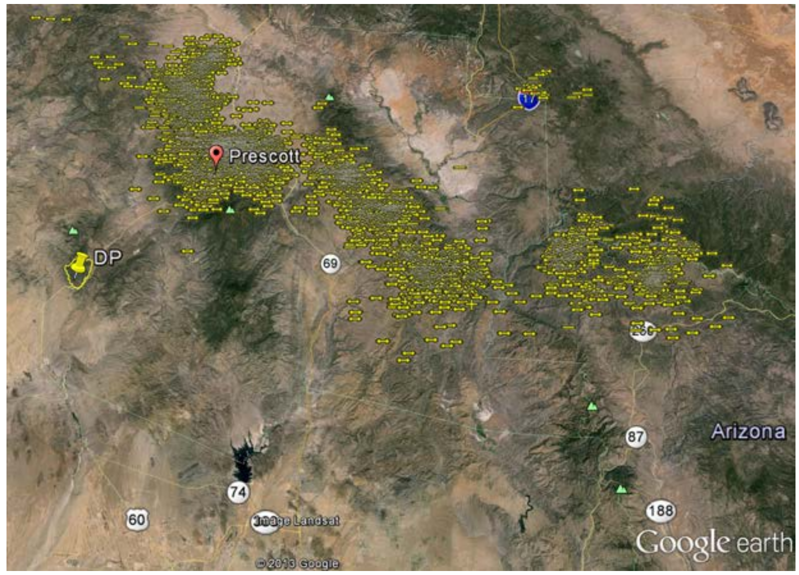


Figure 8. Thunderstorm generated lightning activity 1300-1530 MST. Image courtesy of Earth Networks

From 1500 to 1530 MST, the FAA radar showed an outflow boundary originating from the thunderstorms to the northeast. An outflow boundary, or gust front, is the leading edge of an outflow wind system caused by downdrafts from cumulonimbus clouds. It acts similarly to a cold front, bringing a wind shift and usually a drop in temperature. The yellow arrows on Figure 9 show the outflow boundary has raced out ahead of the parent line of storms towards the fire

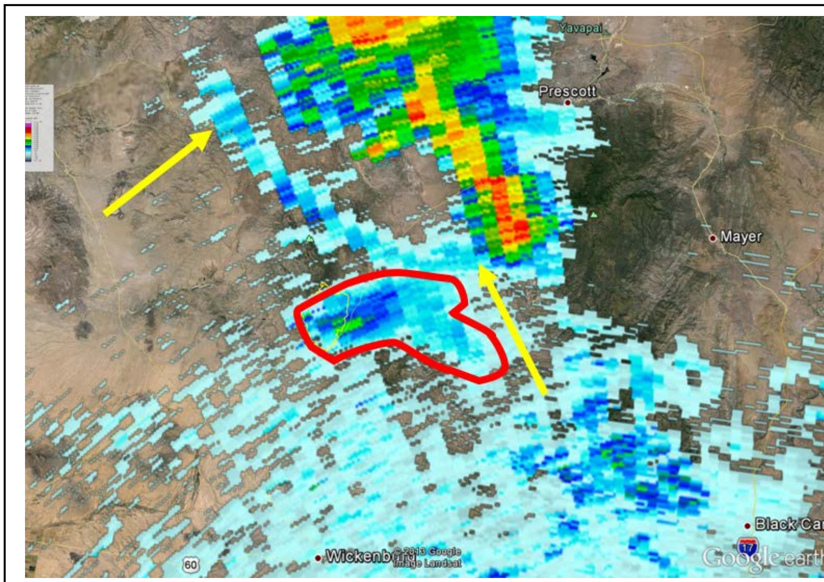


Figure 9: FAA radar detects a distinct outflow boundary at 1604 MST moving towards the fire area.

area at 1604. The red shape shows the fire plume. After this movement, the original line of storms slowly began to weaken. Lightning trends associated with this decaying line of storms showed no change in location. Skies remained dark towards the north and northeast and field personnel would have had a harder time gauging storm movement and the potential threat to the Yarnell area.

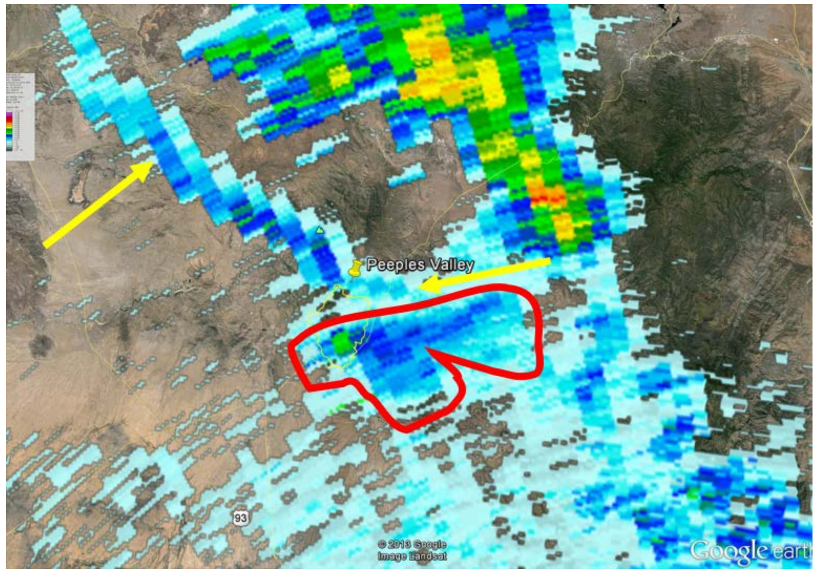


Figure 10. FAA radar detects an outflow boundary very near the northern end of the fire area at 1618 MST.

As the outflow boundary approached the fire area, the wind field gradually shifted to the west-northwest, pushing the fire towards the east-southeast. At 1618, the FAA radar showed the outflow boundary nearing the northern most end of the fire area (Figure 10). The boundary had traveled 16 mph, covering 13.5 miles in 50 minutes. The mid and upper-level winds influencing the smoke plume had also begun to shift. The red shape in Figure 10 shows the smoke plume. Two fingers of concentrated smoke had begun to develop by this time.

Around 1620 MST, field personnel near Highway 89 in the Yarnell area began to hear thunder, and shortly afterward noted spritzes of rain or mist mixed with ash. The Earth Networks Total Lightning Network verified the thunder, showing two in-cloud lightning flashes at 1620 (Figure 11).

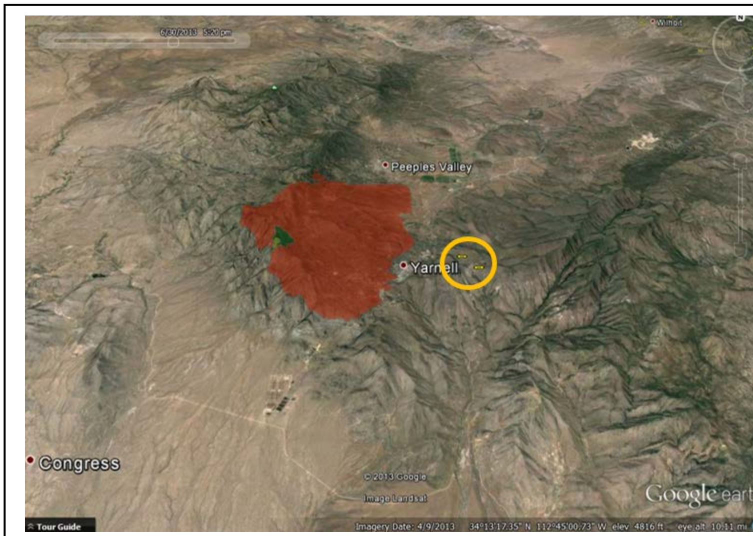


Figure 11. Earth Network's in-cloud lightning detection on a Google Earth map at 1620 MST.

Meteorologists use Doppler radar to detect thunderstorm height, generating imagery called echo-top data. The imagery, which the general aviation community uses for monitoring trends in thunderstorm intensity, can help detect trends in fire behavior based on smoke plume development. The Flagstaff Doppler radar showed an increase in plume height shortly after the outflow boundary initially passed, likely indicative of increased fire behavior.

At 1624, Doppler radar indicated a 31,500-foot MSL plume top. By 1633, the plume top (Figure 12) had pulsed up to 38,700 feet. The plume during this time began to shift towards the southeast (yellow circle on Figure 12) as the outflow boundary crossed the northern half of the fire area. The NWS uses Doppler radar to detect various kinds of moving particles in the atmosphere. At 1629, the Flagstaff Doppler radar showed a distinct contrast between the smoke plume and the approaching shower band (Figure 13). The main smoke plume, indicated by blue and white colors, shows a shift towards the south-southeast. The red and yellow colors indicate mixed precipitation such as ice crystals and water droplets to the north and east of the fire area. The line of thunderstorms that had initially affected the Bradshaw Mountains and Prescott area the past few hours had weakened and turned into higher-based showers and virga.

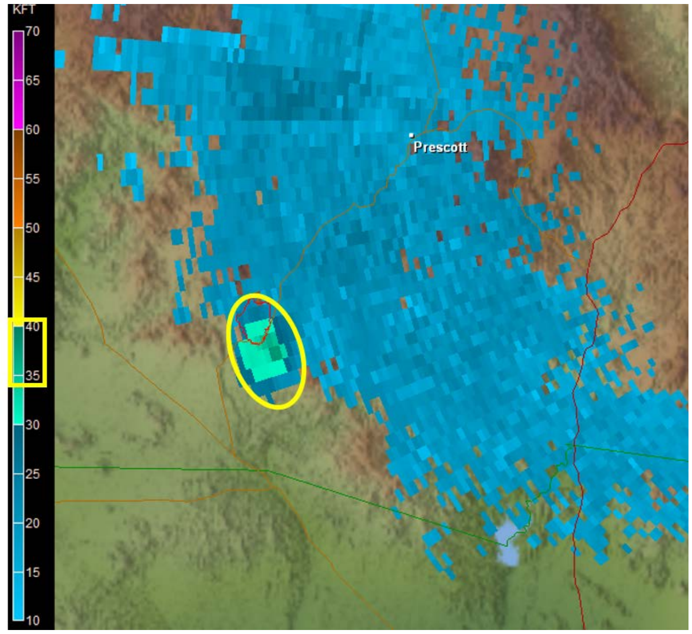


Figure 12. NWS Flagstaff Doppler radar echo-top image 1633 MST

The FAA radar at 1630 showed the outflow boundary draped across the southern end of the fire area. Yellow arrows on Figure 14 show the boundary. A photo taken by a professional photographer showed the outflow boundary initially cresting the ridgeline at 1639 (Figure 15). Another photo taken at 1642 (Figure 16) shows the outflow boundary spilling over the ridgeline further south of the initial crest.

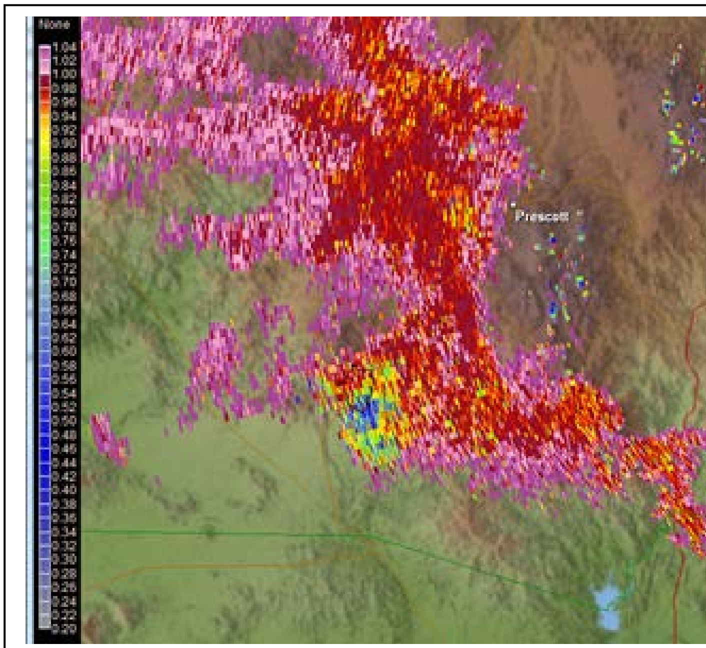


Figure 13. Specialized Doppler radar image showing moving particles in the atmosphere at 1629 MST

During 1643 to 1652, the Flagstaff radar showed significant growth in the fire column. The top of the fire column grew from 32,800 to 40,000 feet MSL. This was the peak value observed by the Doppler radar on June 30. A satellite image provided by the Cooperative Institute of Meteorological Satellite Services showed a well-formed pyro-cumulus punching through the mid-level cloud deck that had overtaken the fire area at 1645 MST. The red circle in Figure 17 shows the pyro-cumulus cloud.

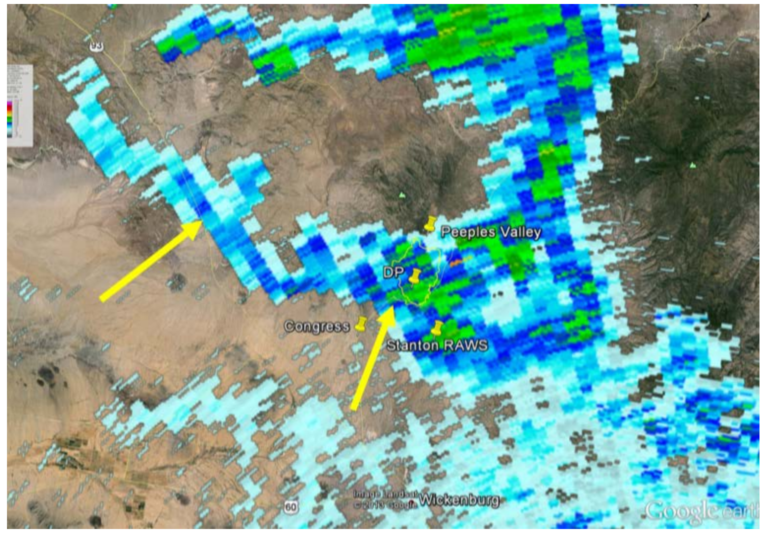


Figure 14. Outflow boundary on FAA radar at 1642 MST.

Temperatures between 1600 to 1700 MST declined slightly while humidity values rose following the outflow passage. Winds increased substantially and direction changed from out of the west-northwest to out of the north-northeast. Based on weather-observing equipment and interviews, the wind speed varied significantly. Wind speeds associated with the outflow boundary generally ranged between 30 to 40 mph, with gusts recorded as high as 43 mph at the Stanton RAWS. Stronger wind most likely would have occurred across portions of the fire area due to fire plume dynamics and terrain channeling. During this intense fire period, the smoke column began to rotate, and may have been rotating in two locations.

Figure 15. Initial outflow signature northeast of Congress, Arizona at 1639 MST. Photo courtesy of Matt Oss Photography.

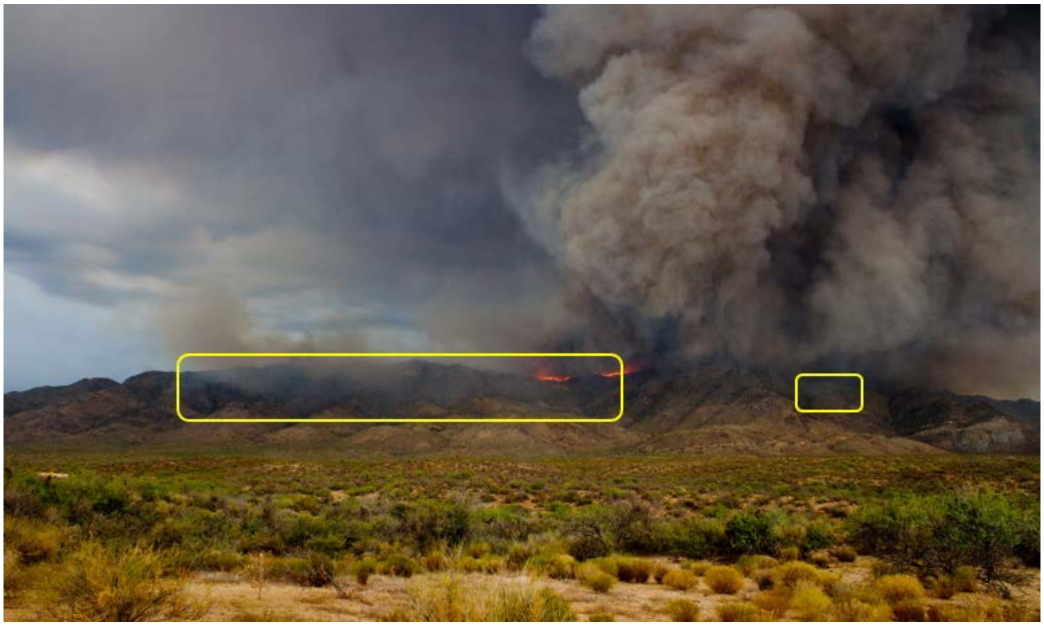


Figure 16. A more pronounced outflow signature is observed over the ridgeline Northeast of Congress, Arizona. Photo courtesy of Matt Oss Photography.

The post-fire analysis included asking some field personnel whether they had noted any helpful weather indicators. Traditional Southwest area indicators include lightning trends, cell movement and buildups, as well as blowing dust as a precursor to potential erratic and strong winds. The above-normal and continuous grass crop in the area reduced the amount of barren or open ground lowering the potential for raised dust. Radar analysis up until 1430 MST showed distinct and singular thunder cell development to the north and east of the fire area. This activity would have been easier for the fire crews to visually track, especially personnel on a ridgeline. After 1430, a long line of storms formed to the north and northeast and the skies would have shown less contrast. One interviewee mentioned, “It was dark to the north all the way to the horizon and grey above.” As the outflow boundary raced towards the fire location between 1500 to 1600 MST, the parent line of storms lagged several miles behind. Various lightning

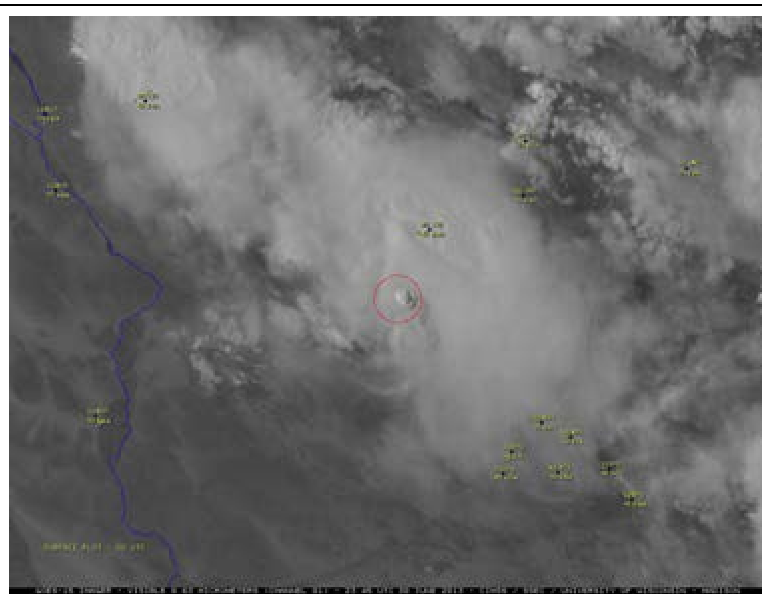


Figure 17. Visible satellite image at 1645 MST.

detection systems showed lightning flashes within the parent storms, but lightning strike locations and trends would not indicate a significant change in storm movement. Field personnel, using traditional visual indicators, would not easily have noted the approaching outflow boundary.

Some indicators appeared after 1600. Subtle indicators included the gradual change in wind direction as the boundary approached (west-northwest) as well as a brief lull just prior to the outflow passage. Distinct indicators included an abrupt change in wind direction and speeds, referred to as "ripping" when the outflow boundary hit the northern end of the fire. Other distinct indicators included "spritzes" of rain, thunder, and some flashes of lightning (both cloud-to-ground and in-cloud) that coincided with the rapidly increasing fire column and fire behavior.

FIRE BEHAVIOR

Local firefighters shared that, in their experience during a "normal" year, a strong wind is required to support active fire spread in the Arizona chaparral, but that this year was not a normal year. Prior to the Yarnell Hill Fire, local firefighters had been observing higher fire intensities and rates of spread on other fires. Two contributing factors that can help explain these observations are:

- Above-average loading of cured grass fuels which increased the horizontal fuel continuity
- Drought-stressed live fuels

These factors combined to allow for faster-moving fires, with or without winds, and for increased fire intensities and flame lengths.

The Yarnell Hill Fire exhibited problematic fire behavior almost from the start. Active fire behavior on the flanks and heel of the fire where there were continuous fuels hampered initial attack. At one point, the fire burned over a cache of food, water, and other equipment.

Early in the morning of June 30, fire activity was minimal. Mid-morning burning activity picked up due to a south wind. Variable winds caused the fire flanks to increase and decrease in activity, best described as pulsating in character. The fire began to spread to the north, eventually accelerating to one mile per hour. Flames at the head were 15 to 20 feet in length. By noon, the fire was a long finger that had moved approximately two miles to the north.

Around 1200, the wind developed a partial westerly component and the fire started moving northeast toward the Incident Command Post in Peeples Valley. By 1500, the wind shifted to out of the west, and the east flank transitioned into a two-mile wide head of flames. The northern and southern perimeters continued to spread as flanking fires.

An outflow boundary originating from a line of thunderstorms to the north-northeast swept over the fire area approximately between 1618 to 1630 MST. The outflow boundary moved from north to south affecting the fire area near Peeples Valley first. The effect on the fire was immediate and impressive. The primary fire spread direction changed to the south; fire intensities and resulting flame lengths doubled while rates of spread tripled. What had been problematic fire behavior became extreme.

The fire made a major run into the town of Yarnell. The fire reached the west side of the main part of town and then moved through the southern Glen Ilah neighborhood.

These changes dramatically affected the fire in the flatter terrain east of the origin. It moved from along the base of the main ridge and reached the bottom of the middle bowl, one-half mile south-southeast of the origin, and split into two heads. The southern head entered an unnamed drainage that this report refers to as the “middle bowl.” The northern head continued burning along the base of the ridge. (Figure 18)

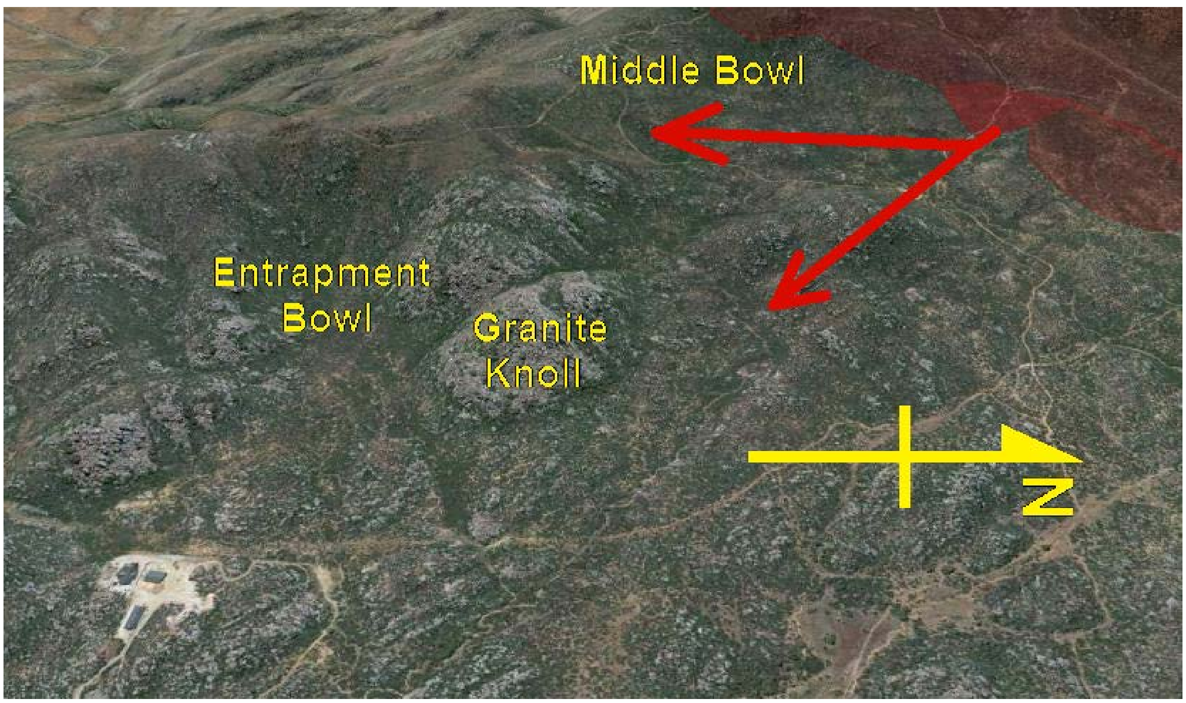


Figure 18. Fire splitting with south head entering the middle bowl and north head moving toward the entrapment bowl.

The fire entered the middle bowl and moved southwest. The middle bowl, a natural chimney, funneled the fire at a rapid rate of spread toward the top of the ridge. A professional photographer took a series of time-lapse images from a location near Congress and compressed 20 minutes of images into a 16-second video. The footage captured vortices that developed in the smoke. The fire crested the ridge top and was described as a “dragon’s tongue” by one of the aircrews in orbit over the fire. Estimated flame lengths were 150 to 200 feet above the ridge top (Figure 19).

Figure 19. Fire cresting the ridge top as seen near Congress, Arizona. Image courtesy of Matt Oss Photography.

The in-draft from the fire in the middle bowl temporarily slowed the advance of the second head. The second head continued southeast from the base of the middle bowl, around a granite knoll. Once past the knoll, the fire accelerated into the deployment bowl. A drainage bottom exits the bowl to the northeast, which was the direction of approach by the main fire. This drainage bottom would have had thicker stands of chaparral capable of supporting much higher fire intensity. The drainage was also parallel with modeled wind vectors that would have resulted in increased rates of spread. The fire accelerated a second time as it entered the deployment bowl and winds aligned with the drainage, funneling to increase velocities (Figure 20). The estimated time between the sighting of the fire front from the deployment site to the time the fire reached the deployment site was less than two minutes.

Fire behavior estimates for the deployment site is a rate-of-spread of 10 to 12 miles per hour with flame lengths of 60 to 80 feet. The effect of uneven terrain on wind speeds caused variability in fire spread and intensity. A combination of factors influenced wind speeds in and around the deployment site, including general outflow winds, topographic channeling and eddying, and the influence of the fire’s convective heat. Evidence found at the site indicates that the combined influences resulted in winds causing flames to impinge the entire deployment site. The fire front continued past the deployment site and topped out at the crest of the ridge, merging with the fire from the middle basin.

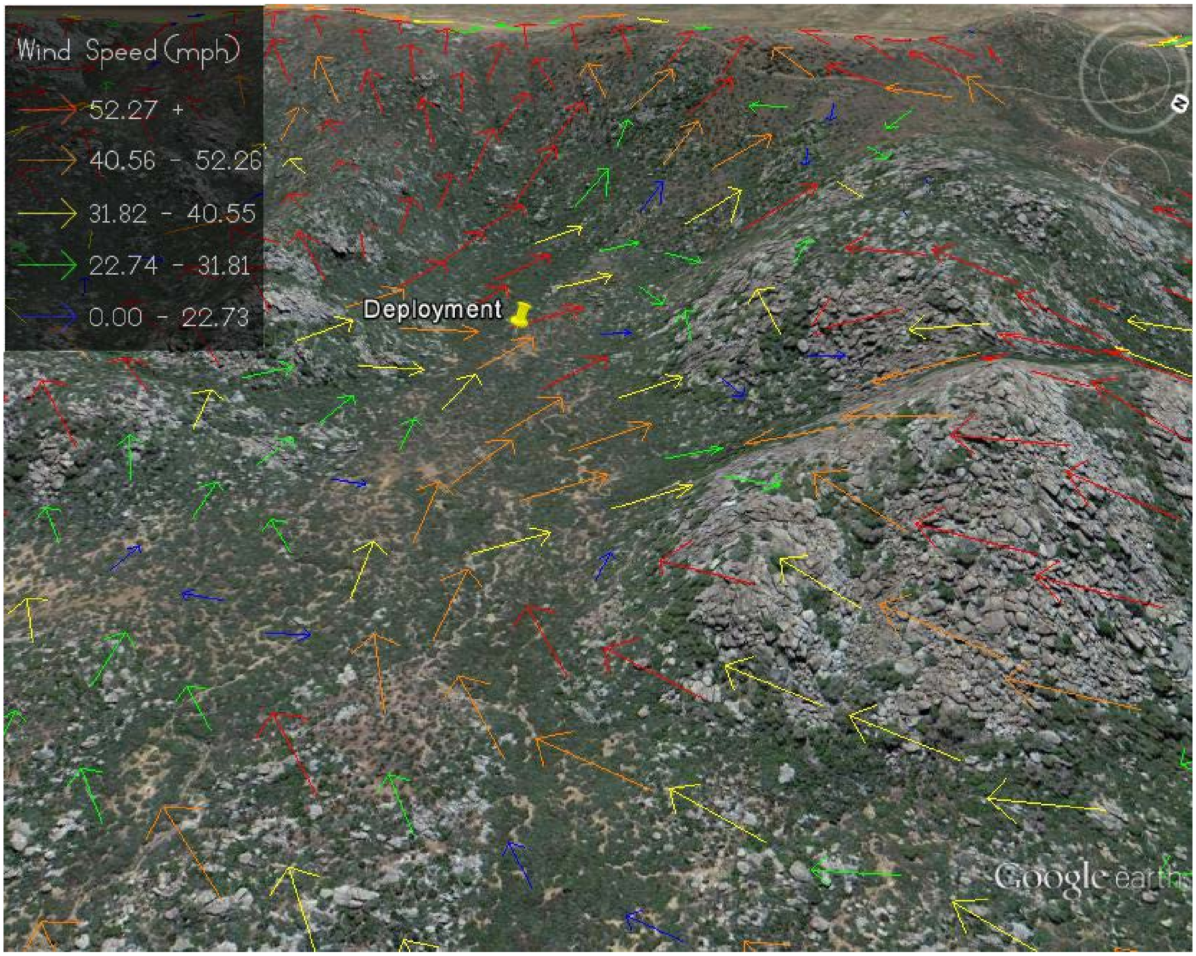


Figure 20. Wind vectors around the deployment site modeled using WindWizard

The fire shelter deployment was at a time and in a location where all fuels, weather, and topography aligned to produce rapid rates of spread, long flame lengths, flames being bent to nearly parallel with the surface, and extreme heat estimated at 2000°F. The fire shelter deployment drainage showed evidence of these extreme conditions throughout.

METHODOLOGY

Winds: The WindWizard simulates wind flow under different general (synoptic) wind speed and direction scenarios based on user-specified parameters. It is a gridded wind model that uses computational fluid dynamics to generate information about the effect of topography on local wind flow. WindWizard generates a predicted wind speed and direction at a user-specified height above the ground (i.e., 20 feet) useful for mapping of surface behavior. For this simulation, the program calculated wind speeds at 20 feet above the assumed vegetation (brush/shrubs) and output the speeds in miles per hour. Wind direction, output in degrees, represented the direction the wind came from. The fire behavior/weather team for the investigation received outputs in multiple formats, including Google Earth KMZ files, GIS-ready shape files, and ASCII Grids.

Fire Behavior Experts created an estimate of the Yarnell Hill Fire behavior using various methods:

Figure 21. Extreme heat in the fire shelter deployment area caused this granite boulder to spall (flake).

1. **Eyewitness accounts.** Interviews of many personnel assigned to the incident included time and location of significant weather and fire behavior events.

2. **Photographic images and videos.** Numerous individuals documented fire activity during the Yarnell Hill Fire. Many still digital images had time stamps. Photographs have varying degrees of precision in time stamps so experts used images taken at verifiable times showing a locatable feature on the fire perimeter to document fire location and activity. Many digital photographs may be geo-referenced if the device that takes them has location tracking enabled. Where possible, the team used geo-referenced information to ascertain locations for photographs. This information was very valuable in determining locations, views, and fire activity and was useful in validating fire perimeter reconstruction. Other images lacking credible time stamps and/or geo-reference information were validated through a comparison with Google Earth pre-fire images, visible landmarks, and known time-stamped photographs to add information about fire perimeters.

3. **Remote Sensing.** The team modeled fire perimeters and intensities using remote sensing. US Forest Service National Infrared Operations imagery taken from nighttime flights supports daily fire growth documentation. The satellite-based Moderate Resolution Imaging Spectroradiometer system heat imagery helped to verify fire locations at various times.

4. **Modeling Rates of Spread and Fire Intensities.** The team used the BEHAVE Plus program and the embedded Short Term Fire Behavior Model in the Wildland Fire Decision Support System to model fire behavior. Inputs were from site visits, fuels data, the closest RAWS, fireline weather observations, local fuels information, and wind models. Photographic time-stamped information corroborated fire locations, active flaming fronts, and smoke columns around the fire and pinpointed on the landscape. This verified fire behavior modeling, specifically rate of spread and flame length.

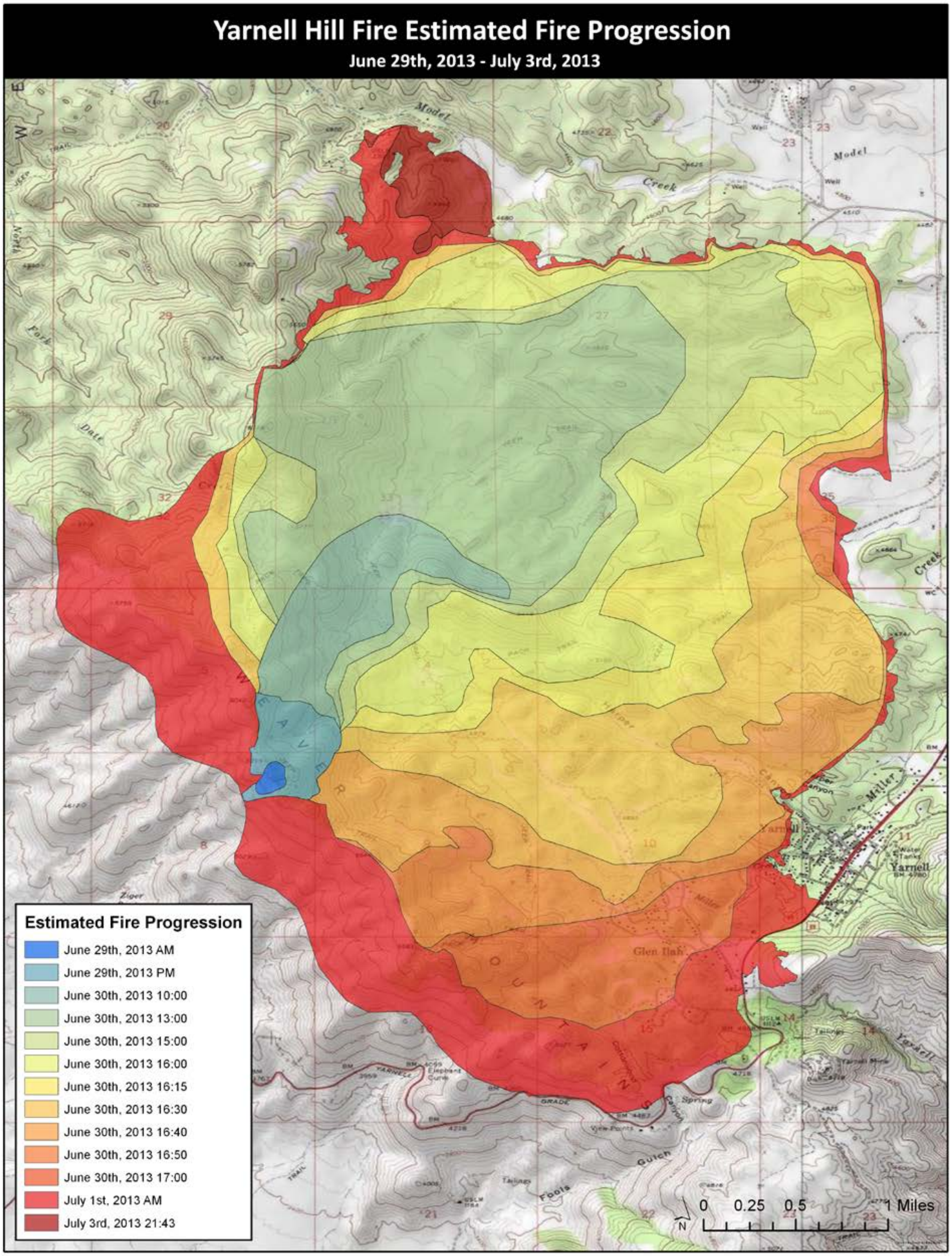


Figure 22. Yarnell Hill Fire Progression Map, June 29 through July 3, 2013.

Appendix C: Personal Protective Equipment Analysis

Note: This appendix contains graphic information. Reader discretion is advised.

INTRODUCTION

PPE Inspection: This report compiles information from accident site visits, examination of photographs of the site taken by the Yavapai County Sheriff's Department and the accident investigation team, and inspections of recovered personal protective equipment (PPE). All PPE inspections occurred at the Yavapai County Sheriff's Office Evidence Building. The condition of fire shelter materials is expressed in percentage of the item burned away. This was done by using visual estimates.

Fire Shelter Construction: The fire shelter is made of two separate layers of laminated material. The outer shell is aluminum foil laminated to a silica cloth; the inner shell is aluminum foil laminated to a fiberglass cloth. The floor of the shelter is a silica cloth laminated with aluminum foil on both sides. The shelter is sewn with both fiberglass and quartz thread.

Figure 1. The fire shelter is constructed to be rounded.

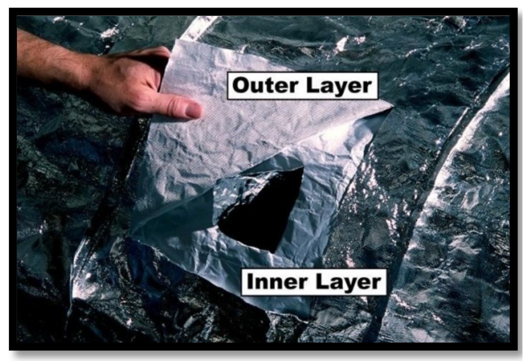


Figure 2. The fire shelter consists of two layers.

Deployment Site: Satellite imagery shows heavy brush surrounding the deployment site before the fire. There appear to be very few, if any, survivable shelter deployment sites within the general location of the deployment site (Lat 34 13.228, Long -112 46.654).

Figure 3. Satellite photo of shelter deployment site

Figure 4. Representative brush of the area

DISCUSSION

Deployment Site Preparation:

In radio transmissions, the crew superintendent stated they were preparing a deployment site and burning out around the crew. Chainsaws were audible in the background and it is clear the crew was taking steps to improve the deployment site. Burning out and removing brush would make the deployment site larger, which would improve their chances of survival. From their first known radio transmission at the deployment site (where chainsaws can be heard) to the last known transmission, less than 2 minutes transpired.

A chainsaw gas/oil bottle was found by itself 30 feet from the north corner of the deployment site. This particular bottle was not ruptured, in contrast to most fuel bottles found in and around the deployment site. In addition, another bottle was found by itself off the south corner of the site and some fusees without ignition caps were found to the northeast of the site. The crew may have used these gas/oil bottles and fusees during a deployment site burnout attempt.

There were up to eight sawed brush stumps of one to two inches in diameter found on the northeast and southeast sides of the deployment site. The fire most likely consumed the ends of the smaller cut brush. There were three saws found 20 to 40 feet off the southeast and east side of the deployment site. The furthest cut brush stump is approximately 45 feet from the east corner of the site.

The estimated fire rate of spread near the deployment site was about 11 miles-per-hour. At this rate, the fire front would have travelled 100 yards in about 19 seconds. It takes a well-trained firefighter approximately 15 to 25 seconds to deploy a fire shelter from pulling the shelter PVC bag tear strip to fully deployed.

After the last heard radio transmission from Granite Mountain, there were several audible radio squelch breaks of unknown origin and radio frequency. It is unclear if anyone from Granite Mountain IHC made radio transmissions while inside their fire shelter.

Fire Shelter Deployment:

A few packs were thrown clear of the deployment site, but some fireline packs with fusees and saw gas and oil, hand tools, and a chainsaw were found throughout the deployment site. Some firefighters lied on or directly next to some of these items.

Nine firefighters were wearing gloves.

Seven firefighters were found inside fully deployed fire shelters. Another four firefighters were inside their shelters mostly deployed. Eight of the firefighters were found with partially deployed shelters; five of the eight were outside of their shelters, lying supine. The evidence is unclear as to whether the partially-deployed firefighters were in the process of deploying their shelters when they were overtaken, or if they were fully deployed inside their shelters and then attempted to move with the shelter or attempted to exit the shelter.

Figure 5. The area northeast of the deployment site contained sawed and burnt brush stobs, and the burned remnants of a hand tool, chainsaws and packs.

During a shelter deployment, it is normal to see higher temperatures at the end facing the oncoming fire than on the lee side of the shelter. In this case, the condition of the shelters does not indicate a difference between the two ends. The only difference seen was among the fully deployed fire shelters; the firefighter clothing from the east corner had a higher amount consumed by fire versus the firefighter clothing from the west corner. This evidence would suggest the west corner received slightly less intense heat and flame exposure than the east corner of the deployment site.

Two Fire Shelter PVC Bags were recovered from the deployment site; it appears that those two bags functioned as designed.

Rescue and Recovery:

The Department of Public Safety officer who confirmed the fatalities reported that he checked the condition of each firefighter who was deployed in a fire shelter. Some of the shelters' conditions (e.g. seam separation, tears, and holes to the brittle material) likely happened during this check as well as during body recovery.

Condition of Fire Shelters:

All firefighters were equipped with the required fire shelter made to Forest Service specification 5100-606 (M-2002).

The temperature and flame contact during this event burned away much of the aluminum foil and fiberglass cloth. Much of the remaining fiberglass cloth was very brittle. The remaining silica cloth was generally intact, though many areas were brittle. The fiberglass and quartz thread were also brittle, which allowed seams to come apart. The violence of the fire motion and air turbulence during the event as well as the disturbance during rescue and recovery worked to break apart the seams when both the thread and cloth became too brittle to hold.

Figure 6. The burned remnants of a fire shelter that was recovered from the Yarnell Hill Fire deployment site shows signs of extremely high heat. The photo was taken during equipment inspection.

Flame-Resistant Clothing and Protective Equipment:

The Individual PPE Analysis section of this appendix lists all items of PPE recovered with each firefighter. The inspected clothing appeared to have been appropriate, according to NWCG standards. All the inspected pants appeared to meet Forest Service specification 5100-92, Type II – para-armid (Kevlar) blend. All inspected shirts appeared to be made of meta-aramid (Nomex) blend cloth.

Tools:

The fire totally consumed many wooden tool handles, leaving only the metal parts of the tools. Tool handle areas that were covered by firefighters and shelters remained uncharred. Fiberglass fibers were all that remained of tool handles constructed of fiberglass composite.

SUMMARY

Several observations point to a very rushed shelter deployment:

1. The firefighters needed to take time to saw brush and burnout around the deployment site prior to deployment.
2. The furthest saw cut was only 45 feet from deployment site.
3. Fireline packs with fusees and chainsaw gas and oil bottles, hand tools, and a chainsaw were left within the deployment site.
4. Ten firefighters were not wearing gloves.
5. Seven firefighters were fully deployed inside shelters, while 12 firefighters had shelters either mostly or partially deployed.
6. Not all firefighters deployed shelters with their feet toward the oncoming fire.

7. In the vicinity of the deployment site, the fire front travelled an estimated 100 yards in 19 seconds.

Winds modeled in excess of 50 miles-per-hour pushed a flaming front that was very deep and turbulent. Flame lengths, estimated at 70 feet, tilted to near horizontal as the fire moved through the deployment site. Several observations point to extremely high temperatures and radiant and convective heat exposure with extremely high heat flux (rate of energy transfer). Observations include:

1. The fire's consumption of the heavy brush surrounding the deployment site left very little in the way of blackened stobs of brush.

2. Thermal breakdown of the high temperature-resistant materials used in the fire shelters.

3. No evident difference in fire exposure between the front sides versus the lee sides of the fire shelters.

4. Only slight differences in flame and temperature exposure between the leading (northeast side) and the back side (southwest side) of the deployment site.

The temperatures, heat flux, and the radiant and convective heat of this burnover appear to have been well beyond the protective capabilities of the fire shelters and protective equipment.

Figure 7. The box canyon opens to the northeast; the south end of Yarnell is visible in the distance.

Temperatures:

The table below lists temperature data corresponding to the various post-incident material conditions, as reported by manufacturers and independent testing. For human tenability, the National Research Council of Canada (NRCC) fire tests indicate that 300°F is the maximum survivable breathing air temperature, but only for short periods and in the absence of moisture.

Material	Temperature
Silica cloth – Brittle	Estimated 2000°F
Quartz Thread – Brittle	2000°F
Fiberglass – Brittle	1350 to 1610°F
Aluminum Foil – Melt	1,220°F
Aramid Cloth – Char	824°F
Aramid Cloth– Stiff/Brittle	710°F
Glove Leather – Shrinkage 45%	600°F
Foil/Shelter Cloth Bond – Delamination	500°F
Aramid Cloth Dye – Sublimation (Discolored)	400°F
Glove Leather – Shrinkage 10%	350°F
Helmet Polycarbonate – Softens	325°F
Human Tenability	300°F

Deployment Site of the Yarnell Hill Fire:

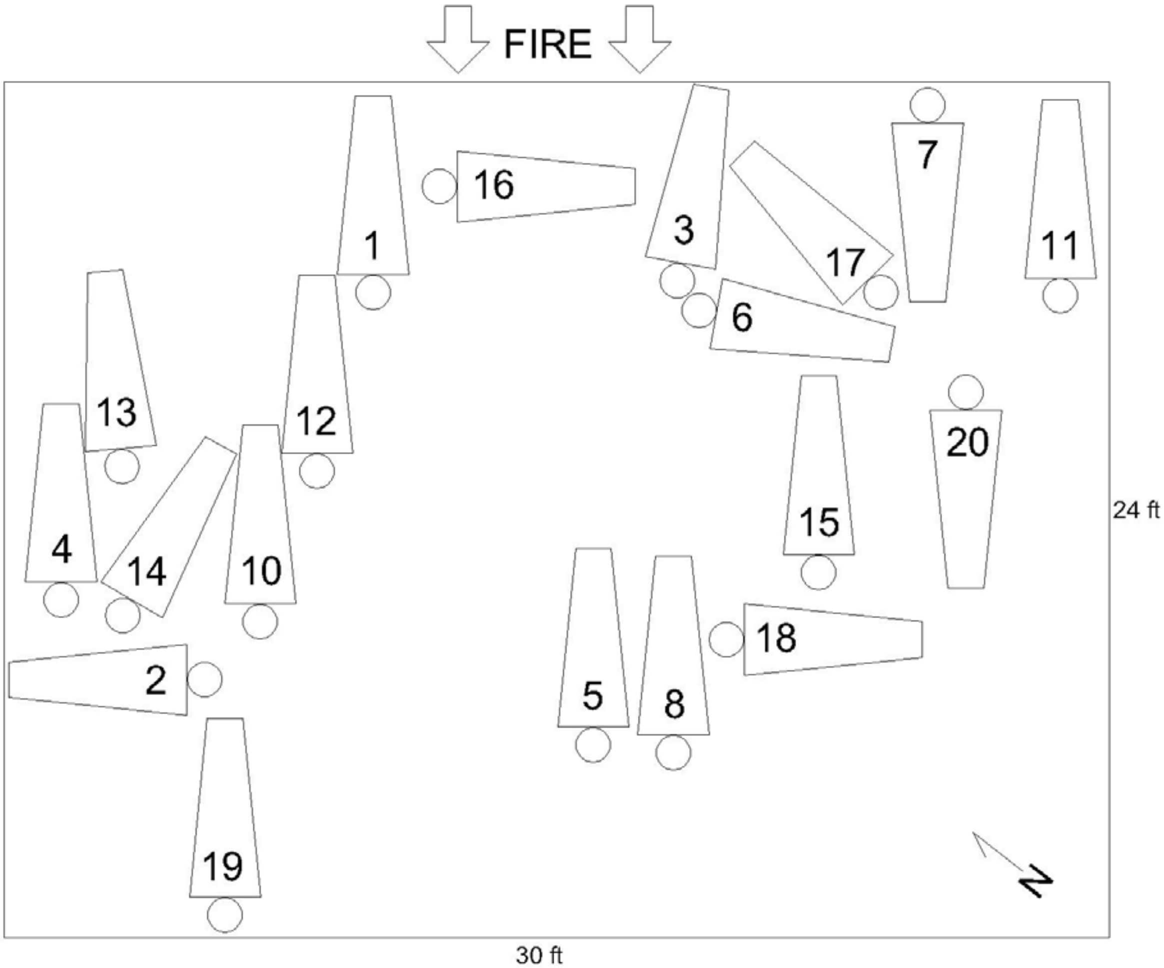


Figure 8. Body positions at the deployment site. Numbers are based on the crew manifest.

1. Eric Marsh
2. Jesse Steed
3. Clayton Whitted
4. Robert Caldwell
5. Travis Carter
6. Christopher MacKenzie
7. Travis Turbyfill
8. Andrew Ashcraft
10. Joe Thurston
11. Wade Parker
12. Anthony Rose
13. Garret Zuppiger
14. Scott Norris
15. Dustin DeFord
16. William Warneke
17. Kevin Woyjeck
18. John Percin, Jr.
19. Grant McKee
20. Sean Misner

Individual PPE Analysis:

Eric Marsh, Granite Mountain #1

1. Shelter Condition:
    a. Outer Shell: 100% of foil burned away; silica cloth brittle with numerous small holes.
    b. Inner Shell: 98% of foil burned away; 95% of fiberglass burned away.
    c. Floor: 95% of foil burned away; silica cloth brittle in some areas.
    d. Seams: End cap seam had a 20 inch separation.
2. PPE Items:
    a. Clothing: Shirt, collar, front and some sleeve intact, but was discolored and charred, the shirt back was burned away. Only pants waistband recovered.
    b. Helmet: The firefighter's red helmet was found melted on the foot end of the fire shelter of Granite Mountain #12.
3. Body Position: The firefighter was found lying prone with feet towards the northeast.
4. Shelter Use –The firefighter was not fully deployed. Feet were through the separated end cap seam, most of the shelter was found by the right side of the firefighter.

Jesse Steed, Granite Mountain #2

1. Shelter Condition:
    a. Outer Shell: 80% of foil burned away; silica cloth brittle in some areas.
    b. Inner Shell: 75% of foil burned away; 50% fiberglass burned away.
    c. Floor: 70% of foil burned away, silica cloth brittle in some areas
    d. Seams: Intact.
2. PPE:
    a. Clothing: The shirt back charred and burned away; the front area tucked into pants and parts of the sleeves remained yellow and intact. Pants, back of legs and seat charred. Much of the front of pants remained intact and green in color.
    b. Helmet: Right side of red helmet melted.
3. Body position: The firefighter was found lying prone, feet toward the northwest.
4. Shelter Use: The firefighter was fully deployed inside the shelter.

Clayton Whitted, Granite Mountain #3

1. Shelter Condition:
    a. Outer Shell: 99% of foil burned away; silica cloth brittle in some areas.
    b. Inner Shell: 90% of foil burned away; 50% of fiberglass burned away.
    c. Floor: 80% foil burned away; silica cloth brittle in some areas.
    d. Seams: Middle seam, one end cap seam, and one middle seam of floor separated.
2. PPE Items:
    a. Clothing: Back of shirt was charred and burned away; front and one sleeve was discolored, but mostly intact. Most of the pants were charred and burned away, only the front waist area remained intact.
    b. Gloves: Right glove was intact with some fingertips charred; left glove was shrunken 40%.

    c. Helmet: Melted on the back half.
3. Body Position: The firefighter was found lying prone with feet towards the northeast.
4. Shelter Use – It is unclear whether the firefighter was able to fully deploy the shelter. The firefighter was mostly deployed inside the fire shelter; the legs and back were covered by the shelter.

Robert Caldwell, Granite Mountain #4

1. Shelter Condition:
    a. Outer Shell: 98% of foil burned away; silica cloth brittle in some areas
    b. Inner Shell: 98% of foil and fiberglass burned away
    c. Floor: 50% of foil burned away. One side of floor remained mostly intact.
    d. Seams: One inside corner of floor was separated.
2. PPE:
    a. Clothing: Shirt shoulder area was charred and burned away, front was mostly intact and yellow. Pants, buttocks and back of legs area was discolored and charred, front was mostly intact and remained green.
    b. Helmet: Back one quarter of helmet was melted.
    c. Gloves: Intact, little shrinkage.
3. Body position: The firefighter was found lying prone with feet toward northeast.
4. Shelter use: The firefighter was fully deployed inside the shelter.

Travis Carter, Granite Mountain #5

1. Shelter condition:
    a. Outer Shell: 100% of foil burned away; silica cloth brittle in some areas.
    b. Inner Shell: 100% of foil burned away; 90% of fiberglass burned away.
    c. Floor: 100% of foil burned away; silica cloth brittle in some areas.
2. PPE:
    a. Clothing: Most of shirt was burned away, part of the collar and front were discolored and charred. Most of the pants were burned away; the upper front legs were discolored.
    b. Chainsaw Chaps: One chainsaw chap pad remained.
3. Body position: The firefighter was found lying prone with feet towards northeast.
4. Shelter Use: It is unclear if the firefighter was able to fully deploy the shelter. The firefighter was mostly deployed inside the fire shelter; the shelter was not covering the left leg and right foot of the firefighter. The burned remnants of a fireline pack were found outside of the shelter next to the left side of firefighter.

Christopher MacKenzie, Granite Mountain #6

1. Shelter Condition:
    a. Outer Shell: 95% of foil burned away; silica cloth brittle in some areas.
    b. Inner Shell: 95% of foil burned away; 50% of fiberglass burned away.
    c. Floor: 50% of foil burned away; silica cloth brittle in some areas.
    d. Seams: End cap seam has 12-inch separation.

2. PPE Items:
    a. Clothing: Back of the shirt was charred and burned away; the collar, front, sleeves and bottom (tucked into pants) were still intact. The front of the pants was still intact and only showed a small amount of discoloration and char. Back of the lower pants legs was burned away. Most of the upper legs and seat of pants was discolored, but still intact.
    b. Gloves: Both gloves appear shrunken 10%.
    c. Helmet: Back of the helmet was melted.
3. Body Position: The firefighter was found lying prone with feet towards the southeast.
4. Shelter Use: It is unclear if the firefighter was able to fully deploy the shelter. The firefighter was mostly deployed inside the fire shelter; the shelter was not covering the lower legs.

Travis Turbyfill, Granite Mountain #7

1. Shelter Condition:
    a. Outer Shell: 98% of foil burned away; silica cloth brittle in some areas.
    b. Inner Shell: 75% of foil burned away; 50 % of fiberglass burned away.
    c. Floor: 90% of foil burned away; silica cloth brittle in some areas.
    d. Middle seam separated.
2. PPE Items: None recovered.
3. Body Position: Firefighter was found lying supine with feet towards the southwest.
4. Shelter Use: It is unclear if the firefighter was able to fully deploy the fire shelter. The fire shelter was found under the firefighter.

Andrew Ashcraft, Granite Mountain #8

1. Shelter Condition:
    a. Outer Shell: 100% of foil burned away; silica cloth brittle in some areas
    b. Inner Shell: 100% of foil burned away; 95% of fiberglass burned away.
    c. Floor: 100% of foil burned away; silica cloth brittle in some areas.
    d. Seams: Both end cap seams separated; parts of floor seams separated.
2. PPE:
    a. Clothing: Most of the shirt was burned away; the front and parts of the sleeves remained. Most of the pants were burned away; the front waist area remained intact.
3. Body position: The firefighter was found lying prone, feet towards the northeast.
4. Shelter Use: It is unclear if the firefighter was able to fully deploy the shelter. The firefighter was mostly deployed inside the fire shelter; the shelter was not covering the right leg of the firefighter. The burned remnants of a fireline pack with saw gas/oil bottles was found directly next to the right side of the firefighter.

Joe Thurston, Granite Mountain #10

1. Shelter Condition:
    a. Outer Shell: 95% of foil burned away; silica cloth brittle in some areas.

b. Inner Shell: 95% of foil burned away; 80% fiberglass burned away.
c. Floor: 50% of foil burned away; half of floor intact.
d. Seams: End cap seam separated. Floor seam separated 15 inches. Burned side of floor, corner seams separated.

2. PPE:
   a. Clothing: Shirt back charred and burned away, much of the front and sleeves remained yellow. Pants, back of legs charred and burned away, much of the front remained intact.
   b. Gloves: Some areas of char, but mostly remained intact.
   c. Chainsaw chaps: Both leg pads remain mostly intact; nylon webbing was melted.
3. Body position: The firefighter was found lying prone with feet toward northeast.
4. Shelter Use – Fully deployed, right foot through a section of the separated floor seam. The burned remnants of a fireline pack were found next to the firefighter.

Wade Parker, Granite Mountain #11

1. Shelter Condition:
   a. Outer Shell: 100% of foil burned away; silica cloth brittle in some areas.
   b. Inner Shell: 100% of foil and fiberglass burned away.
   c. Floor: 100% of foil burned away; silica cloth brittle in some areas.
   d. Seams: One end cap seam separated. The floor inside corner seams separated.
2. PPE Items:
   a. Clothing: None recovered.
   b. Gloves: Charred and shrunken 50%.
   c. Helmet: Melted.
3. Body Position: The firefighter was found lying prone with feet toward the northeast.
4. Shelter Use: It is unclear if the firefighter was able to fully deploy the fire shelter. The firefighter's right foot was through the separated end cap seam, the rest of the shelter was beside the firefighter.

Anthony Rose, Granite Mountain #12

1. Shelter Condition:
   a. Outer Shell: 100% of foil burned away; silica cloth brittle in some areas. The red helmet of Granite Mountain #1 is melted on the foot end.
   b. Inner Shell: 100% of foil burned away; 80% fiberglass burned away. The melted black helmet of the firefighter was found in the fire shelter.
   c. Floor: 80% of foil is burned away; silica cloth brittle in some areas.
   d. Seams: Mid seam separated; one end cap seam separated.
2. PPE:
   a. Clothing: Shirt collar and small portion of back of shirt were discolored and charred, other parts of shirt burned away. Pants waistband and left front and rear pocket area were discolored and charred, other parts of the pants burned away.
   b. Gloves: Right only, 40% shrunk.
   c. Helmet: Melted.

3. Body position: The firefighter was found lying supine with feet toward northeast.
4. Shelter use: It is unclear if the firefighter was able to fully deploy the fire shelter. The fire shelter was found under the firefighter. Since the melted helmet was found inside the shelter, the firefighter was most likely at least partially deployed inside the shelter.

Garret Zuppiger, Granite Mountain #13

1. Shelter Condition:
   a. Outer Shell: 80% of foil burned away; silica cloth brittle in some areas.
   b. Inner Shell: 95% of foil burned away; 90% fiberglass burned away.
   c. Floor: 60% of foil burned away, silica cloth mostly intact.
   d. Seams: Intact.
2. PPE:
   a. Clothing: Shirt, shoulder areas were charred and burned away, the rest of the back was discolored and charred. The front button area and area tucked into pants was mostly intact and yellow. Pants, right leg mostly charred and burned away. Back of the left leg was charred, front of the left leg was mostly intact and green.
   b. Helmet was melted on the back.
   c. Gloves are intact, little shrinkage.
   d. Chainsaw Chaps, bottom edges are charred.
3. Body position: The firefighter was found lying prone with feet toward the northeast.
4. Shelter Use: The firefighter was fully deployed inside the shelter; tip of right foot was exposed under the shelter.

Scott Norris, Granite Mountain #14

1. Shelter Condition:
   a. Outer Shell: 98% of foil burned away; silica cloth brittle in some areas.
   b. Inner Shell: 95% of foil was burned away; 75% fiberglass burned away.
   c. Floor: 50% of foil was burned away, silica cloth mostly intact
   d. Seams: Shell/floor seam separated where right foot was through.
2. PPE:
   a. Clothing: Shirt upper back and sleeves were discolored, charred and brittle. The area tucked into pants remains intact and yellow. The back of legs and seat of pants were discolored, charred and brittle. Front of legs mostly intact and green.
3. Body position: The firefighter was found lying prone with feet towards east
4. Shelter Use: The firefighter was fully deployed inside the shelter; right foot was exposed through a separation of the shell/floor seam. A hand tool was under the upper body. Fireline pack next to left side of the firefighter.

Dustin DeFord, Granite Mountain #15

1. Shelter Condition:
   a. Outer Shell: 100% of foil burned away; silica cloth is brittle in some areas.
   b. Inner Shell: 90% of foil burned away; 85% of fiberglass burned away.
   c. Floor: 15% of foil burned away; silica cloth is brittle in some areas.

   d. Seams: End cap seam separated. Floor seam had a 48-inch separation.
2. PPE Items:
   a. Clothing: Shirt was mostly intact except for the area of the upper back that was charred and burned away. Much of the back side of the pants was charred and burned away. The front areas of the pants remain mostly intact.
   b. Gloves: Both gloves appeared shrunk 10%.
   c. Helmet: Most of the helmet was melted.
   d. Chainsaw chaps: Edges of the nylon chap shell, nylon webbing and 1-inch buckles were melted. Kevlar pads remained mostly intact.
3. Body position: The firefighter was lying prone with feet towards the northeast.
4. Shelter Use – The firefighter was fully deployed inside the shelter. The burned remnants of a chain saw were next to the right side of the firefighter.

William Warneke, Granite Mountain #16

1. Shelter Condition:
   a. Outer Shell: 100% of foil burned away; silica cloth was brittle in some areas.
   b. Inner Shell: 100% of foil was burned away; 98% of fiberglass burned away.
   c. Floor: 98% of foil burned away; silica cloth brittle in some areas.
   d. Seams: 10 inch tear in silica cloth at end cap.
2. PPE Items:
   a. Clothing: Shirt collar and bottom area where shirt was tucked into pants was intact. Pants waistband was intact; all other parts of clothing were burned away.
   b. Gloves: Shrunken 40%
3. Body Position: The firefighter was found lying supine with feet towards the southeast.
4. Shelter Use: It is unclear if the firefighter was able to fully deploy the fire shelter. The firefighter had feet inside end cap of shelter; the rest of the shelter was underneath the firefighter.

Kevin Woyjeck, Granite Mountain #17

1. Shelter Condition:
   a. Outer Shell: 100% of foil burned away; silica cloth brittle in some areas.
   b. Inner Shell: 80% of foil burned away; 40% of fiberglass burned away.
   c. Floor: 40% of foil burned away; silica cloth brittle in some areas.
   d. Seams: One end cap seam separated; one middle seam of floor separated.
2. PPE Items:
   a. Clothing: Back of shirt was charred and burned away, front of shirt and medial areas of sleeves were discolored, but mostly intact. Pants not recovered.
   b. Gloves: Left glove appeared charred and shrunken 40%; right glove charred on the fingertips.
   c. Helmet: Partially melted on the back half, the bill was cracked on the right side.
3. Body Position: The firefighter was found lying prone with feet towards the north.
4. Shelter Use: The firefighter was fully deployed inside the shelter.

John Percin, Jr., Granite Mountain #18

1. Shelter Condition:
    a. Outer Shell: 100% of foil burned away; silica cloth brittle with numerous holes.
    b. Inner Shell: 100% of foil burned away; 80% of fiberglass burned away.
    c. Floor: 98% of foil burned away; silica cloth brittle in some areas.
    d. Seams: Middle seam had a 30-inch separation.
2. PPE Items:
    a. Clothing: Only small pieces of shirt recovered. Pants waistband and upper right rear leg intact, rest of pants charred and burned away.
    b. Gloves: shrunken 45%.
3. Body position: The firefighter was found lying supine, feet towards the southeast.
4. Shelter Use: It is unclear if the firefighter was able to fully deploy the shelter. Part of the fire shelter was found wrapped around the left foot, with the rest of the shelter laid out on the ground toward the north.

Grant McKee, Granite Mountain #29 (believe manifest has typo error, should be #19)

1. Shelter Condition:
    a. Outer Shell: 95% of foil burned away; silica cloth brittle throughout.
    b. Inner Shell: 100% of foil burned away; 98% fiberglass burned away.
    c. Floor: 95% of foil burned away; silica cloth brittle in some areas.
    d. Seams: One end cap seam separated.
2. PPE:
    a. Clothing: Only a small area of the back of the shirt remained. The rear pocket area of the pants remained.
3. Body Position: The firefighter was found lying supine with feet towards northeast.
4. Shelter Use: Only the firefighter's left foot was in one end of shelter. The shelter was underneath the firefighter. The burned remnants of a fireline pack are underneath the right leg of the firefighter.

Sean Misner, Granite Mountain #20

1. Shelter Condition:
    a. Outer Shell: 99% of foil burned away; silica cloth brittle in some areas.
    b. Inner Shell: 100% of foil burned away; 90% of fiberglass burned away.
    c. Floor: 98% of foil burned away; silica cloth brittle in some areas.
    d. Seams: Middle seam of shell separated.
2. PPE Items: None recovered.
3. Body Position: The firefighter was found lying prone with feet toward the southwest.
4. Shelter Use: It is unclear if the firefighter was able to fully deploy the shelter. The firefighter's feet were in one end of the shelter, the rest of the shelter was lying on the ground behind the firefighter. The burned remnants of a modified combi-tool and a fireline pack were found under the right side of the firefighter.

Appendix D: Aviation Summary

June 28, 2013

Arizona Dispatch Center (Dispatch) placed the first aviation orders for the Yarnell Hill Incident on June 28 at 2253 hours Phoenix Standard Time (PNT). As is the norm with emerging fires, Dispatch requested exclusive use of the pre-authorized “Air to Air” AM and “Air to Ground” FM communication frequencies under aircraft orders A-1 and A-2. Incidents routinely order such frequencies to ensure mission aircraft flying the incident have private clear channels to communicate with each other and with ground personnel absent radio interference from civilians or other incidents.

The Air Attack assigned to the Doce Fire flew from Prescott that evening to assess the Yarnell Hill Fire.

June 29, 2013

The following morning, June 29, the incident ordered a Fixed Wing Air Tactical aircraft, dispatched as an air attack platform to carry the Air Tactical Group Supervisor (ATGS).The ATGS, addressed on the radio as “Air Attack,” is responsible for supervising and coordinating tactical and logistical aircraft operations when fixed and/or rotary-wing aircraft are working an incident. Incident specifics and complexities dictate the level of supervision required to conduct safe and effective aerial operations.

The next aviation orders were for two Type 3 or 4 Single Engine Airtankers (SEATs) to report directly to the incident, and the incident requested activation of the State of Arizona’s Wickenburg SEAT retardant reloading base located 14 nautical miles from the fire. The aircraft dispatcher filled the aircraft orders with Tanker 413 (T-413) and Tanker 830 (T-830). T-413 departed the Marana Regional Airport at 0924 with 450 gallons of fire retardant. The second aircraft, T-830 left Wilcox en route to the fire at 0943 carrying 750 gallons. At 0953, Dispatch informed Air Attack that T-830 was 1 hour and 25 minutes from arriving on the fire and T-413 was 25 minutes out. These SEATs initially worked out of the Prescott Airtanker Base (ATB) while the Wickenburg Base, being a “Call When Needed” operation, took the necessary four to six hours to prepare for operations.

Concurrent with the SEAT operations, at 1018, ICT4 requested that Dispatch divert a Bureau of Land Management (BLM) contract helicopter from a recon mission to use as an incident crew shuttle. At 1048, BLM helicopter 4HX to drop six firefighters from the Department of Corrections’ Lewis Crew and one helitack crewmember approximately one-quarter mile from the incident and establish a helispot. At about 1220, ICT4 sized up the incident as two acres (as reported to him by Air Attack, down from eight acres in the original report), noting that the south and west flanks were “hit” with retardant and the east flank was an old road. A crew was working the ridge top and planning to prepare for the next lightning event and possible new starts.

The SEATs released fire retardant on the incident under the supervision of an ATGS until Dispatch placed them on hold at 1225 in Prescott, when the incident reported the retardant had secured the south and west flanks of the fire and a road secured the east flank. Aircraft use reports indicate that the SEATs each made two retardant drops prior to this time. While on the ground at Prescott, Air Attack and the SEATs fueled and ate lunch. ICT4 instructed the SEATs to fly to the Wickenburg base as soon as it opened in case “something happens this afternoon.” At 1238, the Air Attack platform pilot noticed an oil leak and took the aircraft out of service. Dispatch notified ICT4 of the Air Attack platform’s unavailability and stated, “We don’t need the air attack unless we get more starts.” At 1438, the ATGS reported the Air Attack aircraft back on contract availability. At 1442, ICT4 released the Air Attack from Prescott to return to their home base at Phoenix-Mesa Gateway Airport. Dispatch relayed the release to the pilot at 1525.

By mid-afternoon, State of Arizona personnel opened the Wickenburg base, approximately 36 nautical miles closer to the incident than the Prescott ATB. At 1455, Dispatch ordered the SEATs T-413 and T-830 to ferry (fly) from Prescott to the Wickenburg base. A few minutes after the SEATs departed, a general weather update noted, “thunderstorms are building up northeast of Kingman to the I-40 moving south.” At 1511, T-413 announced, “Landing assured at Wickenburg” where both SEATs went on hold to respond to any new fires.

At about 1600, ICT4 requested the launch of an Air Attack for a recon flight over the fire, followed 10 minutes later by a request to launch two SEATS. Dispatch informed ICT4 that only one of the two SEATs at Wickenburg was available, as they were holding the other SEAT for a potential launch to a new fire near Kingman. ICT4 reported to Dispatch they were still having problems catching the fire and were going to sling more retardant on it if needed, but would wait until Air Attack got over the fire to determine if more was necessary. At 1620, Air Attack reported they were 20 minutes out from the fire (ETA 1640). Shortly after Air Attack arrived, ICT4 ordered the closest heavy helitanker, which is based at Prescott. Over the next 20 minutes, there was confusion about the status of the helitanker order, between the dispatcher, the Southwest Coordination Center (SWCC), and ICT4.

At about 1700, ICT4 reported the fire had jumped the road on the east side, but had quieted down some, was about two acres, and the SEAT should be effective. About 15 minutes later, ICT4 ordered a heavy airtanker and reported that the slop over was about two acres and increasing, the overall fire was about six acres, and that there were 12 to 15 personnel on the hill that would stay in place. He further reported that there were no structures threatened at the time but in the next 24 to 48 hours, the towns of Peeples Valley and Yarnell may be threatened. At 1703, ICT4 asked Dispatch if the other SEAT was available and about the status of the helitanker. Dispatch replied they had not had time to look at that. At 1707, ICT4 ordered one Type 1 large airtanker (LAT). The remaining SEAT, which had been holding in Wickenburg, launched at 1722 to support the incident.

At 1742, Dispatch reported that the LAT T-06 in Albuquerque (308 nautical miles away) and Helitanker H-736 in Prescott (23 nautical miles away) had declined the resource orders due to severe weather concerns. Aviation Resource Orders A-7 and A-8 show “Cancelled UTF” for T-06 and H-716.

At 1745, Dispatch offered the incident a Very Large Airtanker (VLAT), a DC-10 capable of carrying 5,000 gallons of fire retardant when ordered in the large airtanker class and 11,400 gallons when ordered as a Very Large Airtanker (LAT). ICT4, after conferring with Air Attack, declined the VLAT offer at 1750.

At about 1800, SWCC notified Dispatch, who in turn briefed ICT4, that SWCC would not be able to support the Yarnell Hill Fire with heavy airtankers due to weather concerns and other priority fires. At 1924, the incident reported they were continuing to utilize SEATs T-413 and T-830 until cut off (one-half hour after sunset). On the evening of June 29, the incident placed multiple aircraft orders for the next day (see Table 2, orders A-11 through A-23).

June 30 2013

Status 0335– *Model Creek Subdivision Peeples Valley 42 homes 1 mi. away threatened in next 12 hours from the head of the fire. Yarnell with 500 homes is 1 1/2 miles away from fire with the threat coming from the flank in the next 12 to 24 hours. There was slop over on the west side of the fire, no threat unless the winds shift.*

Status 0450- *Fire is still moving and active. Get aviation up early; it will help on the southern flank and the eastern part in the interior and on the northern flank.*

The Wickenburg SEAT Base started the day with 35 SEAT loads of retardant to support the Yarnell Hill Fire. The SEAT Base told Dispatch that operations may have to relocate to the Prescott ATB later in the day due to this limitation and that more retardant was on order. At the base, SEAT T-810 became available at 0759, completed launch documentation at 0817, and subsequently left for the incident at 0904. At 0802, Dispatch checked the Show Low SEAT base for aircraft availability, and Show Low managers made SEAT T-874 available. T-874 departed empty for the Wickenburg base, arrived at 1039, and departed at 1107 to join T-413 and T-830. The incident also ordered Helitanker 716, but they learned it would take about 45 minutes to get ready plus one hour to fly to Prescott for fuel before it could report to the incident.

Around 0830, the fire became increasingly active and incident management requested a VLAT and two LATs. At 0915, the two LATs, T-06 from Albuquerque, NM and T-45 from Durango, CO, and the Aerial Supervision Module (ASM) launched to the incident. While they were en route, Dispatch diverted both of the LATs to the Dean Peak Fire. To fill the orders of the diverted LATs, Dispatch ordered LAT T-07 from the Fort Huachuca ATB (departed at 1033) and a military C-130 from Pueblo, CO with a Forest Service (slip on) retardant-dispensing system. The latter, known as MAFFS, was loaded with retardant for the mission but was unable to depart due to weather that moved rapidly into the area.

At about 1000, the incident ordered an Air Attack relief platform but SWCC asked them to consider using ASM1 until SWCC was able to fill the order. After some confusion between ASM1 and SWCC, SWCC informed Dispatch that the ASM would be over the fire in time to relieve the local Air Attack (at approximately 1135 hours). SWCC also notified Dispatch that the VLAT T-910 was preparing to depart and would arrive in 1 hour and 45 minutes (ETA 1150).

At 1100, Air Attack reported the Yarnell Hill Fire was approximately 1500 acres and moving to the north and east. SWCC directed T-06 and T-45 (previously diverted to the Dean Peak Fire) back to the Yarnell Hill Fire. Due to the fire's rapid spread and resources at risk, the incident then requested a second VLAT, an order SWCC filled as requested. VLAT T-911 departed Pueblo, CO at 1304, which committed both DC-10 airtankers in the nation to the Yarnell Hill Fire.[13]

At 1145, Air Attack departed the fire to refuel at Prescott and conducted a hand off with incoming ASM1. At approximately 1200, ASM1 began conducting retardant operations with the VLAT working from the Phoenix-Mesa Gateway Airport ATB, the four SEATs from the Wickenburg SEAT Base, the three LATs from the Prescott ATB. At 1201, Helitanker 716 reported to be in contact with ASM1.

At 1603, the ASM1 requested Dispatch to place resource orders for six additional LATs with SWCC, necessary due to the wind shift of 300 degrees, structures threatened and thunderstorms pushing the fire in multiple directions. At 1608, SWCC sent these orders to the National Interagency Coordination Center (NICC) in Boise, ID, which denied all the requests as UTF due to the "Very limited availability of airtankers with increasing activity in the western states. Unable to fill at this time." The NICC Coordinator on Duty followed direction from the Multi-Agency Coordinating Group, responsible for the national reallocation of scarce resources at the National Interagency Fire Center, in issuing the airtanker UTFs to SWCC.

UTFs: *The UTFs did not affect the tragic outcome. When Dispatch placed the orders at 1603, the incident team already had half of the available airtanker fleet, representing 74% of the retardant dropping capability in the nation, the equivalency of fourteen 2,000-gallon airtankers.*

At 1312, Dispatch informed the incident that ASM2 would arrive over the fire at 1430 to relieve ASM1, and orders for large helitankers were being UTF'd as they [SWCC] were tapped out. At about 1425, VLAT 911 arrived over the fire, the last airtanker assigned during the shift.

Shortly after ICT2 assessed the fire, at 1444, the LATs (T-06, T-07 and T-45) and large helitanker T-716 went on a tactical hold at the Prescott ATB, due to severe weather in the area. At 1447, ASM2 arrived over the fire, relieved ASM1 and, after a handoff, coordinated retardant application with VLATs T-910 and T-911 who continued to load at Phoenix-Mesa Gateway Airport ATB and the SEATs working from the Wickenburg SEAT base. The ASM1 reported, as he was flying to Wickenburg for fuel, that he would return to the fire to relieve ASM2 at 1715 hours.

At 1544, Air Attack notified Dispatch that the Wickenburg base was running out of retardant and that the SEATs would have to begin reloading at the Prescott ATB. Prescott ATB recommended not using their base due to adverse weather and already-grounded heavy airtankers, and recommended using the Phoenix-Mesa Gateway Base instead.

During the LATs' tactical hold for weather at the Prescott ATB, VLATs T-910 and T-911 continued operating from Phoenix-Mesa Gateway Airport ATB, delivering three retardant loads for a total of 32,457 gallons to the incident. At 1646, weather conditions at Prescott improved to allow the resumption of operations from there with T-06 departing at 1659, T-07 at 1706, and T-45 at 1712.

[13] Assigning both VLATs to single fire occurs on less than one-third of all dispatches.

At approximately 1615, ASM2 heard radio traffic between Division Supervisor A (DIVS A, which included Granite Mountain Hotshots) and Operations about Granite Mountain going down their escape route to a safety zone. ASM2 asked Operations if they should check on the crew in the safety zone. After Operations stated that Granite Mountain was "in a good place" and safe, ASM2 continued retardant applications, including dry practice runs that are conducted to properly align the live drop, west to east behind Yarnell. After one dry run, ASM2 heard DIVS A say over the radio, "that's what we are looking for." Approximately eleven minutes later at 1648, ASM2 relayed notification of shelter deployments to Dispatch. At 1712, ASM1 arrived over the fire and relieved ASM2 who departed for Prescott to refuel.

Weather: *Although there were sufficient airtankers assigned to the fire, the afternoon's severe weather hampered the tankers' effectiveness by closing reloading bases periodically and at other times by making flying to and from the fire unsafe. However, this was not the case at the time of the entrapment as a Very Large Airtanker (VLAT) was over the fire carrying 10,743 gallons of retardant and was prepared to drop at the ASM's order if the crew could be located.*

At 1707, LAT T-43, responding to the Yarnell Hill Fire from Southern California suffered a left reciprocal piston engine mechanical failure that forced them to jettison their retardant load and return to the base of departure. Dispatch revised this order to UTF as T-43 went out of service the remainder of the day. At 1729, the Wickenburg base closed due to weather and the SEATs began using the Prescott ATB. Aviation operations ended 30 minutes after sunset (2017), the Official Cutoff Time for the day.

Table 1. Aircraft Hourly Rates and Flight Hour Summary

VLAT – DC-10 Flight Rate (5000 gallons of retardant or less)	$ 4,553/hr.
VLAT – DC-10 Flight Rate (5000 gallons of retardant or more)	$ 12,500/hr.
LAT – P2V Flight Rate (2,082 gallons of retardant)	$ 8,495/hr.
SEAT – Single Engine Airtanker Flight Rate (750 gallons of retardant)	$ 3,242/hr.
SEAT – Single Engine Airtanker Flight Rate (450 gallons of retardant)	$ 2,305/hr.

Date	Type	Flights	Gallons	Hours
29 June 2013	SEAT	15	7,626	6.92
30 June 2013	SEAT	47	31,268	15.2
	LAT	17	35,379	15.36
	VLAT	8	88,106	10.52
1 July 2013	SEAT	25	15,990	6.71
	LAT	2	4,887	2.1
	VLAT	2	22,458	2.22
Totals		**116**	**205,714**	**59.03**

Table 2. Resource Ordering

Resource Requested, listed by Request Number	Date & Time Needed	Resource Assigned	ETA
A-3 Fixed Wing, Air Tactical Air Attack Platform	6/29 0900	N9QY originally assigned, broke down before T/O. Replaced by 9WA[1]	6/29 1000
A-4 Airtanker Type 3 or 4	6/29 0900	Airtanker 830 Type 3 SE, N802SG	6/29 1738
A-5 Airtanker Type 3 or 4	6/29 0900	Airtanker 413 Type 4 SE, N32973	7/4 0800
A-6 Fixed Wing, Air Tactical	6/29 0930	N50AB	6/29 1525
A-7 Helicopter Type 1 Limited	6/29 1707	Unable to Fill (UTF), gusts to 37[2]	NA, UTF
A-8 Airtanker Type 1	6/29 1707	UTF, T-06 declined due to weather[3]	NA, UTF
A-9 Helicopter Type 2 Standard	6/30 0800	Type 2 S – N215KA	7/3 2030
A-11 Type 1 or 2 Airtanker	6/30 0900	Type 2, T-45, P2V N445NA[4]	6/30 2005
A-12 Type 1 or 2 Airtanker Heavy	6/30 0900	Type 2, T-06, P2V N9855F	7/1 0840[5]
A-13 Fixed Wing Leadplane	6/30 0900	Fixed Wing Leadplane, N38V	7/1 0905
A-14 Type 3 or 4 Airtanker	6/30 0800	Type 3 SE, T-830 N802SG	6/30 2000

[1] Footnote for A-3, ROSS
[2] Footnote for A-7, ROSS
[3] Footnote for A-8, ROSS
[4] Revised original request from Type 1 to Type 1 or 2 according to Footnote for A-12 in ROSS
[5] Footnote 6 in ROSS report shows 07/01 as the reporting date for T-06. The national ATKR Report reflects T-06 reported to the incident on 06/30.

Table 3. Large and Very Large Airtanker Record

Flight Date	ATKR	Gallons	Origin	End	FLT HRS	Start	Stop	Notes
6/30/2013	T-06	2,070	ABQ	PRC	2.38	0851	1114	Divert from Dean Peak
6/30/2013	T-45	0	DRO	PRC	1.45	0909	1036	Direct PRC
6/30/2013	T-07	2,079	FHU	PRC	2.02	1033	1234	
6/30/2013	T-910	11,400	ABQ	IWA	1.85	1046	1237	
6/30/2013	T-45	2,083	PRC	PRC	1.1	1053	1159	
6/30/2013	T-06	2,081	PRC	PRC	0.98	1129	1228	
6/30/2013	T-45	2,082	PRC	PRC	0.67	1213	1253	
6/30/2013	T-07	2,082	PRC	PRC	0.5	1252	1322	
6/30/2013	T-911	10,441	PUB	IWA	2.13	1304	1512	
6/30/2013	T-45	2,082	PRC	PRC	0.53	1307	1339	
6/30/2013	T-910	11,119	IWA	IWA	0.95	1313	1410	
6/30/2013	T-06	2,082	PRC	PRC	0.68	1325	1406	
6/30/2013	T-45	2,083	PRC	PRC	0.47	1351	1419	WX Closes PRC
6/30/2013	T-910	11,061	IWA	IWA	1.03	1440	1542	IWA Open
6/30/2013	T-911	10,743	IWA	IWA	1.13	1543	1651	IWA Open
6/30/2013	T-910	10,653	IWA	IWA	1.32	1615	1734	IWA Open

Flight Date	ATKR	Gallons	Origin	End	FLT HRS	Start	Stop	Notes
6/30/2013	T-06	2,082	PRC	PRC	0.62	1659	1736	PRC Reopens
6/30/2013	T-07	2,084	PRC	PRC	0.58	1706	1741	
6/30/2013	T-45	2,083	PRC	PRC	0.63	1712	1750	
6/30/2013	T-911	11,400	IWA	IWA	1.08	1723	1828	
6/30/2013	T-06	2,082	PRC	PRC	0.58	1748	1823	
6/30/2013	T-07	2,081	PRC	PRC	0.62	1755	1832	
6/30/2013	T-45	2,083	PRC	PRC	0.48	1803	1832	
6/30/2013	T-910	11,089	IWA	IWA	1.03	1806	1908	
6/30/2013	T-06	2,079	PRC	PRC	0.52	1857	1928	
6/30/2013	T-07	2,081	PRC	PRC	0.55	1919	1952	
7/1/2013	T-911	11,364	IWA	IWA	1.1	1143	1253	
7/1/2013	T-41	2,543	IWA	IWA	1.12	1223	1330	
7/1/2013	T-911	11,094	IWA	IWA	1.12	1323	1435	
7/1/2013	T-41	2,344	IWA	IWA	0.98	1345	1444	

Table 4. Single Engine Airtanker Record

Flight Date	ATKR	Gallons	Origin	End	FLT HRS	Start	Stop
6/29/2013	T-413	450	AVQ	PRC	1.24	0924	1048
6/29/2013	T-830	750	P33	PRC	1.37	0943	1120
6/29/2013	T-413	399	PRC	PRC	0.44	1127	1211
6/29/2013	T-830	627	PRC	PRC	0.34	1137	1211
6/29/2013	T-830	0	PRC	E25	0.27	1453	1520
6/29/2013	T-413	450	PRC	E25	0.25	1628	1653
6/29/2013	T-413	450	E25	E25	0.22	1659	1721
6/29/2013	T-830	750	E25	E25	1.11	1722	1833
6/29/2013	T-413	450	E25	E25	0.24	1726	1750
6/29/2013	T-413	450	E25	E25	0.23	1755	1818
6/29/2013	T-413	450	E25	E25	0.23	1838	1901
6/29/2013	T-413	450	E25	E25	0.22	1906	1928
6/29/2013	T-830	750	E25	E25	0.24	1911	1935
6/29/2013	T-413	450	E25	E25	0.27	1933	2000
6/29/2013	T-830	750	E25	E25	0.25	1943	2008
6/30/2013	T-810	750	E25	E25	1.50	836	1026
6/30/2013	T-413	450	E25	E25	0.24	838	902
6/30/2013	T-830	750	E25	E25	0.24	843	907
6/30/2013	T-413	450	E25	E25	0.23	906	929
6/30/2013	T-830	750	E25	E25	0.24	912	936
6/30/2013	T-413	450	E25	E25	0.23	935	958

Flight Date	ATKR	Gallons	Origin	End	FLT HRS	Start	Stop
6/30/2013	T-874	0	SOW	E25	1.04	940	1044
6/30/2013	T-830	750	E25	E25	0.23	943	1006
6/30/2013	T-413	450	E25	E25	0.25	1005	1030
6/30/2013	T-830	750	E25	E25	0.23	1012	1035
6/30/2013	T-413	450	E25	E25	0.25	1034	1059
6/30/2013	T-830	750	E25	E25	0.24	1041	1105
6/30/2013	T-810	750	E25	E25	0.23	1051	1114
6/30/2013	T-874	710	E25	E25	0.25	1103	1128
6/30/2013	T-830	750	E25	E25	0.21	1112	1133
6/30/2013	T-810	750	E25	E25	0.27	1120	1147
6/30/2013	T-413	450	E25	E25	0.34	1130	1204
6/30/2013	T-874	710	E25	E25	0.30	1141	1211
6/30/2013	T-810	750	E25	E25	0.31	1158	1229
6/30/2013	T-830	750	E25	E25	0.33	1204	1237
6/30/2013	T-413	450	E25	E25	0.34	1210	1244
6/30/2013	T-874	710	E25	E25	0.26	1222	1248
6/30/2013	T-810	750	E25	E25	0.27	1236	1303
6/30/2013	T-830	750	E25	E25	0.25	1243	1308
6/30/2013	T-413	450	E25	E25	0.29	1249	1318
6/30/2013	T-874	710	E25	E25	0.26	1300	1326
6/30/2013	T-830	750	E25	E25	0.26	1315	1341
6/30/2013	T-413	450	E25	E25	0.33	1325	1358
6/30/2013	T-874	710	E25	E25	0.28	1331	1359
6/30/2013	T-810	750	E25	E25	0.42	1341	1423
6/30/2013	T-830	750	E25	E25	0.27	1351	1418
6/30/2013	T-810	750	E25	E25	0.25	1435	1500
6/30/2013	T-830	750	E25	E25	0.23	1435	1458
6/30/2013	T-413	450	E25	E25	0.27	1439	1506
6/30/2013	T-874	710	E25	E25	0.26	1447	1513
6/30/2013	T-413	0	PRC	E25	0.30	1451	1521
6/30/2013	T-810	750	E25	E25	0.34	1507	1541
6/30/2013	T-874	710	E25	E25	0.28	1519	1547
6/30/2013	T-830	750	E25	E25	0.28	1534	1602
6/30/2013	T-413	450	E25	E25	0.29	1542	1611
6/30/2013	T-810	750	E25	E25	0.34	1547	1621
6/30/2013	T-874	710	E25	E25	0.36	1600	1636
6/30/2013	T-830	750	E25	E25	0.25	1616	1641
6/30/2013	T-413	450	E25	E25	0.26	1619	1645
6/30/2013	T-830	750	E25	E25	0.24	1644	1708
6/30/2013	T-810	750	E25	PRC	0.28	1647	1715
6/30/2013	T-830	750	E25	PRC	0.58	1718	1816
6/30/2013	T-810	688	PRC	E25	0.51	1734	1825

Flight Date	ATKR	Gallons	Origin	End	FLT HRS	Start	Stop
6/30/2013	T-830	750	PRC	E25	0.30	1908	1938
7/1/2013	T-874	710	E25	E25	0.32	926	958
7/1/2013	T-810	750	E25	E25	0.31	933	1004
7/1/2013	T-413	450	E25	E25	0.33	944	1017
7/1/2013	T-874	710	E25	E25	0.23	1004	1027
7/1/2013	T-413	450	E25	E25	0.28	1021	1049
7/1/2013	T-810	750	E25	E25	0.24	1035	1035
7/1/2013	T-874	710	E25	E25	0.25	1035	1100
7/1/2013	T-413	450	E25	E25	0.28	1053	1121
7/1/2013	T-874	710	E25	E25	0.24	1106	1130
7/1/2013	T-810	750	E25	E25	0.24	1107	1107
7/1/2013	T-413	450	E25	E25	0.29	1128	1157
7/1/2013	T-874	710	E25	E25	0.25	1137	1202
7/1/2013	T-810	750	E25	E25	0.24	1140	1140
7/1/2013	T-810	750	E25	E25	0.25	1214	1214
7/1/2013	T-413	450	E25	E25	0.28	1229	1257
7/1/2013	T-874	710	E25	E25	0.27	1241	1308
7/1/2013	T-810	750	E25	E25	0.25	1246	1246
7/1/2013	T-413	450	E25	E25	0.30	1302	1332
7/1/2013	T-874	710	E25	E25	0.25	1315	1340
7/1/2013	T-413	450	E25	E25	0.26	1339	1405
7/1/2013	T-874	710	E25	E25	0.30	1349	1419
7/1/2013	T-810	750	E25	E25	0.24	1354	1354
7/1/2013	T-413	450	E25	E25	0.27	1419	1446
7/1/2013	T-810	750	FHU	E25	0.25	1428	1428
7/1/2013	T-874	710	E25	E25	0.29	1428	1457

Appendix E: Work/Rest & Qualifications Summary

WORK/REST EVALUATION

A review of Crew Time Reports and Prescott Fire Department (PFD) time records for the Granite Mountain IHC's last 30 calendar days prior to the accident (June 1-30, 2013) shows compliance with the appropriate work/rest guidelines. The crewmembers were currently on Day 3 of a continuous fire assignment (June 26 and 27 were 8-hour days spent at their home unit doing fuels work) and on Day 13 since their last days off (June 16-17).

Federal guidelines suggest two days off after working 14 days (exclusive of travel) on fire assignments or two days off after 21 days (inclusive of travel) on fire assignments. Although these are federal standards and do not apply to State or local firefighters, the Granite Mountain IHC abided by them.

TRAINING EVALUATION

A review of training records shows Granite Mountain IHC, which was vetted under the IHC certification process in 2008, followed all standards and guidelines found in the Standards for Interagency Hotshot Crew Operations and in the Arizona State Forestry Division's Standard Operational Guideline 804 (SOG 804) with one exception. Reviewers could not confirm whether all crewmembers completed the course titled "IS-700 - National Incident Management System (NIMS): An Introduction," which became a required course by the National Wildfire Coordinating Group (NWCG) in October 2012 and by the PFD in January 2013. The course "provides a basic introduction to NIMS. It is not designed to replace Incident Command System (ICS) and position-specific training."

While the City of Prescott hosted the Granite Mountain IHC, it is clear they were exclusively hired and trained as an Interagency Hotshot Crew. They operated within a much larger system, that of the NWCG where local, State and Federal firefighting agencies come together as part of the nation's wildfire response.

DISCUSSION

NWCG Compliance with NIMS Training

Homeland Security Presidential Directive (HSPD-5) requires training for all emergency responders to support the National Response Framework (NRF). Required courses include NIMS: An Introduction (IS-700) and NRF: An Introduction (IS-800B).[14] All positions identified in the *National Interagency Incident Management System Wildland Fire Qualification System Guide, PMS 310-1,* have National Interagency Incident Management System (NIIMS) training requirements attached.

[14] "NIMS and the Incident Command System," http://www.fema.gov/txt/nims/nims_ics_position_paper.txt.

According to the NIMS Integration Center, emergency management and response personnel already trained in the ICS using the NIMS ICS curriculum model do not need retraining if their previous training is consistent with the Department of Homeland Security standard. This previous training would include (but not be restricted to) courses managed, administered, or delivered by the Emergency Management Institute, the U.S. Fire Administration's National Fire Academy, the National Wildfire Coordinating Group, the U.S. Department of Agriculture, the Environmental Protection Agency, and the U.S. Coast Guard.

The 2013 Fire Manual for the PFD states the NIMS requirement is now mandated. All fire personnel will take IS-700 starting January 2013 and, when needed, will take IS-800.

PMS 310-1

The *National Interagency Incident Management System Wildland Fire Qualification System Guide, PMS 310-1*, is in compliance with and supports the ability of agency personnel to meet the requirements of the NRF and the NIMS. Developed under the sponsorship of the NWCG, PMS 310-1 is designed to:

- Establish minimum requirements for training, experience, physical fitness level, and currency standards for wildland fire positions, which all participating agencies have agreed to meet for national mobilization. Standards may be augmented to meet specific needs within an agency, but the augmentation cannot be imposed by an agency on its cooperators who meet the minimums outlined in this guide.
- Require any organization or agency providing resources for a national interagency request for all types of wildland fire incidents to meet the minimum NWCG requirements described in the PMS 310-1.
- Allow cooperating agencies to jointly agree upon training, experience, physical fitness level, and currency standards to meet fire management needs for wildland fire (wildland fire includes wildfire and prescribed fire).

SOG 804: Arizona's Supplemental Requirements

AZSF adopted "Standard Operational Guideline Section 800, Training/Qualifications (SOG 804)" as a supplement to the PMS 310-1. Effective May 6, 2013, it superseded the State's FM Policy 25 dated November 22, 2005. SOG 804 establishes the minimum criteria required for certification as an AZSF employee or as personnel operating within a Cooperative Fire State Agreement with the AZSF. SOG 804 exceeds federal agency requirements and should be acknowledged for establishing and launching highly skilled and qualified wildland firefighters.

The number of hours, the variety and complexity of assignments (experience), and the diversity of training evaluators are important to the Arizona State Wildfire Qualifications Review Committee in determining whether an individual is fully prepared for wildland positions. Examples of SOG 804 requirements that supplement the PMS 310-1 requirements are as follows:

Position	Required Training	Required Experience	Required Experience before Advancing to the Next ICS Level	Required Documented Hours
FFT2	No additional training	FFT2 PTB[1] optional and if completed, 1 evaluator completion during class	120 Fireline hrs (60 Hotline) [2] as a **FFT2** to include the following assignments: • 2 type 1, 2, or 3 incidents • 3 type 4 or 5 incidents • 1 grass/desert/chaparral fuel type • 1 timber fuel type • 1 urban interface[3]	Classroom training plus 120 additional FFT2 hours (60 hotline) ***120 hours as a FFT2 (60 hotline)***
FFT1	No additional training	120 Fireline hours (60 Hotline) as **FFT1 trainee:** • 3 different evaluators from 3 separate incidents • 2 fuel types	60 Fireline hrs (30 Hotline) as a **qualified FFT1** to include the following assignments: • 2 type 1, 2, or 3 incidents • 1 type 4 or 5 incident • 1 grass/desert/chaparral fuel type • 1 timber fuel type • 1 urban interface	120 hours as a FFT1-T (60 hotline) plus additional 60 hours (30 hotline) ***300 hours as a FFT2/FFT1 (150 hotline)***
CRWB	No additional training however the Committee strongly recommends completing S-234 & S-260	120 Fireline hours (60 Hotline) as **CRWB trainee:** • 3 different evaluators from 3 separate incidents • 2 fuel types	120 Fireline hrs (60 Hotline) as a **qualified CRWB** in the equivalent STL Position to include the following assignments: • 2 type 1, 2 or 3 incidents • 1 grass/desert/chaparral fuel type • 1 timber fuel type • 1 urban interface	120 hours as a CRWB-T (60 hotline) plus additional 120 hours (60 hotline) ***540 hours as a FFT2/FFT1/ CRWB (270 hotline)***

[1] PTB = Position Task Book.
[2] Hotline Hours = Actual time on fireline prior to containment with active flame in the vicinity. Twenty percent of the total required fireline hours (24 hours) may be from a controlled or prescribed fire project.
[3] In the FFT1 PTB and in the Single Resource Boss PTB there are no "urban interface" tasks required to show knowledge and competency in their performance.

By the time an AZSF employee (or personnel operating within a Cooperative Fire State Agreement with the AZSF) is qualified as a Crew Boss, Single Resource, they will have over 540 hours of documented wildland fireline proficiencies, with 270 of these hours being hotline hours. They will also have multiple experiences in five incident levels and various fuels types, and at least three urban interface experiences.

Per the SOG 804, it is the local unit's responsibility to maintain training records for their wildland firefighters. The PFD uses the Incident Qualification System (IQS) software application developed by the National Association of State Foresters (current version is IQSweb V3.0). The Prescott Fire Department 2010-2011 Annual Report summarizes the PFD's multiple training opportunities and achievements.

Appendix F: Fire Acronyms & Terminology

ADC	Arizona Dispatch Center
ASM	Aerial Supervision Module
ATB	Airtanker Base
ATGS	Air Tactical Group Supervisor
AZSF	Arizona State Forestry Division
CRWB	Crew Boss
CWPP	Community Wildfire Protection Plan
DIVS	Division Supervisor
DPS	Department of Public Safety
FAA	Federal Aviation Administration
FBAN	Fire Behavior Analyst
FFT1	Advanced Firefighter/Squad Boss
FFT2	Firefighter
IC	Incident Commander
ICP	Incident Command Post
ICS	Incident Command System
ICT1	Incident Commander, Type 1
ICT2	Incident Commander, Type 2
ICT4	Incident Commander, Type 4
IHC	Interagency Hotshot Crew
IMT	Incident Management Team
LAT	Large Airtanker
LCES	Lookout(s), Communication(s), Escape Route(s), and Safety Zone(s)
MSL	Mean Sea Level
NASF	National Association of State Foresters
NICC	National Interagency Coordination Center
NIIMS	National Interagency Incident Management System
NIMS	National Incident Management System
NWCG	National Wildfire Coordination Group
NWS	National Weather Service
OPS	Operations Section Chief
PPE	Personal Protective Equipment
PTB	Position Task Book
RAWS	Remote Automated Weather Station
SEAT	Single Engine Airtanker
SME	Subject Matter Expert
SPG	Structure Protection Group
SPGS1	Structure Protection Group Supervisor 1
SPGS2	Structure Protection Group Supervisor 2
SWCC	Southwest Coordination Center
SWCWZ	Southwest Area Central West Zone
VLAT	Very Large Airtanker

WFLC	Wildland Fire Leadership Council
WUI	Wildland-Urban Interface
YCSO	Yavapai County Sheriff's Office

Aerial Supervision Module: A fixed wing aircraft with two crewmembers who perform the functions of traditional air attack and low-level leadplane operations.

Air Attack: The deployment of fixed-wing or rotary aircraft on a wildland fire, to drop retardant or extinguishing agents, shuttle and deploy crews and supplies, or perform aerial reconnaissance of the overall fire situation.

Anchor Point: An advantageous location, usually a barrier to fire spread, from which to start constructing a fireline. The anchor point is used to minimize the chance of being flanked by the fire while the line is being constructed.

Backfire: A fire set along the inner edge of a fireline to consume the fuel in the path of a wildfire or change the direction of force of the fire's convection column.

Backing Fire: 1) Fire spreading, or ignited to spread, into (against) the wind or downslope. A fire spreading on level ground in the absence of wind is a backing fire. 2) That portion of the fire with slower rates of fire spread and lower intensity normally moving into the wind and/or down slope. Also called: heel fire

the Black: A burned area.

Burn Out: Setting fire inside a control line to consume fuel between the edge of the fire and the control line.

Cell: Convection in the form of a single updraft, downdraft, or updraft/downdraft couplet, typically seen as a vertical dome or tower as in a towering cumulus cloud. A typical thunderstorm consists of several cells.

Chain: Unit of measure in land survey, equal to 66 feet (20 M) (80 chains equal 1 mile). Commonly used to report fire perimeters and other fireline distances, this unit is popular in fire management because of its convenience in calculating acreage (e.g., 10 square chains equal one acre).

Clear Text: The use of plain English in radio communications transmissions. No Ten Codes or agency specific codes are used when using Clear Text.

Cloning Radios: Automated copying of radio frequencies from one radio to another via a cable.

Cold Black: A burned area that cannot re-burn and no longer retains heat.

Cold Trailing: A method of controlling a partly dead fire edge by carefully inspecting and feeling with the hand for heat to detect any fire, digging out every live spot, and trenching any live edge.

Direct: Any treatment applied directly to burning fuel such as wetting, smothering, or chemically quenching the fire or by physically separating the burning from unburned fuel. Known more fully as “Direct Attack.”

Fusees: A colored flare designed as a railway warning device, widely used to ignite backfires and other prescribed fires.

Head Fire: A fire spreading or set to spread with the wind. (Synonym: Advancing Fire)

Head of a Fire: The most rapidly spreading portion of a fire’s perimeter, usually to the leeward or up slope.

Heel of a Fire: The area of the fire with the lowest rate of spread.

Indirect: A method of suppression (known more fully as “Indirect Attack”) in in which the control line is located some considerable distance away from the fire's active edge. Generally done in the case of a fast-spreading or high-intensity fire and to utilize natural or constructed firebreaks or fuelbreaks and favorable breaks in the topography. The intervening fuel is usually backfired; but occasionally the main fire is allowed to burn to the line, depending on conditions.

Outflow: Air that flows outward from a thunderstorm.

Point Protection: Firefighting tactics that are specific to a given location, usually used for structure protection where individual structures are being protected instead of large areas.

Red Flag Warning: A warning in which critical fire weather conditions are either occurring or will occur shortly. A combination of strong winds, low relative humidity, and warm temperatures will create explosive fire growth potential.

Safety Zone: An area cleared of flammable materials used for escape in the event the line is outflanked or in case a spot fire causes fuels outside the control line to render the line unsafe. In firing operations, crews progress so as to maintain a safety zone close at hand allowing the fuels inside the control line to be consumed before going ahead. Safety zones may also be constructed as integral parts of fuelbreaks; they are greatly enlarged areas which can be used with relative safety by firefighters and their equipment in the event of blowup in the vicinity.

Square Up: To burn out fuel along the control line to a point that is even with the lowest point of active fire, then “squaring” up the corner.

Staff Ride: A case study of a previous incident that is conducted on the actual physical site where the incident occurred. A staff ride is an experiential learning method that involves three distinct parts: a preliminary study, a site visit, and a post-visit integration session.

Tone Guard: Controls access to a specific frequency on a two-way radio. Tone guard provides a way for radio users to transmit and monitor only the transmissions with the same tone. A radio will only activate if another radio is transmitting with the same tone guard.

Trigger Points: Geographic points on the ground or specific points in time where an escalation or alternative of management actions is warranted. These points are defined and the management actions to be taken are clearly described in an approved Wildland Fire Implementation Plan or Prescribed Fire Plan. Timely implementation of the actions when the fire reaches the action point is generally critical to successful accomplishment of the objectives. Also called Management Action Points.

Two-Track Road: Ungraded dirt roads where people have driven enough times to leave two tire ruts in the soil.

Appendix G: Delegation of Authority

Janice K. Brewer
Governor

Scott Hunt
State Forester

Arizona State Forestry Division

Office of the State Forester
1110 W. Washington St., Suite 100
Phoenix, AZ 85007
(602) 771-1400

ARIZONA 1966 FORESTRY

Serious Accident Investigation Team
Delegation of Authority

On the afternoon of June 30, 2013, nineteen members of the Granite Mountain Type 1 Hotshot Crew from Prescott, Arizona were killed while fighting the Yarnell Hill Fire.

As the State Forester of Arizona, I authorize Jim Karel's Serious Accident Investigation Team to conduct the accident review of the Yarnell Hill Fire. This delegation is to perform the serious accident review of the Yarnell Hill Fire with the final objective of providing a factual and management report for accident prevention. I also authorize Mike Dudley as the Deputy Team Leader.

Your duties include but are not limited to:

1. Organizing, conducting, and controlling the accident investigation.
2. Providing for in briefings and out briefings with affected agency officials.
3. Coordinating information exchange between team members, local law enforcement, coroner's office, and others.
4. Requesting technical, logistical, or other support as required to conduct the investigation.
5. Assist the State Forester's information staff with addressing the media on your makeup, purpose, methodology, and estimated timelines, including attending press conferences if necessary.
6. The Forestry Division shall be the final repository for all team paperwork and reports.
7. Provide the following formal briefings/reports:

   a. Expanded Report (72 Hours)
   b. Factual and Management Report.

Scott Hunt 7-3-13
Scott Hunt, State Forester

Jim Karel 7-3-13
Jim Karels, Team Leader, SAIT

Mike Dudley 7/3/13
Mike Dudley, Deputy Team Leader, SAIT

Appendix H: Team Members & Signature Page

INVESTIGATION TEAM

Jim Karels, Team Lead
State Forester, Florida Forest Service

Mike Dudley, Team Deputy Lead
Director, State and Private Forestry
USFS Intermountain Region/Northern Region

Godot Apuzzo, Equipment Specialist, USFS Missoula Technology and Development Center

Lance Carbone, Division Chief of Logistics, Boise Fire Department

Randy Draeger, Investigator/Process Coach; Regional Safety and Health Director, USFS Intermountain Region

Tim Foley, Fire Behavior Analyst, Rocky Mountain Area Type 1 IMT; BLM (retired)

Ralph Gonzales, Fire & Fuels Program Leader, USFS San Dimas Technology and Development Center

Jay Kurth, Forest Fire Management Officer, Eldorado National Forest

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Brad Mayhew, Investigator/Human Factors, Fireline Factors Consulting

Randy Okon, Captain, Missoula Fire Department

Tony Petrilli, Equipment Specialist, USFS Missoula Technology and Development Center

John Phipps, Senior Advisor, USFS State and Private Forestry

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J. Brent Wachter, Incident Meteorologist, National Weather Service – Albuquerque

Richa Wilson, Documentation Specialist/Writer; Historian, USFS Intermountain Region

Dr. Jennifer Ziegler, Associate Professor of Communication, Valparaiso University

Dr. Tom Zimmerman, Senior Wildland Fire Management Specialist, Tom Zimmerman Consulting

SUPPORT TEAM

Sam Amato, Fire Technology Specialist, Wildland Fire Management RD&A, USFS Rocky Mountain Research Station

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Chuck McHugh, Fire Spatial Analyst, Wildland Fire Management RD&A, USFS Rocky Mountain Research Station

Billy Phillips, Technical Specialist, Geospatial Equipment and Technology Application Group; Squad Leader, Missoula Smokejumpers

Jennifer Plumb, Dispatcher, Apache-Sitgreaves National Forest

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Carrie Templin, Public Information Officer, Bureau of Land Management, Arizona

Jim Saveland, Human Factors Specialist, USFS Rocky Mountain Research Station

Larry Sutton, Fire Operations Risk Management Officer, National Interagency Fire Center

Elizabeth (Betsy) Walatka, Editor; Management & Program Analyst, USFS Business Operations

Appendix I: Subject Matter Experts

Brian Cardoza, Superintendent, Idaho City IHC, Boise National Forest

Paul Cerda, Superintendent, Alpine IHC, Rocky Mountain National Park

Heath Cota, District Fire Management Officer, Sawtooth National Forest

Sarah Doehring, Smokejumper Program Manager, Grangeville Smokejumpers, Nez Perce National Forest; IC Type 3

Frank Esposito, Superintendent, Big Bear IHC, San Bernardino National Forest

Rich Harvey, Deputy State Forester, Nevada Division of Forestry; IC Type 1, Great Basin IMT 2

John Kennedy, Captain, City of Reno Fire Department; Operations Branch Director, Great Basin IMT 1

Erik Litzenberg, Fire Chief, Santa Fe Fire Department

Elizabeth Lund, Deputy Director, USFS R4 Fire & Aviation Management; IC Type 1, Great Basin IMT 1

Kelly Martin, Chief of Fire & Aviation Management, Yosemite National Park; Operations Branch Director, California Interagency Incident Management Team 5

Leif Mathiesen, Superintendent, Kern Valley IHC, BLM Central California District

Ted Mead, Chief of Fire and Aviation, Montana Dept. of Natural Resources & Conservation

Les Rogers, Chief of Law Enforcement, State of Texas; IC Type 2

Brit Rosso, Center Manager, Wildland Fire Lessons Learned Center

Aaron Schuh, Superintendent, Rogue River IHC, Rogue River- Siskiyou National Forest

Bobbie Scopa, Assistant Director of Fire Operations, USFS R6 Fire & Aviation Management

Terry Sonner, Engine Module Leader, BLM Boise District

Eddie Tudor, Resource Management Bureau Chief, New Mexico State Forestry Division; ICT3

John Wood, Superintendent, Bitterroot IHC, Bitterroot National Forest

Appendix J: Acknowledgements

The following people and organizations contributed to this report by providing information, assistance, and resources. Their efforts profoundly contributed to the investigation process.

Arizona Department of Public Safety
Arizona Dispatch Center
Arizona Game and Fish Department
Arizona State Forestry Division
Bureau of Land Management, Arizona
Colorado State Forest Service
Joy Collura and Sonny Gilligan
Lee and DJ Helm
Matt Oss Photography
National Interagency Fire Center
National Oceanic and Atmospheric Administration
National Weather Service—Albuquerque, Flagstaff, and Phoenix Offices
Peeples Valley Fire Department
Prescott Chapter, International Association of Firefighters Local 3066
Prescott Fire Department
Rick Tham
Sean Kriner
Shawn Sonnentag
Southwest Area Geographic Area Coordination Center
Southwest Area Type 1 Incident Management (Templin) Team
Tom Garigan
Tom Story
US Forest Service, Missoula Technology and Development Center
US Forest Service, San Dimas Technology and Development Center
US Forest Service, Wildland Fire Management Research, Development, and Application Program
Warner College of Natural Resources, Colorado State University
Yarnell Fire Department
Yavapai County Sheriff's Office