Angora Fire – Entrapment & Fire Shelter Deployment Accident Prevention Analysis Report

Pacific Southwest Region - Lake Tahoe Basin Management Unit

January 17, 2008

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Executive Summary

On June 26, 2007, two Forest Service firefighters assigned to the Angora Fire were entrapped by fire and forced into their fire shelters. Fortunately, they were uninjured. This report tells what happened and examines the social and organizational causes that led to this outcome. In conducting an investigation, the review team learned of another story—that of a near-catastrophic tragedy for dozens of other firefighters who were within minutes of also being entrapped. Accidents and near-misses such as this are proof of the high risks of wildland firefighting as well as proof that our firefighting organization could better manage these risks.

The review team consisted of two line officers under delegations from the Chief and Regional Forester, a peer subject matter expert (engine captain), local and national NFFE representation, and experts in Fire Safety, Information, Behavior, and Personal Protective Equipment.

With the encouragement of the Forest Service National Director of Safety, this accident was investigated using the new *Accident Prevention Analysis (APA) Guide*. This guide is an outcome of the Foundational Doctrine and recognizes that a learning culture is crucial to safe, principle-centered management. The APA process guides a review team to treat any incident, such as this deployment, as an organizational accident. As such, honest human errors are not causal factors; they are the consequences of organizational and social factors. APAs are conducted within a learning culture and feature a report designed to be, in itself, a learning tool.

In an effective learning culture, mistakes, near misses, and accidents are framed, publicized, and exploited as opportunities to learn, focusing on the factual and perceived events in the eyes of the actual participants. Consequently, the focus of this investigation was *not* to document where employees went wrong or who should be held accountable for performance, but instead to understand and display why their actions made sense to them at that time, given the information they evaluated. Importantly, if their risky decisions made sense to them at the time, the same risky decisions will make sense to other employees, given similar circumstances. The review team believed that, given the same set of information, another team of firefighters was likely to have the same responses on future events. Correcting this response through a learning culture will strengthen future team actions and lead to an increase in firefighter safety.

Thanks to the open and frank discussions with those involved, the investigation revealed numerous upstream factors that enabled this unintended outcome. Unless mitigated, these factors will remain resident and may provide a pathway for disaster. The report concludes with ten recommendations believed by the team to address complex organizational issues such as:

- ill-defined and conflicting risk management principles in the urban interface,
- ill-defined standards for fitness for command in key field leadership positions,
- interagency relationships between the Forest Service, CAL FIRE and local fire departments often strained by cultural and financial differences, and
- a culture that encourages "hot hand offs" (fast team transitions) between Initial Attack, T-2 and T-1 IMTs during events with rapidly escalating complexity, such as the Angora Incident.

Introduction

On June 26, 2007, two Forest Service employees assigned to the Angora Fire on the Lake Tahoe Basin Management Unit were entrapped by fire and deployed fire shelters. No significant injuries were sustained, neither individual was hospitalized, and all firefighters in the vicinity were safely evacuated from the fire. This incident qualifies as an "entrapment," according to FSM 5100, Chapter 5130, section 5130.3, which states,

> *"...entrapments are situations where personnel are unexpectedly caught in a fire-behavior-related, life-threatening position where planned escape routes or safety zones are absent, inadequate, or compromised. An entrapment may or may not include deployment of a fire shelter. These situations may or may not result in injury; and include near misses."*

The *Interagency Standards for Fire and Fire Aviation Operations* (page 19-2) states that entrapments will be investigated utilizing the Serious Accident Investigation Process. Recently, the Forest Service Risk Management Council wrote and finalized an accident investigation process that meets the legal intent of an accident investigation and is believed to substantially enhance a learning culture. This process, called Accident Prevention Analysis, incorporates concepts of 21st century High Reliability Organizing and Normal Accidents Theory into the review and analysis of the human and organizational factors related to an accident. (See Appendix C - Forest Service Risk Management Council briefing paper, "Examining Unintended Outcomes.")

Accordingly, the Washington Office delegated authority to the Pacific Southwest Regional Office to use the Accident Prevention Analysis process to investigate this accident. The Accident Prevention Analysis (APA) Team consisted of a team leader, chief investigator, union representative, a chief's representative, technical specialists, and a peer (engine captain) from a similar type of Forest Service engine. The APA process is designed to meet the technical requirements of an accident investigation, while producing a report that serves as a teaching tool. Another significant difference between a serious accident investigation and an APA is that an APA focuses on the organizational and cultural factors that can be identified as causal to the accident.

This report presents the results of the Angora Fire shelter deployment review, documents the event and associated circumstances, and provides a discussion of the fire, lessons learned, and recommendations.

Review Objectives

Objectives of the Angora Fire Entrapment and Shelter Deployment Accident Prevention Analysis were to:

- Evaluate employee performance under the assurance of a learning culture.
- Evaluate organizational and cultural factors contributing to the accident.
- Develop recommendations to correct or change organizational factors and culture that may impede organizational reliability or increase risk to employee safety.
- Produce a report that serves as an effective firefighter and organizational learning tool.
- Recommend actions that address and mitigate the organizational and cultural factors identified as causal.

Description of the Angora Wildland Fire

The Angora Fire was located in California's Sierra Nevada mountain range on the U.S. Forest Service's Lake Tahoe Basin Management Unit (LTBMU) (see Angora Fire Location, Figure 1). The initial dispatch for the Angora Fire was at 1423 hours on Sunday, June 24, 2007. The fire was started by a campfire east of Angora Lakes in the LTBMU. During the initial size up, the Initial Attack Incident Commander located a 15- to 20-acre fire burning in mature mixed conifer timber with a minor shrub component and heavy dead and down fuel load. The fire exhibited extreme behavior and a rapid rate of spread. Evacuations of numerous subdivisions in the path of the fire were immediately ordered. Within one hour from the initial size up, homes were destroyed. By Monday morning, June 25, the Angora Fire had consumed 237 structures and more than 2,500 acres.

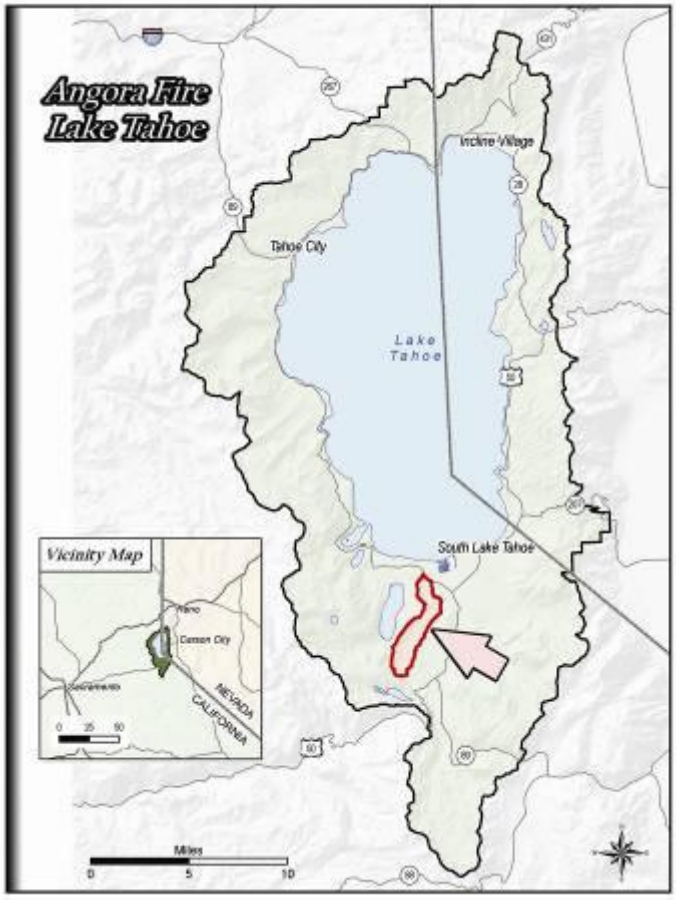

Figure 1. Angora Fire Location

Due to calm winds and aggressive suppression, efforts, the fire had minimal growth on June 25. On June 26, afternoon winds caused the fire to spot over containment lines and consume an additional 356 acres before it was contained that evening (see Angora Fire Progression Map, Figure 2).

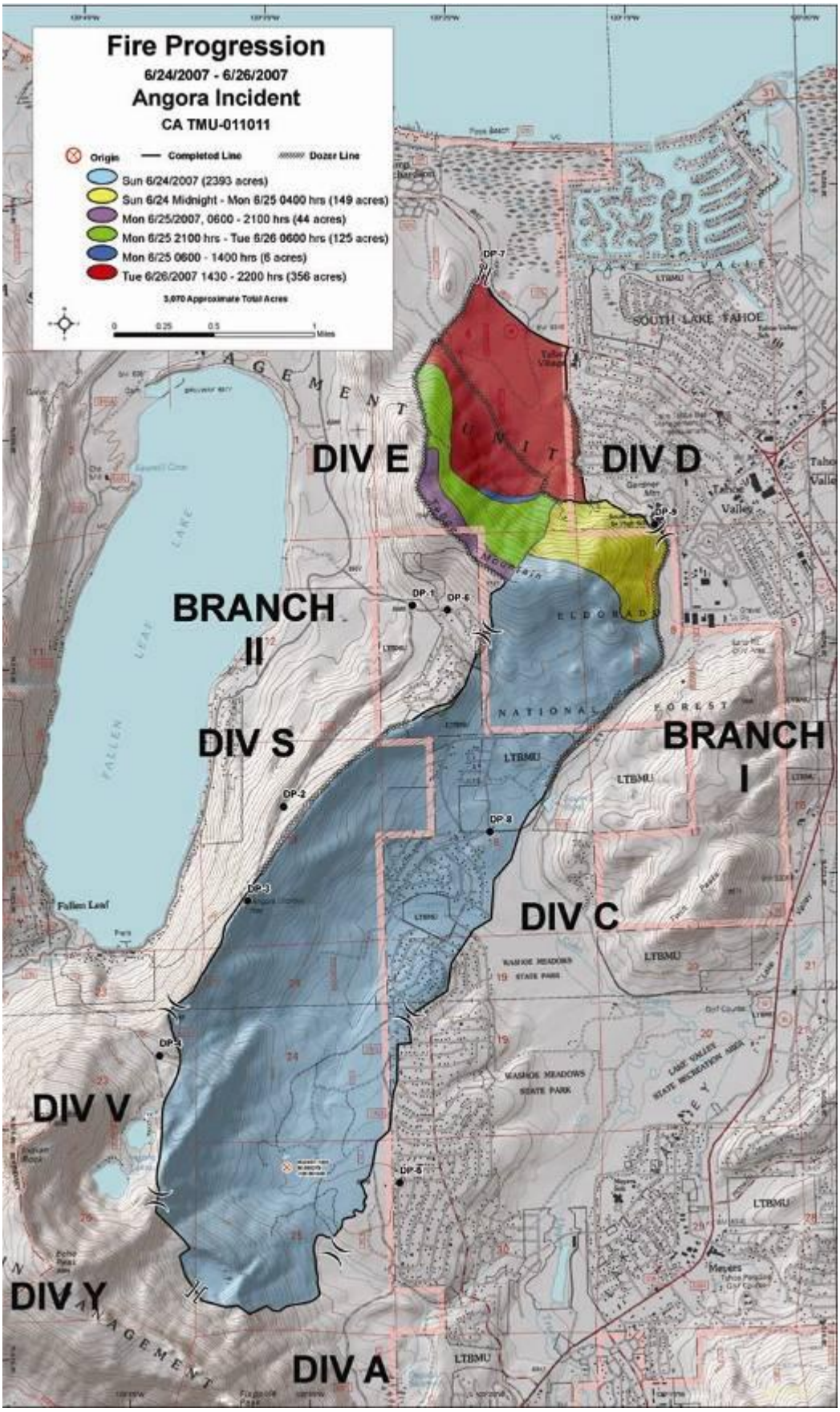

Figure 2. Angora Fire progression map

Story of the firefighters who deployed on the Angora Fire

Forest Service Engine 34 (E-34) was one of many resources ordered to help fight the Angora Fire. They received their dispatch call at about 1730 on Sunday, June 24, 2007. The engine's captain and one of the firefighters normally assigned to the engine were not available for this assignment, so the engine module was staffed by a Red-Carded engine boss from a different engine and a firefighter from one of the forest's water tenders. The engine module configuration for this assignment consisted of an engine boss (GS-07), an engineer (GS-07), an assistant fire engine operator (GS-05), and two firefighters (GS-04 and GS-03).

The module leader who would serve as the engine boss for E-34 had been serving as the engine boss for a different local engine a month earlier. He had completed his task book for the engine boss qualification the previous September, so the Angora Fire detail was a great opportunity to gain experience. The Angora Fire would be the first time this engine boss would take an engine off the forest for an assignment and the first time this engine module responded together as a crew. His crew included three members who were normally assigned to FS E-34. They included the assistant fire engine operator, the engineer, and an apprentice firefighter who had not yet been to the Wildlands Firefighters' Academy. The fifth member of the crew was a firefighter normally assigned to a water tender on the forest. These five firefighters would be the crew of E-34 during their assignment to the Angora Fire.

E-34 left its station at 1900 Sunday night and drove for three hours before spending the night at a hotel in Willows, California. On Monday morning, June 25, 2007, the crew was on the road to the fire at 0630 and arrived at the Incident Command Post (ICP) in South Lake Tahoe at 1100.

Upon arrival, E-34 was assigned to engine strike team 3630-C, a group of 5 federal type-3 engines from northern California. Strike team 3630-C consisted of one U.S. Fish and Wildlife Service engine, one National Park Service engine, and three Forest Service engines, including E-34. The strike team's mission that day was to clear the brush from a mid-slope road, known as the 12N19 road, located near the northern perimeter of the fire on Division D (see Incident Action Plan Map, Figures 3 and 4).

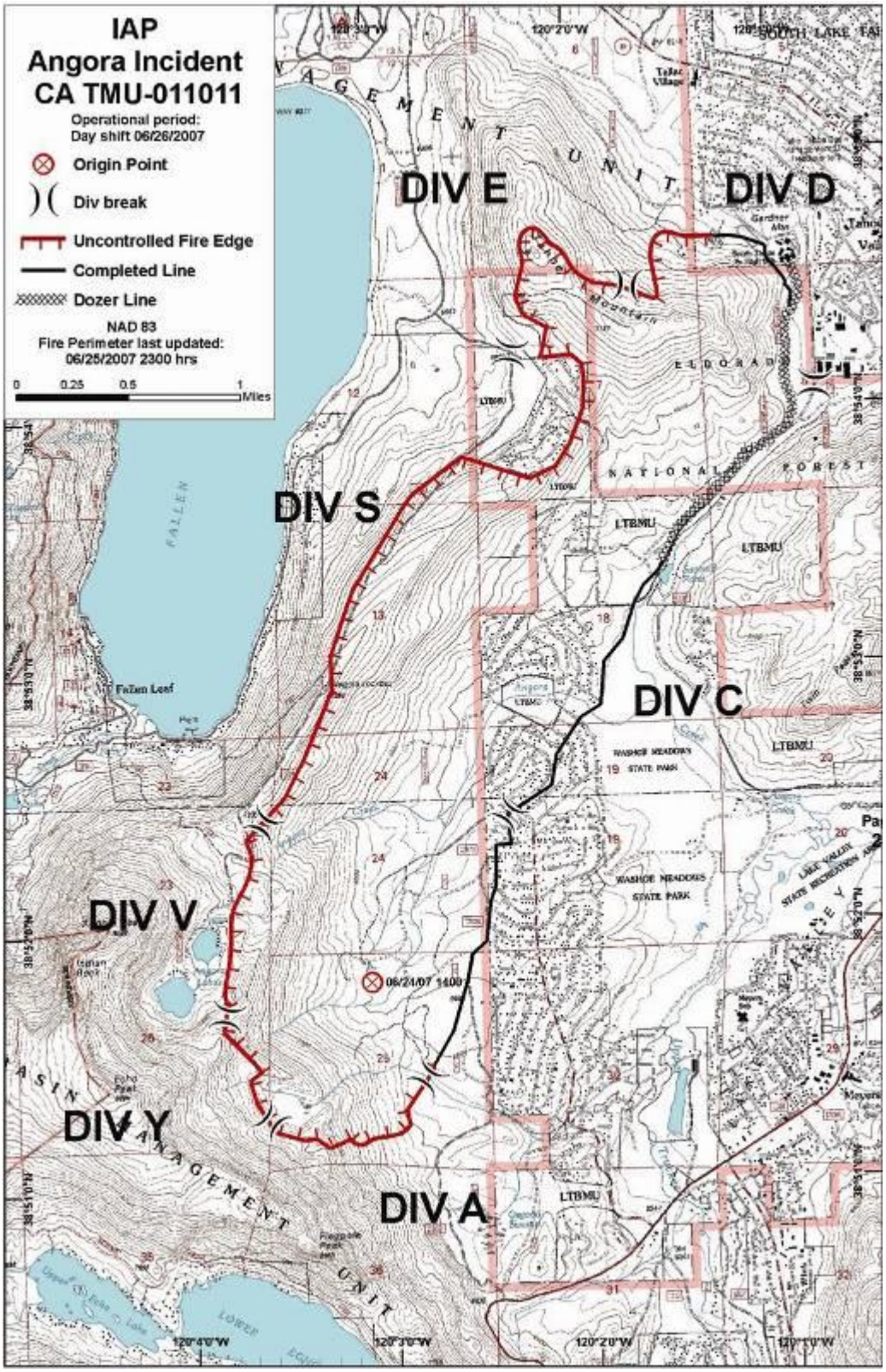

Figure 3. Incident Action Plan Map

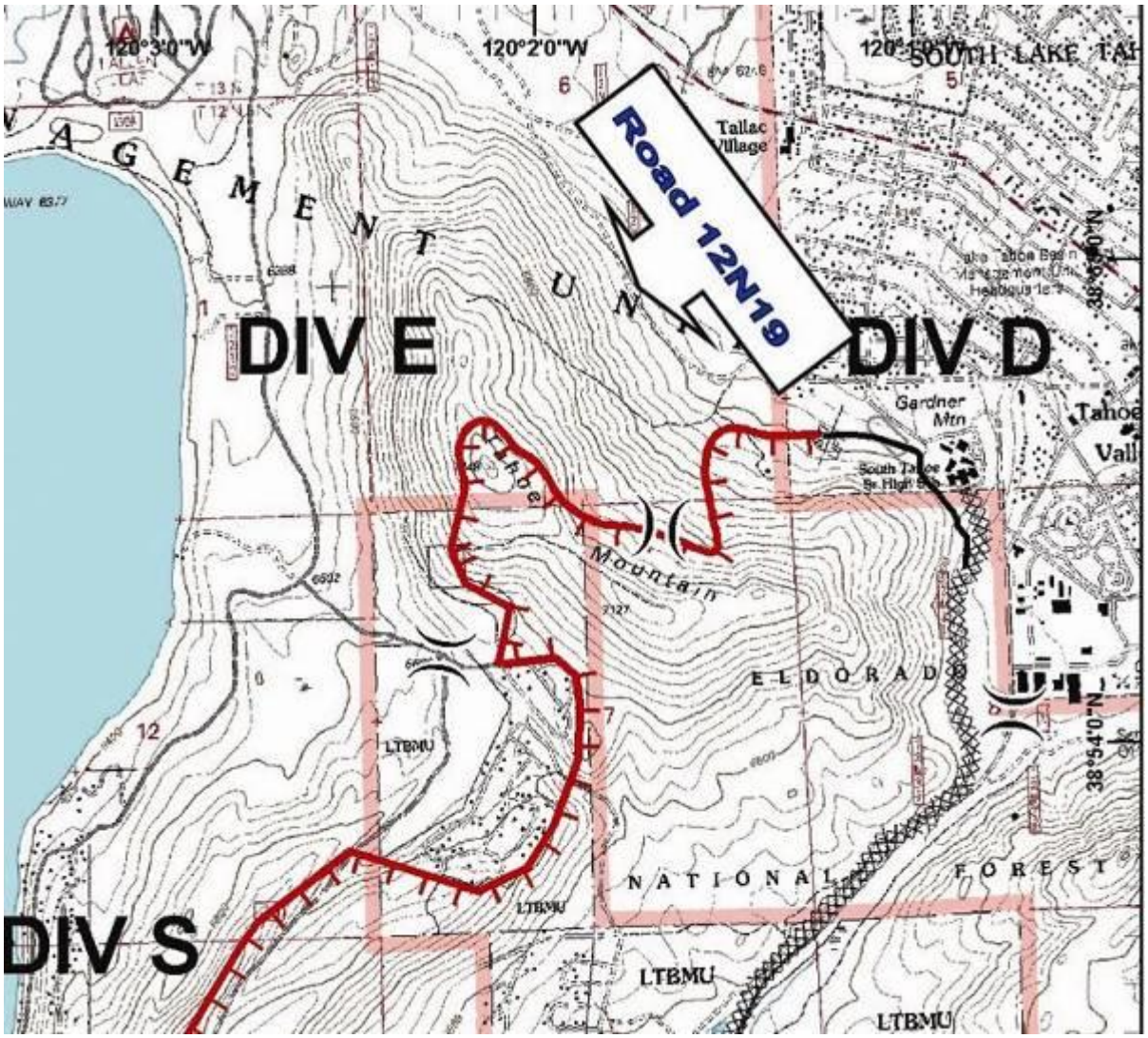

Figure 4. Incident Action Plan map showing the 12N19 road

The winds that drove the fire's rapid growth on Sunday night were predicted to return later in the week, and the road that engine strike team 3630-C was working on would be the line that was to be used to stop the fire from spreading further to the north and threatening a housing subdivision in South Lake Tahoe.

Although they shared a common mission, the engines in the strike team mainly worked independently along their assigned sections of the road, as they were separated physically by being strung out along this road segment. Occasionally, the crew of E-34 could see the main fire

backing down the hill above them on the far eastern end of the road near the local high school. However, the winds were light and the fire was moving slowly. Due to the dense vegetation along the road, the fire couldn't be seen at all from most of the locations they worked that day (see Picture 1).

All members of the crew at this time indicated that they felt like this was a typical assignment for an engine module.

Picture 1. Fuels along 12N19

By 2200, E-34 completed its shift and returned to the Incident Command Post (ICP). In all, it was a rather uneventful day on this fire perimeter road.

The next morning, Tuesday, June 26, was the third day since the fire started. Tuesday morning was also the first shift for the Type 1 Incident Management Team (IMT), which transitioned the night before with the Type 2 team, which had been in command since Monday morning. Along with their strike team leader, the engine boss for E-34 attended the morning briefing at 0600.

There were approximately 1,000 people present at the briefing, including large numbers of reporters and contractors. It was noisy with a lot of distracting side conversations taking place. Adjacent to the briefing area was a long snaking firefighter line for breakfast with literally hundreds of people filing through. The briefing this morning emphasized a red flag warning for high winds on Wednesday. The strike team leader briefed his engine bosses at the ICP and told them to head out to the 12N19 road, where they would receive a specific briefing on site.

The traffic at ICP, along with the lines for food, delayed their departure, but, by about 0830, E-34 and the other engines of strike team 3630-C were staged near 12N19 and were receiving their on-site briefing from the division supervisor and their strike team leader. This briefing indicated that the previous evening's night shift had conducted a "burnout" to Road 12N19 (see Figure 4) and that a dozer line had been constructed from the top of Tahoe Mountain down to Road

12N19. Their mission for Tuesday was to plumb a hose lay along the dozer line and then hold the fire perimeter on the 12N19 road adjacent to the area that had been burned out overnight.

To the engine boss of E-34, the morning's briefings indicated substantial progress overnight in containing the fire. Their objective would be to hold on to what was done the night before. The engine boss had an Incident Action Plan (IAP) and used it to brief his crew. The plan included a Fire Behavior Forecast, shown below in Figure 5.

Figure 5. Fire Behavior Forecast

(Note: typically in California, Incident Meteorologists and Fire Behavior Analysts do not use or discuss the Haines Index. The actual Haines Index for that day and location was a 4 or 'low')

FIRE BEHAVIOR FORECAST	
FORECAST NUMBER: 01	**FIRE: ANGORA FIRE**
OPERATIONAL PERIOD: Day, Tuesday, June 26, 2007	
DATE ISSUED: 06/25/2007	**TIME: 2100**
UNIT: USFS Lake Tahoe Basin MU	**SIGNED: /s/ xxxxxxxxxxx - FBAN**

WEATHER SUMMARY: ***See attached Fire Weather Forecast for details.***

1. HOT DRY CONDITIONS – EXPECT TO SEE AN INCREASE IN FIRE BEHAVIOR TODAY AS COMPARED TO YESTERDAY. IF OPEN FLAMES ARE NOT CONTAIN QUICKLY THIS COULD TRIGGER A FUELS/SLOPE RUN WHERE SLOPE ASPECT AND FUELS ARE ALIGNED

MIN RH: 10 - 15% ***DOWN 5% FROM MONDAY***
MAXIMUM TEMP: 77-80 at 6300 ***UP 5 DEGREES FROM MONDAY***
WINDS (20 FT): E5-10 becoming SW 10-15G22 after 1300 ***STRONGER WINDS!***
PROBABILITY OF IGNITION: 85%

WATCH OUT FOR WEDNESDAY – GUSTY WINDS SW35MPH
WATCH OUT FOR THURSDAY – STEADY WINDS 15-20 GUSTING TO 40!!

GENERAL FIRE BEHAVIOR: Look for fire behavior to increase today with the winds increasing after 1300.
What to watch for today:
1 - Open flame that could develop into a run near you;
2 – Torching and spotting as winds pick up could spot 1/4 mile from the spotting source.

- **SPECIFIC:**

NORTH END OF FIRE: Expect increasing fire behavior as winds pick up early afternoon and as the inversion lifts earlier today than Monday. Uncontained fire edge will likely develop into short crown fire runs with spotting 1/4 of a mile in front of the spotting source

WESTERN EDGE: Ridgeline should contain torching and spotting. Lookout of potential spots to the west of the ridge that could develop into a wind driven fire.

EASTERN EDGE: As winds begin to materialize early afternoon, torching and spotting near the fire edge could cause fire brands to land in receptive fuel beds up to 1/4 mile from the main fire edge.

SOUTH END: Unburned fuels will continue to torch and provide fire brands that may spot to the east given enough loft with increasing winds by early afternoon.

AIR OPERATIONS: Winds will increase today with potential gusts up to 22 mph beginning after 1300 – heavy smoke will linger until the inversion begins to lift.

SAFETY: ***When working on direct line construction make sure you know where all potential sources of open flame can originate from. Pay particular attention to where a fire could start a slope and fuels***

driven run.

The engine boss of E-34 recalls that the morning briefings emphasized the high winds predicted for the following day. Additionally, the safety officer's message in the IAP stated, "Today is the day to get it wrapped up, wind picking up on Wed. though Sat."

As the engines drove along 12N19 toward the dozer line, it was obvious that the area along the road had not been burned out to the road as they had been led to believe. In fact, along the entire length of 12N19, there was no evidence of the previous night's burnout. Some confusion arose as plans were changed by the division supervisors to match the reality on the ground, but the engine boss of E-34 understood that his mission was still valid: plumb the dozer line and then hold 12N19. While the on-the-ground situation did not match the briefing, the firefighters felt comfortable that the overhead would sort out what had actually happened the night before and then re-brief the crews on what would happen that day.

At approximately 0900, E-34 and three other engines from the strike team arrived at the west end of 12N19 where the dozer line connected to the road. The winds were calm under the inversion, which made for smoky conditions for their planned work. The four engines intended to begin laying hose up the dozer line from their location at the bottom of the line. The fifth engine was assigned to an area east of the 12N19 road near a local high school, where it would patrol that section of the line for the rest of the day. However, before the strike team of engines on the 12N19 road could begin their work, they had to wait for hose to be delivered from ICP.

As they waited for the hose to be delivered, a member of the Sierra Hotshots came down the dozer line to their location. The Sierra Hotshots and the Laguna Hotshots had been assigned to finish the burnout that was begun the night before. The Sierra Hotshot superintendent mentioned to the strike team leader that he would be the lookout for his Hotshot crew during the burnout operations. The Hotshot superintendent also mentioned that a good escape route existed by going straight out the 12N19 road to the northwest. During this conversation, several members of E-34 were nearby and listened to the Hotshot's advice. At this point, all of the engines were facing southeast toward their primary escape route as planned.

By 1000, the strike team still had not received the hose they needed to plumb the dozer line. The strike team leader contacted ICP and learned that due to a shortage of drivers in logistics, he would go to the high school to pick up the needed hose, fittings, and folda-tanks. Leaving the strike team on the 12N19 road, the strike team leader drove to the high school and returned with half of the needed supplies by 1100. The other half of the supplies was delivered by a camp driver and was staged at a parking area at the east end of the 12N19 road.

As the strike team began to plan its hose lay, the division supervisors for Divisions D and E devised a new plan, reevaluating the burnout operation and how the dozer line should be plumbed. It was agreed between the two Divisions that a third Hotshot crew from Division E would plumb the dozer line and that Division D, including E-34's strike team, would focus upon holding the 12N19 road. This decision moved the D & E Division break and gave the entire burning and holding operation to Division D (see Figure 6, Map of revised plan).

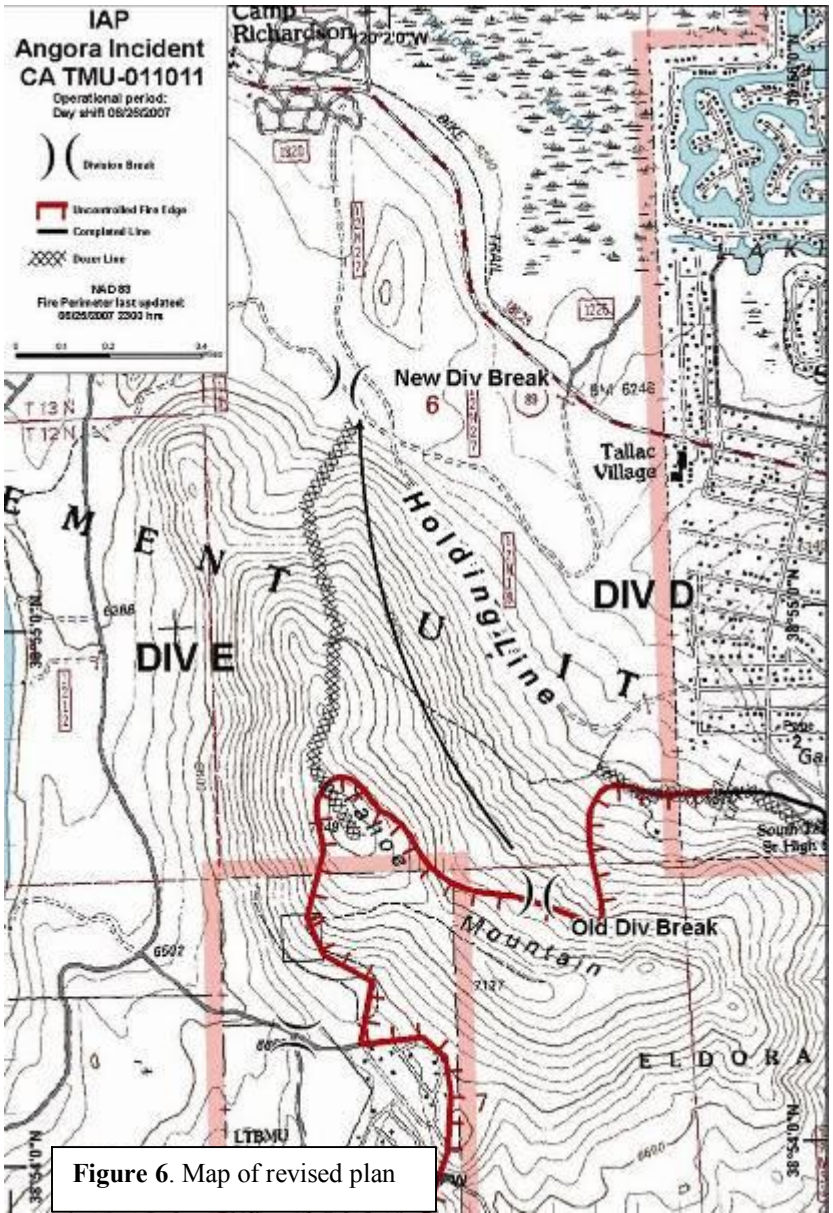

Figure 6. Map of revised plan

In order for Division E's Hotshots to plumb the line, the strike team leader would need to drive the hose and other equipment to the top of the dozer line. Before leaving to shuttle the hose, the strike team leader ordered his four strike team engines to spread out along the 12N19 road and prepare to hold the road for a burnout operation. The strike team leader then took the apprentice firefighter from E-34 with him to help deliver the hose to the top of the mountain to the Hotshots. The trip took the strike team leader approximately one hour, and he returned to the 12N19 road by 1200.

Following the strike team leader's order to spread out and hold the road, the crew of E-34 headed east approximately halfway down the 12N19 road away from the dozer line and toward their planned escape route. E-34 was the furthest engine east in their strike team, and, like the other engines, they were facing east toward their primary escape route. The engines were spread out 200-300 feet apart (see Figure 7, Map @1300).

This map depicts the approximate location of major resources assigned to Division D at 1300. These resources include CAL FIRE engine strike teams 9271-C and 9141-C; CAL FIRE hand crew Strike Teams 9232-G and 9273-G; Sierra and Laguna Interagency Hotshot Crews; Iron Mountain hand crew, and the individual engines assigned to the federal engine strike team 3630-C. The strike team leader for 3630-C is shown as "STEN" and the Division D, Division Supervisor is shown as DIVS.)

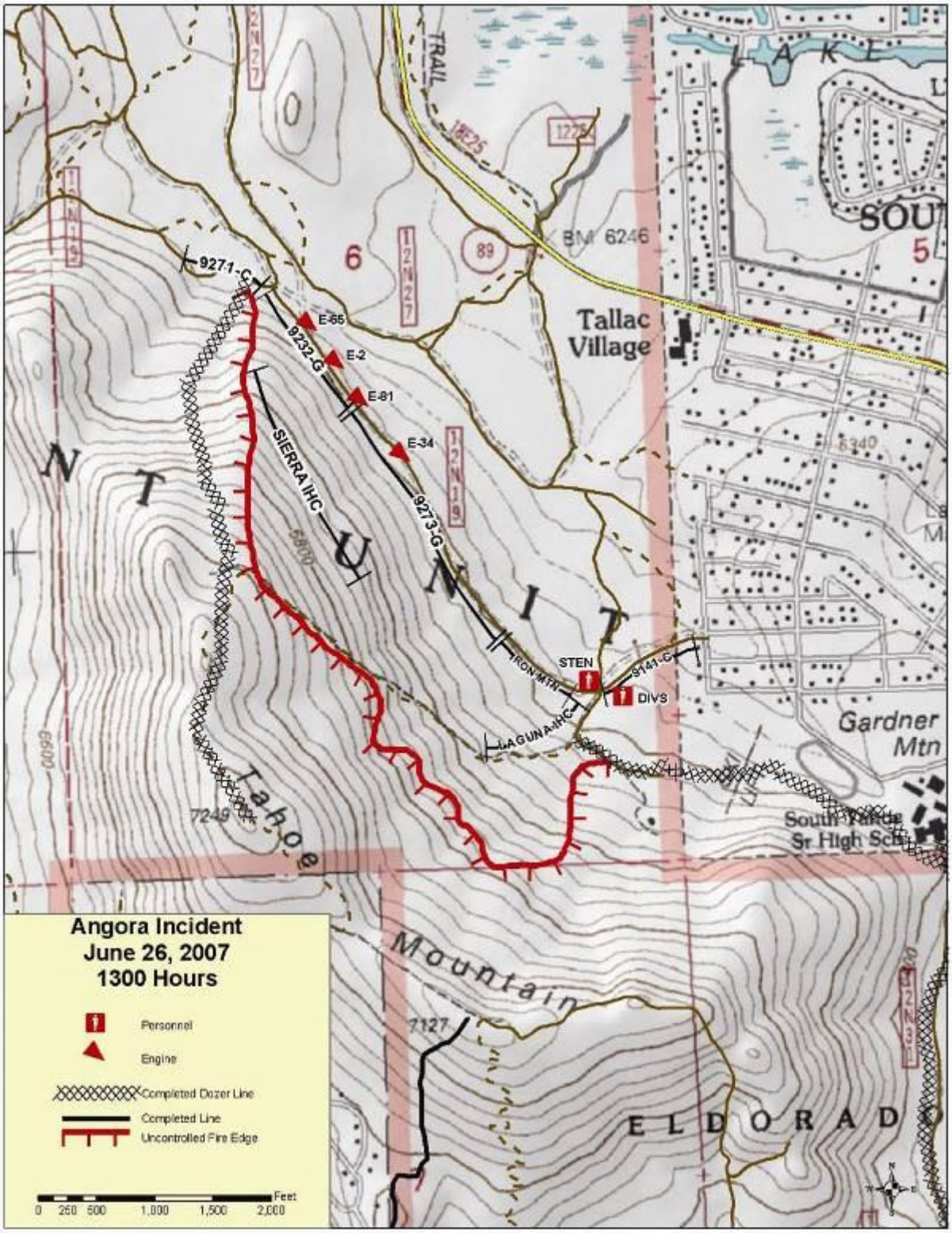

Figure 7. Approximate resource locations at 1300.

As the crew of E-34 sat on the road, they could hear on their radios that the Hotshots were beginning the burnout operation above them. However, the only evidence of the operation from the road was the sound of an occasional tree torching out and radio chatter between the two Hotshot crews and the lookout (see Picture 2).

Picture 2. Aerial photo looking southwest at the most easterly portion of Division D. Smoke in the center is from ignition by Laguna IHC. The IHC was attempting strip firing so that it could be brought down evenly to 12N19.

While they waited on 12N19, the engine boss and the assistant fire engine operator walked down the road to the southeast to talk with the other forces assigned to hold the road. In addition to their strike team, there were two CAL FIRE strike teams of hand crews (9273-G and 9232-G) spread out along the road and two CAL FIRE strike teams of engines on the road (9271-C and 9141-C), one at each end of 12N19.

The engine boss for E-34 was keeping the assistant fire engine operator close to him during this assignment because the assistant fire engine operator had recently started his task book for engine boss. It was the engine boss's intention to help train the assistant fire engine operator and help him get a few things signed off on his new task book. When they reached the east end of the road, the two firefighters tied in with CAL FIRE engine strike team 9141-C and noted that they had not spread out along the road like their own strike team had. When asked about their tactics, 9141-C's strike team leader replied that he did not want to block the escape route on such a narrow road. Following this conversation, the two firefighters returned to E-34 to wait for the fire to back down to their position on the road.

By 1200, E-34's strike team leader took up a position southeast of E-34 along the 12N19 road and the firefighter he had taken with him was back at E-34 (refer to Figure 7, Map @ 1300). As the crew waited on the road, they cut holes through the brush on the downhill side of the road so

that they could see into the brush and access the area in case there were any spots. The firefighter who was on detail to E-34 from his regular job as a tactical water tender driver began taking weather observations. At 1200, the temperature was 70 degrees with 32% relative humidity, and light winds were estimated SW at 0-2 mph. At this time, the inversion still had not lifted.

During the next hour and a half, the inversion began to lift and the smoke was beginning to clear. Crew members could hear the Hotshots talking on the radio about their burnout operations, but they still couldn't see the burnout from their position on 12N19 (see Picture 3). By 1300, some torching was observed near the ridge above them, but the smoke was headed uphill away from them. At 1300, the weather observed was 72 degrees, 22% relative humidity, and estimated winds SW at 0-2 mph.

Picture 3. Burnout operations on Tahoe Mountain above the 12N19 road at approximately 1330.

The crew of E-34 overheard Hotshots talking about their burnout operation being extremely hot and that some of the trees in the area were torching. Additionally, the lookout for the Hotshots reported that he was observing the developing column battling with the wind. By 1334, both of the Hotshot crews ceased their burnout operations. The Hotshot crews reported to Division that they were ceasing their burn, saying that it was too late in the day and that the burnout was increasing the torching.

Not long after E-34's engine boss heard that the Hotshots had ceased burning, he heard from one of the strike team engines to his west that there was a spot near the line, but still within the potential black side of the line. By 1400 southwest winds began to develop, and, although E-34 could not see it, the fire on the slope above the 12N19 road was being pushed downhill. Additionally, the winds started to push the column toward the NE over the top of E-34 and the rest of the crews along the road.

The winds were variable but still light along the road. The inversion was lifting and there was blue sky on either side of the column above them. By 1415 ashes were falling around E-34. The crew continued watching the downhill side (northeast) of the road for spots. The detailed firefighter on E-34 noticed an ember drop in the brush just below the engine, so he headed down to it. He picked it up with his shovel and carried it back to the road. By the time he reached the road with his shovel full of grass, needles and twigs, he had a shovel full of open flame. The firefighter dropped the burning shovel load on the road and the assistant fire engine operator and a nearby hand crew member with a backpack pump put it out. The engine boss was concerned about what he had just witnessed and began to wonder how many more of those were in the green below the engine.

With more and more ash and embers falling from the sky, the engine boss of E-34 told the three regular members of E-34 to stay with the engine while he and the detailed firefighter paired up and began to grid for spots below the engine. This left the three permanent members of E-34 on the road with the engine and the two detailed module members gridding for spots below (north of) the engine.

The column above 12N19 was getting darker. The winds along the road were generally calm, but occasionally gusts would battle back and forth. Finding another spot north of 12N19 (below the road) the engine boss and the firefighter were busy and focused on getting it out and looking for more. To the engine boss, the spots below his engine posed the most significant threat to the safety of his engine.

As the two members of E-34 were working on spots below the engine (approximately 800 feet from the road), the assistant fire engine operator stood at the side of the road, communicating with the engine boss by radio, as he tried to keep them both in sight. The apprentice firefighter climbed on top of the engine to help serve as a lookout.

Picture 4. View of the "meadow" after the fire passed through.

As the engine boss and the firefighter ventured further and further into the area below (north of) the road to attack spots, they weren't alone. A CAL FIRE crew captain and nine firefighters were also in the same area working on spot fires. At the same time, the winds on the road were getting very gusty, generally blowing northeast, toward the main fire. The column, going in the opposite direction, was flattening out and casting a brown shadow over Division D. The CAL FIRE Captain and his firefighters, along with E-34's engine boss and firefighter, dropped below a bench below the 12N19 road and were no longer visible to E-34's assistant fire engine operator. The assistant fire engine operator radioed the firefighter and asked him to move back toward the engine so he could keep an eye on him. As the firefighter began moving back toward the engine, the engine boss redirected him to help with a spot fire he and the firefighters from the CAL FIRE hand crew were working on near a grassy area they were referring to as "the meadow" (see Picture 4).

Unknown to the firefighters chasing spots north of 12N19, the fire behavior at the southeast end of Division D was increasing dramatically. The Iron Mountain hand crew, assigned to patrol the eastern end of 12N19, noticed bats flying overhead at about 1420, and several members of the Iron Mountain crew saw a bear running away from the main fire across 12N19. Shortly thereafter, the roar of trees torching out and strong convective winds made it obvious that the fire was about to crown across the road. The Iron Mountain Crew Boss, on an intra-crew channel, ordered his crew to evacuate to the east (see Picture 5). The Laguna IHC crew and the Division D Supervisor were in the same vicinity. They both noted that spots were crossing 12N19 and both realized the plan to hold the road was rapidly becoming impossible.

Picture 5. Iron Mountain Hand Crew evacuating Division D at approximately 1430

At the time Iron Mountain was evacuating the line, the strike team leader for 3630-C (E-34's strike team leader) was near one of the Iron Mountain crew's squad bosses. He noticed that the hand crew was moving out, but he didn't know why. He asked if there was "a spot or something." The squad boss may not have heard the question and did not answer. Upon seeing the hand crew leave, the strike team leader was concerned that his eastern flank would be undefended. He did not realize that the fire had already spotted across the road and that the entire eastern end of their line was about to be compromised by a crown fire.

With the intent of protecting the eastern end of the road and their escape route, he ordered his engines to "bump down to his location" toward the southeastern end of 12N19. Two of his engines heard and responded to the order to "bump down." E-34's assistant fire engine operator did not hear the strike team leader's order but noticed two engines from his strike team drive past him to the east. He wondered where they were going but was more concerned with the whereabouts of his engine boss and firefighter.

Picture 6. Picture taken from a helicopter at approximately 1450 showing evolving spot fires near the location where E-34 engine boss and firefighter were last working on spot fires.

As Iron Mountain was evacuating to the east and the two strike team engines were moving southeast to assist the strike team leader, E-34's engine boss took a moment to look around and began to understand the precarious situation that he, the firefighter with him, and the CAL FIRE firefighters were in. The engine boss could see multiple spots around him and could feel the wind gusting, but he could not see his engine or the 12N19 road. The engine boss called out to the firefighter, "We gotta go!" He then radioed back to his assistant fire engine operator that there were "six or seven spots" in the area, but they were headed back to the engine (see Picture 6).

The two engines from the west end of the 12N19 road arrived at the strike team leader's position at approximately 1440. Minutes later, the strike team leader recognized that the fire was threatening the road at the east end, cutting off the strike team's planned escape route. In fact, although the strike team leader could not see it from his position, the fire had already crossed the road. Recognizing that their position on the road was no longer defendable and that the engines were now facing the wrong way for egress, the strike team leader ordered the engines to turn around and drive out of the area to the west. The strike team leader called his Division to notify him that they were evacuating the line. Simultaneously, the Division Supervisor was already ordering the evacuation of the division (see Figure 8, Map @ 1438).

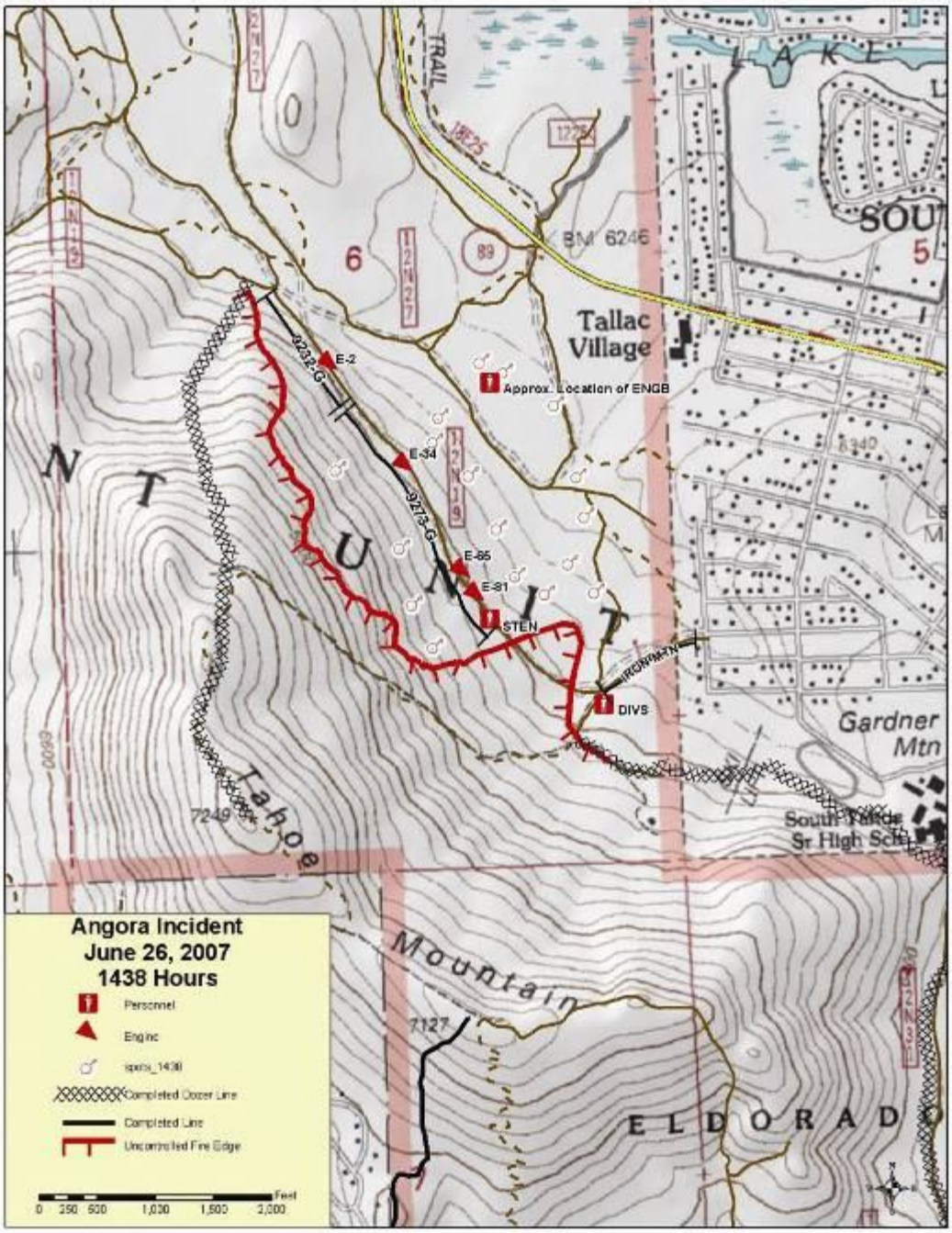

Figure 8, Map @ 1438. This map depicts the approximate location of resources at the approximate time the fire crossed road 12N19.

As the engine boss and the firefighter started back up the hill toward their engine, the engine boss heard his strike team leader on the radio ordering the strike team to turn around and evacuate the division. Meanwhile, the CAL FIRE firefighters, with whom they were working, also heard the order to evacuate. As the engine boss and firefighter looked back, they saw the CAL FIRE firefighters lined up and running east down a two-track road toward Tallac Village.

Although the engine boss and firefighter were headed uphill toward where they believed their engine to be, they were also headed straight toward the oncoming head of the fire. There were spots in almost every direction they looked. As they ran back up the hill, they scanned the hillside for the road and their engine. At the same time, the assistant fire engine operator from E-34 was pacing along the side of the road, scanning the area below for any sign of the two firefighters. Although he had heard the order from the strike team leader to turn the engines around and head out 12N19 to the northwest, he was determined not to abandon the two firefighters. The assistant fire engine operator sent the engine's engineer and apprentice firefighter to drive E-34 down the road to the southeast, to find a place to turn around and then come back. The assistant fire engine operator radioed his strike team leader to let him know that he was waiting for two of the engine's firefighters to return to the engine.

Right after E-34 had turned around, Engine 2 (driving southeast down 12N19 also looking for a place to turn around) met E-34 head on. Fortunately, the point where the engines met was wide enough to pass.

By the time E-34 got back to the assistant fire engine operator's position on the road, there was still no sign of the engine boss and the firefighter. The sky now was dark from the column. The number of spot fires was increasing in all directions as was the sound of trees torching. As E-34 waited, numerous CAL FIRE firefighters on foot were hustling past them towards the northwest and the other three engines from the federal strike team pulled in behind E-34 (see Figure 8).

As the engine boss and firefighter were running uphill, trying to find 12N19, they knew they had to hurry and get to their engine or their engine would be forced to leave without them. As they climbed what they thought was the last bench just below 12N19, a wall of fire stopped them. They tried to go around but were cut off by another emerging spot fire. The engine boss radioed

back to his crew on the engine, “We’re cut off! We’re heading back to the meadow!” The assistant fire engine operator asked him if they were heading back to the village. The engine boss replied “affirmative!”

Because E-34 was now the lead engine for the western egress from 12N19, they were effectively blocking the road as long as they stayed to look for the two crew members below. The main fire above the line of engines was getting more intense as it pulsed with groups of trees torching down the hillside toward the strike team. The driver of E-34 began to idle slowly along the road with its three crew members looking for the other two in the woods below them. The other three engines were pressing behind them. After a short distance, E-34 stopped in a wide spot and tried to wave the rest of the engines by, but they would not pass. The assistant fire engine operator called his engine boss to let him know that they had to evacuate the road immediately. The reply he received from the engine boss was, “We’re okay! You go on! Leave us!” Hearing that message from his engine boss, the assistant fire engine operator directed his driver to lead the evacuation northwest down the 12N19 road and eventually to Highway 89.

Picture 7. Angora plume, looking southeast from Highway 89, shortly before the estimated time of deployment.

The engine boss and the firefighter were now running back downhill toward the meadow area where they had been working on spots with the CAL FIRE hand crew. When they got down to that location, they stopped on a two-track road. In every direction they could see only fire or heavy smoke. At first they tried running back toward the east to reach the community of Tallac Village, but as they ran in that direction, spot fires cut off their route. They turned around and ran toward the west and ended up right back where they started. The location where they were standing was a wide spot on a two-track road with green grass and 10–15 yards of space between them and the nearest tree. The firefighter was exhausted and wanted to deploy at this location. The engine boss wanted to keep running. They both remembered from their fire shelter training that you shouldn’t

keep running past a good deployment site in hope of possibly finding a better site. They decided to deploy their shelters right where they stood (see Picture 7 and Figure 9).

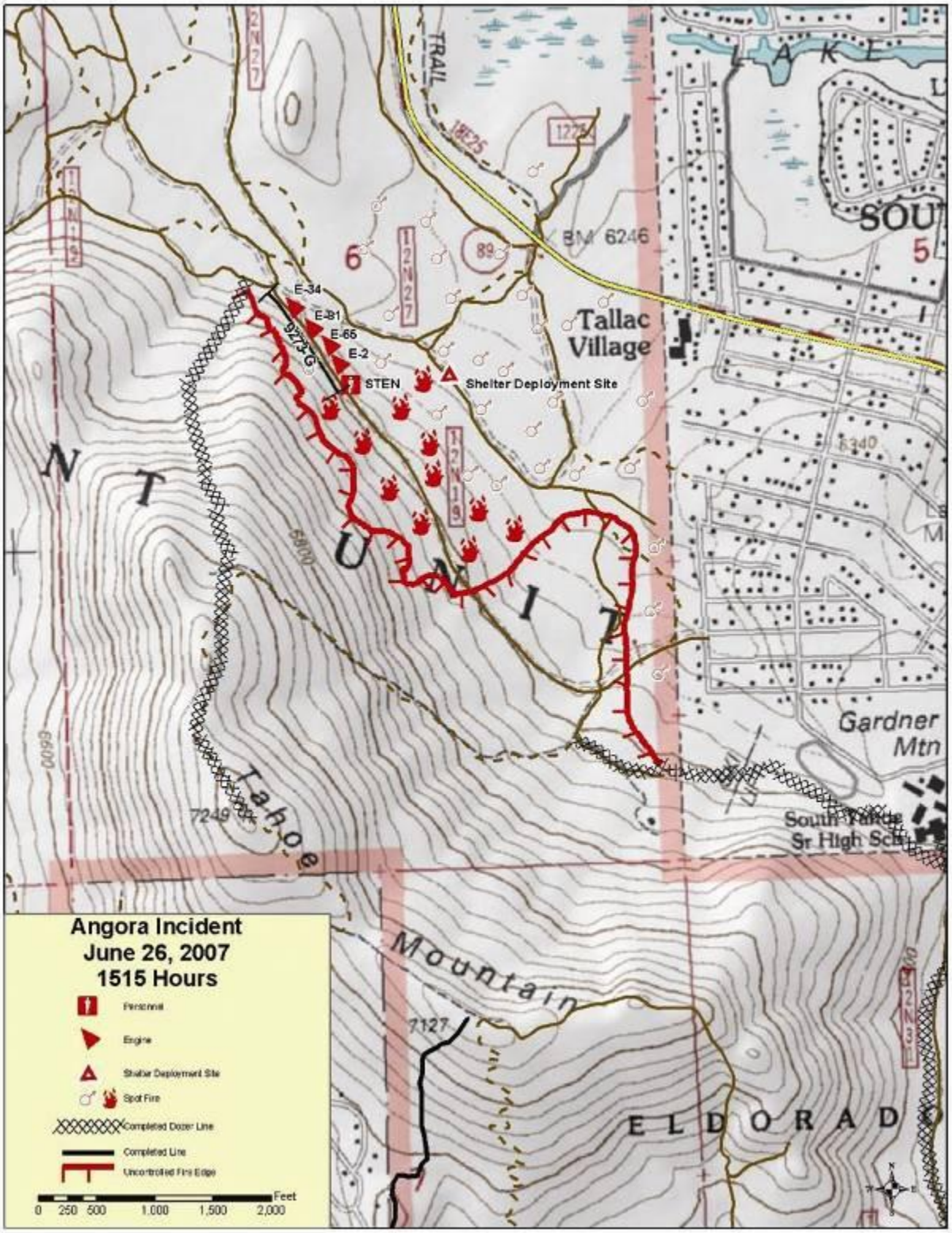

Figure 9. This map depicts the approximate location of resources at the time of deployment.

The two firefighters pulled their shelters out and deployed as quickly as they could. The firefighter got into his shelter quickly, but the engine boss was surprised by the difficulty of opening his shelter. He thought to himself, “This is harder to use than the practice shelters.” With anxiety about the situation, gloves wet from sweat, and a lack of familiarity with a new-generation fire shelter, it seemed like minutes to the engine boss before he was finally able to get in his shelter.

Once inside the shelter, the engine boss repeatedly tried to call the strike team leader and his assistant fire engine operator, but he never received a reply. He suspected that his batteries were low and yelled to the firefighter next to him that he needed his batteries. After a battery exchange, there was still no reply on the radio. The flame front had yet to arrive, so he stuck his radio outside of the shelter and called again. This time he received a quick reply. The engine boss announced over the radio, “We have deployed.” Someone answered his call and asked if he was going to deploy. Loudly and as clearly as possible, the engine boss repeated, “We HAVE deployed!” The engine boss described his location as being on a two-track road north of the fire. He was thinking that the road they were on would not show up on maps but that local people in the area would know the road system, so he radioed, “someone local would know where we are.” Just then it got hotter and the engine boss pulled his radio back inside and sealed his shelter to the ground.

Approximately 5 minutes after they entered their shelters, a blast of hot gas washed over them. The air inside the shelters got extremely hot, making breathing difficult. They both dug into the dirt and buried their faces as far into the ground as they could manage. It seemed to the firefighters that there were at least three more flame or heat pulses passing over them, and then it got quiet. The engine boss peeked outside of his shelter. There was a hole in the smoke and blue sky directly above. He could hear helicopters close by. He switched his radio to air-to-ground and began trying to relay his position to the helicopters so they could drop water on them. The smoke and heat returned but the engine boss continued to peek outside of his shelter whenever he thought it was safe so that he could communicate with the helicopters and others who may be trying to rescue them. As he opened and closed his shelter, he could see trees torching and feel the heat of the oncoming flames. At some point during the deployment, a chipmunk pushed

underneath the edge of the engine boss's shelter and nuzzled up next to him. The engine boss reached down and with his gloved hand held the animal, but the chipmunk died within a few minutes.

At one point, the firefighter peeked out of his shelter, but got a shelter full of hot smoke. He decided that he wasn't going to open his shelter again until somebody told him it was safe to come out. As he lay on the two-track road, the firefighter was worried that an evacuating engine or an over-zealous rescuer would come barreling down the road and run them over.

Picture 7. Aerial view of the deployment site.

As soon as the announcement that the two men had deployed came across the radio, rescue operations began. Within about 5 to 15 minutes of deploying, helicopters were scanning the area for the shelters. It is estimated that water drops near the shelters began within 15 minutes of deployment. From Highway 89, several firefighters could see that the helicopters were dropping water only a few hundred yards from the highway. Two safety officers and a CAL FIRE strike team leader hiked to where the helicopters were dropping and found the deployed firefighters.

Once they were found, the engine boss and the firefighter were given a quick health check. It was determined that they could walk out to Highway 89, approximately ¼ mile away. When they arrived at the road, EMTs performed a more thorough check on the health of the two men. As a precaution, both crew members were taken to the local hospital, where it was determined that they had come through their shelter deployment completely unharmed. In total, they had spent approximately 30 minutes inside their shelters.

Epilogue – a larger story

The Accident Prevention Analysis Team mission and delegation reviewed the entrapment and shelter deployment. The entrapment was a very close call for two firefighters assigned to E-34 and ten CAL FIRE firefighters who were forced to flee into Tallac Village. However, as is clearly shown by the maps and alluded to in the story above, the Angora Fire was nearly a catastrophic event for two strike teams of hand crews and a strike team of engines—a total of nearly 70 firefighters. With their primary escape route compromised by the main fire near the southeast end of Division D, four type 3 engines had to turn around and evacuate, and the two strike teams of hand crews had to reach the west end of Division D before the main fire cut off their escape route or the emerging spots north of Road 12N19 were drawn into the main fire. One of the last people out, the 3630-C strike team leader stated, "It was pretty squirrelly. The fire was right on my tail." The APA team estimated the last firefighters escaped Division D only a few minutes before they would have been entrapped by the ensuing crown fire. Had the wind speed been higher or vectored more northerly, or had an engine gotten stuck turning around, the outcome of this event would have been tragically different.

The following five pictures were taken by a crew member in Engine-65, the second to last engine out (see pictures 9 through 13).

Picture 9. Though blurry, this picture vividly shows the profuse spotting occurring near 12N19 just after the engine had turned around and was beginning escape to the northwest.

Picture 10. Fire as see by from Engine-65 near the center of the division along 12N19

Picture 11. Engine-65 behind Engine-81 and a slow moving Engine-34.

Picture 12. Fire as seen from Engine-65 on 12N19 near the location where the engines were bunched behind E-34.

Picture 13. Fire as seen from Engine-65 on 12N19 near the northwest corner of the Division, close to where the dozer line connects with the road.

Lessons Learned by Peers

Lessons Learned by those directly involved in the accident:

The Accident Prevention Analysis Review Team interviewed personnel who appeared to have had a significant role in the Angora fire entrapment and shelter deployment. At the conclusion of each interview, all participants were asked a series of questions regarding what they have learned for themselves from this accident and what they believed the greater wildland fire community needs to learn from it. The following is a list of their responses. These responses were edited to eliminate redundancy and personal references and to improve clarity but otherwise are not categorized or prioritized. A comment from an operations section chief may appear adjacent to a comment from a firefighter. These comments were evaluated by the review team and considered when developing the recommendations.

The statements below are real, candid, open, honest, and in their own words. Reading through these gives the reader a good understanding of the passion and thoughts of what those most directly affected by the accident perceive as lessons all firefighters and fire managers need to learn to prevent a similar accident.

What firefighters learned for themselves from this incident:

- Talk to the engines on either side of you.
- Make sure you have lots of places to turn around the engine.
- This year's national refresher training (put out by the BLM) video with the Little Venus firefighter interviews worked well.
- Make sure you know the trigger points for disengaging.
- Communicate and coordinate better with CAL FIRE folks. We thought we were integrated but we obviously weren't.
- Take better care of fellow firefighters.
- Watch the watch-outs closer.
- Talk to the team members individually and ask if they are really comfortable taking over the fire. Then talk to the out going team members to see if they are comfortable giving up the fire. (comment made by a C&G staff member).
- Be especially heads up when my hand crews are split up.
- My attitude on the fire line will be: we are all one, regardless of which agency we work for.
- When the fire behavior is increasing, don't let your crew members get out of sight.

- When nothing is going on, use that time to scout and learn the landscape.
- Act on the watch-outs. When they are present, do something about it.
- Stop other firefighters from going too far chasing spots.
- Don't just tell your firefighters to look for spots. Be specific in telling them how far to go and specifically what the triggers are for disengaging.
- Take the time to know your firefighters. Especially understand their experience level.
- Make sure your have plenty of space to maneuver engines around with turnouts, passing areas, etc.
- Make sure your other crew members know where you are.
- Pay attention to what the lookouts are saying to others.
- If the team transition feels rushed, take action to slow it down. (Comment from a C&G staff member)
- Make sure the command frequency on the helicopter works before I take off.
- Do a lot more scouting before I start working on spots.
- Get my questions answered before accepting the assignment.
- When your firefighters start to ask, "Which way is the fire going?" it's time to get out of there.
- Won't let my head get lost in chasing spots.
- Know who is in charge of you.
- If you have helicopters available, use them sooner rather than later.
- Empower your lookouts to pull the evacuation trigger.
- A trigger point that is "more spots than you can pick up" isn't clear. It's too subjective.
- Scout your escape routes. Scout. Scout. Scout.
- Always let your adjoining forces know what you're doing.
- Don't compromise safety by trying to burn gently.
- Ask operational folks, "What is your fall back, what is your contingency?"
- Time the burnout with the forecast. If you can't time it right, don't do it.
- Knowing which way to go when our escape route was cut off was the one thing I did right.
- Don't put the least experienced crew in the most risky area.

What the firefighters said the greater wildland fire community needs to learn from this incident:

- Training on fire shelter use and selecting a deployment site worked.
- LCES worked for those using it.
- Always know and evaluate trigger points. Set valid trigger points for disengagement.
- Put timeframes and trigger points on the burning operation.
- When doing a big burnout operation, establish a burn organization with a holding boss, lighting boss, etc.

- All firefighters must know: you don't chase spots with a column cranking above you.
- Culturally it is not okay for a team to say they are not ready to take over a fire. We need to fix that culture.
- Don't allow important information to be discussed over squirrel (intra-crew frequencies) channels.
- We have set up firefighters by teaching them that someone else is responsible for their safety (a "victim mentality" - if something bad happens to them, they are not at fault someone else is). We've taught them that someone is watching out for them. We need to teach folks to take responsibility for their own safety.
- The 10 & 18 & LCES doesn't mean a lot to someone without experience. We need to appreciate that firefighters have to have seen enough fire and fire behavior to recognize and understand a watch-out, or a fire order.
- We should minimize overhead transitions.
- We need a better way to manage the press. They were a huge distraction.
- The FS's 2 to 1 and CAL FIRE's 24-hour shifts and local government's "anything goes" on shift lengths is not only a logistical nightmare, it's totally unmanageable. Everyone on the incident must be on the same work schedule (it is meaningful to note that this comment came from C & G member of the Type 1 IMT).
- Use this incident as a training exercise or simulation for engine bosses and strike team leaders.
- Everyone from individual firefighters to incident management teams should base all actions on current and expected weather and fire behavior.
- Use this incident for training FBANS and in FBAN work shops.
- Chasing spots is seductive; it's really hard to resist. We need a training module that teaches firefighters to react instinctively and appropriately to spotting.
- Managers need to be honest and upfront and face the truth. When structures are involved we take more risks. We give lip service to the company line and say we don't risk lives for structures, but that isn't real.
- Use available technology to get better intel on the fire. (Live link was available but not used)
- We need a way to better mentor our firefighters. Young folks are coming into leadership positions too quickly.
- If leadership doesn't change where we are going and continue to ignore retention, work force development and lower budgets, this and worse accidents will continue to get more frequent.
- We need a way to weed out incompetent people in leadership positions.
- Practice shelters are easy to deploy. It's harder on a real fire.
- Don't expect to be able to transmit inside a shelter. They definitely interfere with radio use.

Additional Issues Raised

Immediately preceding this event, Region 5 was experiencing rapid turnover of firefighters and was implementing new hiring, promotion, and retention policies. These were the issues most often mentioned by the firefighters involved. Whether or not it is true, in the minds of many of these firefighters, attrition and human resource practices played a role in this accident. The majority of the comments given to the review team were redundant with the five listed below and therefore were not displayed individually.

- Pay differences between the Forest Service and our cooperators are resulting in too many holes in leadership and too many vacancies. As long as the huge gap in pay exists, leadership holes will continue to exist everywhere. R-5 needs to be careful not to promote inexperienced people to leadership positions too quickly in order to staff more modules.
- Our rapid promotion process is setting us up for another disaster.
- This will happen more and more if we don't address Forest Service pay issues.
- You cannot retain experienced firefighters in Region 5 due to the pay differences between state and local agencies and the Forest Service.
- To prevent this in the future, the Forest Service must have the following as its top three priorities:
  - Recruit and hire only high quality employees.
  - Ramp up retention incentives to a level where they actually work.
  - Base promotion policies only on quality performance and demonstrated fitness for command.

Equipment, Environmental, and Human Factors

Equipment

There were no equipment issues discovered that contributed to this accident. All equipment performed as designed, and the fire shelters used were likely life-saving personal protective equipment. The only equipment failure noted was that the OSC1 (Operations Section Chief Type 1) could not transmit on command net from his observation helicopter. That failure had no effect or influence on the accident. Therefore, the team did not invest any time in evaluating the cause of that communication failure.

Environmental

The environmental factors of significance are those that led to the volatile and extreme fire behavior conditions on the afternoon of June 26th. While the fire behavior was predictable, it was nevertheless so unusual that numerous highly experienced firefighters were surprised. For further discussion on the fire behavior see Appendix B.

Human

Human factors explain how humans come to make sense of behaviors that are, in hindsight, unnecessarily risky behaviors. In an Accident Prevention Analysis, human factors are displayed in the listing of "Causal and Latent Factors" below.

Lessons Learned Analysis

Development of causal factors and recommendations based on lessons learned and team analysis of Key Issues, Decisions, and Behaviors.

With perfect hindsight, some of the risk management decisions displayed below may appear to arise from a lack of skill or experience. Minimum skill and quality experience is clearly an issue of concern to the firefighters involved in this incident as well as a major focus of the APA review team.

However, it is important to note that every person interviewed for this accident met or exceeded the agency's minimum qualifications for that position. In other words, the agency certified that every person involved in this incident accident review had the necessary knowledge, skill, and experience to perform satisfactorily on the incident. Consequently, if an employee's error is due to a lack of experience, the root cause of that error isn't the employee's lack of experience; rather the root cause or "causal factor" is that the agency's standard for qualifying experience or evaluation process may be inadequate.

Likewise, everyone directly involved appeared to be appropriately motivated. The team found no evidence of behavior that arose from recklessness or malicious intent. The decisions, which in hindsight may seem unreasonable to the reader, seemed reasonable to those involved at the time based upon their understanding of the situation, their experience, their training and their expectations.

In the Accident Prevention Analysis process, the review team continuously engaged in a substitution test. As stated in the guide,

> *Throughout the investigative process the team should be performing a "Substitution Test" – this is asking: could another employee (or supervisor of the activity) meeting the agency's minimum competency standards make the same decisions and have the same (or worse) outcome? If the answer to this question is "yes," then it is likely a similar or worse accident will occur again unless the latent causes are identified and mitigated.*

In analyzing each of the following "Key Issues, Decisions, and Behaviors", the determination of the review team was "YES" to the substitution test.

I. Key issues, decisions, and behaviors

- The Type-1 IMT (Incident Management Team) accepted managerial control of the incident soon after arrival;
  - before some key operational team members could transition with their counterparts on the Type-2 team.
  - before accurate fire location information was mapped or known to critical operational leadership, causing parts of the plan to be inaccurate.
  - before Operations and Planning had adequately evaluated and prepared for predicted fire behavior, media control, logistical support, and contingencies for failure.

Related elements

- The T-2 OSC2 debriefed with the T-1 OSC1 after the 6/26 day-shift Incident Action Plan was developed.
- The organization of the T-1 IMT was non-standard (explained below).
  - There was only one branch and this person supervised 8 divisions and 2 groups.
  - In compliance with national T-1 standards, the T-1 IMT had two qualified Operation Section Chiefs; however, one of them oversaw night-shift and the other, day-shift. The person operating as (and listed on the IAP as) "Planning Ops" was an OSC1-trainee.
  - DIVS - D directly supervised at least 14 resources.
  - DIVS - D and E planned the burnout operation but did not believe they had the time to, or believe it was necessary to, establish a standard firing and holding structure.

Causal and latent factors

The timing of a transition between IMTs is a very complicated risk management process. Incoming IMTs must balance the need to assume command as quickly as possible with the need to obtain enough intelligence to be effective. Actions such as those listed above may have been the least risky option available, given the expanding and urgent need for protection of life and property. The agency's expectation for IMT's is to transition as rapidly as is possible to reduce existing risk to the firefighters and the public.

During the first operational period of the incident, the Lake Tahoe Basin Management Unit (LTBMU) ordered a Type-2 IMT to take command of the incident on day two, and a Type-1 IMT to take over the incident on day three. The rationale was that the Type-2 would arrive quickly and be able to relieve the extended attack IC within 12 to 24 hours. The Type-1 IMT

would be scheduled to transition with the Type-2 IMT and take command of the incident on day three. It is beyond the scope of this analysis to determine if the decision to order two teams at once was appropriate. Nevertheless, that decision resulted in three incident transitions over a three-day period and the inevitable confusion associated with those transitions.

Recommendations #1-2 (of 10)

1) **The Regional Forester should request that the T-1 and the T-2 IMT work with the National Fire Operations Risk Management Officer to facilitate a small High Reliability Organizing (HRO) workshop surrounding and focused on the issues surfaced in this report. In particular, issues such as "hot hand offs" transition culture, transition information standards, protocols, and shadowing should be evaluated under doctrinal and HRO precepts. Following this workshop, the teams should then work with the Wildland Fire Lessons Learned Center to display the lessons learned, with respect to High Reliability Organizing, other IMTs, and the greater wildland fire community. If possible, the workshop should include the team's command and general staff, division supervisors, situation unit staff, and the fire behavior analyst. The review team believes this recommendation is the cornerstone of learning within this report and that the IMT is the best qualified to address these complex issues. The team believes this process will strengthen the incident management process and address any inter-team policies or operating cultures the review team may not be aware of within a learning framework.**

2) The Regional Forester should request that the Washington Office Fire and Aviation Management evaluate strategies to ensure Incident Management Leadership is ordered relative to the expected and current complexity and that geographic area coordinators continue to provide oversight to Forest Supervisors for the efficient and effective team placement that strives to minimize multiple rapid team transitions.

II. Key issues, decisions, and behaviors

Beginning at 0600 on Tuesday, June 26, 2007, up until approximately 1300, highly experienced operational personnel throughout the incident management organization underestimated the expected fire behavior and consequently the risks to assigned resources along road 12N19 at the head of the fire.

It appears that, incrementally, virtually all leadership involved accepted more and more risk. It also appears that leadership—from the OSC1 down to the E-34 engine boss—uniformly did not adjust for the widening gap between what was likely to happen and what they could do about it. The notable exception to the widespread normalization of increasing risk was both of the IHCs, which recognized at approximately 1330 that their planned mission could not be accomplished and ordered their personnel to withdraw to a safe area on road 12N19 by 1400.

Related elements

- The Fire Behavior Analyst (FBAN) for the T-1 IMT was not utilized in planning the holding and burnout operation, nor was the FBAN's fire behavior forecast adequately considered by leaders or personnel in mitigating safety hazards for either Division E or D.
- An infra-red thermal mapping flight was not ordered for Monday night.
- The 215-A developed for 6/26 did not include analysis of firing operations in Division D. When the division break was moved and Division D took control of the burning operations from E, the burning operation did not comply with the recommendations stated in the 215-A such as a written plan, assignment of a Firing Boss, etc.
- The night-shift operational personnel referred to the fire's location near a "jeep road." Some day shift operational personnel interpreted "jeep road" to mean Road 12N19. In fact, the jeep road was actually several hundred feet upslope of Road 12N19.
- Contingency plans for the fire breaching Road 12N19 were not developed; e.g., Tallac Village was not evacuated. The lack of trigger points may have reinforced the "stand and defend tactic" and "must do" mentality of some holding operations on DIVS-D. There were clearly other options below 12N19 where dramatic changes in slope and fuels existed.
- The order to evacuate Division-D was given only after it became evident the fire had or soon would cross Road12N19 with a high intensity crown fire.
- Based upon interviews, few firefighters on either division appreciated the significance of the IHCs disengaging from the burnout operation.
- When asked, "What was your trigger for withdrawing?" most of the supervisory firefighters assigned to hold 12N19 replied with indefinite and vague answers such as "If we got more spots over the road than we could catch."

Causal and latent factors

The understanding of OSC1(t), OSC1, OPBD, and DIVS-D & E at the beginning of the 6/26/2007 shift was that the previous night shift had completed a burnout operation effectively to the 12N19 road (this misunderstanding may be partly due to the night-shift reference to the "jeep road," which was later interpreted to mean Road 12N19). For example, the Incident Action Plan stated that Division D's mission that day was to "Improve line, mop-up around structures and 100' in from the line." When Division D resources arrived on their division, the location of the fire was entirely different from their expectations. Their briefings, preparations, and planned actions were no longer relevant. DIVS-D and DIVS-E, along with other highly experienced and skilled operational personnel, invested several hours in obtaining an accurate location of the fire and devising a new plan. This was frustrating to many because the calm morning hours would have been the best time to conduct a burnout operation. However, they could not start the burnout until they were sure they had accurate intelligence on the location of the fire.

The new plan, finalized late in the morning, changed DIVS-D from a mop-up and holding operation to a burnout and holding operation. Importantly, based on extensive interviews, the strike team leaders and the IHC leadership on division D felt comfortable with, supported, and concurred with the new plan.

An appropriate quote obtained in the interviews related to these decisions and behaviors is: "It's like everyone forgot what Sunday was like." In fact everyone interviewed from Division D, including numerous highly experienced firefighters and inexperienced firefighters, shared virtually identical expectations of success up until approximately 1300.

We rely on Recognition Primed Decision-making skills of experienced firefighters to enable them to make rapid, safe, and time-critical decisions. This skill depends upon a reasonable match of a present condition with a past experience. The fact that so many highly experienced firefighters were surprised by the rapid escalation of spot fires and the rapid change of fire behavior indicates that this phenomenon must have been a very rare event. In other words, the past experiences of over a dozen seasoned firefighters on Division D at 1300 were inadequate to enable them to perceive the risks they would face an hour and a half later.

Among the reasons for an underestimation of fire behavior and a consequent misperception of risk were:

- The fire behavior of the previous day's (Monday) fires was minimal and the T-2 IMT made substantial progress on containment. For the most part, those T-1 IMT members who had been involved in the transition had seen only minimal fire behavior on this incident.
- As the inversion cleared, winds were initially light and generally up slope—favorable for continuing holding operations.
- There was high concern and focus by the T-1 IMT on Wednesday's forecasted high winds. Messages conveyed on Tuesday morning, such as "Today is the day to get it wrapped up," (Safety Officer's Message in the IAP) served to overshadow the accurately forecasted weather for Tuesday's day shift.
- The Operational Plan for Tuesday's day-shift was based on misinterpreted field intelligence from Monday's night-shift including the incomplete burnout work remaining above 12N19 road. Based on this intelligence error, the members of the T-2 IMT involved in planning for Tuesday's day shift believed that Division D & E would have a simple clean-up operation and that the fire would be fully contained early in Tuesday's day-shift. This perception helped to create a group mind-set, pervasive throughout the leadership on Division D, that the task before them was clear: "wrap-up" the fire in preparation for Wednesday's winds. Their expectation was that their job was neither complicated nor difficult. Their expectation of "wrapping up the fire" was reinforced by their original understanding of the fire's location. Gradually, over several hours that morning, pieces of information and signs of inconsistency began to contradict leadership's perception of reality. Lacking big-picture information, virtually all leaders involved clung to the previous and comfortable reality. It wasn't until the IHC reported that the intensity of the fire was too great for the burnout to continue (about 1330) that there was sufficient evidence to seriously challenge their optimism.
- The T-2 IMT on Monday and Monday night invested considerable resources in preparing road 12N19 as a fire break and holding line (brushing, limbing, etc.). Abandoning this road for a more viable contingency would have required a fundamental reevaluation of their plan.
- The NWCG's application of Incident Command System places the FBAN position as a technical specialist under Situation Unit Leader. Consequently the ability for an FBAN to influence Planning, Operations, or Safety is largely a function of the social relationships between these functions.
- The rate of change from moderate fire behavior to extreme fire behavior was a rare event.
- The Division Supervisors of D and E, along with IHC leadership and several strike team leaders, invested hours of work developing a plan to burnout to 12N19. This could have resulted in one or all of three common decision traps. First, there could have been a group mindset of optimism. That is, a shared opinion that with so many "experts" involved in developing a plan, that the plan must be very good one. Secondly, there are legitimate and subtle social pressures against changing plans that involve numerous resources. Because of the effort expended in developing the new plan, advising all the resources on two divisions

of the new plan, and formally and publicly announcing the new plan over the radio to the Branch Director, the leadership on Division E and D were reluctant to make additional major adjustments to the plan and would have naturally sought confirming evidence of the validity of their new plan. Finally, the mindset of the leadership was focused upon holding the fire on Road 12N19. This may have predisposed the group of decision makers to "Frame Blindness" in that the new plan had to fit with in the frame of holding the fire on 12N19. Other options, outside of this frame, were not explored.

Recommendation #3 (of 10)

Implement Recommendation #1. Failure to establish meaningful and relevant trigger points for withdrawal is a frequent and recurrent concern in accident and near-miss incidents. The HRO workshop should focus on trigger points as they relate to situational awareness. A goal of the workshop could be to help the agency move to a culture where situational awareness is not only constantly reevaluated but also where fire ground leaders routinely mentally simulate, game-play, or fantasize about failure <u>and</u> articulate events or scenarios that demand a fundamental reevaluation of strategies or tactics. In this particular instance, it is unhelpful hindsight to say that the Division D personnel should have had a trigger point for withdrawal. Rather, a focus of the HRO workshop should be how to share the lessons learned here to foster a culture where fire ground commanders exercise a proper preoccupation with failure.

3) The Regional Forester should request Forest Service FAM to evaluate strategies for integrating FBANs into the scenarios of S-420 and S-520 to train OSCs and FBANs to share critical information and to help develop effective working relationships. The Regional Forester should request that the NWCG review and evaluate the position of the FBAN within the Incident Command Organization and recommend changes if appropriate.

III. Key issues, decisions, and behaviors

Early in the afternoon Tuesday, the Line Safety Officer was diverted from patrolling Division D & E and directed to dissuade media entering the fire area from the north.

The Operations Section Chief had not yet seen the fire but felt compelled to give a Senator's Aide an overview flight that started approximately1400 the day of the deployment. The OSC

relayed to the team that this delayed his earlier flight plans and reduced his personal SA development for the shift.

Related elements

None

Causal and latent factors

Dozens of reporters were entering the fire area from HWY 89 and walking in toward the head of the fire. A high ranking operations official evaluated the situation and reasoned that these persons posed not only a substantial risk to themselves but also to the firefighters who, in the event of a breach in containment lines, would inevitably risk their lives to save the media personnel. This official requested the assistance of the Division D/E Line Safety Officer to mitigate this risk. While this request removed the Line Safety Officer from the holding lines, it did not remove the Safety Officer from the general vicinity of Division D, nor did it preclude communications between the Safety Officer and either Division Supervisor.

The Operations Section Chief felt compelled to fly with a political VIP at a critical time of operations. This aerial tour also delayed the observation flight of the FBAN. The aerial recon was critical to the OSC's situational awareness as neither he nor the FBAN had seen the fire.

Recommendations

Implement recommendation #1. It is not known if the IMTs underestimated the amount of media attention this incident would generate and was thus unprepared to manage the media or if the actions of the media would have overwhelmed any reasonably prudent contingency plan. The team can resolve this question and supply recommendations in conjunction with the HRO workshop.

IV. Key issues, decisions, and behaviors

Over a period of approximately one hour, the engine boss of E-34 and his subordinate firefighter focused increasing effort and attention on suppressing spot fires north of Road 12N19. At approximately 1415 they were working on a spot fire out of sight and over 800 feet away from Road 12N19.

Related elements

The strike team leader of 3630-C did not recognize the experience level of the engine boss, had no visual contact with his strike team from approximately 1100 through 1400, and was engaged in logistical operations (hauling hose) from approximately 1000 to 1200

A 0.9 acre parking/staging area was constructed near the Division C/D break. On June 26, 2007, at least one person with leadership and supervisory responsibility understood this to be a safety zone. Several persons in leadership roles assigned to Division D referred to the area as a combination of a staging area and a safety zone. A safety zone in this fuel type, under these conditions, and with the number of resources involved would need to be 20 to 30 acres in size.

During and immediately after the deployment, a key supervisor was asked twice for a "PAR." This supervisor did not understand what a PAR (Personnel Accountability Report) request was but nevertheless twice replied all was okay. PAR is common terminology used by CAL FIRE, local fire departments, and others working on structure fires.

Causal and latent factors

Although the engine boss met the minimum national and regional engine boss qualifications, this was his first off-forest assignment as an engine boss. With little supervision that day, the engine boss relied on briefings that morning, his past fire experience, and his observations of the fire the day before. The briefings indicated that June 26th was a "wrap up" day and that the significant threat was the following day. His observations of fire behavior the day before could have reassured a firefighter with minimal experience that the Angora fire would behave in a predictable way. Importantly, the engine boss was not a lone supervisor "chasing spots" out of sight of his engine. Working alongside the engine boss and his firefighter was a CAL FIRE

Captain and nine CAL FIRE firefighters. The presence of other firefighters no doubt provided confirming reassurance that their actions were appropriate.

At approximately 1000 on the day of the entrapment, the engine boss received a briefing in person from the strike team leader. Both the strike team leader and the engine boss recall the briefing including instructions to patrol and hold the road, but the briefing did not contain specific or clear expectations on what was meant by "hold the road" or what was expected if spot fires appeared across the road. The engine boss was instructed to brief his module on the Incident Action Plan, although by that time the objectives of the division had become largely irrelevant. Specifically, the IAP stated their assignment was to: "Improve line, Mop-up around structures and 100+ feet in from the line."

E-34's position along Road 12N19 isolated the engine boss from sight of the rest of the strike team. Communication between the engine boss, the strike team leader, and the rest of the engines on the strike team was minimal. E-34 was "sandwiched" between two CAL FIRE hand crews. Even though they were adjacent to each other, communication between the module members of E-34 and the CAL FIRE firefighters was minimal.

The first spot seen by the engine boss was near the engine and the road. The need to suppress this spot was obvious and the task was easy. Gradually over at least an hour, additional spots appeared farther and farther away. With the gradual passage of time the engine boss and his firefighter found themselves farther and farther from the road and their engine. The engine boss had reassurance that his actions were valid as a much more experienced CAL FIRE Crew Boss was also working with nine firefighters further and further off the road in the same vicinity.

By 1415 the engine boss, the firefighter, nine CAL FIRE firefighters, and the CAL FIRE Crew Boss were all working together on the same large spot fire approximately 800 feet north (down slope) of Road 12N19. The effort to contain this spot fire was significant and moderately difficult. Both the engine boss and his firefighter did not notice or appreciate the consequences of the column directly above them that was dropping embers throughout the area they were working. None of the firefighters engaged in holding activities re-evaluated the changing conditions and therefore did not adjust their actions.

As the fire behavior began to increase, so did the amount of radio traffic on the assigned tactical frequency. The high volume of traffic on the radio made it difficult to discern important information concerning escalating fire behavior.

When the engine boss was asked how it made sense to him to be so far from the road working on spot fires, he replied, "I felt the greatest threat to the safety of my engine was fire below the road." While that statement is generally correct, the engine boss and his firefighter lacked the experience to recognize the risks of their actions under the changing conditions, and lacked the supervisory oversight to mitigate the lack of experience.

Engine 34 was not able to fill two key leadership positions for this assignment because of several vacancies on the home unit. The positions were filled with fully qualified individuals (the two who deployed their shelters) but who had minimal experience, and who had not worked together as a module. From a safety standpoint, the difference between a *highly qualified* firefighter and a *fully qualified* firefighter, particularly in leadership positions, can hardly be overstated.

Both the engine boss and firefighter who were entrapped were not normally assigned to this engine module. A lack of crew cohesion (though not believed to be an issue by the module members themselves) was readily apparent to the APA Team evidenced by the delegation of daily duties and the grouping of crew members. Other engines assigned to the 12N19 identified clearly defined duties and detailed direction regarding the suppression of spot fires that kept them working as a unit that day.

There is a trend of increased attrition in Region 5, which leads to modules having a lower cumulative experience level than was realized historically. The APA Team believes this increasing trend to be a potentially serious safety issue.

CAL FIRE, like many non-federal cooperators in California, sometimes uses the acronym "PAR" when requesting a Personnel Accounting Report. If a Task Force Leader asks a Crew Boss for a "PAR," for example, the requestor is asking if the Crew Boss knows that all members of the crew are safely accounted for. Forest Service employees that do not train with or regularly work with CAL FIRE and local California cooperators are unlikely to have heard that acronym. In this incident, when the Forest Service fire line leadership was asked for a PAR, he not only

did not know what was being asked of him but, given the rapidly deteriorating conditions, he also did not have the time to find out. The use of this acronym is one example of a problem arising from the cultural differences between the Forest Service and non-federal cooperators in California. In the words of one firefighter, *"We think that we think alike but we don't. Our vocabulary and tactics are very different, especially in northern California."*

Recommendations #4-7 (of 10)

4) The Regional Forester should request that the Forest Service FAM review and evaluate the existing process for assuring Forest Service employees in all fire line leadership positions meet an appropriate standard for command fitness. An evaluation process focused on developing principle-centered leaders and decertifying persons in critical positions who lack the qualities of integrity, experience, and skill is recommended. FAM should consider simulation exercises for all fire line leadership positions.

5) The Regional Forester should request that the Forest Service FAM evaluate if the minimum training and experience necessary to achieve engine boss certification is adequate and appropriate considering the increasing complexity of the wildland fire environment. Implement changes to FSH 5109.17 as necessary.

6) The Regional Forester should request that the Forest Service FAM review and evaluate the existing process for assuring Forest Service employees in all fire line leadership positions meet an appropriate standard for command fitness. An evaluation process focused on developing principle-centered leaders and on decertifying persons in critical positions that lack the qualities of integrity, experience, and skill is specifically recommended. The ICT3 simulation and certification process may be a model that works well to ensure leadership skills are present in high pressure situations for a critical leadership position.

7) The Regional Forester should request that the Forest Service FAM consider incorporating this scenario into the training for engine boss, strike team leader, and division supervisor positions.

V. Key issues, decisions, and behaviors

The decision to evacuate Road 12N19 was not made until approximately 1430 – or about the time Division D's primary escape route was within minutes of being compromised.

Many firefighters interviewed stated they accept greater risk to themselves when the fire threatens structures, as compared to wildland-only fires.

Related elements

Tallac Village was not evacuated nor was there a contingency plan that was known to any resources on Division D should the fire breach Road 12N19.

The command frequency did not work in the helicopter used by OSC1 to scout the fire at 1435 (unclear if it was due to mechanical or operator error).

Forest Service engine bosses along 12N19 were not given clear instructions regarding their assignment or adequate direction concerning trigger points for disengaging.

Causal and latent factors

From the physical location of both Division D Supervisor and strike team leader of 3630-C, they could not have seen the spotting that was occurring near the center of the division. While there was some discussion of spotting across the road to these firefighters, their resources did not convey that the spotting was a serious threat to Road 12N19 until approximately the same time as the road was about to be breached by the main fire (about 1430).

The wind direction at around 1430 was aligned with the slope at the eastern head of the fire. This resulted in a momentary high intensity fire run that crossed the road near the location of the Division Supervisor (see Appendix B, fire behavior analyst report).

The use of Minimal Impact Suppression Techniques (MIST) in the Lake Tahoe Basin Management Unit was embedded in the minds of many firefighters on this incident. In the words of one high ranking LTBMU fire manager, "MIST is how we do it around here, and everybody knows it." This bias influenced tactical decisions. For example, even though two dozers were available, they were not used to create contingency lines or reinforcement holding lines on

Division D. Also, burnout operations were slowed in part to minimize intensity and tree mortality. The letter of delegation, however, clearly permits the full range of suppression tactics and encourages aggressive actions to minimize the size of the fire. In this case, the leaders' intent did not permeate through the incident command structure to the ground level. When asked why dozers were not used on Division D until after the fire escaped, a member of the command and general staff referred to the need to protect the visual quality of the area, stating, "The politics overruled the tactics."

With respect to this particular incident, all leadership on the incident knew that if the fire jumped Road 12N19, the fire was very likely going to enter Tallac Village. In the words of one firefighter, "We all knew the consequence of losing this road was that houses would burn." And in another's words, "When houses are involved, the firefighter can-do sprit becomes the must-do spirit." We know from review that the first statement was overstated and the perception was not a true reflection of all the tactical options available.

Knowing that Tallac Village was not yet evacuated, there was a mind-set among several of those interviewed that the firefighters along Road 12N19 were there to "stand and defend," not only to protect structures, but also to protect human life.

Interviews with those involved revealed a sense of resignation as if keeping the fire from jumping the 12N19 road was something that they had to do and there were no other good options.

Many of those most directly affected by this accident stated in the interviews that, if given the same situation, they would likely try to hold the fire at the 12N19 road again. After further questioning, firefighters discussed tactics they would do to increase their own safety and chance of success (see the individual lessons learned section beginning on page 35) but no one directly said they would not try to hold that road again. This is remarkable because as hindsight clearly demonstrates, holding the fire on 12N19 was among the most risky of the available strategies.

In many respects, wildland firefighters share a similar culture with cooperating fire departments. They work and train together often, read the same publications, and speak the same language. To

the broader public, certainly the media, we are one-and-the-same. As with structural firefighters, society expects our public servants to rescue us from the dangers of fire. We expect these *soldiers* to have a sense of duty, which includes values of self-sacrifice, courage, and public service. We reinforce values of integrity, which include values of compassion and selflessness. A common saying applicable to both cultures is, "We go in when everyone else is running away." The individual and peer pressures on the firefighters on Division D to do everything possible (including accepting additional personal risk) to protect the property and perhaps the lives of Tallac Village influenced many decisions that day.

Line officers and many senior fire management leaders, including incident commanders and their staffs, are often insulated from these pressures and thus they do not share a common paradigm with the firefighters faced with the difficult risk-mitigation decisions. Upper-level leadership may direct line firefighters to not "… compromise firefighter safety to save structures." However, this direction is filtered by a culture that has always been expected to—and be publicly rewarded for—rescue fellow humans from the perils of fire.

Ultimately, the values of firefighters on the line concerning the level of appropriate risk-taking are not in alignment with the expressed values of their leaders.

Recommendations #8 (of 10)

Implement recommendation #1. The issue of appropriate risk and appropriate involvement in the urban interface is a national issue. Because of this accident, this T-1 IMT may have insight into national solutions.

8) The Regional Forester should ensure the completion of the ongoing California Wildfire Coordinating Group (CWCG) effort to identify the operational principles for fire suppression for all wildland fire suppression agencies in the Wildland Urban Interface (WUI).

VI. Key issues, decisions, and behaviors

Interagency personnel conflict, jealousy, and distrust interfered with communications.

Interagency rivalry and low levels of inter-module trust interfered with the free flow of critical intelligence on the fire line among agencies. Unauthorized channels used to communicate within modules hampered the sharing of fire behavior information throughout the entire division.

Causal and latent factors

The degree to which a lack of trust and communication between agencies assigned to this incident that may have contributed to this accident is unknown. Nevertheless, a majority of persons interviewed in the conduct of this analysis referenced interagency communications outside the assigned control structure as a serious problem.

It is widely recognized that a standard for safe practices is inter-crew communications and maintaining communications between adjoining forces. In interviews, firefighters stated the following as reasons or causes for the lack of communications between agencies:

- Jealously between ground personnel regarding disparity in pay between agencies.
- Differences in working conditions such as hotels versus tents, and 16- versus 24-hour shifts.
- Use of intra-crew nets or "squirrel channels" when passing important information
- Forest Service promotion and hiring in R-5 from a diminishing applicant pool, coupled with high turnover rates, has had the potential of selecting minimally qualified applicants where, historically, candidate hiring lists once had more depth.

Recommendations #9-10 (of 10)

9) The Regional Forester should request that the California Wildfire Coordinating Group survey and evaluate to determine if interagency communications or their cultural issues are significantly affecting safety and/or efficiency at the ground level. If these issues are significant, CWCG should develop strategies for resolution.

10) The Regional Forester should request that the NWCG safety and health working team consider ways to reinforce the importance of sharing information critical to situational awareness on command and tactical frequencies.

Summary of All Recommendations (#1-10)

1) The Regional Forester should request that the T-1 and the T-2 IMT work with the National Fire Operations Risk Management Officer to facilitate a small High Reliability Organizing (HRO) workshop surrounding and focused on the issues surfaced in this report. In particular, issues such as "hot hand offs," transition culture, transition information standards, protocols, and shadowing should be evaluated under doctrinal and HRO precepts. Following this workshop, the teams should then work with the Wildland Fire Lessons Learned Center to display the lessons learned, with respect to High Reliability Organizing, to other IMTs and the greater wildland fire community. If possible, the workshop should include the team's command and general staff, division supervisors, situation unit staff, and the fire behavior analyst.

2) The RF should request that the WO FAM evaluate strategies to ensure Incident Management Leadership is ordered relative to expected and current complexity and that geographic area coordinators fulfill their oversight role of efficient and effective team placement to ensure only the resources necessary are ordered and team transitions are minimized.

3) The Regional Forester should request that the Forest Service FAM evaluate strategies for integrating FBANs into the scenarios of S-420 and S-520 to encourage OSCs and FBANs to share critical information and to help develop effective working relationships The Regional Forester should request that the NWCG review and evaluate the position of the FBAN within the Incident Command Organization and recommend changes if appropriate.

4) The Regional Forester should request that the Forest Service FAM review and evaluate the existing process for assuring Forest Service employees in all fire line leadership positions meet an appropriate standards for command fitness. A meaningful and iterative evaluation process, focused on developing principle-centered leaders and decertifying persons in critical positions who lack the qualities of integrity, experience, and skill, is specifically recommended. The ICT3 simulation and certification process may be a model that works well to ensure leadership skills are present in high-pressure situations for a critical leadership position.

5) The Regional Forester should request that the Forest Service FAM evaluate whether the minimum training and experience necessary to achieve engine boss certification is adequate and appropriate, considering the increasing complexity of the wildland fire environment. Implement changes to FSH 5109.17 as necessary.

6) The Regional Forester should request that the Forest Service FAM engage NWCG to evaluate the ENGB, CREW, STCR, STEN, DIVS, OPBD, and OSC1/2 task books for needed updates that reflect the increased complexity of modern urban interface wildland firefighting. Also, evaluate the need for individual single resource boss task books to replace the current combined task book system.

7) The Regional Forester should request that the Forest Service FAM consider incorporating this scenario into simulation-based training for engine boss, strike team leader, and division supervisor positions.

8) The Regional Forester should ensure the completion of the ongoing CWCG effort to identify the operational principles for fire suppression for all wildland fire suppression agencies in the WUI.

9) The Regional Forester should request that the California Wildfire Coordinating Group survey and evaluate whether interagency communications or their cultural issues significantly affect safety and/or efficiency at the ground level. If these issues are significant, CWCG should develop strategies for resolution.

10) The Regional Forester should request that the NWCG safety and health working team consider ways to reinforce the importance of sharing information critical to situational awareness on command and tactical frequencies.

Evaluation of lessons learned relative to principle-based decision making and the Forest Service Fire Suppression Doctrine

The Review Team analyzed the lessons learned by the firefighters involved in this incident and evaluated them relative to the Operational Environment and Five Key Areas found in the *Foundational Doctrine Guiding Fire Suppression in the US Forest Service*. This evaluation serves as this Report's Lessons Learned Analysis and is intended to further the doctrine's understanding and application in wildland fire management.

The Operational Environment

As stated in the Doctrine, "To succeed and survive, the agency's firefighters must first perceive these complexities, then think, plan, manage risks and engage." The firefighters involved in Division D were actively mitigating the risks they believed were present. In hindsight however, virtually everyone on Road 12N19 seriously underestimated the fire behavior and failed to perceive the increasing complexities resulting in a failure to re-evaluate their actions.

Mission

The mission of the firefighters to protect life and property, and to keep the fire south of Hwy 89 and east of Fallen Leaf Lake Road and the Wilderness Area, was appropriate. However, the ambiguity of the agency's responsibilities for fire suppression within the urban interface resulted in the acceptance of greater risk by the firefighters.

Leadership and Accountability

The Doctrine states, "Leaders in the organization must be capable of independent intelligent action." It goes on to state, "Leaders demonstrate respect by 'knowing and looking out for the well-being of their subordinates.'"

Demonstrated fitness of command is a requirement for leadership positions associated with fire suppression. In this situation, a partially inadequate plan, based on bad intelligence, was changed in the field to adequately reflect the remaining work to be completed that day. Leaders at all levels—from the IMT to the two employees who deployed—did not recognize the changing

conditions, re-evaluate their actions, or maintain a high level of situational awareness causing them to make poor decisions

Roles and Relationships

The Agency Administrator's intent was clearly stated at the in-briefing and in the letter of delegation. However, the "cultural" understanding that the politics in the Lake Tahoe Basin were so critical that those perceptions drove some of the tactical decisions and the Fire Leadership's perception of acceptable suppression impact. The "Commander's Intent" to hold the road became the only focus until it was necessary for firefighters on Division D to quickly disengage, and for the two employees of Engine 34 to deploy their fire shelters.

Operations

The division, IHC, and strike team leaders on Division E & D were empowered to take initiative and make operational decisions. These leaders were creative and decisive in developing a new plan that matched the updated intelligence of the fire's location and was geared toward accomplishing their leader's intent. However, since they underestimated the expected fire behavior, they chose a high-risk strategy and tactics that placed multiple crews of engines and hand crews in a situation where they would eventually be forced to retreat with great urgency.

A critical lesson learned from this incident is that "rare event" fires will behave in ways far outside of the expectations of experienced firefighters. Basing risk mitigation decisions on experienced-based fire behavior estimates alone is insufficient to ensure a safe working environment. In addition to sound judgment and an emphasis on Situational Awareness, adherence to basic safety protocols—specifically LCES, the 10 Standard Firefighting Orders, and the 18 situations that shout "Watch Out"—will mitigate substantial risks associated with human error. Additional lookouts could have been posted, inter-module communications could have been improved, and adequate safety zones were not developed. The fact that Division D resources had an alternate escape route narrowly precluded a tragedy. Throughout the hours leading up to the incident, many actions were taken based on incorrect assumptions of the potential fire behavior. For example, the weather forecast predicted increasing winds at 1300, but most firefighters were surprised when the winds picked up. There was only one lookout

assigned. There were not adequate safety zones. The instructions to catch the spots were not clear.

Risk Management

Foundational Doctrine recognizes that, unlike a typical workplace, which can be engineered to be safe, the wildland fire environment is inherently and invariably hazardous. Because safety in a typical workplace relies on managerial controls, the environment is safe until human behavior makes it unsafe. In the wildland fire environment, safety relies on employee creativity. We depend on wildland firefighters to create safety in an unsafe environment. In other words, the doctrine recognizes that wildland fire safety is not an end state; it is continuous employee creativity in response to ubiquitous risk.

The first step in risk management is to secure a clear understanding of the mission and goal (commander's intent) of the operation. This incident shows the goal of holding the fire at 12N19 was poorly understood at multiple levels. From understanding the tactical decision to hold the road to the Agency Administrator's intent to fight the fire aggressively, up through the ranks to understanding the agency's mission in the wildland-urban interface, the commander's intent in this situation was poorly defined and poorly understood by the leadership and firefighters of Division D.

The second step in risk management is incorporating judgment and experience with standard operating procedures to reduce risks to acceptable levels relative to the mission at hand. This incident demonstrates that, due to conditions of heavy fuels and drought, past experience alone could not be relied upon to estimate fire behavior. Basic standard operating principles, including establishing lookouts, communications, multiple escape routes, and legitimate safety zones, should be implemented regardless of the perception of risk.

Summary

High reliability organizing is fundamentally about developing a learning culture where we are constantly improving our understanding and perception of risk by constantly learning from our past misunderstandings. In a learning culture, accidents and near-misses are fully disclosed, framed, and exploited as opportunities to learn.

The individual and personal lessons to be learned from this accident are numerous for firefighters, agency administrators, engine bosses, strike team leaders, division supervisors and incident management teams. Sharing this report and developing training and dialogue exercises using this scenario with the widest possible audience will enhance the safety and reliability of many firefighters. Even more effective learning will occur if this report is developed into training exercises or staff rides.

Another key trait of high reliability organizing is embracing accidents and near-misses as warnings of latent pathogens within the social organization of work. The analysis of this accident has yielded several warnings for the Agency. These are not proximal root causes of the accident. They are, however, the back layers of cheese in the swiss-cheese model of accident causation, and they signal normalizing deviance in the organizational accident model. Warnings addressed by the 10 recommendations include:

- ambiguous and conflicting responsibilities and risk management principles for the Forest Service in the urban interface,
- no current standards for fitness for command in field leadership positions such as engine boss,
- engine modules with cumulative low experience levels and cohesion,
- interagency relationships and the lack of communication and trust between agencies (the Forest Service, CAL FIRE, and local fire departments) that are strained by numerous cultural and financial differences at the ground level.
- a culture that encourages “hot hand offs” (fast team transitions) between T-2 and T-1 IMTs.
- lack of situational awareness and the ability to recognize and react to changing conditions and risks, and
- poor communication between resources on the line.

Appendix A

Chronology of events (all times are approximate)

Date	Time	Event
06/24/2007	1423	Initial attack dispatched to Angora Fire
	1600	Type II IMT ordered to report to incident, Type I IMT ordered to stage in Sacramento
	1700	E-34 dispatched to Angora Fire
06/25/2007	0600	In-briefing for Type II IMT
	0800	Type II IMT takes command of the Angora Fire
	1100	E-34 arrives at ICP and is assigned to interagency strike team on Division D. Mission for the day is brush removal along 12N19 road.
	1600	In-briefing for Type I IMT
	2200	E-34 off shift and back at ICP.
06/26/2007	0600	Type 1 IMT takes command of the Angora Fire.
		Briefing at ICP.
	0730-0900	4 engines move to intersection of 12N19 and the dozer line.

	0800	Weather observations on Div. E: 60˚, 37% RH, light winds out of the west, location was 300' up dozer line.
	0900	Weather observations on Div. E: 61˚, 37% RH, light winds from the west and southwest, 6000' elevation.
	0915	CAL FIRE hand crew paired up 100' apart along road to watch for spots.
06/26/2007	0900-1000	Div E Hotshot superintendent discusses with STEN and engines the plan worked out for burnout of the hill. Engine ST's – Learn of additional escape routes and safety zone to the west.
	1000	9273-G Strike Team Leader– Briefs Captains then leaves to get lunches.
		STEN leaves to staging to pick up hose, fittings and 2 folda tanks.
		Weather observations on Div. E: 65˚, 34% RH, light westerly winds almost calm, 6300' elevation.
	1100	Senator's Aide to ICP for recon flight.
		Agreement between Divisions D and E, and STEN, that the Klamath Hotshots would plumb dozer line. Meanwhile, Division D would hold the burnout along 12N19 while the Laguna Hotshots and Sierra Hotshots would conduct the burnout jointly.

		STEN orders his 4 engines to face east and spread out along 12N19 for holding.
		STEN takes FFT from E-34 to help him shuttle hose to top of Tahoe Mountain.
		Weather observations on Div. E: 65˚, 29% RH, 0-2 mph wind WSW
06/26/2007	1130	Hotshots on east side of Tahoe Mountain start burning.
	1145	E-34 cuts key holes along road.
		9273-G Strike Team Leader completes lunch delivery.
	1200	STEN and E-34 FFT return to 12N19. STEN positions himself east of E-34 along the road.
		E-34 takes weather on 12N19 road. 70˚ dry blub, 52˚ wet bulb, 32% RH, estimated wind was 0-2 SW.
		Air Attack – Smoke starting to clear out.
		Weather observations on Div. E: 68˚, 30% RH, 1-3 mph wind WSW; occassional gust from NE also switching from NW, ¼ mile up dozer line. 6678' elevation. Smoke crossing dozer line occassionally.
	1215	Sierra IHC test burn. Burn was hot and the crew determined they couldn't run strips and would only apply fire in dots.

	1218	Division confirms with operations that they have moved the division D/E break.
	1230	Sierra Hotshots begin burning in the southeast corner of Division D.
	1300	Air Attack advised Div. D/E fire activity is picking up. Minor torching, black smoke, intensity increasing. Wind picks up.
06/26/2007	1300	E-34 takes weather on 12N19 Road. 72˚ dry bulb, 50˚ wet bulb, 22% RH, estimated wind 0-2 SW.
		Weather observations on Div. E: 75˚, 25% RH, 1-2 winds with gusts of 4. Winds battling NE & NW winds aloft out of SW. 6148' elevation.
		Some people along the 12N19 road notice torching near ridge.
	1315	Air attack tells Div. E that Fallen Leaf Lake has white caps and high winds headed his way.
	1330	Hotshot superintendent reports via radio that the column is battling the wind.
	1334	Hotshots cease burnout operations on Tahoe Mountain.
	1330-1345	Hotshot superintendent/lookout reports that the column is starting to lay over.
	1345	Air attack advised he could not see under smoke.

		Several engine bosses hear reports of a small spot fire over line at Div. D/E break.
	1400	E-34 takes weather on 12N19 Road. 75˚dry bulb, 54˚wet bulb, 28% RH, estimated wind 3 mph, East.
		Weather observations on Div. E: 77˚, 26% RH, gusty winds, significant wind increase, WNW and shifting from the NE. 4 – 6 mph with gusts to 10mph. Elevation was 6650'. Winds aloft out of the SW.
06/26/2007	1400	Hotshots on northwest end of Division D observe significant torching uphill along dozer line.
		Air attack orders lead plane and air tankers.
		Flames shift downhill from slope driven to wind driven.
		Division D/E line safety patrolling Hwy 89 for media.
		E-34 crew observes an ember fall north of road. FFT picks it up with shovel and carries open flame up to road.
		CAL FIRE hand crew calls in spots below road. E-34 engine boss and FFT are activly working on spots. Later, they see spotting below the bench & go there to work with the hand crew.
		Hotshots on 12N19 and near D/E break. They note that the CAL FIRE strike team is repositioning to point their engines northwest.

		Column is dropping ashes on E-34. The AFEO catches a few, but they are cold.
	1415	CAL FIRE hand crew goes down below 12N19 road to work on spots.
		E-34 AFEO notices winds picking up and hears Hotshots on radio talking about battling winds.
	1420	OPS takes off in helicopter to recon with Senator's Aide.
06/26/2007	1420	Forest Service hand crew at east end of 12N19 reports bats and a bear exit from fire area and cross road.
	1424	Weather observations on Div. E: 77˚, 26% RH, steady 4 mph wind out of N, switching NE gusting up to 12mph. Column building winds pushing from the SW.
	1430	STEN calls for two engines to come down to his location.
		OPS sees white caps on Fallen Leaf Lake. Orders first PAR… all is well.
		OPS helicopter lands and unloads Senator's Aide.
		CAL FIRE hand crew Captain calls for the rest of his crew to go below bench. The CAL FIRE STCR stops them.
	1435	OPS helicopter takes off again with FBAN.

		Engines respond to STEN's request to bump down. Engine 65 & 81 pair up and slowly drive East. E-34 stays put. Engine 2 drives a few hundred feet east and stops.
	1435-1445	Engine boss and FFT abandon the spot they are working on below the bench and begin making way back to engine.
	1438	Div. D to Branch – Report of fire crossing 12N19
	1443	Iron Mountain hand crew completing egress to east along 12N19.
	1445	Div. D orders all resources to safety zones.
06/26/2007	1445	STEN orders his resources to turn around & head west to Hwy. 89.
		E-34 hears from STEN that escape route blocked. They drive east 100 yards or so and turn around to face west.
	1448	Branch to Div. D – possibly need to close Hwy. 89.
	1449	CHP closes Hwy. 89.
	1455	OPS sees spot north of Hwy. 89.
		OPS attempts 4 times to contact Div. and 2 times Branch on Command. Helicopter radio not working.

		OPS orders pilot to land due to no communications. OSC1 (T) observes fire on both ends of 12N19 road, intense fire, and column bending over to NE.
	1500	The engine boss and firefighter believe they are cut off from the engine & tell the AFEO to go on. Nine CAL FIRE firefighters and a Captain run to Tallac Village.
		Engines are facing west and evacuating the road. E-34 is going slow looking for their crew below the road. E-34 tries to stop, but is forced to keep going by engines behind it.
		Command Net and TAC 3 traffic intensifies.
	1505	OSC's helicopter lands.
		Branch gets confirmation of 2nd PAR… all clear.
06/26/2007	1505-1515	Engine boss and FFT run back down to the 2-track, then down the 2-track to the east to try and reach the community.
		Engine boss and FFT decide to run to west instead because escape to village too risky.
		Engine boss and FFT reach grassy opening and discuss shelter deployment.
	1515	Engine boss and FFT deploy and enter their shelters.
	1515-1520	OPS learns of deployment.

	1520-1544	FFT says that they got a blast of hot air, then 2 more blasts. The 3rd "sounded like a frieght train."
		Engine boss gives helicopter incorrect cardinal directions trying to direct them to his location.
	1520	DIVS-D flooded with requests from OPS for his resources.
		Radio Traffic: Branch to unknown – Shelter deployment of 2 firefighters (Communications log).
		Sierra Hotshots return to 12N19 road to assist with the rescue and see helicopter dropping water below the road.
	1522	Cell phone call from OSC1 (T) to IC that Branch received notification of shelter deployment.
06/26/2007	1523	Branch to unknown – Helicopter dropping water at Divs. D. (Comm log).
	1525	Line Safety (Division) and the IMT's Safety Officer start looking for crew.
		Unit FMO arrives at Hwy. 89 to assess threats to structures.
	1532	Branch contacts engine boss to make sure he was okay and let him know help was on the way.

	1544	Divs Safety, Team Safety and 9232-G Strike Team Leader find firefighters at the deployment site. They performed a primary survey on the firefighters. Deployment site was flagged and photographed.
	1547	Communications overheard: “no injuries… attempting to get 2 firefighters out to safety zone.”
	1430-1600	Water dropping on Division D from 1430 – 1600 by H516, H780, H720, H718 - drop a total of 59,850 gallons.
	1610	Deployed firefighters departed in ambulance to emergency room.
		Resources from Division D regroup in village to do structure protection.

Appendix B, Fire Behavior Summary

Fire Environment

This section is a summary of the fire environment of the Angora fire on the afternoon of June 26, 2007. It discusses the topography, condition of the vegetation or fuels in the area, and the weather related factors that influenced the fire behavior.

Topography: The Angora fire was in mountainous topography with slopes ranging from 0% at the north end of the fire to 90-100% on the southwestern flank of the fire. Elevations ranged from 6246 to 7290 feet. The two shelter deployments were on a road where the terrain was flat at 6315 foot elevation. Just uphill of the road the terrain sloped uphill from 20 to 40% toward Tahoe Mountain at 7249 feet.

The most prominent topographic feature affecting the fire run on June 26 was Tahoe Mountain. It clearly illustrates the influence of terrain on local winds, which is discussed in the weather section.

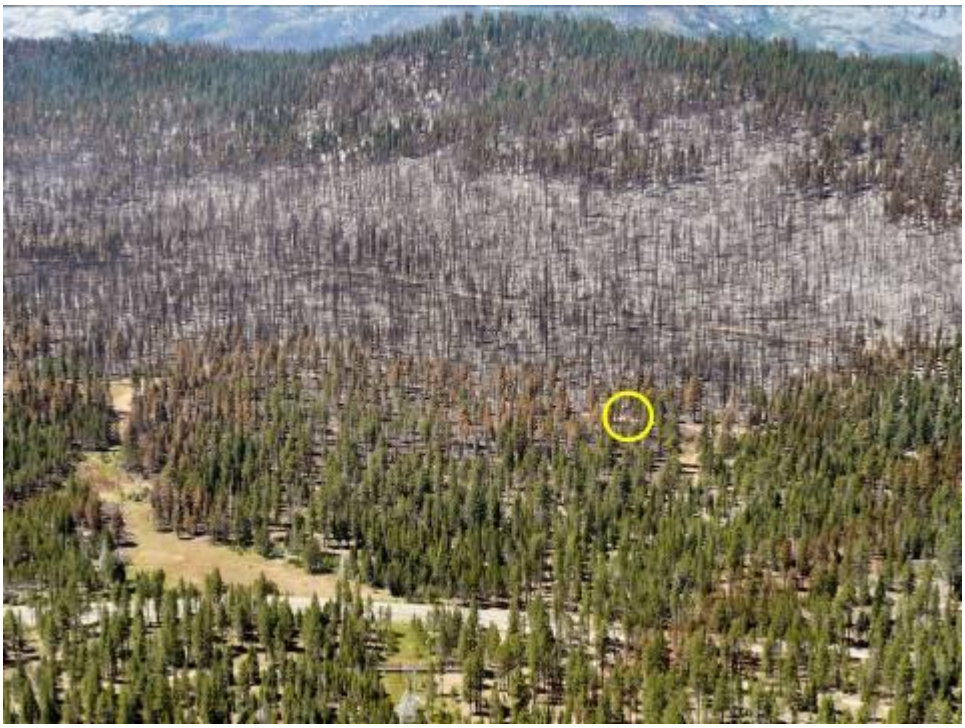

Photo 1. Topography of the area looking to the South with State Highway 89 in the foreground and Tahoe Mountain in the background. The shelter deployment site is indicated with a yellow circle.

Fuels: Multi-storied mixed conifer timber was the primary fuel type during the June 26th fire run. Heavy fuel loadings and significant ladder fuels existed. Herbaceous and woody live fuels were present but were not a significant contributor to fire spread. Live and dead fuel moistures were at critical levels and 1 to 2 months ahead of typical moisture value levels for that date. NFDRS 1000 hour fuel moistures of 9% at nearby Meyers RAWS station are the lowest values recorded for that date in the past 10 years.

Photo 2. Aerial view of fuels. Arrows indicate fire spread direction on the afternoon of June 26, 2007

Photo 3. Surface fuels above the 12N19 road near intersection with dozer line on the west end. Surface fuel loadings ranged from 40-60+ tons per acre.

Photo 4. Unburned fuels between the fires edge below Tahoe Mountain and the 12N19 road. Photo was taken by an IHC crewmember in the area they planned to conduct firing operations.

Weather: The 2006-2007 winter and spring season in the Lake Tahoe Basin area was drier than normal. Drought conditions existed in the area prior to the fire due to slightly above normal temperatures and below normal precipitation for the 2006-2007 water year. The May 1st snow pack in the area ranged from near zero to about 49% of normal.

The weather pattern for Tuesday, June 26, 2007 was one of transition. Higher pressure over the Great Basin and lower pressure over California on Monday reversed early that afternoon. As a result, light northeast winds during the morning hours with a cooler, moister Lake Tahoe influence became a drier south to southwest wind. The winds switched around 1400 hours with sustained winds 8-15 mph at 20-feet with peak gusts to 25 mph. Temperatures also warmed in the afternoon into the upper 70s with relative humidity dropping to near 20% during the late morning hours and rising slightly to 25% in the mid-afternoon.

Near the shelter deployment, terrain played a large role. Observations from the fireline indicate that the area just uphill from the deployment site had sustained northeast winds at 4-6 mph with gusts to 12 mph at 1424 on a north aspect. Further south, on a south aspect of Tahoe Mountain, winds were south at 10-15 mph with gusts to 25 mph at 1400. Both sites indicated winds increasing rapidly around 1400. Due to the steep north aspect of Tahoe Mountain, the south winds were not able to surface right away and likely remained 200-500 feet above the surface. As a result, a rotor circulation (eddy effect) developed where the winds will reverse at the bottom of the circulation. Thus general southwest winds over Tahoe Mountain resulted in northeast winds on the north aspect. These conditions lasted through approximately 1530 hours based on the behavior of the smoke column. After this time, winds lightened dramatically with eye-level south winds becoming less than 3 mph by 1700 hours south of Tahoe Mountain.

The fire weather forecast from the 6/26/2007 Incident Action Plan is attached on page 76. It should be noted that the forecasted weather verified well with actual weather conditions, especially the winds and timing of when the inversion would lift, which are some of the most challenging weather elements to forecast.

Fire Weather Forecast

FORECAST NO: 2 **NAME OF FIRE:** Angora

PREDICTION FOR: Tuesday **SHIFT** Day **UNIT:** CA-TMU

SHIFT DATE: 6/26/06 0600-2000 **SIGNED: XXXXXXXXXX Incident Meteorologist**

TIME AND DATE FORECAST ISSUED: 2100 6/25/06

******Fire Weather Watch for Gusty Winds and Low Humidity Wednesday******

WEATHER DISCUSSION: Low pressure over the Gulf of Alaska will slowly move towards the Tahoe Basin today and through the week. Winds will be light northeast in the morning with afternoon south to southwest winds developing by 1400. It will be a little warmer and drier today than Monday. The next big wind event is expected to begin Wednesday and last into the weekend.

WEATHER FORECAST:

WEATHER: Sunny. Smoky through 1200.

TEMPERATURES: MAX 77-80 at 6300 feet. 73-76 at 7200 feet. Up 5 degrees from Monday.

HUMIDITY: MIN 10-15% all elevations down 5% from Monday. RH will drop below 25% around 1100.

20-FOOT WINDS:

RIDGETOP (7500 feet) – East 5-10 mph becoming southwest 10-15 mph with gusts to 22 mph after 1300.

SLOPE - Light becoming northeast around 0800 then south-southwest 6-10 mph with gusts to 20 mph around 1330.

LAL: 1 **CWR:** 0%

STABILITY/INVERSION: Strong low-level inversion around 500 feet AGL lifting around 1200.

OUTLOOK FOR TUESDAY NIGHT (1800 TO 0600): Clear. Winds southwest 5-10 with gusts to 20 mph becoming downslope 3-5 mph after 2100. Min temperature 36-46. Min RH 60-70% valley to 30-40% ridges.

EXTENDED FORECAST (Winds are for average afternoon conditions):

WEDNESDAY 6/27

WEATHER: Sunny.

TEMP: Max: 75-80 **RH:** Min: 10-15%
Min: 37-47 Max: 35-50%

WINDS: Slope: S-SW 10-16 mph with gusts 30 mph
Ridgetop: SW 12-20 mph gusts 35 mph

LAL: 1 **CWR:** 0%

THURSDAY 6/28

WEATHER: Partly cloudy.

TEMP: Max: 71-76 **RH:** Min: 14-20%
Min: 40-50 Max: 32-45%

WINDS: Slope: S-SW 14-20 mph gusts 35 mph
Ridgetop: SW 17-24 mph gusts 40 mph

LAL: 1 **CWR:** 0%

OBSERVED WEATHER 6/25/07 – Day shift:

Meyers RAWS – 6310 ft: MAX Temp: 74. MAX Humidity: 16%. Winds NE 3-5 mph gusts to 10 mph.
DL Bliss St. Park RAWS - 6942 ft: MAX Temp: 75. MAX Humidity: 15%. Winds NE 3-5 mph gusts to 10 mph.
South Lake Tahoe AP (6263 feet): MAX Temp: 73. MAX Humidity: 18%. Winds NE 3-5 mph.

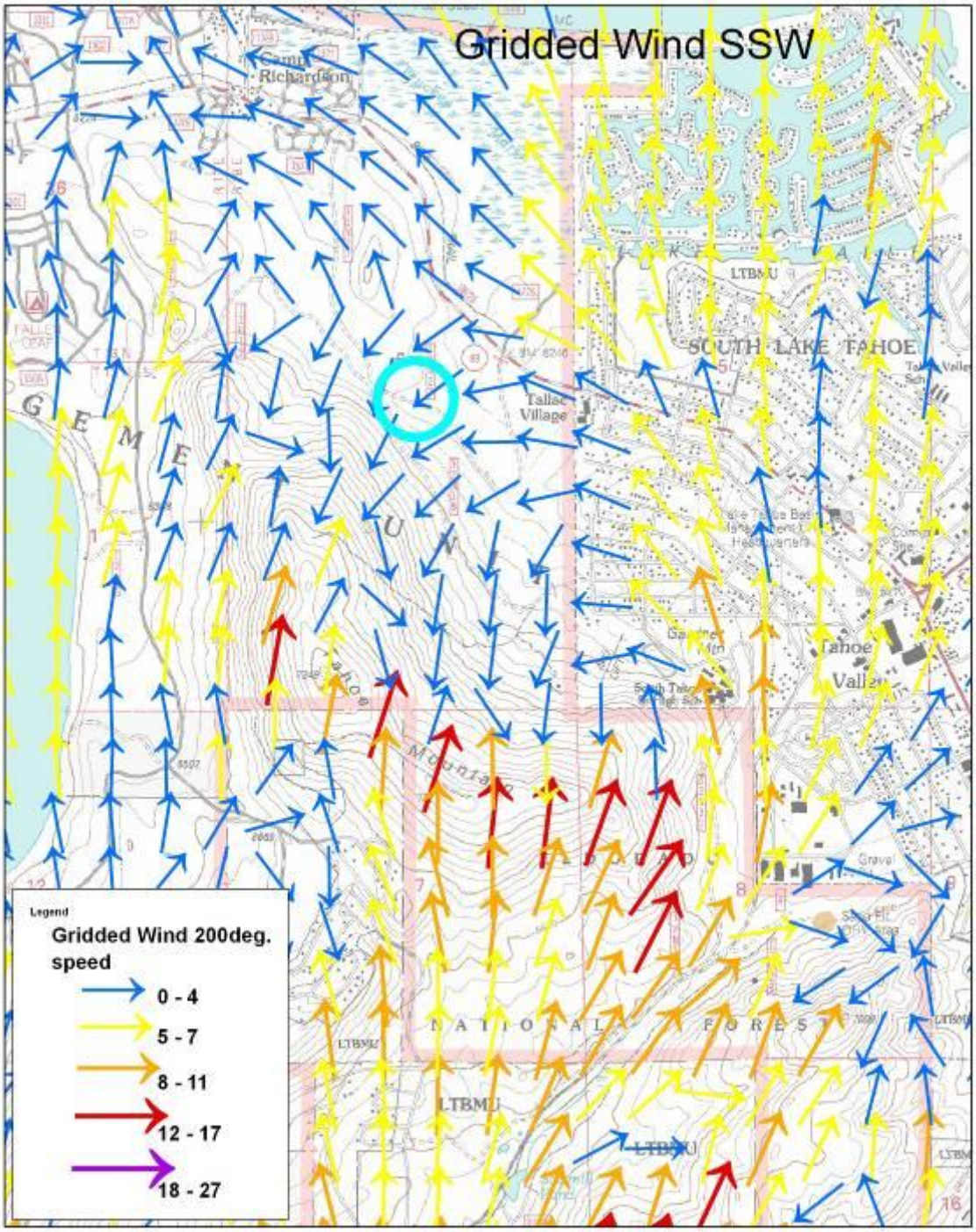

Figure 1: Gridded wind simulation
This gridded wind simulation helps to illustrate the influence of topography on local winds. It describes wind speed and direction for a 200 degree south-southwest wind. Note how wind speeds increase along the ridge top on Tahoe Mountain and how the winds then eddy around the sides of the mountain changing direction 180 degrees while decreasing in speed. While this simulation model does not attempt to forecast winds or represent on-site wind conditions, this information is very useful for planning, fire behavior modeling, and graphically displaying the complex interactions of terrain and wind. The light blue circle indicates the shelter deployment site

Fire Behavior, General

The fire behavior on June 24 and 26 could be characterized as extreme fire behavior but is not uncommon given the high winds, low fuel moistures, heavy surface fuel loadings, significant ladder fuels, and continuous canopy fuels. Given the similar alignment of these common environmental conditions, fires can quickly transition from a surface fire to a high intensity, fast-spreading, active crown fire.

June 24 – Wind Driven Spread and Extreme Fire Behavior

When the Angora fire started mid-afternoon on Sunday, June 24, it quickly transitioned from a surface fire to both passive (torching) and active (dependent) crown fire with significant short and long range spotting. Winds were reported to be 20-30 with gusts to 40 miles per hour. The fire had a forward spread of approximately 3 miles in a 4-hour period. It burned over 2500 acres and consumed 237 residences.

June 25 – Moderated Fire Behavior with Decreased Winds

On Monday, June 25, the fire behavior was still active on the north end of the fire but the winds had decreased significantly. A considerable amount of uncontained fire perimeter existed on the north-northeast aspect of Tahoe Mountain. The fire was now backing on a sheltered and shaded northeast aspect. While backing spread rates were low, the fire burned with high intensity and intermittently torched individual trees or small groups of trees. It was described by Air Attack as being "in a protected bowl and not marching upslope or downslope". The night shift (1800-0600, 6/25-6/26) worked on firing unburned fuels between the fires edge on the upper slope, northeast aspect of Tahoe Mountain and the 12N19 road. The 12N19 road was located just below midslope and was the planned control line at the north end of the fire. The nighttime burning progressed slowly in the timber understory due to high intensity burning created from the heavy fuel loadings. Critically low live and dead fuel moistures meant all size classes of fuels were available for consumption.

June 26 – Afternoon Wind Driven and Plume Dominated Fire Spread, Extreme Fire Behavior, Entrapment and Fire Shelter Deployment

On June 26th, increased south-southwest winds in the afternoon caused a rapid increase in fire behavior. The strong winds combined with heavy fuel loading, extremely low live and dead fuel moistures, and continuous canopy cover allowed for quick transition from a slow backing surface fire in the morning to a running head fire with torching, crowning, and significant short and long range spotting up to ½ mile in the afternoon. The fire spread approximately .8 miles in 2½ hours and consumed an additional 356 acres before it was contained that evening.

On the morning of Tuesday, June 26, the fire's edge on the northeast aspect below Tahoe Mountain was free burning and was a critical part of the suppression effort for the day. The night shift had burned downhill on established control lines on the west and east flanks. This left a large horseshoe shaped area of unburned fuels between the fire's edge and the 12N19 road (see Photo 5). Approximately 140 acres remained to be burned out. Many personnel on the day shift were briefed that the burning had almost been completed and the major focus would be on holding. The fire had reached portions of a jeep trail approximately 1500 feet above the 12N19 road. This may have led to misunderstanding on the amount of firing left, because some referred to the 12N19 road as the jeep trail.

0800 – 1200 Hours: Temperatures started out at 60° and increased to 70° and relative humidity decreased from 37% to 29%. Winds were calm to light from the west, southwest. Fire behavior was reported as active even with the presence of a nighttime radiation inversion over the fire. Air Attack was over the fire at 1035 and reported stable conditions and poor visibility. A southwest flow had trapped smoke in the bowl on the northeast side of Tahoe Mountain. The Laguna IHC crew began burning on the eastern side of the horseshoe on Division D at approximately 1130. The crew used only one drip torch and lit strips 15 feet apart to keep fire intensity as low as possible. Their plan was to even out the fire's edge by burning down to the jeep trail. When that was accomplished, another IHC crew would assist them in burning out from the jeep trail to the 12N19 road.

1200 – 1330 Hours: Air Attack reported the smoke begins to clear out at about 1200. As the inversion lifted, eye level winds on the Division E dozer line begin to change. Winds were 1-3 mph from the west-southwest with occasional gust from the northeast and intermittently come from the northwest. This wind direction change caused smoke to cross over the dozer line occasionally. Temperatures went from 70° to 75° and RH decreased from 32% to 25% during this time period.

At 1215, the Sierra IHC lit a test fire near the dozer line on the northwest end of Division D. The burn was hot and they determined that they could not run strips; rather they would try to bring fire down from Tahoe Mountain along the dozer line to 12N19. They begin burning at 1230 and progressed very slowly due to the high intensity. Both hotshot crews ceased burnout operations approximately one hour later at 1330. They were concerned with the high intensity, the amount of tree torching the burning was causing, and the time of day.

Photo 5. Taken from a helicopter looking south at approx. 1224 hours. Photo shows the horseshoe shaped island of unburned fuels above the 12N19 road. The Tahoe Mountain ridgeline runs across the upper part of the photo. The smoke indicates calm to light surface winds, moderate fireline intensity, and an unstable atmosphere.

At 1300 hours Air Attack advised Divisions D and E that fire activity was picking up with minor torching, black smoke, and increasing intensity. Around 1315 he advised Division E that Fallen Leaf Lake (approx. ½ mile west of Angora Fire) had whitecaps on it and warned them that winds would be headed their way.

1330 – 1430 Hours: At 1330 hours a hotshot superintendent serving as a lookout reported on the radio that the smoke column was battling with the wind and approximately 15 minutes later

reported the smoke column was beginning to lay over. At 1345 the fire spread had increased significantly and Air Attack was unable to see under the smoke.

Around 1400 hours on the south aspect of Tahoe Mountain, winds were south at 10-15 mph with gusts to 25 mph. At 1424 the northeast aspect of Tahoe Mountain had sustained northeast winds at 4-6 mph with gusts to 12 mph. Analysis from the Incident Meteorologist indicates that *"Due to the steep north aspect of Tahoe Mountain, the south winds were not able to surface right away and likely remained 200-500 feet above the surface. As a result, a rotor circulation (eddy effect) developed where the winds will reverse at the bottom of the circulation, thus the northeast winds on the north aspect."*

Photo 6. Burnout operation near dozer line (west flank) at approximately 1348. Photo was taken about 15 minutes after crew ceased burning operations.

During this time period, fire behavior increased noticeably as the predicted south-southwest winds surfaced on the fire, causing increased torching of individual trees and small groups of trees on the upper ½ of the slope. A well developed convection column formed and the south-southwest flow aloft carried embers across the control line. The embers caused numerous spot fires as they landed in the highly receptive fuel bed of timber litter with heavy fuel loadings, critically low dead fuel moistures (see Figure 2), and punky logs. The flaming front transitioned from a backing fire to downhill wind driven head fire spread.

Figure 2: Calculated Dead Fuel Moistures for Afternoon Burning Period on June 26, 2007. Ranges are displayed as they vary by aspect, elevation, and shading:

Fuel Moisture Timelag Category	1 Hour	10 Hour	100 Hour	1000 Hour
Size Class	0-1/4”	¼-1”	1-3”	3-8”
Fuel Moisture Content	**3-5%**	**5-7%**	**5-7%**	**8-10%**

Photo 7. Looking north toward Tahoe Mountain and increased fire behavior on northeast aspect of Tahoe Mountain as S-SW winds increased around 1400 hours. Refer to Figure 1 for a modeled representation of the surface winds.

1430 – 1510 Hours: Fire behavior during this period can best be characterized as active crowning, where fire in the tree crowns is dependent upon the surface fire. As torching in trees occurs, embers are lofted into the well developed convection column and land ahead of the main fire to the north. As spot fires become established in the surface fuels and grow together, they increase in intensity and preheat the canopy fuels to ignition temperature, and another pulse of torching occurs. Fire behavior is now predominately influenced by considerable spotting, active crowning, and a strongly developed convection column creating its own winds. Several spot fires developed north of Highway 89, indicating spotting approximately ½ mile from the main fire front.

At 1438 hours, Division D advised Branch that the fire has crossed the 12N19 road. At 1445 Division D ordered all resources to their safety zones. At the same time, a spot fire was reported north of Highway 89, which was closed approximately 5 minutes earlier.

Photo 8. Increasing fire behavior at approximately 1430 with smoke laying over 12N19 road on the east side of Division D.

Photo 9. Increased fire behavior on upper portion of slope at approximately 1445 hours. Smoke indicates rapid combustion and high intensity fire behavior.

Photo 10. Picture taken from a helicopter at approximately 1450 showing evolving spot fires near the location where FS E-34 engine boss and firefighter were last working on spot fires. "Clear" air near the fire's edge indicates surface wind indrafts into the base of the convection column. Figure 1 also provides insight into the surface winds at this time.

Fire Behavior Estimates at 1300, 1438, and 1515

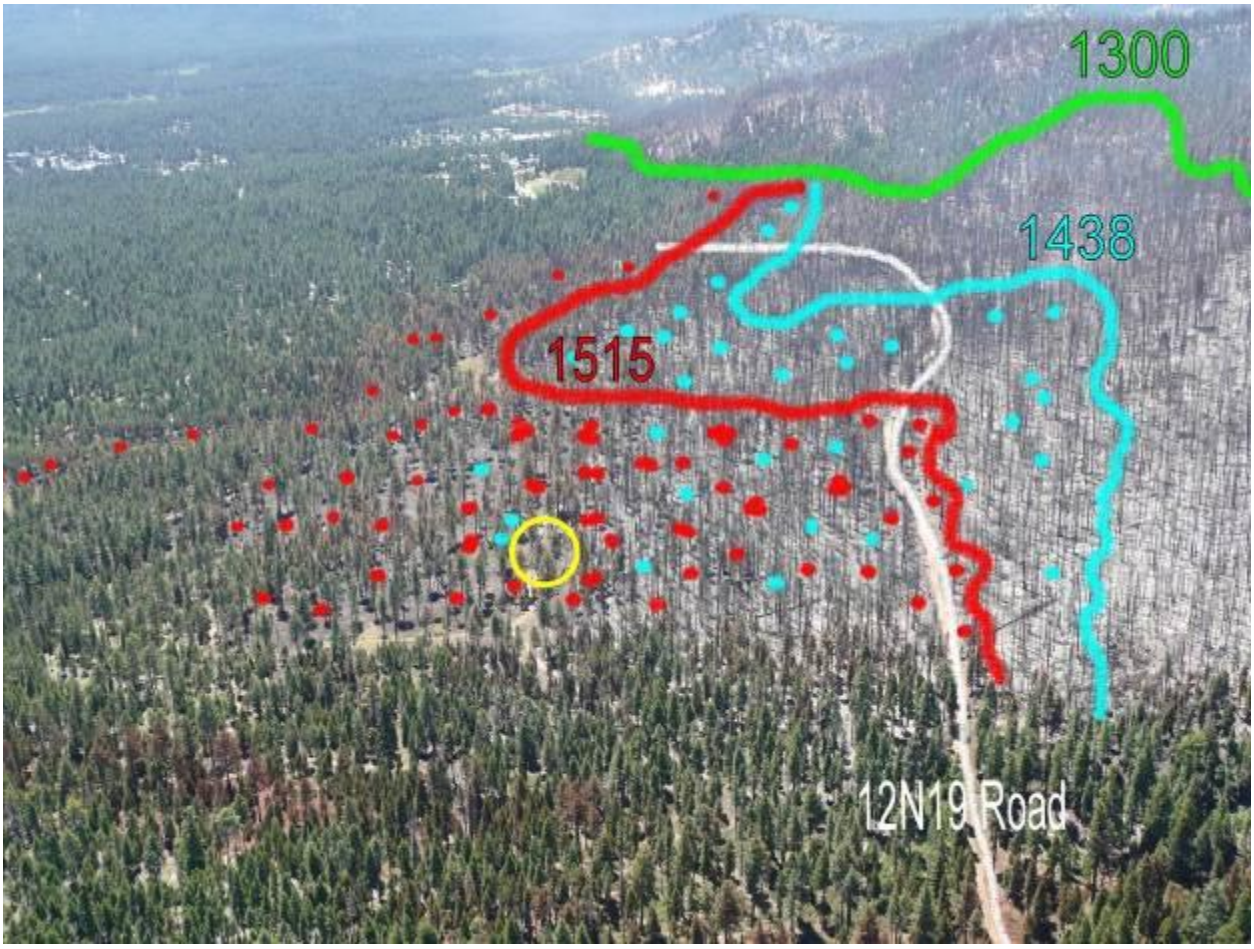

Figure 3: Fire progression estimates are based on witness statements, photographs, and burn indicators. Colored dots indicate approximate spot fire locations. Estimations are subject to some uncertainty. Yellow circle indicates the shelter deployment site.

Fire Behavior, Deployment Site

1510 – 1545 Hours: Frequent spotting and highly receptive fuelbeds led to numerous spot fires in the area where the engine boss, firefighter, and CAL FIRE hand crew were working to contain spot fires. The numerous intense, rapidly spreading spot fires prevented the engine boss and firefighter from going back uphill to the 12N19 road where their engine was located. Winds in the area were gusty, erratic, and strongly influenced by indrafts into the base of the convection column.

Photo 11. Picture taken at approximately 1523 of helicopter (in dashed circle) dropping water near shelter deployment site.

At approximately 1515 hours, the two firefighters deployed their fire shelters on a two-track road below the 12N19 road. They reported receiving 3 separate blasts of hot air. Helicopters began dropping water shortly after Operations received notification of deployment. The water drops most likely reduced the fire intensity, but it is impossible to quantify how much. As shown in Picture 13 (Appendix B) and Picture 8 (in the main report), there was unburned grass directly around the shelter deployment site. One of the safety officers first on scene to assist the

Photo 12. At approximately 1530 hours the winds lightened dramatically. Fire personnel observed that the smoke column shifted from a horizontal profile to a vertical profile. At 1700 hours eye level winds were south at less than 3 mph just south of Tahoe Mountain.

firefighters reported that the surrounding grass was damp.

There was a significant change in vegetation structure that occurred at the shelter deployment site. The timber transitioned from a denser mixed conifer stand (Jeffrey pine, *Pinus jeffreyi,* White Fir, *Abies concolor,* and Incense Cedar, *Libocedrus decurrens*) to a more open Jeffrey pine *(Pinus jeffreyi)* dominated stand. Fuel loading, ladder fuels, canopy closure, and tree density all decreased significantly in the Jeffrey pine stand, while the crown to base heights increased. The change in fuel characteristics and arrangement allowed the fire to drop from the tree crowns back to the surface. This reduced the fire intensity to the two firefighters in their shelters.

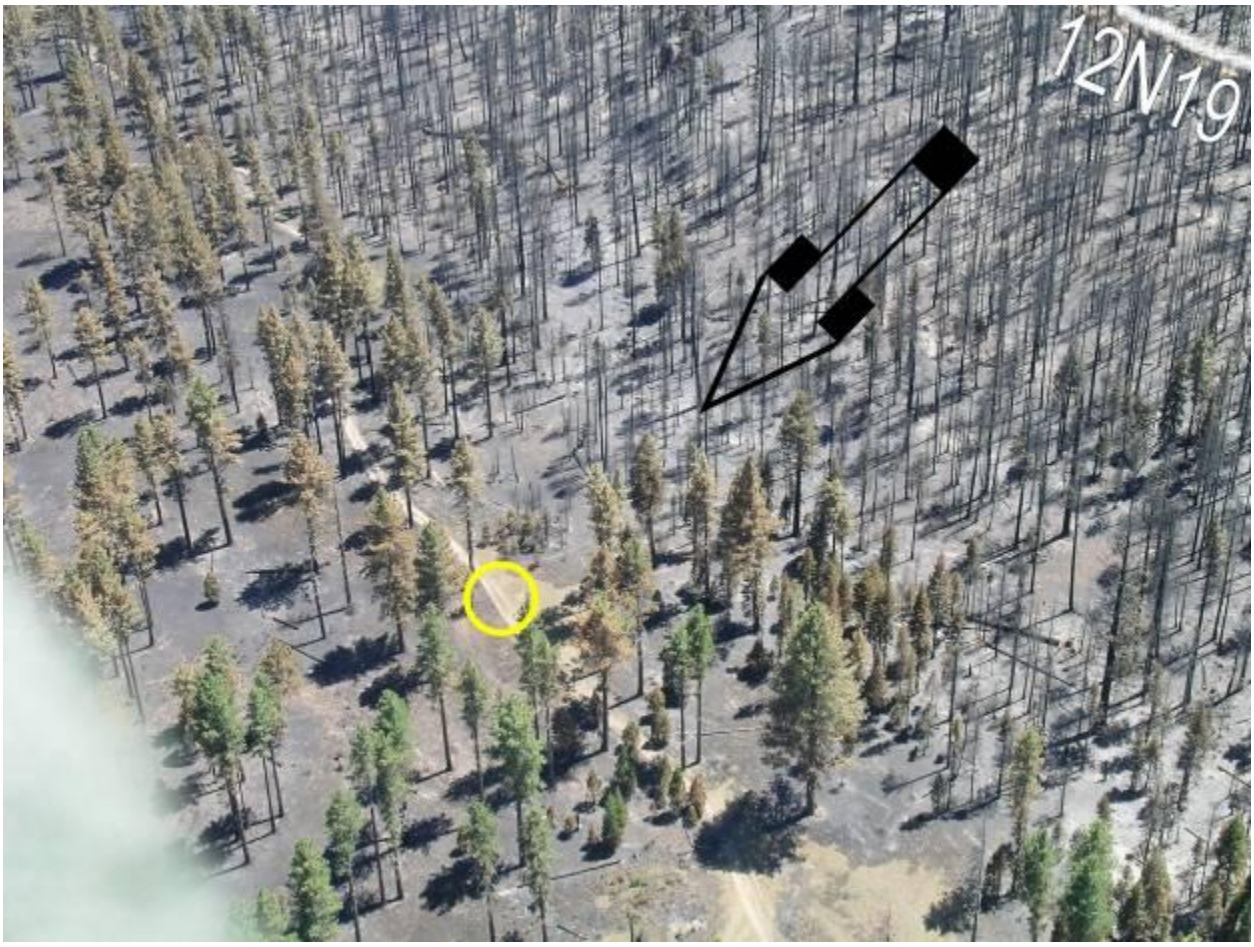

Photo 13. Shelter deployment site indicated by yellow circle. Arrow indicates direction of fire spread. Note striking change in crowning and scorch directly above site in comparison to the deployment site and surrounding area

Angora Fire Environment Summary for June 26, 2007

Fuels

Topography and Fire Spread

SSW Gridded Winds

All descriptions are specific to the north end of the fire and times are approximate.

0800 – 1200 | 1300 | 1400 | 1500 | 1600

Fuels:

Multi-storied dense mixed conifer timber stands. Heavy dead and down fuel loading. Significant ladder fuels. Highly receptive fuel beds for spotting. Afternoon dead fuel moistures of 3-5% for 1 hour timelag fuels and 8-10% for 1000 hour timelag fuels. (Photos 1,2,3,4)

Open Jeffery pine stand with significantly reduced fuel loading, tree density, canopy cover, and ladder fuels. (Photo 13)

Topography:

Mountainous terrain with elevations from 6246 to 7290 feet. Fire is located on the north, northeast aspect of Tahoe Mountain, 20 – 40% slope. (Photos 1,2)

Flat to gently sloping terrain, 6315 foot elevation. (Photos 12, 13)

Weather:

Stable conditions with inversion over fire. Smoke trapped in bowl on northeast side of Tahoe Mountain. Winds calm to light from the west, southwest. Temps 60-70°, RH 37% at 0800 and 29% at 1100.

Smoke begins to clear out as inversion lifts. Atmosphere above fire transitions from stable to unstable. Surface wind speed and direction more gusty and variable. (Photo 5)

South winds aloft surface on the south aspect of Tahoe Mountain. 10-15 with gusts to 25 mph. The northeast aspect of Tahoe Mountain has sustained northeast winds 4-6 with gusts to 12 mph. (Figure 1)

Winds decrease and smoke column shifts from horizontal to vertical profile. (Photo 12)

Angora Fire Behavior Summary for June 26, 2007

Fire at 1224 hours

Fire at 1450 hours

Fire at 1545 hours

All descriptions are specific to the north end of the fire and times are approximate.

0800 – 1200 | 1300 | 1400 | 1500 | 1600

Fire Behavior:

Backing moderate to high intensity surface fire. Slow rate of spread but still burns actively under the inversion.

Fire activity picks up with torching, black smoke and increasing intensity.

Burning operations cease due to high intensity, torching trees, and time of day. (Photo 6)

Single tree and small group torching increases on upper ½ of slope. Strong convection column forms. Numerous firebrands are transported north of the fire causing prolific spotting. Flaming front transitions from backing fire to wind driven downhill fire spread. (Photos 7,8,9)

Active (dependent) crown fire develops. Long range spotting up to ½ mile ahead of main fire. Rapid fire spread as numerous spot fires grow together. The power of the convection column becomes greater than the power of the wind. Indrafts into the main fire dominate spread rates and spread direction. Fire crosses 12N19 road at about 1438. (Photos 8,9,10,11)

Active crown fire drops to the surface at fuel type change near shelter deployment site. Surface winds decrease and smoke column shifts from horizontal to vertical profile. (Photos 12, 13)

Appendix C: Briefing paper: Accident Prevention Analysis

Examining Unintended Outcomes - Gaining the Greatest Benefit

Fire Operations Risk Management Council - USDA Forest Service

Safety is not a goal that an organization can reach. Safety is not an end state. In contrast, safety is continuous employee creativity in response to ubiquitous risk. This can be a challenging paradigm but it has immense implications for how we should value operational accidents.

A foundational principle of high-reliability organizing is a commitment to continuous learning. Learning from success is essential but learning from failure is crucial. In fact a key trait of reliable organizations is a preoccupation with failure. Rarely do we experience a serious nonrandom unintended outcome. But when this does happen, the occurrence provides tangible evidence that there are latent flaws in the organization of our work. Because the events are rare, the insights they provide into organizational deviance are also rare and thus enormously valuable. Fidelity to our values demands we treat accidents and near misses as precious learning opportunities and exploit their full value to enhancing system reliability.

Human error is implicated in 70-80% of all accidents. Learning from human error should be among the highest priorities for managers committed to high reliability organizing. The Forest Service has not done well in this regard. Overwhelmingly in fact, Forest Service accident investigations terminate upon "findings" of employee error. Errors are then constructed to be the cause(s) of accidents. In fact for decades, essentially all investigations have concluded, "An employee directly engaged in operations made a faulty decision; or failed to .....". In other words: "An employee caused the accident." Accident prevention actions stemming from such a conclusion invariably are driven to recommend, " additional specifications, rules or procedures to guide employee decisions." After half a century laboring under this paradigm, we have three clear results: 1.) employees fear disclosing their errors because (ethically or not) their errors will be labeled as a causal factor of the accident; 2.) we have generated so many rules that in aggregate they are reducing employee reliability; 3.) dozens of opportunities to learn from serious accidents have been compromised or lost by the quick, convenient and practically meaningless conclusion in the accident investigation report of "human error".

In 2004 the Forest Service Fire Operations Safety Council began to focus intently at learning from accidents and especially from human error. The Nuttall and then the I-90 fire entrapments provided excellent opportunities. Using a learning approach, rather than a hunt for employee error approach, we found that many employees were eager to share behavioral information with accident investigators.

In 2006 a more sophisticated approach was used to investigate the Balls Canyon and Little Venus entrapments. Referencing 21st century safety professionals, these investigations asserted that employee errors are more effectively viewed as organizational failures. Seeing the value of this approach for preventing future accidents, the Fire Directors ordered the Council to develop a guide for conducting learning investigations. The Accident Prevention Analysis Guide is the product of our experience with these four investigations combined with additional research into human error and refinements from critiques of professionals in the disciplines of psychology, sociology, safety, law and emergency management.

In 2006 the Forest Service Foundational Doctrine was signed by the Chief. Under this leadership direction, employee reliability (safety) is managed through alignment with principles and values. This places additional and crucial importance on learning from unintended outcomes. Under Doctrine, if there is a gap between operations as imagined and operations as done, then a thorough understanding of this gap is critical to cultivate the continuous risk management creativity of our employees. This guide provides Line Officers with tools they can choose to use (in lieu of the Serious Accident Investigation Guide) to investigate and learn from unintended outcomes.

Appendix D

Personal Protective Equipment Report
Angora Fire Shelter Deployment

This equipment report is based on both inspection of equipment and interviews of the firefighter and engine boss who deployed shelters on June 26, 2007 at the Angora Fire. Equipment inspection, firefighter interviews and follow-up interviews occurred between June 28 and July 18, 2007.

Personal Protective Equipment – According to interviews, both firefighters were appropriately equipped with personal protective equipment.

Clothing –The clothing showed no signs of heat and performed as designed.

Training – According to the firefighters' red cards and interviews, both firefighters had fire shelter training with the New Generation Fire Shelter. Each had watched the training video and practiced shelter deployments with practice shelters.

Fire Shelters and Fire Shelter Bags – The fire shelters were inspected at the deployment site on June 28 and 29 and at MTDC on July 18. They were examined for signs of heat and other structural damage.

- The shelters showed very little signs of heat – only a few isolated spots, less than 1 inch in diameter, on the shell of each shelter. These spots were most likely from hot embers directly contacting the shelters.
- The condition of the shelters indicated that the combination of radiant and convective heat was not sufficient to raise the temperature of the material above 500 degrees F.

- Engine Boss Shelter:

New Generation Fire Shelter, Revision C
Manufacturer – Weckworth Manufacturing
Date Mfg – Label not found
Size: Regular

  - Label sewn into floor seams missing due to floor seam tears.
  - Structural damage – the inside corner seams of the floor are torn in varying lengths: 2, 6, 8 and 10 inches.

- Firefighter Shelter:

New Generation Fire Shelter, Revision A, Retrofit, GSA
Manufacturer – Anchor Industries
Date Mfg – August 2003
Size: Regular

  - Floor material, physical delamination of foil on 1/3 of the floor area
  - Floor material tore away from reinforcement at one end across the width of shelter; the reinforcement remained in place.
  - Hole worn into floor material – 6 X 6 inch.

The fire shelter bags were also inspected:

- Both bags were found at the deployment site.
- Both bags had a few, less than ½ inch, melt marks, most likely from hot embers.

Discussion – The fire shelters and bags performed as designed. The amount of wear observed on the engine boss' shelter is as expected under the conditions of this deployment. The firefighter's shelter however, showed considerable delamination of the floor material, much more than expected under the conditions of this deployment. In neither case does it appear the degradation of shelters affected performance. The unexpected amount of delamination was likely caused by the substantial movement, shifting, crawling, etc. of the firefighter while he was inside of the shelter.

Shelter Experience – Believing all viable escape routes cut off and after a short discussion, both firefighters deployed their fire shelters.

- The firefighters reported the temperatures inside the shelter were very hot. They found it uncomfortable to breathe, so they both dug small holes and cupped their hands around mouth and nose in order to breathe more comfortably.
- The firefighter poured water in the small hole he dug.
- After a hole developed in the floor of his shelter, the firefighter tucked the floor material under himself and received no additional smoke or heat.
- The engine boss moved with his shelter to get batteries from his pack and lifted his shelter to communicate on the radio and observe the fire several times.

Discussion – The deployment site was in a small green meadow in an area transitioning from closed canopy to open canopy. Just south of the deployment site almost all tree crowns were consumed and just north of the site, almost all crowns remained after the fire passed. (See fire behavior report) Ultimately, it was the combination of an adequate deployment site, the bucket drops from helicopters and the performance of the fire shelters which resulted in two uninjured firefighters.

- The grassy area chosen for their deployment site offered sufficient protection from direct flame contact.
- Both firefighters used their time at the deployment site wisely and deployed with time to spare before the initial heat wave arrived.
- Both firefighters tossed their packs clear of the shelters.
- The engine boss reported he had difficulty unfolding the shelter for deployment. He performed a practice deployment with a real New Generation Fire Shelter several days after the deployment and was able to deploy quickly and efficiently with no problems.
- Both reported that the red tear strip of the shelter PVC bag does not tear away as easily as the red Velcro tear strip of the practice shelter PVC bag.
- Both firefighters brought water into the shelters with them.
- The firefighter reported that pouring water into the small hole that he had dug cooled the air that he was breathing.

- Both firefighters commented that they were able to obtain a good seal with the shelter floor and the shelter held its volume and shape well.
- Radio transmissions were hampered while inside the shelter, the engine boss needed to partially peek out of the shelter to transmit with his radio.
- After a few minutes of being deployed, the firefighters received water drops from the helicopters. The water drops helped cool the area more quickly.
- Both firefighters participated in shelter training, but stated they never thought that they would ever need to deploy a fire shelter during their fire careers.
- Both firefighters believe the fire shelters saved their lives.

Deployment Site:

- Size – Approximately 1600 square feet, triangle shape, short green grass with a two-track road on the north end.
- Most areas south of the deployment site burned in a high intensity fire that burned most of the trees' crowns.
- North and west of the deployment site the fire transitioned to mostly a ground fire.

Recommendations and Reminders:

- If at all possible, firefighters should time their deployment so they are inside their shelters before the flame front arrives.
- Firefighters should bring water bottles into the shelter only if time permits.
- Current fire shelter training warns against breathing through wet bandanas.
- At this time it is NOT recommended to pour water into the dirt near breathing areas. Further evaluation of different ways water can be used during a deployment is needed.
- Firefighters should practice shelter deployments in a high stress environment, with time constraints and in different positions (standing, kneeling and lying).
- In addition to practicing deployments with practice shelters, firefighters may need to do practice deployments with an actual New Generation Fire Shelter in order to become as proficient as possible.
- Firefighters should review the 2003 MTDC Fire Tech Tip – *Fire Shelters Weaken Radio Transmissions From Hand-Held Radios*.

The New Generation Fire Shelter:

- This is the fifth known deployment of the New Generation Fire Shelter.
- Information learned from this deployment will be used to continue development work on the New Generation Fire Shelter.

/s/ Tony Petrilli — *August 8, 2007*

Tony Petrilli — Date
Equipment Specialist
Missoula Technology and Development Center

Appendix E, Fire Shelter Tech Tip

Fire Tech Tips

United States Department of Agriculture
Forest Service
Technology & Development Program
December 2003
5100 0351-2342-MTDC

Fire Shelters Weaken Transmissions From Hand-Held Radios

Ted Etter, Project Leader

Firefighters who have deployed fire shelters during training have had difficulty communicating using hand-held radios. The Missoula Technology and Development Center (MTDC) conducted a brief study to determine how well radios worked inside fire shelters.

The study showed that when firefighters were inside fire shelters within 50 feet of each other, they could communicate using the VHF (Very High Frequency, 30 to 300 MHz) Bendix-King radios. They could not communicate using the newer UHF (Ultra High Frequency, 300 to 3,000 MHz) Motorola Astro XTS 3000 radios. In either case, the radio signals were significantly weaker when the radio (figure 1) was used inside the fire shelter, particularly when the radio was inside the New Generation Fire Shelter.

Essentially, firefighters could shout and be heard as far as if they used their new UHF radios inside a fire shelter. Firefighters probably won't be able to make effective use of their hand-held radios when they are trapped inside their fire shelters. Once the fire has passed, and it's safe to leave the shelter, firefighters can use their hand-held radios to establish communications with each other and with their supervisors.

Figure 1—The newer UHF Motorola Astro XTS 3000 radio (left) and the VHF Bendix-King radio. Both radios have "rubber duck" antennas.

Study Details

Various factors influence how effective radio communications will be from inside a fire shelter. Those factors include the location of the fire shelter relative to the radio receiving the signals, the location of the radio inside the shelter, the orientation of the antenna, and the fire shelter model. MTDC also looked at different types of radios and antennas.

For the tests, a ¼-wave vertical whip antenna was used to receive VHF signals at 168 MHz. A log-periodic Yagi antenna was used to receive UHF signals at 870 MHz. The strengths of VHF and UHF signals were measured on a Rohde and Schwartz FSH3 spectrum analyzer (figure 2).

Signal strengths were measured in decibels (dB) and decibels referenced to 1 milliwatt of power (dBm). See the decibel refresher section below for further explanation of these units of measure. Although the

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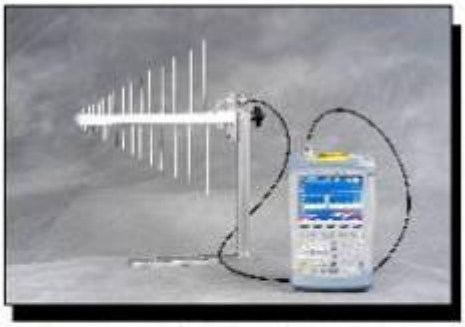

Figure 2—The log periodic Yagi antenna (left) and a spectrum analyzer were used to determine signal strength from the UHF Motorola hand-held radio.

UHF signals were about 5 dB stronger than the VHF signals because of the different types of antennas used to receive the two signals. relative difference in signal strengths did not depend on the type of antenna that was used. The spectrum analyzer and antennas were placed 50 feet from the fire shelters or other radio transmission points. The weather was clear and sunny with a temperature of about 60 degrees F.

The VHF radios tested were Bendix-King GPH5102X models set for 2 W of RF (radio frequency) output. The antennas were 6-in helical "rubber ducks." The UHF radios tested were Motorola Astro XTS 3000 models with 3 W of RF output. The receiver sensitivity specifications were similar for both types of radios, about 0.3 μV for intelligible reception.

For one test, a fire shelter was aligned with the path to the receiver. An individual inside the fire shelter positioned himself with his head at the end of the shelter nearest to the receiver. His feet were at the other end. He first held the radio 6 inches from the end of the shelter nearest to the receiver and then held the radio in the shelter's center.

The radio was tested at three antenna angles: vertical, 45 degrees, and horizontal in the plane perpendicular to a line to the receiving antenna. Although antenna polarization can be a major factor in signal reception at VHF frequencies and above, the aluminized surface of the fire shelter appeared to alter the polarization of the signal so that the receiving radio's orientation wasn't critical.

An FSH3 spectrum analyzer with a 160 MHz ¼-wave antenna 50 ft from the center of a fire shelter was used to test the VHF Bendix-King GPH5102x radios (set for 2 W output at 168 MHz). The same analyzer with an 800 to 2,000 MHz log-periodic Yagi antenna 50 ft from the center of a fire shelter was used to test the UHF Motorola Astro XTS 3000 radio (3 W output at 870 MHz).

During the tests (table 1), the received signals varied by several decibels because the radio's position was adjusted inside the shelter. Therefore, the values in the table should be considered approximate, within several decibels per milliwatt of the precise values for the specified test conditions. The accumulated signal strengths from three radio orientations in two locations within the shelters were averaged to show the attenuation (reduction of strength) more accurately.

Based on the averages for each test setup, the attenuation of radio signals transmitted from inside fire shelters was as follows:

- Old shelter model with a VHF radio: -33 dB
- Old shelter model with a UHF radio: -43 dB
- New Generation Fire Shelter with a VHF radio: -37 dB
- New Generation Fire Shelter with a UHF radio: -47 dB

Firefighters inside fire shelters also have difficulty communicating over the radio to other firefighters inside fire shelters. Another test was conducted to study this problem.

An individual positioned himself inside an old shelter model. Another individual was in a New Generation Fire Shelter about 50 ft away. Communication was possible with the VHF radios, but not with the UHF radios. According to the averaged signal strength measurements, shelter-to-shelter signals for UHF radios would be ~20 dB weaker than VHF signals. This test indicates that communication from inside the New Generation Fire Shelter is more difficult than communications from inside the standard shelter.

Some firefighters have questioned whether they might risk damaging their retinas if they use their hand-held radio inside a fire shelter. The risk of using the radio inside the shelter is essentially the same as that of

Table 1—Test results showing how much transmissions from the VHF Bendix King and UHF Motorola Astro hand-held radios were weakened when the radios were used inside fire shelters. All values are in decibels. The radios were held vertical, 45 degrees from vertical, or horizontal.

	Radio type and antenna orientation					
	VHF vertical	VHF 45 degrees	VHF horizontal	UHF vertical	UHF 45 degrees	UHF horizontal
Shelter						
Old shelter-center	47	44	44	58	59	59
Old shelter-end	63	59	63	58	59	65
New shelter-center	55	59	55	66	63	77
New shelter-end	60	58	57	60	58	63
No shelter	20	22	20	10	16	25
Signal attenuation relative to no shelter						
Old shelter-center	-27	-22	-24	-48	-43	-34
Old shelter-end	-43	-37	-43	-48	-43	-40
New shelter-center	-35	-37	-35	-56	-47	-52
New shelter-end	-40	-36	-37	-50	-42	-38

using the radio elsewhere—negligible. The hand-held radios operate at such low power that the risk is essentially eliminated. The limited amount of energy that is reflected from the inner surface of the shelter to a firefighter's head would be much less significant than the energy transmitted from the antenna when the radio is held in front of a firefighter's face. So, even though hand-held radios don't work very well when they're used inside a fire shelter, they don't present a risk to firefighters who try to use them there.

A Decibel Refresher

Radio technicians and engineers work extensively with signal strengths measured in decibels because they can represent extremely large or small values with two- or three-digit numbers. Decibels work on a logarithmic principle. When working with signal power, the value of a power gain or loss in a system is 10 times the logarithm of that gain or loss. For example, a system with a power gain of 100 would have a gain in decibels of 10 times the log of 100, or 10 • 2 = 20 dB. The log of 100 is two because $10^2 = 100$. Similarly, a circuit whose output is $^1/_{1,000}$ the input power has a gain in decibels of 10 • (-3) = -30 dB. The log of $^1/_{1,000}$ or .001 is –3 because $10^{-3} = .001$.

At radio frequencies in the UHF region (300 to 3,000 MHz), signal power detected from a transmitter decreases by a factor of $^1/_4$, or –6 dB, every time the distance to the transmitter doubles. Increasing the distance 10 times results in a received power loss of $^1/_{100}$, or –20 dB.

This information refers to relative changes in signal strength. It does not describe the signal power being transmitted or received. When absolute power information is required, the unit found most often in communications work is the dBm, or decibels referenced to 1 milliwatt of signal power. A transmitter with an output power of 2 W would provide a signal strength of 33 dBm at its antenna. Good VHF receivers can detect signals in the range of –107 dBm with quarter-wave antennas; "rubber duck" antennas reduce signal detection to the range of –103 dBm.

About the Author

Ted Etter joined MTDC in 2002 to work on electronics projects. He has spent more than 25 years working in the areas of electronic instrumentation and display technology. He received a bachelor's degree in mathematics from the University of Oregon in 1992 and a master's degree in teacher's education from Eastern Oregon State University in 1993. Before coming to MTDC, he taught courses in programming, digital circuits, data communications, radio frequency communications, robotics, microprocessors, and operating systems at the University of Montana College of Technology.

Library Card

Etter, Ted. 2003. Fire shelters weaken transmissions from hand-held radios. Tech Tip 0351-2342-MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 4 p.

Wildland firefighters who try to use their hand-held radios inside fire shelters will be unlikely to communicate with their supervisors and may not even be able to communicate with other firefighters inside fire shelters just 50 feet away. Transmissions from the older VHF (very high frequency, 30 to 300 MHz) Bendix-King radios were not weakened as badly as those from the newer UHF (ultra high frequency, 300 to 3,000 MHz) Motorola Astro XTS 3000 radios. The standard fire shelter being carried by wildland firefighters did not weaken the transmissions as much as the New Generation Fire Shelter that is just beginning to be carried by wildland firefighters. The tech tip includes a table showing exactly how much the transmissions were weakened in different situations. Essentially, firefighters could shout and be heard as far as if they used their new UHF radios inside a fire shelter.

Keywords: Bendix-King, communications, equipment evaluations, Motorola

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Appendix F

Angora Fire Entrapment and Fire Shelter Deployment - Accident Prevention Analysis Team members:

- Ray Haupt, Klamath National Forest, District Ranger (APA Team Leader)
- Deborah Austin, Lolo National Forest, Forest Supervisor (Chief's Representative)
- Joe Duran, Los Padres National Forest, Forestry Technician, NFFE Representative.
- Randy Meyer, Pacific Southwest Research Station, NFFE President
- Mike Simmons, LTBMU, Engine Captain.
- Larry Hood, Pacific Southwest Regional Office, Fire Planner.
- Anthony Petrilli, Missoula Technology and Development Center, Fire Shelter Specialist.
- Jay Kirchner, Pacific Southwest Regional Office, Public Affairs Specialist
- Steve Holdsambeck, Intermountain Regional Office, Fire Operations Safety Manager.
- Randy Draeger, Regional Health and Safety Manager, Intermountain Region
- GIS and Documentation Support provided by Kurt Teuber (Lake Tahoe Basin Management Unit) and Gary Chase (Shasta-Trinity National Forest).