Pole Creek and Bald Mountain Fires
Facilitated Learning Analysis

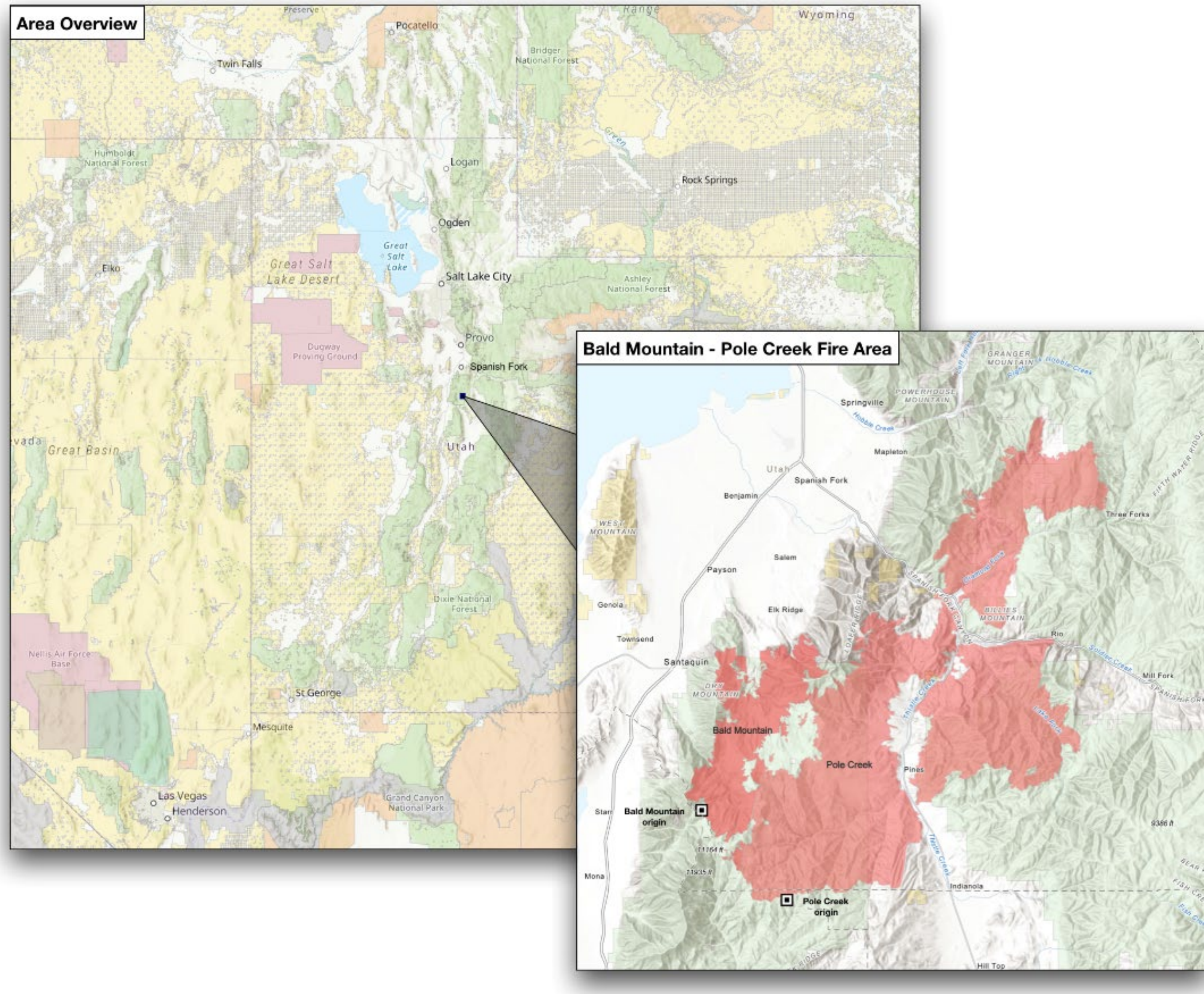
The Pole Creek Fire on September 12, 2018.

"'Modified Suppression' is a spectrum. 'Confine/Contain' is the creation of a box. They are not synonymous, yet not dissimilar."
Type 3 Incident Commander

"Without planning for the worst-case scenario, we were constantly behind the power curve."
Firing Boss

"We're operating so far out of climatology. I've never seen it before."
Great Basin Predictive Services

"I have never seen this before! How do we learn from this and act differently?"
Forest Supervisor


Area Overview
Pocatello
Wyoming
Twin Falls
Bridger National Forest
Humboldt National Forest
Logan
Rock Springs
Ogden
Great Salt Lake
Great Salt Lake Desert
Elko
Salt Lake City
Ashley National Forest
Provo
Dugway Proving Ground
Spanish Fork
Great Basin
Utah
Dixie National Forest
Nellis Air Force Base
St George
Mesquite
Las Vegas
Henderson
Grand Canyon National Park
Bald Mountain - Pole Creek Fire Area
Springville
Mapleton
Spanish Fork
Benjamin
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Mill Fork
Bald Mountain
Pole Creek
Pines
Bald Mountain origin
Mona
Indianola
Pole Creek origin
Hill Top

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Figure 1 – *Smoky view from the Strawberry Reservoir Visitor Center on September 13.*

Introduction

In September of 2018, the Pole Creek and Bald Mountain Fires on the Uinta-Wasatch-Cache National Forest (UWF) in Utah rapidly grew in response to dry fuels and strong winds. The fires and their smoke were visible to the majority of Utah's residents in the greater Salt Lake City area. Over 6,000 citizens from adjacent communities were evacuated from their homes. Private businesses were disrupted for several weeks. Forest recreation and the businesses that rely on tourism dollars were affected. Ultimately, these fires grew together to burn an area of 120,851 acres. The story of how these fires – initially considered by skilled fire managers to be remote, high elevation fires unlikely to ever threaten communities or infrastructure – were able to grow so quickly and become so large is the subject of this Facilitated Learning Analysis (FLA).

While the actions and decisions taken throughout the event made sense to the people involved at the time, there is much to learn from the Bald Mountain and Pole Creek Fires through hindsight. The following are three key learning themes the FLA team heard from the stories that were shared:

1. This event demonstrated the need for a structured, risk-informed decision-making process. There is no national process to follow. Consequently, while the decisions made may have been sound Risk Management decisions, it is difficult to document this and be fully transparent with our partners and the public.
2. Within the Forest Service and the interagency community, terminology surrounding wildland fire management is not standardized. This event showed that this can lead to miscommunication and confusion.
3. The Bald Mountain and Pole Creek Fires exposed a gap of understanding and expectations of what the Red/Green Map is and how this tool should be utilized.

The intent of this analysis is to take a critical look at practices and policies that could lead to unintended outcomes like these fires. The reader is encouraged to use this analysis as a discussion starter that can lead toward greater agency learning by thinking about these themes while reading the story of the Pole Creek and Bald Mountain Fires.

Background: UWF Fire Response Culture

Before delving into the story of the Bald Mountain and Pole Creek Fires, it is helpful to understand the philosophy of fire management on the UWF. The UWF is a high complexity fire Forest with a very large urban-interface challenge which adds to the complexities of maintaining a healthy forest. Staff respond to an average of 91 fires every year. The fire managers on the UWF are as experienced and professional in complex fire management as in any other area of the country. If this could happen here, it could happen anywhere.

The Forest embraces opportunities to allow unplanned fires to reduce fuel accumulations and contribute to landscape sustainability where and when conditions are right to do so with little risk. The intent is for the Forest to communicate this every spring at meetings with neighbors and partners. Each year, Forests improve their outreach to partners to attend these spring meetings, including the UWF. At the meetings, a map showing areas in which fire starts might be considered as a means to meet Forest Plan objectives is shared and discussed. These maps can be amended where appropriate based on these spring conversations. The map is referred to as "The Red/Green Map" (Default Initial Fire Response Map) and is required for each Forest in the Intermountain Region as a consistent means to communicate intent and opportunity. An area marked in red indicates where fire is likely unwanted due to adjacent values. A green area might be evaluated for an approach that would lead to a larger fire footprint.

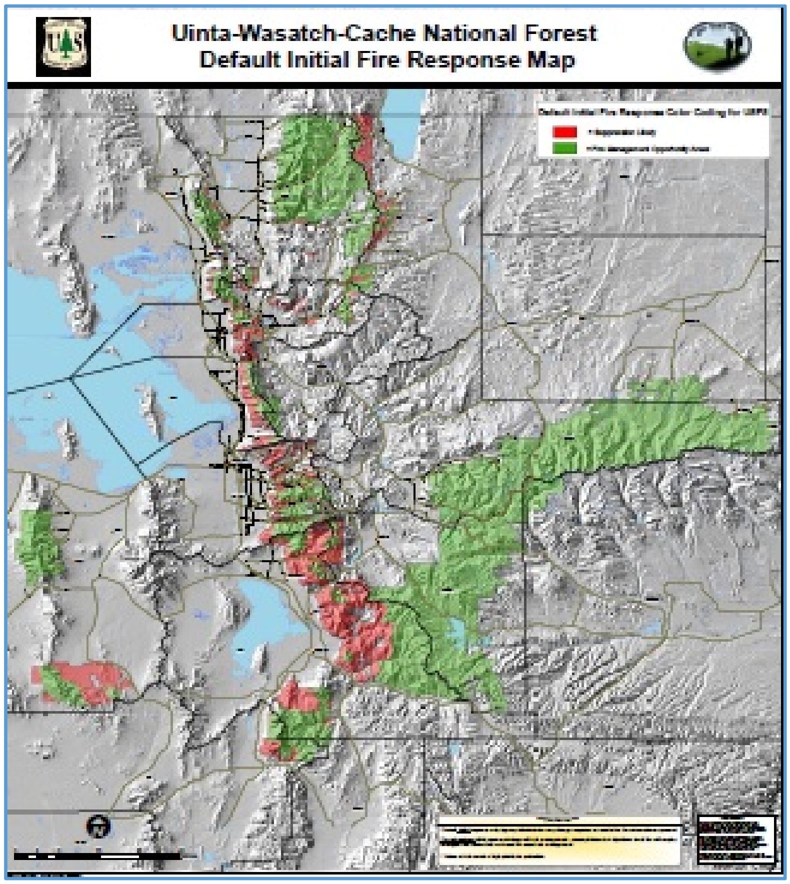

Figure 2 – *Red/Green Map (Default Initial Fire Response Map).*

The value of the Red/Green map is in the conversation with partners pre-season.

The Forest established an approach to Strategic Risk Management in 2015 (Appendix A; Appendix B) that is consistent with the Land and Resource Management Plan, where opportunistic restoration using wildfire is supported under conditions where there is a high probability of success, both for restoration and firefighter safety objectives. While every fire has a suppression objective, variables including where, when and how to engage the fire allow for measured decisions that minimize risks and result in better outcomes. This approach to fire has been very successful, with many examples of similar fires that resulted in good outcomes on the landscape and safer work conditions for fire responders. A local Incident Commander (IC) described how he felt about the UWF's approach to fire management: "We were successful in what we were doing. Success was not putting firefighters in snag patches." The Forest had been successful with this approach of improving forest health conditions over time by using these natural fire ignitions as opportunities to re-introduce wildfire in previously identified remote areas.

The Story

The Bald Mountain Fire

Just a few days before the Bald Mountain Fire was detected, two other natural starts occurred in the Mount Nebo area: the Dry Mountain Fire (August 20) and the Golden Ridge Fire (August 21). The Dry Mountain Fire was a single tree on a ridgeline at 9,600 feet elevation. Due to the fire's low spread potential and to reduce risk to firefighters, the fire was monitored from the air. It went out after receiving some rain.

The Golden Ridge Fire burned at a lower elevation (8,300 feet) and was also monitored as a potential benefit to land management objectives. Once the Bald Mountain Fire started on August 24, the Duty Officer and District Ranger decided to suppress the Golden Ridge Fire to prevent resources from becoming overtaxed by managing too many fires simultaneously. Due to moderate weather and fire behavior conditions, the fire was suppressed at 0.5 acre utilizing direct attack techniques.

The Bald Mountain Fire was in a green area on the Red/Green Map. This fire was located in the Mt Nebo Wilderness area. As fire management was evaluating this fire there was concern for firefighter safety due to steep slopes and 50% dead standing trees. On the day that the Bald Mountain Fire was detected, area Remote Automated Weather Stations (RAWS) showed 1.32-2.29 inches of rain. The Energy Release Components (ERCs[1]) dropped down to the 50th percentile, which was very uncommon for that time of year (see Figures 3 and 4) Based on experience, local Forest personnel believed it was not likely that the ERCs would recover—typically they trend downward after late August.

The general trend for minimum, average, and maximum ERC values in the fall is to decrease. The 1,000-hour dead fuel moisture increases this time of year (see Appendix E). In addition, these conditions seemed to be in alignment to use the Bald Mountain Fire to meet ecosystem restoration objectives.

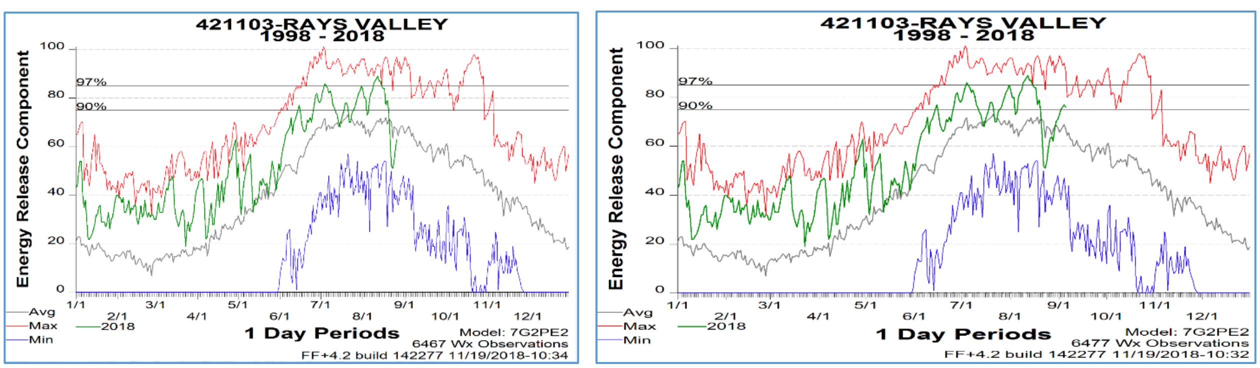

Figure 3 – *ERC comparison from the Rays Valley RAWS. The chart on the left shows the ERC conditions on August 25, the day before Bald Mountain Fire was reported. The chart on the right shows ERC conditions on September 5, the day before the Pole Creek Fire was reported.*

[1] The Energy Release Component (ERC) is based on the estimated potential available energy released per unit area in the flaming front of a fire. The day-to-day variations of the ERC are caused by changes in the moisture contents of the various fuel classes, including the 1,000-hour time-lag class. The ERC is derived from predictions of (1) the rate of heat release per unit area during flaming combustion and (2) the duration of flaming. It is often used as a metric for understanding potential fire severity/intensity at a given time period.

Most fire managers, however, were pretty sure the fire would go out on its own at a small size due to the wetness of recent storms.

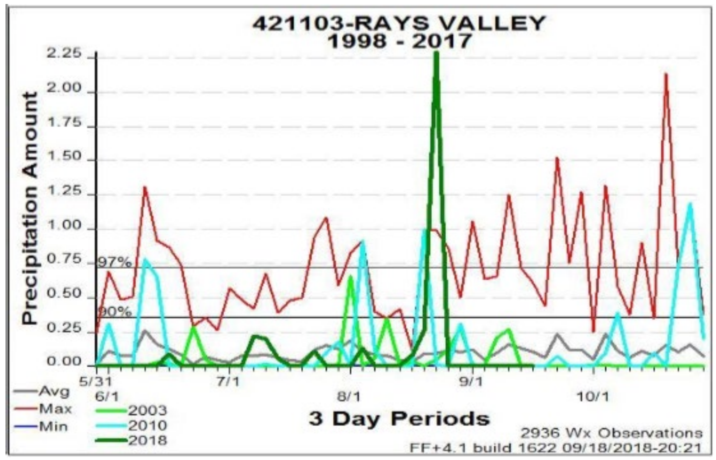

Figure 4 *– Graph showing precipitation received at the nearest RAWS from June to October over the last 20 years. Figure 4 shows the rain event of August 22 was the most significant precipitation event in the area occurring during the summer over the last 20 years.*

August 24: Bald Mountain Fire, the Early Days

Lightning ignited the Bald Mountain Fire in the Mt. Nebo Wildness in a remote pocket of timber. After the fire was reported at 1230 hours on August 24, firefighters located the fire in an area of heavy beetle kill in steep, rugged terrain.

Fire managers assessed the opportunity to take advantage of this fire to meet restoration objectives by taking into account such factors as: a lack of values at risk (campgrounds, private inholdings, powerlines, etc.), the composition of the surrounding vegetation, time of year, remote location, recent precipitation, and potential hazards (standing dead trees, steep terrain, and loose rocks). They expected the fire to go out by itself like other recent fires on the Forest.

“We put the Bald Mountain Fire into monitor status due to issues with snags and associated safety concerns, but also because it was Wilderness where fire is OK as a natural process,” said the Zone Assistant Fire Management Officer/Duty Officer (ZAFMO/DO). “But firefighter safety was the primary driver for our decision.”

Figure 5 *– August 24 ground view of the Bald Mountain Fire.*

Figure 6 *– Aerial view of the beetle kill in the Bald Mountain Fire.*

First WFDSS Decision

Late afternoon on August 24, the District Ranger wrote a Wildland Fire Decision Support System (WFDSS) decision for the Bald Mountain Fire, which was then at 0.1 acre in size. This decision was published on August 27 at 1018 hours. Based on map estimates, the planning area boundary was 3,280 acres.

The relative risk was determined to be low, as were the probability of a significant event or extreme fire conditions. A Type 4 organization was determined as appropriate for staffing. The course of action recorded in WFDSS was to: "Allow fire to burn to north, northeast and east. However, consider and allow suppression actions on the southwest and southern boundaries to prevent fire from reaching private lands and minimizing the need to close the Mona Pole Road. Fire behavior may dictate a different outcome, but where management of the fire through suppression or other tactics allow for steering the fire in the right direction, implement those."

The fire was at 10,300 feet in elevation. When it put up smoke, local Dispatch centers reported receiving numerous calls about the fire, as it was visible at times from local communities, Interstate 15, and the Nebo Loop Road.

Firefighters monitored the fire from the ground and air almost daily for the next 12 days and noted very little growth. By September 5, the aspen on Mt. Nebo was in full fall color. The fire, which had just received more rain, had grown to only 5.5 acres and was creeping in timber. Confidence was high among the experienced fire managers on the district that the Bald Mountain Fire wouldn't achieve much in the way of resource restoration before it went out.

September 6: Pole Creek Fire Ignites

After another storm, Dispatch received a new smoke report at 1041 hours near Nebo Loop Road. A Utah County engine started to respond, but the Zone Fire Management Officer (ZFMO/DO) and the Assistant Fire Management Officer (AFMO), who were in the vicinity monitoring the Bald Mountain Fire, canceled the County engine. They requested a helicopter for a size-up and the local Forest engine with an Initial Attack Incident Commander (ICT5). The ZFMO/DO and AFMO met the engine captain who was an ICT4 at the Summit Trailhead at 1248 hours.

Figure 7 *– Aerial view of the Pole Creek Fire on September 7.*

The helicopter crew reported the Pole Creek Fire as 40 foot by 40 foot in size, burning roughly 6 miles to the southeast of the Bald Mountain Fire. Smoke was visible from the trailhead when the ICT4 hiked to the fire, which was burning in a 40-foot long log, butnot carrying into the fine fuels.

“While we were there, a thunderstorm built to the east of the fire and began tracking towards the area,” said the ICT4. “We were receiving wetting rain as we hiked back to the trailhead.”

FS policy recommends drawing a “containment area” around fires that are not suppressed. This is for decision-making purposes to ensure Line Officers and Fire Management are preparing for contingency actions in the event the fire reached the “containment area“ boundary. The ICT5 Trainee (ICT5t) called Dispatch and reported the initial fire strategy would be “confined, contained, and managed.” They drew a map in Avenza showing an approximately 210-acre potential containment area surrounded by the Summit Trail, a couple of ridges, and a creek bottom.

The recent rains in the area had left the soil moist 6 to 8 inches deep near the fire area. While the fire was outside the Wilderness Area, it was in a green area on the Red/Green Map. As with the Bald Mountain Fire, the Pole Creek Fire met the criteria for restoration. The District Ranger and his fire management staff decided that if the Pole Creek Fire could survive the wet conditions, it would also be a good candidate to achieve some desirable fire effects.

“It began raining as I headed back towards Spanish Fork,” the ZFMO said. “It rained hard enough to form puddles on the road.” The ZFMO and AFMO met with the District Ranger to discuss strategy. They opted for a “confine/contain strategy,” a term used locally to mean fire responders intended to hold the fire growth to a defined area. This term is also used in official dispatch reporting forms. The AFMO assumed the role of Type 4 Incident Commander (ICT4) and the ZFMO assumed the Zone Duty Officer (DO) responsibilities while taking two days off.

The Forest DO’s understanding after the size-up was that the Pole Creek Fire was burning in a small conifer patch with snags and dead/down fuels.

“The risk versus values, location, time of year, all indicated that this is a fire that we should not engage,” the Forest DO said. “The fire was burning in an area where fire was not detrimental, a long way from values at risk. And it was after the September 1 threshold date when Forest leadership agreed that the default response was to allow fire on the landscape.”

From the NWCG Glossary

Confine:

A wildfire response strategy of restricting a wildfire to a defined area, primarily using natural barriers that are expected to restrict the spread of the wildfire under the prevailing and forecasted weather conditions.

Containment:

The status of a wildfire suppression action signifying that a control line has been completed around the fire and any associated spot fires, which can reasonably be expected to stop the fire's spread.

Monitor:

The orderly collection, analysis, and interpretation of environmental data to evaluate management's progress toward meeting objectives, and to identify changes in natural systems. Monitoring is also conducted on wildland fires to observe fire effects and fire behavior, or both.

The Forest DO initially agreed to a monitor strategy and that no action would be taken unless the fire intensity warranted it. In his decision-making process for the Pole Creek Fire, the District Ranger (Agency Administrator of record) considered two primary questions: 1) what do fire folks want to do or think we should do? and 2) what does the modeling or analytics show?

"I recall the fire guys were really excited about Pole Creek in terms of the ability to manage to meet resource objectives while containing the fire to 200-300 acres," the District Ranger said. He requested an "FSPro" run by a local Forest analyst, which seemingly validated the 200-300 acre containment strategy. FSPro is a geospatial probabilistic model used as a strategic decision aid tool. It looks at fire risk as determined by uncertainty in the weather.

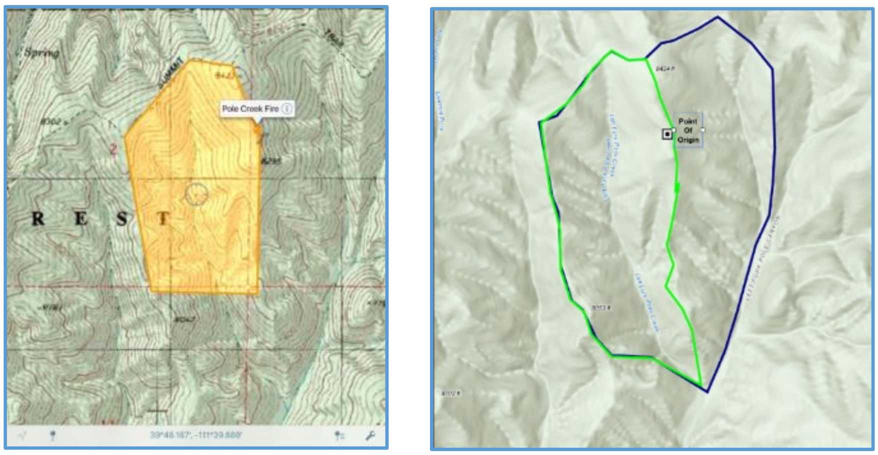

Figure 8 *– <u>LEFT</u>: A sketch of a 210-acre containment area around the Pole Creek Fire as created in Avenza Maps. <u>RIGHT</u>: A sketch of the primary containment area (green line) and a secondary 500-acre containment area (blue line).*

September 7: Implementing the Plan

The following day, Friday, September 7, two 20-person hand crews, an engine crew and miscellaneous overhead hiked into the Pole Creek Fire. They began line prep and scouting in case they needed to take action to contain the fire to the predefined 210-acre box. The log where the fire had started was consumed, but the fire had not spread.

"I initially thought it was too wet to burn," ICT4 said. "The heavy fuels consumed completely, but the fire did not spread into the brush or litter. At the time, it was our understanding that the weather would be favorable until Tuesday [September 11], when there was some chance of increased winds for Tuesday through Thursday."

In spite of the wetness, Pole Creek was surviving and gave managers hope of accomplishing some beneficial effects at a large scale. Late that morning, the District Ranger published a Wildland Fire Decision Support System (WFDSS) decision for the Pole Creek Fire, which was then at 0.1 acre. The District Ranger also designated a 5,700-acre planning area in WFDSS. The relative risk was determined to be low, as were the probability of a significant event or extreme fire conditions.

A Type 4 Incident Commander was determined as appropriate for staffing. The course of action was to construct fireline and implement burnout operations to manage the fire under a confine and contain strategy.

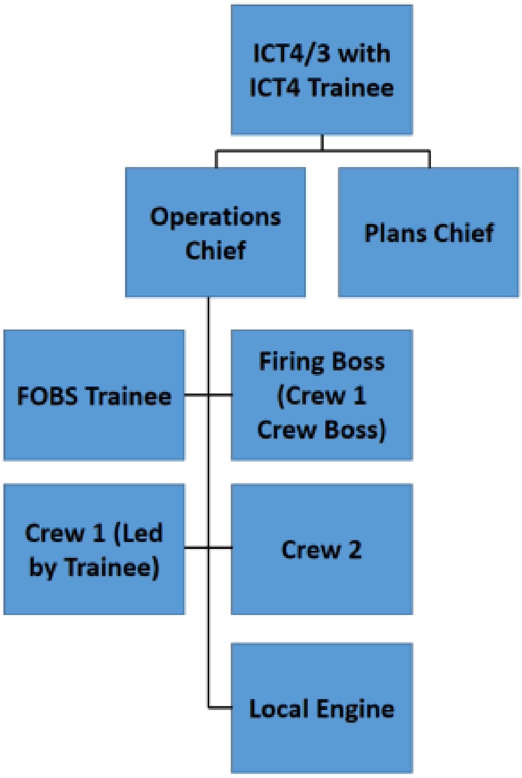

Figure 9 – *Organizational chart of the Pole Creek Fire.*

The crews prepped a helispot and improved fire line along the Summit Trail, the fire's desired north boundary. Firefighters also scouted for any natural barriers that could be used for fire breaks, but found none.

The Field Observer (FOBS) and Field Observer Trainee (FOBSt) collected fuel samples to determine fuel moistures in the live and dead fuels. The Operations (Ops) on the fire selected two approximately 50-foot logs – one 32-inch diameter and one 18-inch diameter – and put some embers in those logs to test consumption. When the firefighters came back the next day both logs had completely consumed to white ash, but the fire did not spread into the fine fuels. The firefighters saw that it was too wet for the fire to spread. If needed, they could burn spotty accumulations of fuel to help achieve fuel reduction goals.

By the end of the day, the Forest DO was informed that the strategy had now shifted to a confine/contain strategy (it was previously "monitor") and that crews were being deployed to do some work on the Summit Trail.

September 8: Benign Weather

Similar work continued on September 8, with crews building line down a west ridge off the Summit Trail. At 1500 hours, the spot weather forecast stated: "Sunday [September 9] will be a good day to work on the wildfire site as rather benign weather is expected behind today's cold front. Next week looks warm, quite dry, with increasingly strong SW winds, especially Tuesday-Thursday [September 11-13]. No chance of precipitation next week either."

By the end of shift, the Pole Creek Fire remained at 0.25 acre in size.

September 9: Connecting the Dots

On the third day, the ICT4 reported that the fire was creeping and smoldering at 0.5 acre. Crews set out to "connect the dots" – in other words, burn small jackpots of fuel. By early afternoon, the firefighters had conducted a successful 0.25-acre test fire on a knob between the main fire and the Summit Trail. They then began igniting down the ridge to the fire. Scouting and line construction continued.

"Early on I noticed a fir tree torch out, but the grass next to it did not consume," said Firing Boss. "It was striking that live fuel was available to torch." By the end of shift, crews had completed approximately 25 acres of jackpotting. The heavy fuels were consuming well, and the results were encouraging to the firefighters.

Figure 10 ***–*** *LEFT: **F**ire behavior on September 9 at 1716 hours. RIGHT: Burnout operation resulting in a fire perimeter of 25 acres at the end of shift on September 9.*

September 10: Activity Picks Up

At the Monday, September 10 morning briefing, crews heard a spot weather forecast that showed a Fire Weather Watch for Tuesday morning through Thursday evening.

At 1000 hours, Dispatch called ICT4 on the radio and read the Red Flag Warning that the National Weather Service (NWS) had issued for winds coming that afternoon, earlier than the firefighters expected. As a result, ICT4t called the NWS directly to inquire about the Red Flag Warning. They said at 1200 to expect to see gusts of 25 mph, increasing to 30+ mph by 1400, and to expect increasingly stronger winds each of the next three days.

With the forecasted winds in mind, firefighters pressed themselves to blackline the Summit Trail from Drop Point (DP) 20 to DP10 ahead of the winds. The Firing Boss asked the on-scene fire leadership what the trigger point would be to begin firing to the east toward DP30 due to the predicted wind switch. But the Firing Boss was told that blacklining to the west was the priority. The east side of the fire had relatively benign fire behavior, with one small hot spot, whereas the west side showed more activity with continuous fuels capable of threatening the containment line.

At 1200 hours, they commenced blacklining from DP20 west to DP10 along the Summit Trail to keep the fire from crossing the trail. During this time, Crew 2 recorded weather observations between DP20 and DP10 that were vastly different from the weather FOBSt observed on the east side between DP20 and DP30. On the west side, winds were gusting around 15 mph. But on the east side, winds were gusting to 35 mph.

During a walk around the perimeter, FOBSt found an active fire edge on the northeast side and requested a short squad to begin putting in check-line and limbing trees to prevent further fire growth. This squad came in twice to work in two different areas on the northeast side of the fire. After the second time, FOBSt noticed a spot established down drainage to the southeast of the main fire. It was torching, throwing spots, and threatening to affect the Summit Trail.

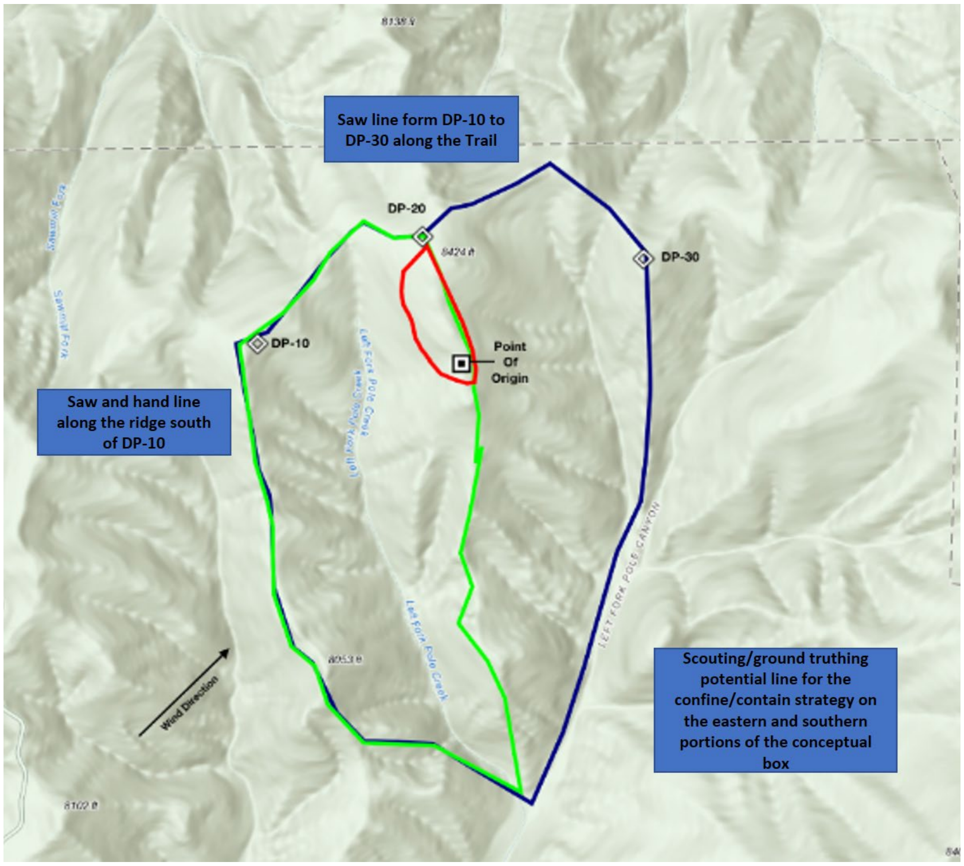

Figure 11 *– A fire area map showing where the saw line was improved along the trail from DP10 to DP30. Crews put in a 20-foot saw line and dug hand line on the ridge south of DP10. The green line is the 210-acre primary containment area. The blue line is the 500-acre contingency area.*

Fire Heats Up on East Side, Firing Operation Ceased for Firefighter Safety

According to Firing Boss, blacklining on Summit Trail from the knob to the west was not progressing well. It was patchy, not consuming the fuels, and definitely not carrying. They moved to the interior, to an area that seemed like it would be more conducive to burning. But nothing would burn on the west aspect. The Firing Boss was surprised by this, especially considering how well the east aspect was burning.

The lack of progress on the west side resulted in a “tactical pause.” The crews abandoned firing and took lunch while the overhead scouted and discussed firing to the east. They noticed that fire was beginning to heat up on the east and establish downslope. Their response was a new plan: carry fire east to DP30.

Figure 12 *– Fire activity at approximately 1330 hours on September 10.*

As crews began firing to the east, fuels responded much differently. “Ignitions to the east were hot and slamming the line!” Firing Boss said. “So much so that I was making the crew ‘baby’ the firing operation.” Ops noticed the crew slowing down and asked them to pick up the pace in order to complete the firing operation before the fire came out of the drainage.

“I told Ops it’s hot, we can’t hold it if we go fast,” Firing Boss said. “Finally, I told them we are ceasing firing operations. I was not putting people in the saddle with fire below them.” Ops and Firing Boss had a quick face-to-face. Ops suggested that the two of them continue blacklining to the east as a “hero or zero” last ditch effort to hold the trail. Firing Boss did not like the chance that their escape route could be compromised, so they both agreed to hold in place.

Figure 13 *– Smoke column from the Pole Creek Fire at 1550 hours on September 10.*

ICT4 Requests Type 2 IMT and Air Resources

ICT4 called for the crews to meet at DP20. But as they were hiking, he changed the order and told them to keep moving to DP10 away from the fire run. At DP10, a firefighter described a “very surreal moment” as the fire crested the Summit Trail.

FOBS(t) looked back toward the east. He watched the fire hit the Summit Trail and spot to the north in heavy conifer in the drainage below.

Shortly after 1400 hours, ICT4 called Dispatch, informing them that the winds had increased and the fire had aligned with the south fork of the drainage and was making a run. He requested that they order a Type 2 Incident Management Team (IMT) and multiple aviation resources. ICT4 was new to the Region but came from a high complexity forest with a heavy fire load. Where he was from, an order for a Type 2 Team and significant aviation resources would have been automatic.

Meanwhile, ZFMO had just left the fire an hour before, when it was still 25 acres. “When I hit the bottom of Nebo Loop [Road] I could hear clearly a Type 2 Team being ordered from the fire,” said ZFMO/DO, a long-time UWF employee who had also been a hotshot superintendent on a northern Utah crew. He thought, “We need to ‘pump the brakes’ on the team order.” He told ICT4, (also a qualified ICT3) to hold on until he could get a look at the fire.

At the time ICT4 was calling for a Type 2 Team, the Forest DO and Forest FMO were briefing the Forest Supervisor. Not knowing the details of the rapidly evolving situation and thinking the fire was approximately 75 acres, the Forest Supervisor asked the Forest DO to put a hold on the aircraft and Type 2 IMT. After the Forest Supervisor’s review of WFDSS, it didn’t make sense to take such aggressive suppression action. The fire was well within the planning area, meeting objectives, and not close to threatening values at risk (see Figure 13). Parts of the order for aircraft went through, however, and shortly thereafter a Type 1 Helicopter and some “Fire Bosses” (water-scooping single-engine air tankers) were on scene.

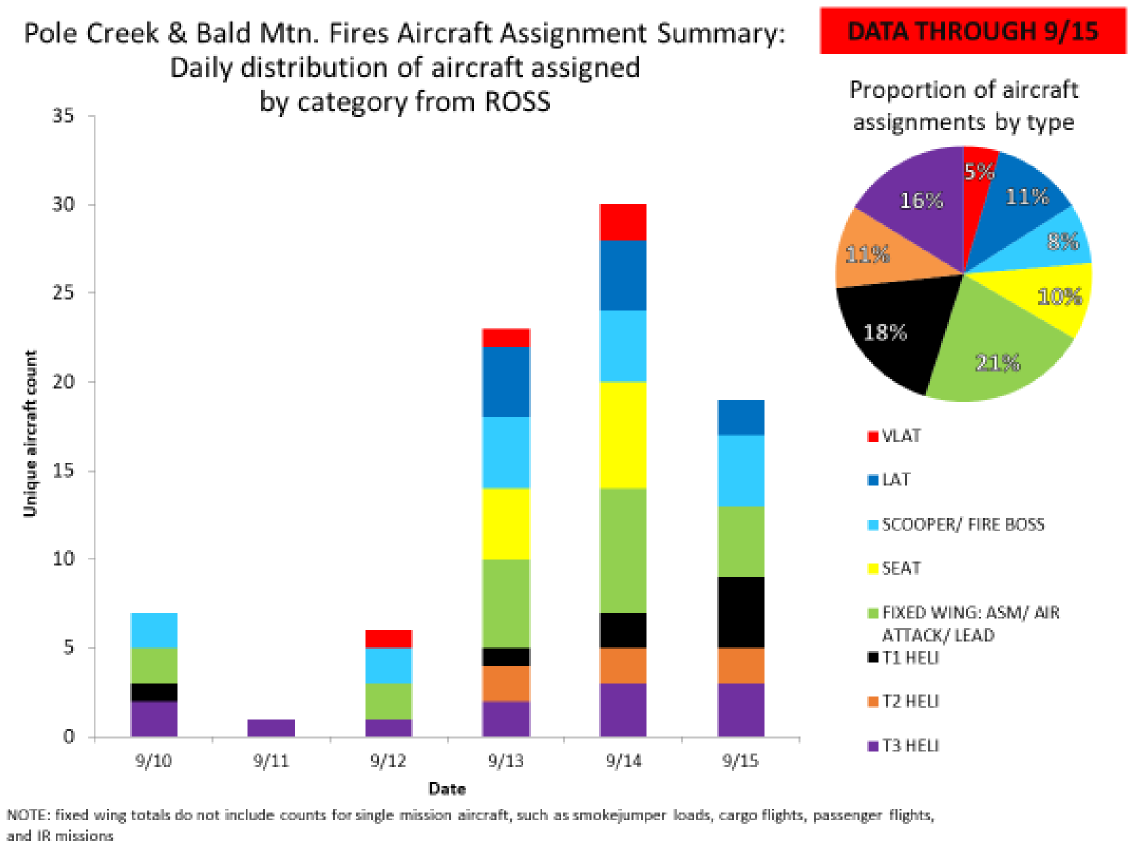

Figure 14 *– This is an aviation use summary for the Bald Mountain and Pole Creek fires. “VLAT” stands for “very large air tanker.” “LAT” stands for “large air tanker.” “SEAT” stands for “single-engine air tanker.” T1, T2, AND T3 HELI stands for heavy, medium, and light sized helicopters, respectively.*

Type 3 Team Ordered; Fire Spots Over Summit Trail

After a discussion between Forest DO and District Ranger, the decision was made to order a Type 3 Team for the Pole Creek Fire.

Meanwhile, overhead on the fire began assessing the viability of a bigger box within the 5,700-acre planning area, as well as using more resources, such as dozers and aircraft. Those with institutional knowledge of the area indicated the fire behavior would likely moderate on the northern aspects.

By the end of the day, the now approximately 75 acre fire had spotted over Summit Trail with multiple spots established in side drainages in heavy timber. At 1742, Dispatch placed an order for the local established Type 3 IMT, with in-brief set for 0930 hours on September 11.

September 11: Day 2 of Red Flag Warnings

Tuesday marked the second consecutive day of Red Flag Warnings, with SW winds expected to gust to 30 mph. After an 0900 flight of the Pole Creek Fire, ICT4 reported that the fire had aligned with the drainage the previous day and made a wind-driven run, spotting across the north line (Summit Trail) of the 210-acre box, but was still within the larger planning area. The northern portion of the fire was already actively burning in timber, oak and maple. Potential values at risk included a high-tension KV line in the Spencer Fork Wildlife Management Area and the Black Hawk Campground, located just outside of the planning area.

Two crews (one Type 2 Initial Attack [IA] Crew and one Type 2 Crew) worked to establish an anchor point and scouted for potential containment lines. The incoming ICT3 and ICT3t took a flight to examine the planning area and noted that the Nebo Creek drainage was not a good spot to hold the fire due to steep, rugged terrain and difficult fuels. They briefed the Agency Administrator, requesting an increased planning area and proposing containment lines consisting of: Golden Ridge, Nebo Creek Road, and Pole Creek Road. While ICT3 suggested dozers as a faster way to build perimeter lines, the Agency Administrator (District Ranger) was uncomfortable with dozers due to resource concerns. ICT3 ordered additional crews instead.

ICT3 updated Dispatch at approximately 1400 hours, saying the fire was still burning primarily in dead and downed fuels. He was unable to fly due to winds, but estimated the fire to be at 100 acres.

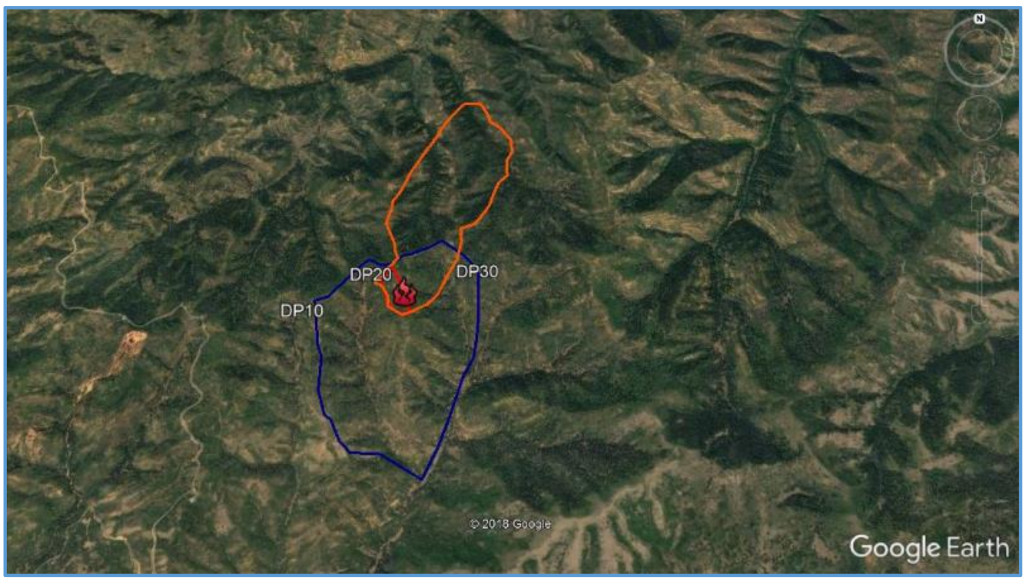

Figure 15 – *This map shows the Pole Creek Fire's: location of the origin (the red fire icon); the conceptual 500-acre box (blue line), the location of the Drop Points (labeled in the map), and the IC's estimation of the fire perimeter (orange line).*

By midafternoon, both the Pole Creek and Bald Mountain fires developed sizeable columns, with a "cap" developing above the fires. By 1730, conditions changed to where it "seemed almost as though a lid had been put on the fire behavior."

By the end of shift, the Pole Creek Fire was 250-300 acres. The nearby Bald Mountain Fire had also grown a little to an estimated 10-12 acres. The incoming ICT3 for the nearby Pole Creek Fire was asked to assume command of the Bald Mountain Fire as well, but he declined due to the complexity of the Pole Creek Fire.

September 12: Everything Changes

The Type 3 IMT assumed command of the fire at 0600 hours on September 12, the third consecutive day under a Red Flag Warning. During morning briefing, the message conveyed to the resources was to use a confine/contain strategy. The Ranger directed the IMT to use aircraft only when necessary.
The District Ranger published a new WFDSS decision, with the fire estimated at 300 acres. After input from ICT3's recon of the fire the previous day, the planning area was now significantly larger at nearly 30,000 acres. The course of action remained the same, but a fourth objective with specific confine/contain parameters was added. The Type 3 IMT formulated a plan that would require the construction of 10 miles of line to confine/contain the fire to a 5,000 to 6,000-acre box.

An early morning flight revealed that the fire was actively burning with wind-driven runs. The fire was backing on the western flank. ICT3 estimated that only about 2% of the nearly 10 miles of fire line had been completed. Based on their experience of fires in this area, the incoming Type 3 Team – comprised primarily of local personnel – thought they would have about a week to plan and complete the strategy in the 5,000-6,000-acre containment area.

Figure 16 *– Pole Creek fire behavior at 1812 hours on September 12.*

Meanwhile, Public Information Officers (PIOs) on the fire were dealing with an increasingly upset public, concerns raised because of 2,000 head of cattle in the area, as well as what some were calling "a once-in-a-lifetime mountain goat hunt."

By mid-morning, the Pole Creek Fire was estimated at 500-600 acres, and the Bald Mountain Fire at 20-30 acres.

By 1700, Air Attack reported that the fire was moving fast toward Golden Ridge. He requested a very large air tanker (VLAT) and a lead plane, noting threats to the community of Birdseye, as well as to other private and state lands.

ICT3t reported to Dispatch at 1700 that the fire had not yet crossed Nebo Creek, a trigger point to evacuate a nearby campground. However, the fire had crossed the Page Trail on the east. Line construction was nearly completed on the heel of the fire. He also reported that he was talking with the District Ranger about closing part of the Nebo Loop Road and the Blackhawk Campground.

Ground Resources Report Fire Could Reach Nebo Creek

That evening, ICT3 headed in to the Incident Command Post (ICP) for the evening planning meeting. He believed that the fire behavior would moderate at night, as fires in this area almost always do, and as this fire had done up until now. Others expressed similar thoughts, including the ZFMO.

During the planning meeting, ground resources called in to report that the fire "might reach Nebo Creek by tomorrow." Consequently, a local Forest Law Enforcement Officer (LEO) was requested and responded to the Nebo Creek Road area to evacuate people from the recreation areas in the vicinity, check for cattle in the Nebo Creek Road area, and lock the gate to bar public access to the area.

Key State Partner Does Not Support the Plan*

Of note, at the planning meeting, a key state partner expressed that he did not support the plan. With the forecasted winds, he believed that the IMT should be in a full suppression strategy. The strategy was not changed and the direction remained confine/contain.

> *Recall the first key learning point above relating to the need for structured risk Assessment Process where risk management decisions can be fully transparent with our partners and the public.

September 12, 2130: Pole Creek Blows Up

At 2130, ZFMO got a call from ICT3t saying there was a wall of fire pushing the Nebo Creek Road and it was moving toward the highway. "After getting to Spanish Fork at approximately 2130, I was notified that the Pole Creek Fire was pushing Highway 89 [indicating a 5 mile run]," ZFMO said. "I could hardly believe what I was hearing."

ICT3 asked LEO to begin evacuating homes along Highway 89. ICT3 also roused two hand crews and an engine crew from camp and sent them to Highway 89 to begin evacuating the community of Birdseye and to look for opportunities to go direct on the fire in the stubble fields behind the structures. That point, according to ICT3t, was the "turning point where all mindsets changed to full suppression."

ZFMO arrived at Birdseye at 2200 to find firefighters were fully engaged in structure protection and evacuations were under way. An order was placed for a Type 2 IMT. The Pole Creek Fire had jumped the Nebo drainage and was burning under a major high-tension powerline. ICT3 reported that the Bald Mountain and Pole Creek fires had the potential to converge.

September 12-13: Bald Mountain Blows Up

Just after midnight, the Bald Mountain Fire was also making a run and threatening an unoccupied girls' camp. ZFMO and the Bald Mountain IC arrived at the girls' camp near the Bald Mountain Fire and tied-in with a local District Recreation Staff employee and a Captain from Utah County Fire. They directly engaged the fire to save some structures and ordered three local engines to help with efforts. They formulated a complex plan to save the girls' camp by burning out a meadow.

At approximately 0200, the wind increased to approximately 40-50 mph from the south and the fire made a major run. Bald Mountain IC pulled everyone out of the girls' camp to the safety of the Nebo Loop Road until the wind subsided. After the winds subsided, they headed back into the girls' camp and resumed the firefight to save structures. The IC requested aircraft to be on hand first thing the next day. Dispatch advised that he'd have to share aircraft with Pole Creek, and Pole Creek was the priority.

September 13, 0100: Pole Creek Slows

Crews successfully stopped the spread of the Pole Creek Fire just before 0100 and were placed on "ordered standby" and sent to get some sleep. Ops remained on duty. A 0200 weather update indicated the strong winds would continue throughout the night before dying down in the morning.

Figure 17 – A firefighter burns out around the girls' camp on the Bald Mountain Fire.

Four large air tankers and the VLAT, along with two CL415 (water scooper) planes were ordered to be available first thing in the morning, recognizing that the strongest winds were forecasted for that day. Early in the morning on September 13, the Type 2 IMT held a conference call to prepare for mobilization to the Pole Creek Fire. Many of the Type 2 IMT members were from the local Forest and included both Forest and Zone FMOs, bringing in a lot of local knowledge and experience.

At 0836, the Forest Supervisor canceled the Type 2 IMT and ordered a Type 1 IMT to assume command for both the Pole Creek and the Bald Mountain Fires. At 1030, ZFMO flew the fires with ICT3 and ICT3t. The flight was rough due to unstable air and high winds. Both fires were actively burning and had already formed columns. They witnessed extreme fire behavior along the Highway 89 corridor with ongoing firefighting efforts. ICT3 noted that the Pole Creek Fire would likely impact Highway 6. ZFMO contacted Forest DO and recommended that the Forest Supervisor order a second Type 1 Team for just the Bald Mountain Fire due to fire behavior, values at risk, and the complexities of both fires.

September 13: Bald Mountain IC Transitions

At approximately 0500, a local Fire Chief arrived on scene and tied-in with Bald Mountain IC. The Chief ordered three engines from his department. All resources on the Bald Mountain Fire were now engaged in evacuations.

After putting in a 26-hour shift, Bald Mountain IC was relieved by a replacement ICT3 from a local municipal fire department. The incoming Bald Mountain ICT3 was handed a list of resources assigned to the fire, but didn't have a clear picture of what had occurred on the fire up to that point. He and the Operations Section Chief (OSC1) for the incoming Type 1 Team re-conned the fire via helicopter.
After the flight, OSC1 headed back to tie-in with his team and ICT3 organized the 37 engines that had been ordered into structure protection strike teams. ICT3 also married a hotshot crew up with three

dozers to punch indirect line between the fire and threatened homes. Throughout the night, the hotshot crew prepped the dozer line for a possible firing operation.

Figure 18 – *The Pole Creek Fire's fire behavior (smoke column on right) as seen on the September 13 morning reconnaissance flight. Bald Mountain Fire is on the left.*

September 13: Continued . . .

The objectives for the day were to evacuate people ahead of the fire, look for opportunities to go direct, and continue constructing an anchor point. Right before in-briefing with the Type 1 Team at 1900, ICT3 began evacuations of Woodland Hills and Elk Ridge due to movement from the fire the previous night and concerns that the fire would make a similar run that night.

"The winds were almost unnatural – it was extreme," PIO said. "Things were changing so quickly it was no longer possible to provide real-time information." Socio-political pressure increased, particularly as comments on social media became more critical. Local unit employees were feeling increased stress and criticism. "At first, the public was pretty understanding and would actually correct inaccurate statements on our social media accounts," said PIO. "That changed after the 'grab your torch and pitchforks' comments surfaced to where people were critical and hostile toward local Forest Service employees."

A Forest Service Spanish Fork District employee working the front desk said the angry calls increased, and people wanted answers. "This is my community, and emotions were so high," she said. "To see these people hurting, hurt me."

WFDSS Decisions

On September 13, a new WFDSS decision was published for the Pole Creek Fire, which was then conservatively estimated at 1,500 acres. The planning area boundary changed shape and again grew significantly, with predictions of movement to the northeast. The risk assessment had also changed dramatically, with each aspect ranking "high" to "very high."

Also on September 13, at 1900 hours, a new WFDSS decision was published for the now estimated 1,800-acre Bald Mountain Fire with a planning area of nearly 39,000 acres. The risk assessment likewise changed to "high," affirming Type 1 Incident Management complexity.

The WFDSS for Pole Creek published on September 13 included these courses of action:

- Only commit firefighters under conditions where firefighters can actually succeed in protecting identified values at risk.
- Utilize direct and indirect tactics to fully suppress the fire. This action will take into account: first, risk and exposure to firefighters and the public; and second, the protection of identified values such as utility corridors and infrastructure, private structures, the railroad corridor, and the Highway 6 corridor.

The WFDSS for Bald Mountain published on September 13 included the previous courses of action for Pole Creek and added:

- Assign a Public Information Officer in order to disseminate timely information to the public, partners, and cooperators, including local government and law enforcement. All closures and evacuations will be coordinated with the Utah County Sheriffs' Office.
- Agency Administrator approval is required prior to any mechanized tool use within the Nebo Wilderness Area. Outside the Wilderness, the full range of tools and tactics are authorized. Work with READ [Resource Advisor] to mitigate impacts and assess rehab needs.

The evening of September 13, Great Basin IMT 1 received a Delegation of Authority (DOA) for the Pole Creek and Bald Mountain Fires, along with a letter of Leader's Intent from the Forest Supervisors of the Uinta-Wasatch-Cache and the Manti-La Sal National Forests and a Utah State Area Manager. The letter of Leader's Intent expanded on the leader's direction relative to firefighter risk, incident objectives, and values at risk, along with expectations and operational procedures. The Great Basin IMT 1 took command of both fires at 0600 on September 14.

The Agency Administrator for the State of Utah expressed concern that this most recent letter of Leader's Intent did not directly state "full suppression fire" as an objective. This was corrected on September 14 and in all subsequent Leader's Intent letters for both fires.

The Forest Supervisor assumed the role of Agency Administrator for both the Pole Creek and Bald Mountain fires on September 14, when the Great Basin IMT 1 assumed command of both the Bald Mountain and Pole Creek Fires (see Figure 19). On September 15, the Deputy Forest Supervisor assumed the role of Agency Administrator for the Bald Mountain Fire, while the Forest Supervisor maintained that role for Pole Creek. One of the Agency Administrators noted that given the operational tempo, he placed higher priority on the DOAs and letter of Leader's Intent at the in-brief to give clear direction to the IMTs, and as a result, WFDSS lagged behind.

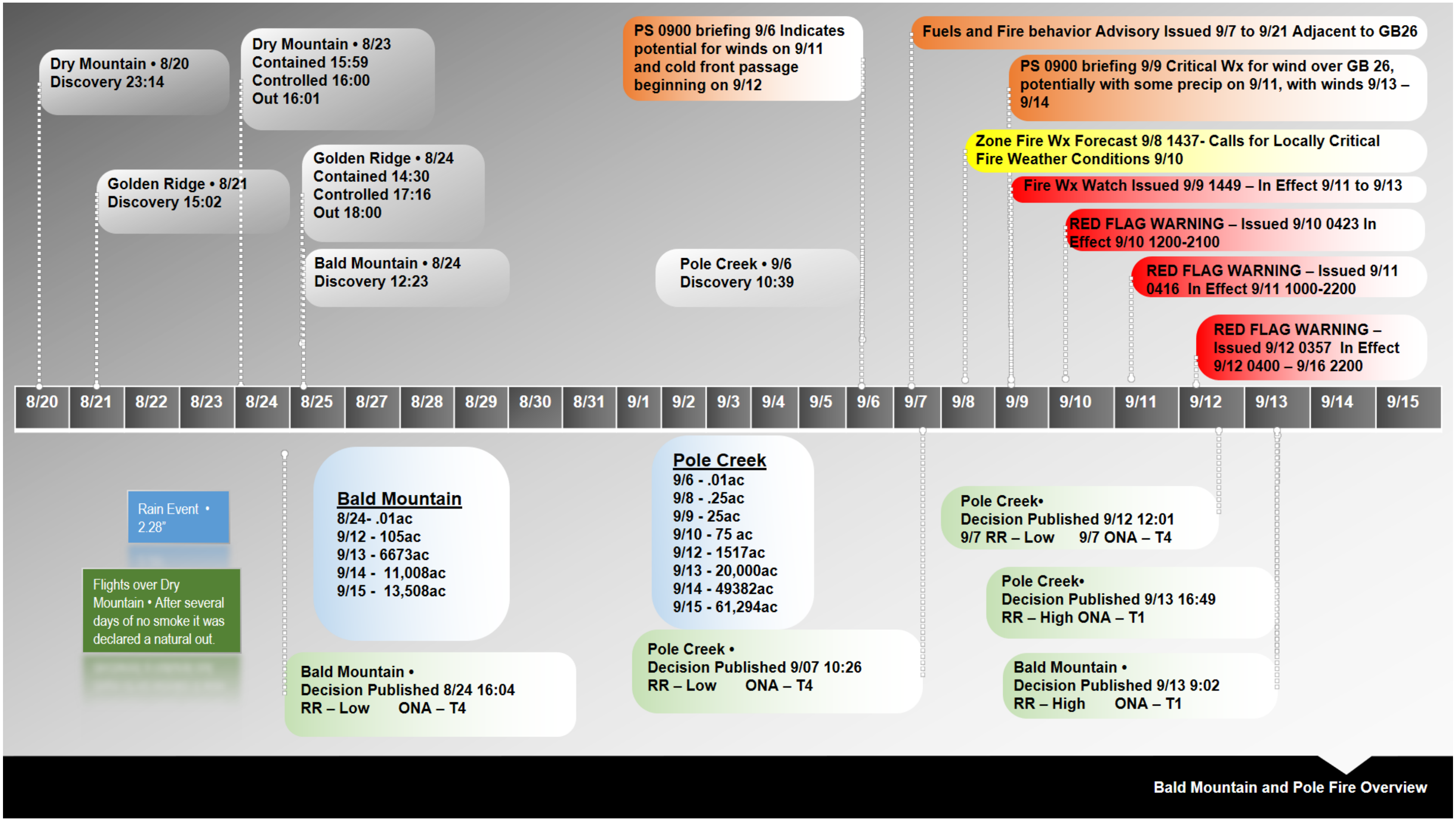

Figure 19 *– A timeline of events starting from the discovery of the Dry Mountain Fire and ending just after the Type 1 IMT took command of the Bald Mountain and Pole Creek Fires.*

The graph in Figure 20 shows a sharp rebound in the ERC index. This is a graphical description of the whiplash that fire responders experienced with respect to fuel conditions. It also shows five consecutive days of Red Flag Warnings (the fire area continued to get Red Flag Warnings for several more days after September 14 for a total of 10 out of 11 consecutive days.

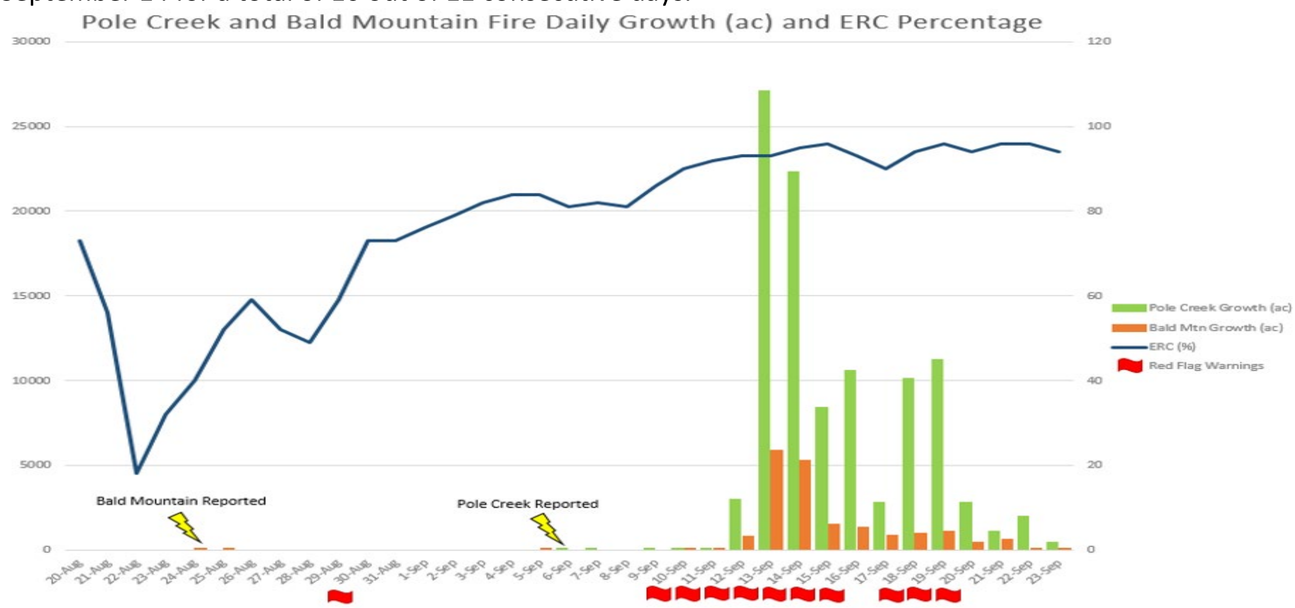

Figure 20 *– This is a display of the daily fire growth of both fires from the time they were reported to September 23. Both fires showed little growth until Red Flag conditions (RFW for high winds, low relative humidity's, and Haines of 6) arrived on September 10 and then continued through September 20. There was a significant drop in the ERC after 2.29 inches of precipitation occurred August 21-23 (Ray Valley RAWS), which was very low for this time of year.*

Near the end of fire season, Pole Creek and Bald Mountain firefighters found themselves in 97th percentile fuel conditions combined with a series of Red Flag Warning conditions, which resulted in unprecedented fire behavior for that time of year. Figure 21 shows the ERCs rebounding from 20-year low levels to 20-year high levels within the space of a very short time period.

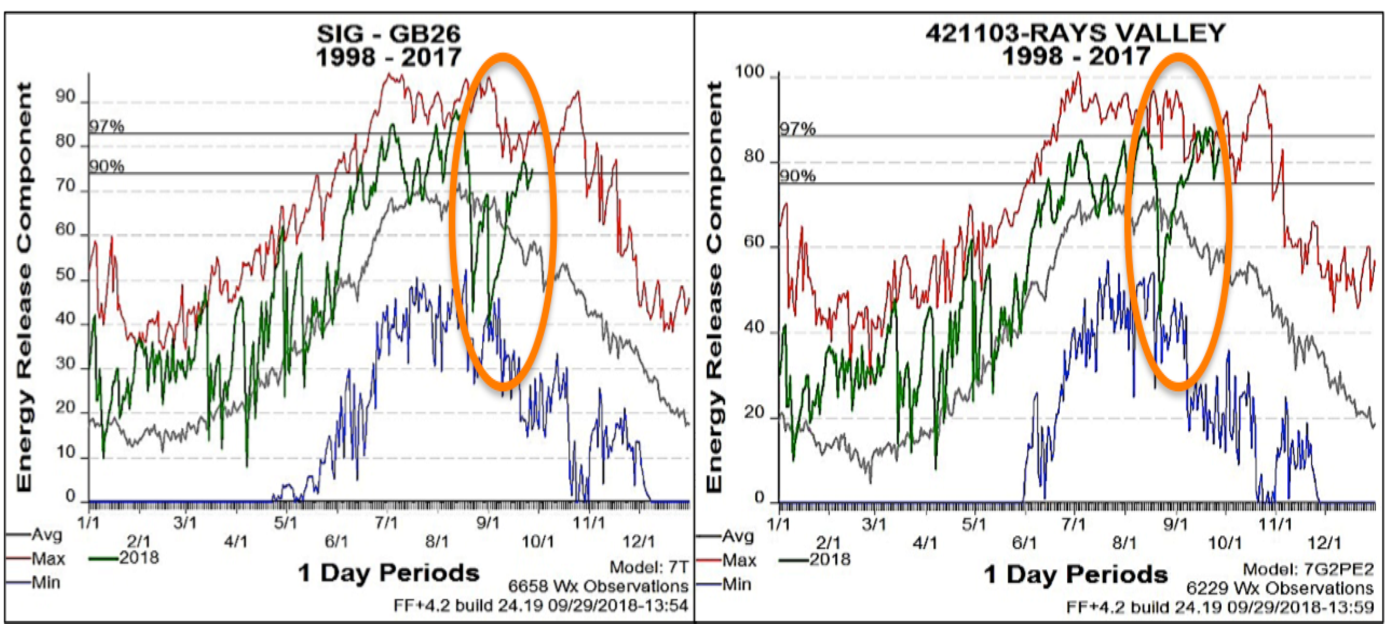

Figure 21 *– ERC comparison of SIG GB26 and Rays Valley. The general duration of the Pole Creek and Bald Mountain Fires are indicated by the orange ovals. Note that the average line descends during September, but the 2018 line spikes sharply up to the 97th percentile.*

Lessons Learned by Participants of the Incidents

Communication

- Telling our story is important, but the timing of delivery can make or break a message.
- Involving partners early, with a clear message, can help them to inform their stakeholders in a timelier and more accurate way.
- Technology can be better used to convey real time situational awareness (live streaming). Accurately painting a picture can more constructively convey thoughts, concerns, and viewpoints upward through the chain of command.
- Clear fire terminology would increase understanding. Terms like confine/contain, monitor, fire use, MMA, and others, create confusion and are broadly used. We need to be sure that both internal and external audiences interpret these terms and concepts the same.
- Calm and informative communication during command transitions can keep frustration low during times of chaos and high stress.
- Resource ordering systems differ across agencies. Good communication and coordination (even coordinating physical location) can reduce confusion and increase accountability of responding resources.
- Asking more clarifying questions regarding strategy, tactics, trigger points and actions helps to understand the changing fire situation.

Preparedness

- Reading the 7-10 day outlook along with the spot weather forecasts can assist in gaining a better long-term perspective, which may lead to making different decisions in long-term events.
- Using the 10 risk questions in WFDSS can open our thinking to options we may not have considered. These questions could encourage us to more carefully consider a wider array of possible outcomes from the decisions we make.
- Fire modelers and weather forecasters are able to make better predictions with accurate and timely field observations.
- Collaboration with predictive services early in an incident around long-term outlooks may help fire decision-makers. They are constantly producing tools to help firefighters in the field.
- "Normalization of deviance[2]" (also referred to as "practical drift") led us to not consider the worst-case scenario. Without planning for the worst-case scenario, we are constantly behind the power curve.

Operations

- Nighttime fire behavior surprised us, especially this late in the season. This experience showed that high winds can override cooler temperatures and still create extreme fire behavior late in the fire season.
- Understanding the capability and capacity of your resources is critical to ensuring the probability of keeping your resources safe.

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[2] "Normalization of deviance" was a quote from an interview. This was likely a reference to Diane Vaughan's work on the Challenger Space Shuttle disaster. This in no way implies that the FLA Team regards the people involved in this incident as behaving in deviant ways.

Conditions that Influenced Decision-Making

Below, the FLA Team discusses three conditions with respect to decision-making on the Bald Mountain and Pole Creek Fires. The following describes each condition and how it influenced decisions on the two fires.

Condition #1

Aspirations to restore ecological resilience by encouraging more fire on the landscape in order to reduce future wildfire risk, and how the evolution of fire response and policy affected this aspiration.

A recent report[3] sponsored by the State of Utah "Utah's Catastrophic Wildfire Reduction Strategy (Cat fire)" describes a vision that generally is in alignment with that of the Uinta-Wasatch-Cache National Forest with respect to wildland fire and land management. The report agrees with the concepts of restoring ecological resilience by encouraging more fire on the landscape in order to reduce future wildfire risk. The divergence between the UWF and the State comes in the implementation of these practices as more communication and clarity is needed with partners in understanding these concepts and how to more effectively implement on the ground. Utah's Catastrophic Wildfire Reduction Strategy and the National Cohesive Wildland Fire Management Strategy are two ways that the federal and state partners are coordinating efforts.

Evolution of Fire Response

Reintroducing fire into the landscape has a storied past. As national and U.S. Forest Service fire management policy has evolved, so too has our corporate knowledge and skill with various approaches to fire response (see Appendix D). Starting with our earliest attempts at strict fire control employed between 1910 and the 1960s, our experience and skill developed primarily around quick and effective control of fire.

As fire policy shifted from strict fire control to fire management, much of our corporate knowledge using naturally occurring wildfires to achieve management objectives came from fires in designated Wilderness areas, where an approach to minimize human impacts to the Wilderness resource is favored.

Even as the prescribed natural fire program gave way to the wildland fire use era, the fire community's early education – gained in the use of naturally occurring fires in the 1970s, 1980s, and 1990s – actually only considered two modes of fire engagement: leave the fire alone to do what nature intended or put the fire out if we cannot tolerate what nature intended.

Starting in 2001 with the emerging notion that fire has a role to play in fire-adapted landscapes, we have increasingly asked fire managers to consider using fire in this way outside of Wilderness areas where objectives like reduced hazardous fuels build-up and improved wildlife habitat, are key considerations.

With all ignitions, there is a need to select when and where firefighters will engage a fire, considering a range of factors, such as firefighter risk, probability of success, cost, duration, firefighter availability and capabilities, and others. While our early education in the use of naturally occurring fires was based on a wait-and-see approach, the modern view developed interest in the use of more aggressive tactics within a manageable containment area and in efficiency in order to release firefighting resources to be available for the next assignment.

[3] Utah Department of Agriculture and Food, (no date). Catastrophic wildfire reduction strategy protecting the health and welfare of Utahns and our lands. Retrieved from: http://www.ag.utah.gov/documents/CatFireFinalReport120213.pdf.

As with all wildfires that present the potential for both positive and negative fire effects, managers on the Bald Mountain and Pole Creek Fires faced the decision of whether to simply react to the fire should it begin to move, or to take a proactive approach by burning out to create a defined containment area before the fire could move. The locations of the fires factored into the response to each: the Wilderness favoring a monitor approach, while the non-Wilderness a more proactive approach, if feasible. Still, the degree of uncertainty associated with predicting weather and actual fire growth over the course of several days, weeks, or even months, presents a challenge for decision-makers.

How should we balance future risk of large fires that are very resistant to control against the present risk posed by an emerging incident?

The U.S. Forest Service, along with the rest of the fire community, is still building experience in taking aggressive action to establish perimeter control in order to create a fire area smaller than the fire's full potential, but larger than if we chose to suppress at the smallest size possible. The first few Forests to experiment with control actions while seeking to achieve beneficial fire effects started doing so approximately 20 years ago. It has only been within the last decade that this approach has gained more wide-spread attention. Much remains to be learned about the complexities that such a management approach presents, as well as what methods and procedures are both technically and socially acceptable in helping us achieve success.

Evolution of Fire Policy – Effects on Terminology

From the first time it was proposed that a response to a wildfire could be something other than immediate suppression, there has been an air of confusion surrounding both the terminology in use at the time and the methods by which these concepts and practices are communicated. As an example of this long-standing concern, in the 2001 Review and Update of the 1995 Federal Wildland Fire Management Policy, it states:

> Policies, manuals, handbooks, procedures, and other aspects of implementation of the 1995 Federal Fire Policy often use a variety of terms such as "wildland fire," "wildfire," "fire use," "wildland fire for resource benefit," and "prescribed fire" interchangeably. The proliferation of similar terms was frequently driven by concerns about the source of ignition of the fire, the land use designation where the fire was located, and administrative considerations such as funding sources. The use of these many similar terms has caused confusion and misunderstanding within the agencies and among cooperators, partners, and the public. In addition, different systems have been developed or perpetuated (based on the "type" of fire involved) for training, qualifications, Dispatch, and other aspects of fire management.

The FLA Team took special interest in the terminology used by those interviewed and took extra care to ask each participant either how they interpreted these terms, or how they believed others interpreted them. Some of the terms that emerged during interviews included "Confine/Contain," "Modified Suppression," "Full Suppression," "Monitor," "Achieving Resource Benefits," and "Wildfire Use." Of these, "Monitor" and "Confine/Contain" were the most frequently referenced with respect to the Bald Mountain and Pole Creek Fires.

These terms can cause confusion about intent, objectives, and outcomes, both internally and externally. This lack of clarity seems to have been driven by the use of vague terminology. In many of the FLA Team's interviews relative to the Bald Mountain and Pole Creek Fires, we heard misunderstanding and confusion around these terms. We heard it from firefighters, we heard it from partners, we heard it from public affairs, and we heard it from Agency Administrators.

As an example, Forest social media accounts indicated frustration from some members of the public surrounding the term "monitoring." Public information officers were repeatedly asked, "Are you still watching it?" as the fire was threatening communities. Some firefighters indicated a need to "just call it all suppression!" and quit trying to delineate between monitoring, modified suppression strategies, and full suppression strategies.

Others seemed to find it useful to have a term that described a response that was more than monitoring (which appeared to mean a situation in which firefighters were not taking direct action on the fire), but less than aggressive suppression action aimed at keeping the fire as small as possible. Currently, there is no term available in the accepted, official lexicon that describes such a response.

Unsanctioned, locally used terms are common. In the FLA Team's experience, the most popular seem to be "resource benefit," "modified suppression," and "wildland fire use." It seems as though, to some firefighters, the accepted terminology with respect to wildfire response is not nuanced enough to allow people to articulate their intent. They resort to making up their own terms or resurrecting terms that are no longer in use to be able to describe their intent.

Confusion in terminology may contribute to other unintended consequences or system issues, such as a lack of clarity or understanding of:

- Desired Outcome
- Leader's Intent/Objective(s)
- Strategy/Course of Action

Do you think there is confusion around the meaning of these three bullets (above)?

How do you communicate Leader's Intent, Objectives, and Strategy?

How do you and your peers talk about fire on the landscape?

The federal land management agencies' 2009 reinterpretation of fire policy eliminated the distinction between wanted and unwanted wildland fires, instead calling any unplanned ignition simply a wildfire. This may have had unintended consequences. The change certainly made sense in terms of eliminating the duplication of efforts from parallel fire response systems, but it inadvertently may have eliminated the language around which we were able to have structured, risk-informed discussions related to our intentions and actions on wildfires.

Do you agree there are unintended consequences as a result of the policy change?
Why or why not?

When asked about whether there was confusion or uncertainty surrounding these terms, several firefighters felt the most common point of confusion did not have to do with the misunderstanding of any particular term in use. Rather, it had to do with the lack of specific knowledge as to the particular timing, place, and methods to be used to achieve fire control.

The FLA Team frequently heard that individuals generally understood the response strategy being employed: it was “monitor” on Bald Mountain, and “confine/contain” on Pole Creek. Very few people seemed to be confused on that point. Almost all who were interviewed described confine/contain as a response where a combination of natural barriers and firefighter-constructed containment lines were expected to be used as part of the strategy.

While the term was generally understood, many of those interviewed who were external to the Forest Service expressed confusion about the specifics of the plan. How long is it going to take to confine/contain this fire? How big is the fire going to get? How long will it take before it is contained? Will they need my organization to help, or do they have all the help they need already?
Similarly, “monitor” was generally described as the act of simply watching for indicators that further action might become necessary. While the term was not confusing in the general sense, what many people said confused them was the purpose and objectives for the monitoring. What specifically are they monitoring for? What happens if they detect the thing they are monitoring for?

In summary, relying on general descriptors or response strategies is not a very useful way to try and communicate what managers have in mind for achieving control. What seems to be causing communication problems is that we, as fire managers, may mistakenly believe that simply describing the general strategy we are employing will be fully satisfactory to the listener.

What does it mean to monitor a fire? If fire managers develop trigger points that describe what will happen when a certain threshold is met, does that constitute more than monitoring?

Who should be aware of what the trigger points are? Who should be aware of what the planned response is once the trigger point is exceeded?

How important is it to set those trigger points on fires where there is no intent to engage unless fire behavior warrants engagement?

Condition #2

Experience-based, intuitive decision-making in a changing environment with the current organizational structure

Wildland firefighters must rely heavily on intuition when solving problems. The wildland fire community places a high value on experience and expertise, and with good reason. Wildland firefighting is a complex task in a complex environment. Decision-making in time-critical situations leads to a heavy reliance on intuition and experience, or using “mental slides” – previous experiences that provide reference for a decision that led to a successful outcome in the past.

Known as Recognition Primed Decision-Making or RPD[4], this model has been shown to function well in time-pressured situations. The limitation of the RPD model is that it requires the decision-makers to have extensive experience and is susceptible to error if decision-makers misidentify important cues or encounter rare situations.

Where firefighters are seeing fuel conditions, weather, and fire behavior they've never seen before, relying on intuition can be misleading because no slide that they have applies to what is happening to them in the moment. There are a number of reasons that have led wildland firefighters down a path where they find their prior experience and intuition insufficient for the situation. This results in the now familiar phrase, "I've never seen anything like that before."

How often do you find yourself relying solely on experience?
When was the last time you said, "I have never seen this before"?

For example, many of the firefighters who engaged the Pole Creek and Bald Mountain Fires (especially the ones with a long history in the area) assumed that fires in this area do not burn aggressively on northern slopes. Time and time again, local fire managers have seen fire behavior moderate after bumping into northern slopes. In this case, however, the northern slopes did not hinder fire progression in the second week in September.

Several managers and firefighters reflected that, in their experience, fire season typically starts to slow down around the first part of September. In addition, everyone interviewed commented on how extraordinary the rain event was that occurred on August 22-23. The amount of rain was well above normal for this area and far more than most anyone could recall having seen before at this time.

The magnitude of this rain event, combined with the idea that fire season typically slows in early September, reinforced the expectation that fire danger had peaked and would be gradually trending down for the remainder of the season. When the Bald Mountain Fire still had not experienced any significant growth a week into September, this appeared to confirm their expectations that the season was winding down.

This scenario speaks to our susceptibility to being reliant on intuition. All of these cues made sense in the moment, but as we now know, a weather and fuel scenario that no one had ever seen before emerged that negated anyone's prior experience.

When was the last time you were surprised by fire behavior? Did you change your tactics as a result? If so, in what ways?

It is not enough simply to say we need to re-calibrate our slide decks because even as we do so, the environment continues to change around us, continually presenting us with new problems that we haven't seen before.

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[4] Klein, G. (1999). Sources of power: How people make decisions. Cambridge, MA: MIT Press. ISBN 0-262-61146-5.

Organizational Structures and Processes on Decision-Making

At various times during these events, responders and managers found themselves making decisions using insufficient or inaccurate information. That this occurred is not attributable to error so much as it is indicative of the complexity of the environment. Within the existing organizational structures, established roles, responsibilities, and processes for information flow all affect the capacity of the organization to support information gathering, analysis, and decision support.

Robust modeling and prediction capacity has been built into large fire response on a national scale through the use of Strategic Operational Planners (SOPL), Fire Behavior Analysts (FBAN), and Long Term Analysts (LTAN) that respond with Type 1 and Type 2 IMTs. These analysts work in concert with observations from the field to calibrate their predictions and understand the fire environment. In our current system, initial responders and District Rangers typically are unable to consult with these specialists. Due to cost and efficiency constraints, these specialist typically become involved at the Type 1 and 2 IMT level, or when Forest-level leadership recognizes that a fire's potential to become large is real.

How do you deal with fires on your home unit that exhibit fire behavior that your most experienced firefighters have never seen before?

When was the last time you looked at a fire behavior model? Did it make sense to you?

How far into the future do you go when you are projecting trends? How far out should you be looking, especially during long-duration fire events?

Have you followed up with your analyst on model results?

Have you been trained how to interpret outputs? Did the model reflect reality?

How do you deal with situations where models conflict with experience?

As we marry our intuitions with analytical models, we can more objectively check our predictions against the way fire actually burns on the landscape. Comparing our predictions against timely feedback (that is so vital to calibrating both our intuitive and our analytical experience base) will set us up better for success moving into the future.

Do you talk to your coworkers (supervisors, peers, and subordinates) about the difference between intuitive and analytical thinking? Would you consider showing this video (link below) and having a discussion with your coworkers after watching it?

https://www.youtube.com/watch?v=JiTz2i4VHFw

Condition #3

The rigor, structure, and organizational support of current decision-making processes

Rigor in Decision-Making Processes

Studying the Bald Mountain and Pole Creek Fires has pointed toward larger agency and system issues. As discussed earlier, the current decision-making environment is heavily reliant on experiential expertise applied to a rapidly changing environment. We are increasingly hearing statements like, "I have never seen THIS before!" This raises questions about why our decision-making process still relies so heavily on past experience when we know that there are limitations to relying almost entirely on experience in a changing environment.

This, combined with a lack of clarity, structure, and documentation of the decision process, exposes our Agency Administrators and FMOs, who are making decisions with little ability to demonstrate their decision rationale. This certainly makes transparency in decision-making difficult, if not impossible.

What is your risk-informed decision process? Is it clear and structured? Did you use a risk assessment on alternatives to inform it?

Do objectives flow from pre-event planning and partner engagement through to incident decisions?

In 2009, WFDSS replaced the WFSA/WFIP decision processes. We now have greater technical capability to perform increasingly robust fire response plans. Appropriate analysis to support decisions is left to the local unit's discretion.

In the 1980s and 1990s, fire management plans required substantial analysis of seasonality, fire occurrence, fuel conditions, and fire danger to help inform decision-makers. These plans often included detailed information concerning conditions or thresholds for the use of naturally occurring fires to achieve resource goals. Fire management plans are now spatially explicit, pre-loaded in WFDSS for the ease of fire managers. With this information already in the analysis software, it's easy to miss details during the press of business.

Lack of a Risk Informed Decision-Making Process

WFDSS provides a much greater capacity to access data and perform analysis than any previous decision support system. The drawback is that WFDSS lacks any structured, risk-informed decision-making process, leading to a lower likelihood that Agency Administrators and FMOs have the ability to plan for alternative courses of action. These alternatives can help balance out our natural bias toward intuitive decision-making.

More recently, the Risk Management Assistance Team (RMAT) experiments have shown the value in conducting trade-off analyses to consider alternative responses in order to better understand the risk trade-offs associated with each option. Similar to the WFSA process in evaluating alternatives, the RMAT trade-off analysis provides additional instruction on how to develop alternatives, as well as weigh the impact on values.

Have environmental or landscape conditions changed on your unit? If so, how?

What have you seen in fire behavior on your forest that could make you think it's changing?

How do rare events (something you have never experienced) factor into your decision-making?

The current system is set up to rely on analysts to provide decision-makers not only with the products themselves, but also with the proper interpretation of those products. With some training, non-analysts might better understand the general utility of various models. But because each product can be calibrated and various inputs and assumptions can be manipulated by the analysts, it remains imperative that the analysts be consulted to fully understand the value and limitations of the predictions.

The only available person trained to perform fire behavior analysis on the UWF during the early stages of these two fires was an adjacent UWF ZFMO, who is typically busy managing fires and running models for the rest of the Forest. Agency Administrators and FMOs are aware of this pressure on Fire Behavior Analysts and often attempt to interpret the results themselves. Without the assistance of a trained analyst, important aspects of various forecast products are not obvious to managers.

Daily spot weather forecasts were the primary means of obtaining weather information on the Pole Creek Fire. The secondary source of weather information was the general zone fire weather forecast that was read over the radio by Dispatch mornings and evenings. The spot forecasts typically only forecast one or two days, while the general forecast gives a similar two-day forecast with an outlook for the next five days.

FMOs, Dispatchers, Center Managers, and even individual Module Leaders are all expected to remain apprised of seasonal and weekly outlooks. It does not appear that there are position(s) within the existing organizations with both the responsibility and training to interact with GACC Predictive Services groups to gather and disseminate the most accurate forecast information and fire danger outlooks. This condition is not unique to the UWF.

Summary

The context surrounding the Pole Creek and Bald Mountain fires was complex. An unusually wet rain storm near the end of the traditional fire season, a desire to restore beneficial fire to the landscape, and multiple lightning strikes igniting two fires in remote locations with unnaturally heavy vegetation loadings followed later by a unprecedented string of red flag warning events and an atypical pattern in the ERC index to produce a situation in which thousands of people were evacuated from their homes. This wildfire situation posed substantial danger to the lives and property of local residents. This FLA was conducted in an effort to learn from these events.

As stated in the introduction, the FLA team heard three key learning themes from participants:

1. This event demonstrated the need for a structured, risk-informed decision-making process. There is no national process to follow. Consequently, while the decisions made may have been

sound Risk Management decisions, there is no way to document this and be fully transparent with our partners and the public.

2. Within the Forest Service and the interagency community, terminology surrounding wildland fire management is not standardized. This event showed that this can lead to miscommunication and confusion.

3. The Bald Mountain and Pole Creek Fires exposed a gap of understanding and expectations of what the Red/Green Map is and how this tool should be utilized.

From this learning, the UWF, the Intermountain Region, and the U.S. Forest Service can enhance their risk-informed decision-making process. This process would be conducive to transparently conveying the risks involved with partners and cooperators, to clarify terminology, and to develop a standardized process to use powerful fire analysis tools to give us the best decision guidance on when it is a good risk management decision to use a fire to meet restoration goals.

Persons who Participated in the FLA Team and Writing this Report

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Appendix A: More Background on the UWF Fire Response Culture

As national policy has encouraged western forests to do, the UWF has deliberately committed to finding opportunities to allow more natural fire on the landscape. In the early 2000s, the Forest Leadership Team (FLT) invested substantial time in the creation of a strong Wildland Fire Use (WFU) plan that aligned with the Land Resource Management Plan, the guiding document for all management actions on Forest Service land administered by the UWF.

In 2009, the Guidance for Implementation of Federal Wildland Fire Management Policy removed "Wildland Fire Use" as acceptable terminology and modified process regarding response to unplanned ignitions (See Appendix D).

While terminology and process changed surrounding the response to planned and unplanned wildfire events, the Intermountain Region and the UWF continued to design a fire response model that encouraged fire responders and Agency Administrators to safely increase the footprint of fire on the UWF.

The Intermountain Regional Office direction encouraged Forests to plan spatial responses to unplanned ignitions through the creation of Default Initial Response Maps (commonly called red/green maps, see Figure 2 and Appendix C). The red portion of the maps connotes areas that typically would not provide opportunities for using fire for resource benefit due to nearby high-value infrastructure, developments, or high potential for resistance to control. The green indicates areas that are more conducive to using fire as means of improving natural resource conditions.

The Intermountain Regional Office intended the maps to be revisited annually as a means of fostering communication with local partners during pre-season meetings and describing individual Forest's fire management vision to the Regional Office. The maps were not created to be a decision document, but rather a map of a potential response that may apply to identified areas.

Strategic Incident Management

In 2015 the UWF FLT approved a fire response document called Strategic Incident Management (see Appendix B) that emphasized risk management, ecological resiliency and forest health, and aligned with the existing Forest LMRP. The plan aimed to increase resiliency on the landscape by taking advantage of unplanned ignitions. To do so, managers determined if criteria was met to achieve those goals, while utilizing the Seven Standards for Managing Incident Risk (see the "Red Book" Chapter 5[5]).

From the Strategic Incident Management, UWF, 2015 (see Appendix B): "Sound risk management will be adhered to regardless of values at risk or negative impacts of a fire. We will choose to fight fires when and where the probability of success is higher and risks to firefighters are lower, or monitor instead of engage until conditions are more favorable. We don't transfer unnecessary risk to partners, or future generations."

'Modified Suppression' Option

Over the next four years, fire responder mentality began to shift away from "extinguish fires as small as possible." UWF fire managers used the colloquial term "Modified Suppression" to describe a middle

[5] Go to: https://www.nifc.gov/PUBLICATIONS/redbook/2018/Chapter05.pdf

ground between full suppression and monitoring, which became the default response in Wilderness and Roadless areas (which are green areas on the Red/Green Map).

The option of a “Modified Suppression” strategy became the norm in the rest of the green areas when fire leadership would review Predictive Services information products and recommend a date to switch the default fire response (which in 2018 was September 1) to the Forest Leadership Team.

When acceptable conditions existed in predefined areas, the default response for initial responders became *“I need to find a compelling reason to put this fire out as small as possible”* as compared to *“I need to put this fire out as small as possible.”* While the motivation for this shift of action manifested differently for different responders, the result was a fire response culture that pursued opportunities to engage fire on the landscape where the probability of success was high and risk to firefighters was low (Appendix B).

Fire Response Culture Successes

Management, Dispatch and responders took pride in the fire response culture on the UWF. A local Incident Commander described how he felt about the UWF’s approach to fire management: “We were successful in what we were doing. Success was not putting firefighters in snag patches.”

In 2015, the Forest Fire Management Officer described a watershed event for the Forest that shifted a number of perspectives. When responding to the human-caused Poison Fire, initial responders aggressively suppressed the fire to keep it as small as possible. This resulted in two minor injuries when falling trees struck two firefighters. This incident was a turning point in how the Forest dealt with fire suppression and responder safety.

The UWF Strategic Incident Management plan (Appendix B) provided strong guidance that allowed for multiple successful examples in 2016, 2017, and in early 2018. In 2016, the UWF responded to the Box Canyon Fire and modeled success under this guidance. In 2017, the Forest utilized a Type 2 incident Management Team (IMT) to aid in modified suppression of the Tank Hollow Fire. Earlier in 2018, firefighters used “Modified Suppression” strategies to contain the Willow Creek fire at just over 1,000 acres.

Appendix B: UWF Direction to the Districts Concerning 'Modified Suppression'

Strategic Incident Management
Uinta-Wasatch-Cache National Forest
Fire Leadership Group
2015

Mission: Resiliency, Risk Management.
Problem Statement: Suppressing Uinta-Wasatch-Cache National Forest fires at the smallest practical size goes against guidance, risk management, and is an increasing detriment to the resiliency mission.
Goals:

1. Restore and maintain fire-adapted ecosystems consistent with land uses, historic fire regimes, and other Forest Plan direction.
2. Manage Fuels to reduce risk of property and ecosystem damage, and of fires outside of the range of historic variability.
3. Increase stakeholder understanding and support of fire strategies.
4. Maintain wilderness ecosystems and character, primarily influenced by the forces of nature, to provide opportunities for public use, enjoyment, and understanding of wilderness, and to preserve high-quality wilderness resources for present and future generations. Manage wilderness to sustain wild ecosystems for values other than those directly related to human uses. Manage areas recommended for wilderness designation for non-impairment.
5. Sound risk management will be adhered to regardless of values at risk or negative impacts of a fire. We will choose to fight fires when and where the probability of success is higher and risks to firefighters are lower, or monitor instead of engage until conditions are more favorable. We don't transfer unnecessary risk to partners or to future generations.

Objectives:

1. Risk management – utilize the Forest Service Wildland Fire Risk Management Protocols.
2. Stimulate aspen regeneration and reduce other encroaching woody species in aspen Forest-wide by treating approximately 4800 acres annually. (LRMP objective)
3. Restore natural disturbance patterns and increase age-class diversity in conifer cover types Forest-wide by treating approximately 1275 acres annually. (LRMP objective)
4. Increase grass and forb production and plant species and age-class diversity in sagebrush and pinyon/juniper Forest-wide by treating approximately 3000 acres annually. (LRMP objective)
5. Manage the Forest for more plants in the combined sprout and young categories than in the combined mature and dead categories. (LRMP objective)

Strategies:

1. Any time of year, use fire wherever possible to enhance resiliency, maintain desired fuel loadings, and to progress landscapes towards properly functioning desired future conditions.
2. Any time of year, allow fire to play a more active role in returning vegetation to historic ranges of variability by developing and incorporating resource benefit objectives for fires wherever possible.
3. Management of natural starts:
    a. Wilderness, roadless, and proposed wilderness –
        i. The norm is to employ a modified suppression strategy.
    b. Rest of forest in green default initial response areas –
        i. Modified suppression strategy is available any time of year, and becomes the norm for the remainder of the fire season beginning approximately August 15th of each year.**
4. Risk management - Manage every fire with strategy and tactical decisions driven by the probability of success to meet reasonable objectives, and a safe, effective, and efficient response (Chief's Letter of Intent). We do not accept unnecessary risk or transfer it to our partners or future generations.

Tactics:

1. Determine if criteria are met to manage natural starts for resource objectives.
2. Clarify and take advantage of flexibility in fire management to achieve goals.
3. Risk management - utilize the 7 Standards for Managing Incident Risk.

*[**Actual date will be set by July 31st each year, based in part on Predictive Services information.]*

Appendix C: Guidance from the Regional Office for the Use of Red/Green Maps in the Intermountain Region

Risk/Planned Response *(RED/GREEN)* SPATIAL PLANNING MAP

The map is a spatial depiction of our intention for unplanned fires. There are two purposes: communication with partners during pre-season meetings and communication with the Regional Office to share your vision about fire management.

This is not decisional but builds on your Forest Plan and other documents such as CWPPs, species Conservation Plans, project NEPA decisions, watershed assessments, Watershed Condition Framework, etc. It is not a decision document. It is simply a map of the planned response that applies to those identified areas. You may want to work with resource specialists who may need to interpret the resource goals and objectives in the Forest Plan and other source documents in order to develop the map, and the map may change after your spring meetings with partners.

Expectations:

- Forest Supervisor would review the map. The map should be sent to the Regional Fire Director by June 1st.
- The map would be used as a communication tool to be shared internally and externally, especially with partners in pre-season meetings.

Map Details (For a map example, see Figure 2 in main body of this FLA):

- PDF format
- Forest map using ownership base
- Include major highways, water bodies, towns/cities
- Show State boundaries if applicable (no county boundaries)
- Scale should be "D" size, preferably 1 sheet (2 at most)
- Consistent title block – see example (Planning Information for Ignition Response)
- Consistent legend – see example

Definitions:

- RED = area where wildland fire is unwanted. It contains high risk values that need to be protected (full suppression) or is directly adjacent to a boundary where neighbors do not want our fire. It means that we intend to suppress unplanned ignitions by controlling the perimeter at the smallest possible size where we can do so safely.
- GREEN = area of low risk, high probability of success to manage for Forest Plan objectives under favorable conditions (modified suppression). It doesn't mean we WILL manage all fires there, it means that we will be evaluating opportunities to meet forest plan objectives.

[Tip: The map may be part of your Fire Management Reference System and could be loaded into WFDSS.]

Appendix D: Chronology of Fire Management Policy

A true "national fire policy" that applied to all federal land management agencies did not exist prior to 1995. Prior to that, each agency had their own unique policy, but after several years of severe fires between 1910 and 1935, they were all pretty much the same. The overriding objective was to control all fires as soon as possible. In the context of the time, fire exclusion was believed to promote ecological stability and reduce commodity damages and economic losses. In 1935, the U.S. Forest Service instituted the "10 a.m. Policy," wherein the objective was to prevent all human-caused fires and contain any fire that started by 10 a.m. the following day. Organizational experience gained during this time period was predominantly related to the immediate control of fire.

By the 1960s, fire management costs were increasing exponentially while the 1964 Wilderness Act, Tall Timbers Research Conferences, and Southern Forest Fire Lab research demonstrated the positive benefits derived from natural and prescribed fire. As a result, fire policies of the agencies began to evolve to address both the economic and ecological benefits of not aggressively controlling fire. Management even got to a point where they started discussing using fire to benefit ecosystems.

In February 1967, the USDA Forest Service permitted leeway from the 10 a.m. Policy for certain early- and late-season wildfires. By 1972 a revolutionary fire management program was instituted. Initially termed prescribed natural fire (PNF), the program was primarily aimed at allowing lightning-caused fire in designated Wilderness to perform its natural role. In the context of the time, prescribed fires ignited by managers were regularly permitted. This response to lightning fires in Wilderness was deemed similar in that prescribed conditions were to be met before such a response would be implemented. The idea of not immediately suppressing wildfire was so radical that this terminology was purposefully chosen to align with management-ignited prescribed fire in order to gain acceptance. While initially advantageous in helping to promote the idea that certain wildfires in Wilderness Areas were capable of producing favorable results, the term "prescribed" proved to be troublesome because it invited some to call for the same level of adherence to environmental and air quality regulation for these unplanned wildfires.

Based on the success of these early experiments, the U.S. Forest Service officially changed policy from strict fire control to fire management by rescinding the 10 a.m. Policy in 1978. In doing so, the Forest Service acknowledged: 1) fire plays a critical role in many fire-adapted and fire-dependent ecosystems; 2) the act of extinguishing naturally ignited fires in designated Wilderness Areas negatively impacted Wilderness characteristics; and 3) some fires can burn while posing a negligible threat to non-wilderness values.

The 1994 fire season triggered a review after the occurrence of 34 firefighter fatalities and a growing recognition of fire problems caused by fuel accumulation. In 1995, the first comprehensive federal fire policy for both the Departments of the Interior and Agriculture was created. The resulting 1995 Federal Fire Policy recognized, for the first time, the essential role of fire in maintaining natural systems.
In May of 2000 the Cerro Grande Prescribed Fire escaped, prompting the Secretaries of the Interior and Agriculture to request a review of the 1995 Federal Fire Policy and its implementation. This resulted in a 2001 document known as the Review and Update of the 1995 Federal Wildland Fire Management Policy.

As fire managers continued to gain experience with Wilderness fires through the PNF program, eventually they came to understand that fire as a naturally occurring process could also have desirable effects for non-wilderness areas. The 1995 Federal Fire Policy and subsequent 2001 Review reflected this shift to "to protect, maintain, and enhance resources and, as nearly as possible, [allow fire] to function in its natural ecological role". This goal was not exclusive to Wilderness, thus broadening the fire policy's scope beyond just Wilderness.

In an attempt to make a distinction from management ignited prescribed fire, policy guidance in 2003 replaced the language of "prescribed natural fire" with "wildland fire use" or WFU as a programmatic alternative to strict fire suppression. Similar to the PNF program in its aim to allow natural fire to play its role in the ecosystem, WFU expanded management's scope to also allow for the use of naturally occurring fires to achieve management objectives outside of Wilderness. Objectives such as reducing hazardous fuel loading and achieving desired conditions for wildlife and vegetation species outside of Wilderness were now supported. Under this version of policy, there were three categories of wildland fire: 1) prescribed fires—those ignited by managers to achieve specific land management objectives; 2) wildland fire use fires—those ignited by natural causes with the primary objective of achieving land management objectives; and 3) wildfires—all other unplanned and unwanted fires which regardless of ignition source, were managed with the objective of minimizing size and cost of the fire.

An unplanned fire was categorized soon after ignition as either WFU or a wildfire, which established both a single objective and an associated response to the fire. Key components of this policy were any unplanned fire (WFU or wildfire) could only have one of two objectives—protect values or achieve benefits. That single objective had to be applied to the entire fire, and the objective required a specific type of response—suppression or appropriate management response. By policy, all wildfires required an aggressive suppression response to meet the objective of smallest size and least cost, whereas WFU could be managed within a prescribed maximum management area (MMA) in order to meet land management objectives. If, at any point, the WFU was not meeting management objectives or exceeded the MMA, it was converted to a wildfire and required an aggressive suppression response.

During this time period, managers first began to experiment with using naturally occurring fires to achieve beneficial outcomes outside of Wilderness. But this type of response was favored in remote areas. Over the years the connotation of "prescribed" fire still applied to WFU fires. Regulatory requirements were pushed on this subset of naturally occurring, unplanned fires.

In 2009, the Guidance for Implementation of Federal Wildland Fire Policy was created to replace the 2003 policy guidance. While the concept of using wildland fire to enhance values remained, the category of "wildland fire use" fires was removed, at least in part, to distinguish between the management of unplanned "wildfires" and planned "prescribed fires." The new guidance allows managers to simultaneously take measures to protect values while also employing alternate strategies on all or a portion of a wildfire. This allows managers to take advantage of wildfire to reduce hazardous fuel accumulations, improve wildlife habitat, or otherwise move vegetation toward desired conditions as defined in Land and Resource Management Plans. Managers also have the flexibility to change objectives as the fire spreads across the landscape and encounters new conditions.

While the elimination of WFU as a category in 2009 is important to understand the shift in policy, equally important is that the definition of "wildfire" also changed radically. Before it was an indication of an unplanned and unwanted ignition; in the updated policy it only refers to the ignition being unplanned.

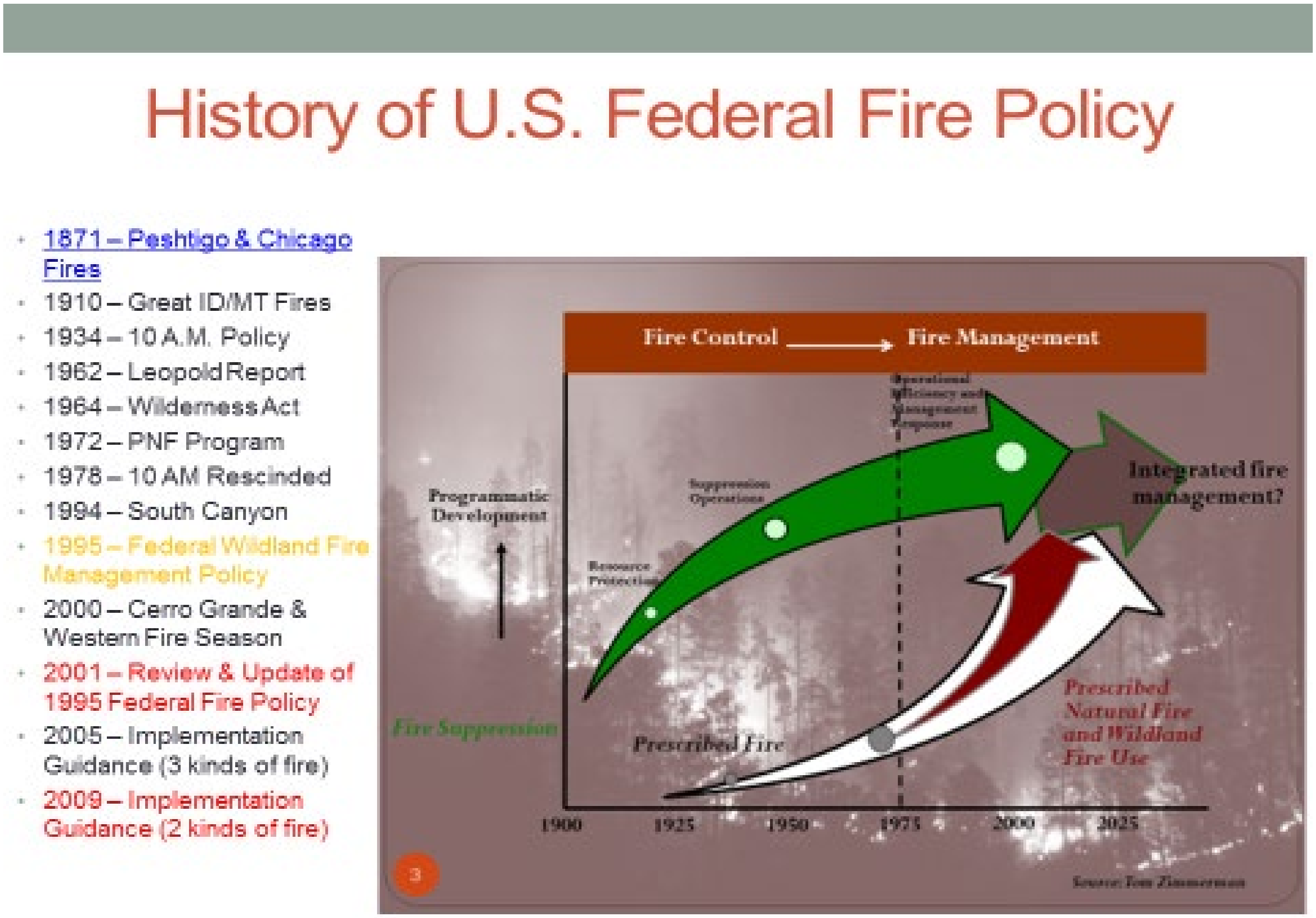


Figure D1 *– This figure depicts the evolution of U.S. Federal Fire Policy as it has transformed from a policy of strict fire control, to recognition that fire in some cases can have utility which led us to the current era of fire management. It also looks ahead toward a possible future where the full spectrum of positive and negative consequences of fire might be integrated into the decision-making process for all fire management activities.*

Appendix E: Climatology and Drought Analysis

Fuel and Climate Conditions

The U.S. Drought Monitor indicated that the fire area was experiencing a severe drought as late as October 16th, which was slightly moderated from the conditions seen during the active period of the Bald Mountain and Pole Creek fires. The current drought condition began to appear as early as last summer and has continued to intensify over the winter and into the summer.

Drought is a result of a prolonged shortage of water supply (including atmospheric, surface water, or ground water). It is entirely possible (as was the case in 2018) to receive a heavy precipitation event in the midst of a drought situation without increasing the water supply enough to end the drought. The Pole Creek and Bald Mountain fires were impacted by the heavy rain event only in the short term. The unprecedented string of red flag warnings that followed the rain event proved to be more than enough to overcome the effects of the heavy rains and dry the vegetation out to the point where extreme fire behavior was possible.

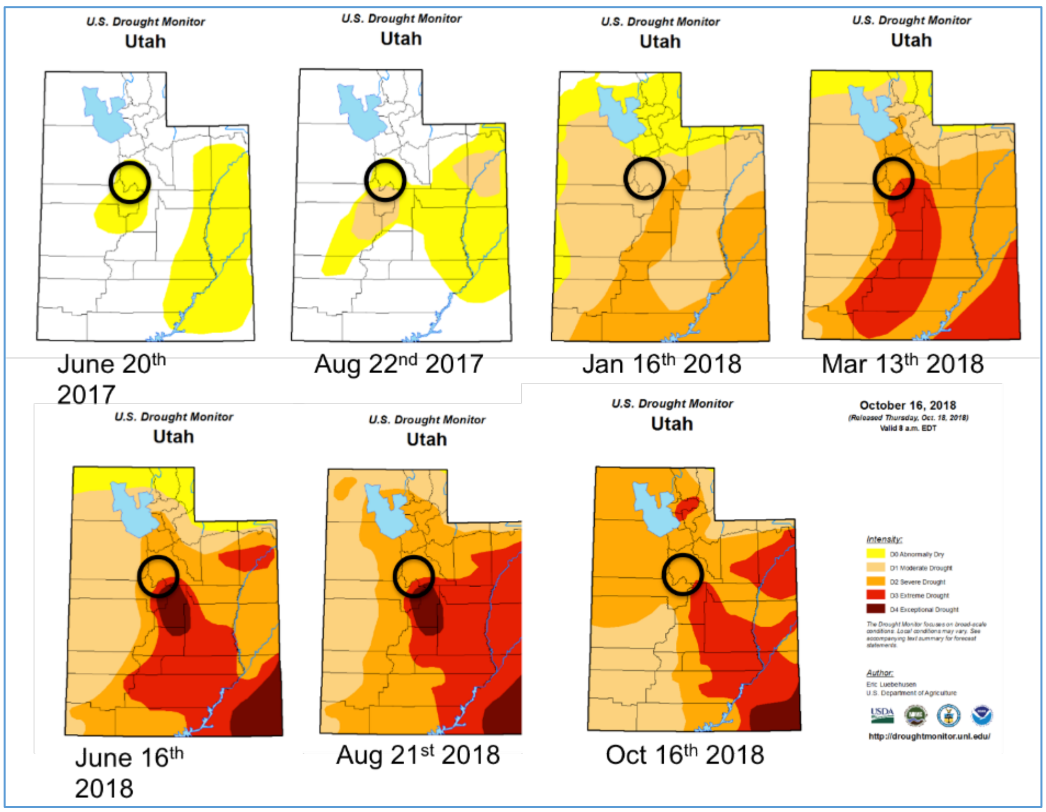


***Figure E1** – Images from the U.S. Drought Monitor https://droughtmonitor.unl.edu. The Pole Creek and Bald Mountain fires' general areas are indicated by the black circle.*

The drought increased from "Severe Drought" to "Extreme Drought" starting mid-March of 2018, with little change except for the worsening to "Exceptional Drought" for the southern part of the fire area from late June for the duration of both fires. The comparison between 2017 and 2018 demonstrates the impact of the reduced fall and winter precipitation in the area. It is important to note that the U.S. Drought Monitor is a course scale interpolated product. Even though the fire area borders a transition in severity, it may have experienced the more severe of the conditions. This product is most valuable when interpreted as a trend of general conditions.

SnoTel sites in the fire area showed less than 40 percent of average snowpack. This slightly moderated by March 1, indicating increased precipitation in February. By May 1, the majority of the area shows less than 25 percent of normal. This reduced snow cover and precipitation resulted in both dead and live fuels becoming available at a much earlier time of season than would be normal.

The Western Regional Climate Center's (WRCC) assessment of percent of average precipitation (Figure E3) helps give context to the distribution and intensity of the precipitation experienced over the last

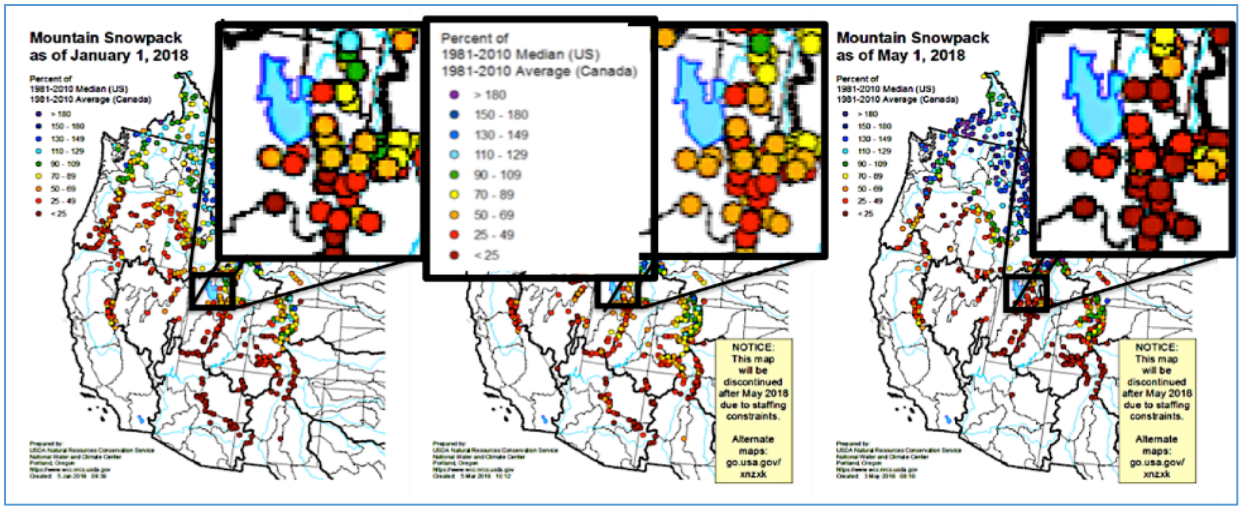


Figure E2 *– NRCS's Percent of Normal Snowpack as of January 1 (left), March 1 (center), and May 1 (right).*

year. The center image in Figure E3 indicates that the sum total precipitation received is normal to slightly above normal for this time of year. The anomaly is the distribution of the precipitation, because the majority of rain fell during one event on August 22.

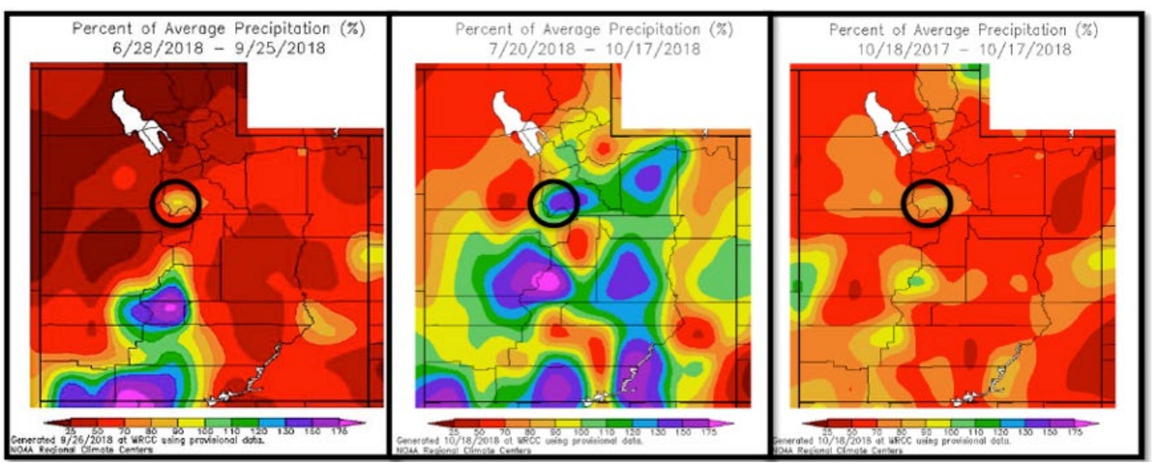


Figure E3 *– The Western Regional Climate Center's assessment of percent of average precipitation for periods noted at the top of the images.*

The effects of the drought on the fuels are apparent in both the ERCs and the 1000 hour fuel moistures as early as January 2018 (see Figures E4 and E5 below). In both the GB26 SIG and the Rays Valley RAWS, the 2018 values for 1000 hour fuel moisture stayed between average and minimum values from late January until late August. The 1000 hour fuel moistures values briefly went above average in late August for the first time since 2017 as a result of the ~2.5" rain event on August 22, but dropped quickly and set new minimum values for the Rays Valley RAWS for that time of year.

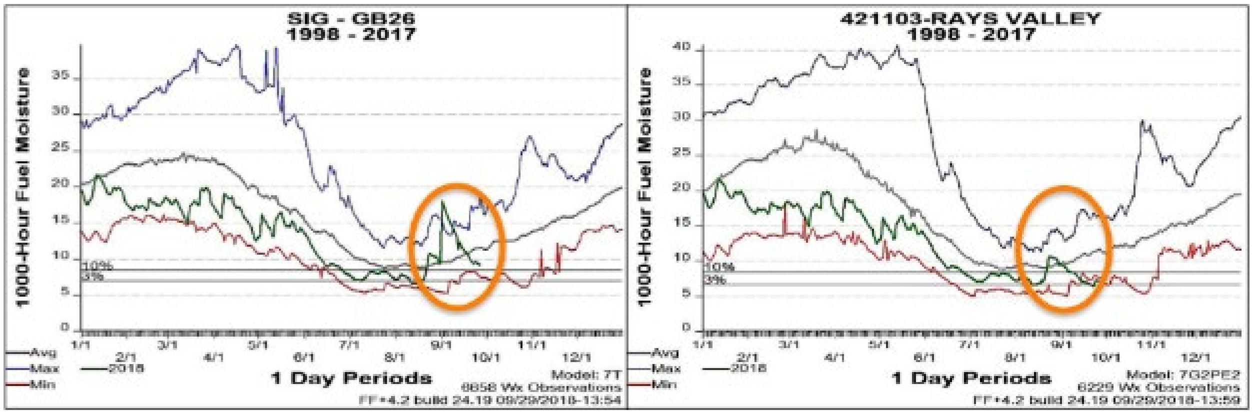


***Figure E4** – 1000 Hour Dead Fuel Moisture comparison of SIG GB26 and Rays Valley RAWS. The general duration of the Pole Creek and Bald Mountain fires is indicated by the orange ovals.*

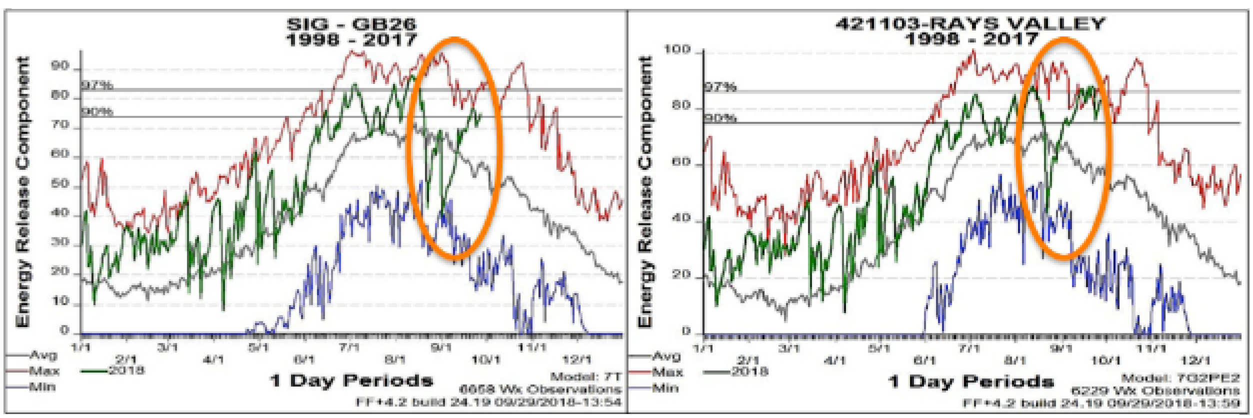
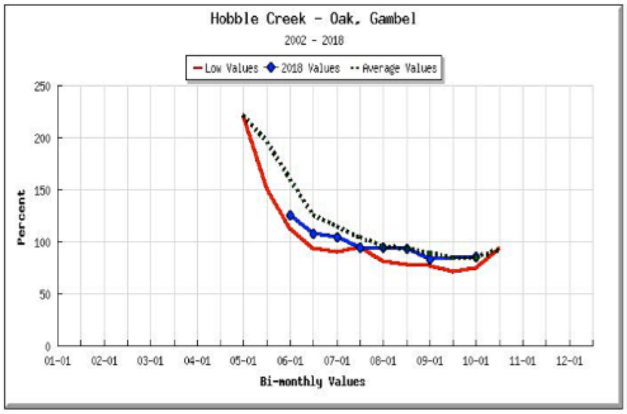
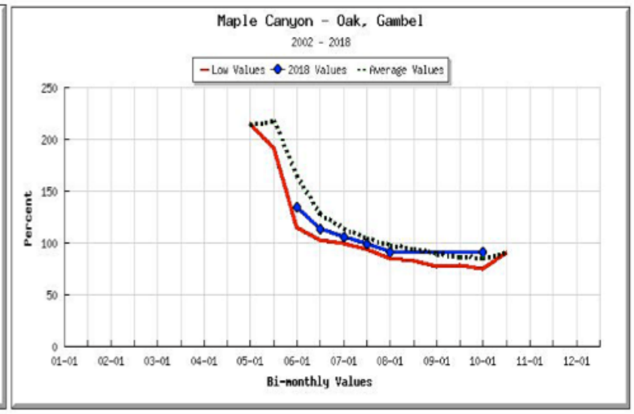


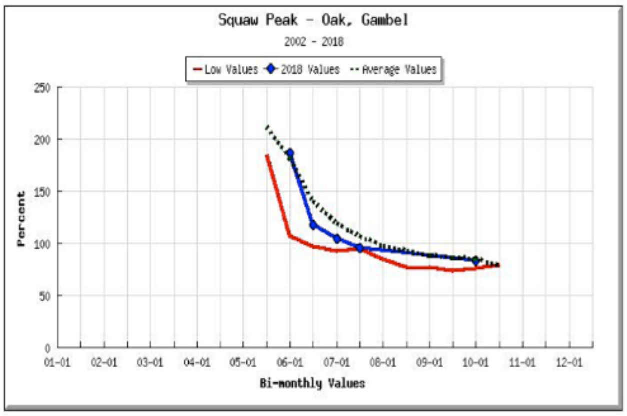
***Figure E5** – ERC comparison of SIG GB26 and Rays Valley RAWS. The general duration of the Pole Creek and Bald Mountain fires is indicated by the orange ovals.*

It is important to note that while the general trend for minimum, average, and maximum 1000 hour dead fuel moisture is to increase this time of year, both the Rays Valley RAWS and SIG for GB26 show a decreasing 1000 hour fuel moisture trend for 2018 in early September (Figure E4). The same trend is also apparent when examining the Rays Valley RAWS ERCs (Figure E5). During the period of rapid growth of the Bald Mountain and Pole Creek fires, both the ERC and 1000 hour fuel moistures were very close to setting new maximums and minimums respectively.

Live fuel moistures in Gambel oak show a lower than average trend early in the season (Figure E6). The timing of the low values was two weeks to a month earlier than usual, depending on the sample site. The fuel moistures were about average at all three sites when these fires were discovered, but they had been at that level for an additional month. This caused not only additional stress on the vegetation, but resulted in additional fuels available to support large fire growth. This was observed on the nearby Coal Hollow Fire that occurred in early August.







UWC Fuels Moisture Data Summary

Site Name	Species	Fuel Moistures 27-Aug-18	Fuel Moistures 10-Sep-18	Fuel Moistures 24-Sep-18
Squaw Peak	Gambel oak	92	89	83
Hobble Creek	Gambel oak	83	93	86
Maple Canyon	Gambel oak	85	91	91
Forest-wide	Gambel oak	92	93	87

Figure E6 – *Live Fuel Moisture graphs from the National Fuel Moisture Database, displaying current LFMs in Gambel oak across three sites on the UWF National Forest. Table is displaying actual LFM values.*

Weather

Extreme fire behavior from September 11-20 was the result of lower-than-normal and episodic precipitation and wind events in combination with the climatic effects on fuels.

Holden and Jolly at the Rocky Mountain Research Station are researching the effect of precipitation duration and intervals between wetting rain events (at least 0.1") on fire behavior, intensity, and size. They are investigating the relationship between large fire occurrence and longer durations between wetting rains. On the UWF, an analysis of periods of greater than 20 days between wetting rains from 2010 to 2018, when compared with fires over 10 acres, seems to show a relationship between large fire occurrence and the distribution of precipitation events (Figure E7).

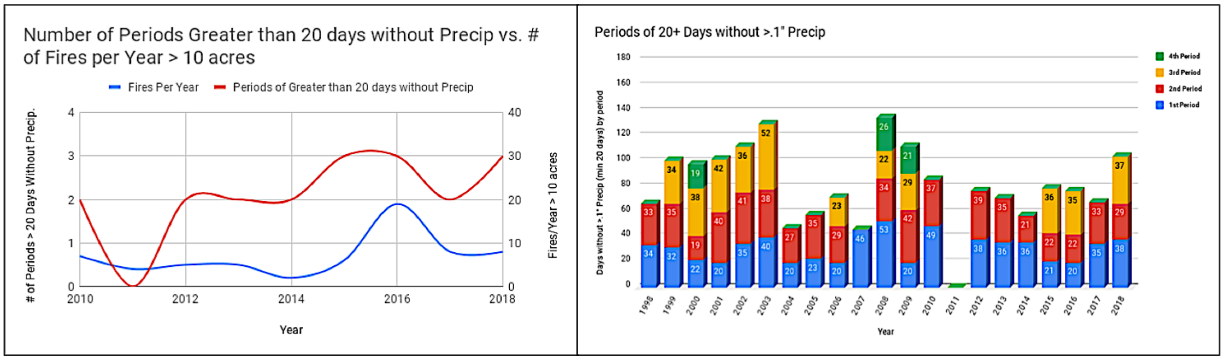


Figure E7 *– Fire data was gathered based on WFDSS records. Precipitation data is for the Great Basin GACC SIG 26 from May 1-October 31, and was analyzed using Fire Family Plus 4.2.*

While it does seem as though the duration between wetting rains and fire behavior leading to the large fire growth are related on the UWF, the large fire growth on the Pole Creek and Bald Mountain fires was so far outside what has been seen in recent history that there are clearly other factors at play. This can be seen when examining the periods of greater than 20 days without a wetting rain in comparison to the average fire size in a logarithmic scale (Figure E8). A general trend of increasing average fire size started in 2016 and 2017 and then increased by 10 fold in 2018, further underlining 2018 as an outlier.

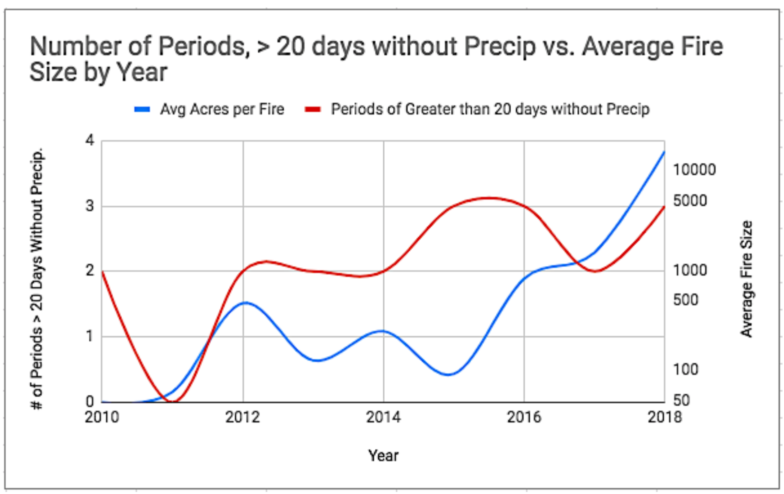


Figure E8 *– Number of periods greater than 20 days between wetting rains vs. average fire size (logarithmic scale) by year. Fire data was gathered based on WFDSS records. Precipitation data is for the Great Basin GACC SIG 26 from May 1-October 31, and was analyzed using Fire Family Plus 4.2 with fire information from WFDSS.*

There is a correlation between the rapid growth of both the Pole Creek and Bald Mountain fires, and the number and timing of Red Flag Warnings and Fire Weather Watches (Figure E9).

Figure E9 shows five or more Red Flag Warning occurrences September of 2018 compared to the two recent large fire years on the UWF (2012 and 2016). This is of importance because the frontal passages that are typical of late August and early September are often the causes of Red Flag Warnings and Fire Weather Watches, but those frontal passages in September 2018 were all dry, causing not only strong and gusty winds but poor night time humidity recovery. The impact of this year's Red Flag Warnings and Fire Weather Watches conditions were exacerbated by the fact that most occurred consecutively

(September 10-16 and September 18-20). This number of Red Flag Warnings was unprecedented and was not predicted when the decision was made to apply a modified suppression strategy to these fires.

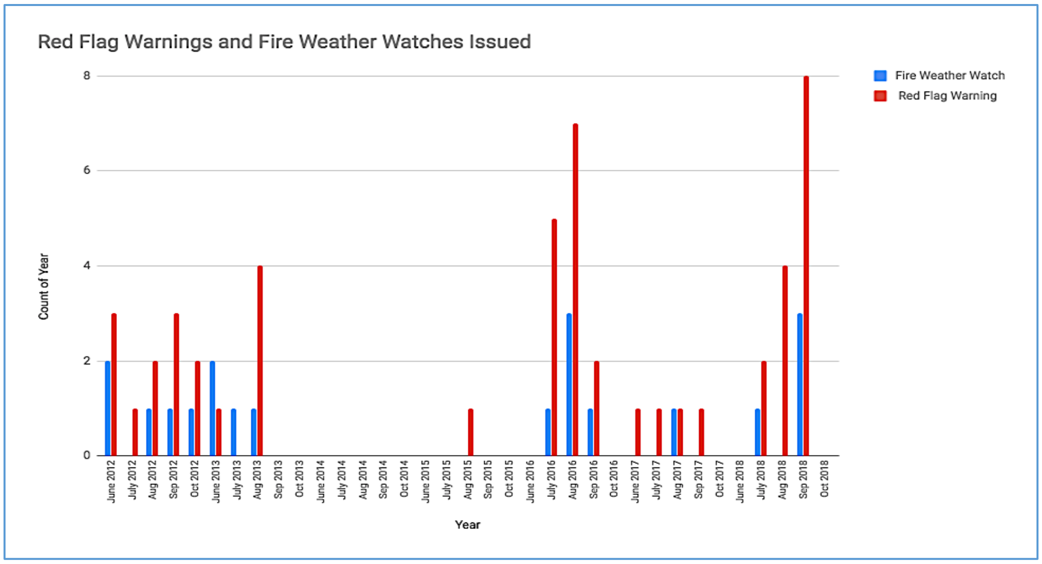


Figure E9 – *Red Flag Warnings and Fire Weather Watches queried from the Iowa State University IEM database 2012-2018. https://mesonet.agron.iastate.edu/vtec/search.php.*

The Red Flag Warning winds of September 10 would not have had nearly the effect they did had the stage not been set by the poor RH recovery beginning on the 9th, which continued through the 16th (Figure E10). By September 12, the maximum RH was only a few points above the minimum RH on the 8th. The low nighttime RH recoveries that began on the 9th allowed dead fuel moistures in 1, 10, and 100 hour fuel categories to stay low day and night until the 17th, when the fire growth moderated before increasing again on September 18th and 19th. The two periods of poor nighttime RH recovery coincide with the strong and gusty winds of the Red Flag Warnings, so it is not possible to determine which had the larger effect on fire behavior. The accounts of increasing fire behavior from line personnel is likely due to a combination of wind and low min/max RH values.

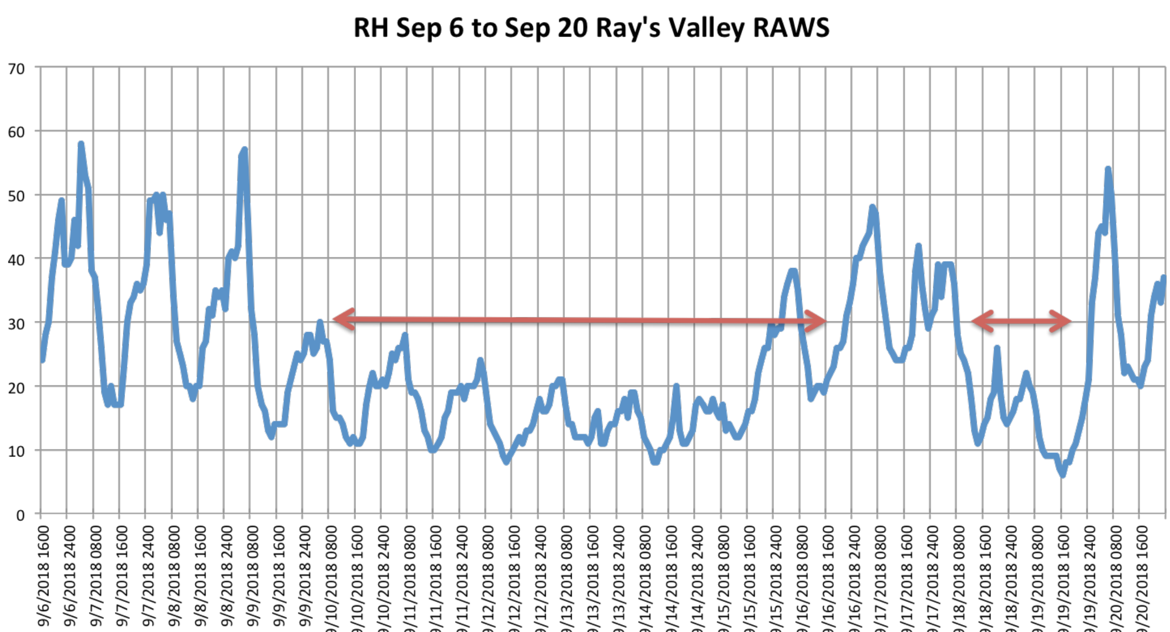


Figure E10 – *Relative Humidity September 6 to 20 from the Rays Valley RAWS, analyzed using Fire Family Plus 4.2.*

Summary

Severe weather, climatic, and fuel conditions combined with a lack of recent burned areas resulted in a combined total of more than 120,000 acres. Where the fires intersected with recent burned areas (within the past 10-20 years) such as the Mollie 2001, Lake Fork 2009, Wood Hollow 2012, Red Ledges 2012, or Sawmill 2016 fires, fire behavior was modified to an extent that either it self-extinguished or moderated to an extent that firefighters could halt fire spread. When the fires reached burned areas less than several thousand acres—such as the Bernie Creek 2002, Diamond 2003, Lake Canyon 2004, or Wignal 2013—the fires either spotted over, burned around, or merely slowed. It should be noted that the presence of Gambel oak and aspen (both of which are shade intolerant species) indicates a history of stand replacement fire. Future high-severity fire occurrence can be expected under suitable conditions. All indications seem to point to the cessation of high-severity fire on this landscape was a result of European settlement.

The drought in this area was temporally mitigated by the 1.32-2.29 inches of rain the fire area received but the benefit of this moisture was quickly reversed by the unprecedented amount of Red Flag wind days. The wind quickly dried the fuels and made them receptive to large fire growth.

Appendix F: Potential Control Locations (PCL) and Suppression Difficulty Index (SDI)[6]

Overview

On September 22, 2018, the Risk Management Assistance Team provided fire managers working on the Pole Creek Fire with new, experimental products that are not yet widely available. These products are in the development phase. While they were not available to the initial or extended attack responders, they provide a glimpse of what may become more widely available products to help with future risk-informed decision-making.

The SDI (Suppression Difficulty Index, also known as Relative Responder Exposure) and the PCL (Potential Control Locations based on historical fires) for the Pole Creek Fire are intended to work together to help firefighters more quickly understand the challenges and opportunities for taking action across the landscape. Note that these are experimental products that should not be relied upon without field verification. The two products show different things but where they align, they are intended to help firefighters to quickly assess the fire situation and accelerate strategic decisions.

Suppression Difficulty Index is a rating of relative difficulty in performing fire control work. It factors in topography, fuels, expected fire behavior under prevailing conditions, firefighter line production rates in various fuel types, and accessibility (distance from roads/trails). Red zones are "watch out" situations where engagement is likely to be very difficult given potential fire behavior, fuels, terrain, and lack of access. Blue zones indicate area of higher likelihood of success due to low fire behavior as a result of gentle terrain, low to moderate fuel conditions, and better access. SDI does not account for standing snags, cliffs/bluffs, or other non-fire hazards to firefighters, so it is not a firefighter hazard map. It is only showing in relative terms where it is harder or easier to perform work. High SDI indicates extreme difficulty, and low SDI indicates more reasonable conditions for fire engagement.

The atlas of potential control locations (PCL) provides a summary of the historical fire perimeter formation probability. It identifies where fires tend to stall or keep spreading on a specific landscape. It does this by comparing historic fires with various characteristics of the landscape such as expected fire behavior, fuels transitions, roads, topographic features, etc. Red zones can be considered wicks, where fires tend to spread into the entire zone. Blue zones in the PCL atlas are areas where fires tend to stall on the landscape due to some combination of site conditions[7].

Areas where both products are red indicate very difficult working conditions and potentially unsafe fire spread conditions. Areas where both products are blue indicate places where it is relatively easy to work and historical fires tended to stop, so these represent the best available locations to engage a fire given the modeled fire weather and other assumptions.

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[6] Created by: C.D. O'Connor, Ecologist, USDA Forest Service Rocky Mountain Research Station, Wildfire Risk Management Science Team.

[7] The scaling of PCL is from 0-100%; Higher % = best likelihood for forming a fire perimeter, Lower % = not likely according to the model that a fire perimeter would be established there, i.e. historically fires don't tend to stop in these places.

Methods

During the Pole Creek Fire an analysis was conducted which included 103 historical fires >500 acres from 2002-2018 to develop the relationships reflected in the PCL model output. Fires were selected based on similarity of terrain, fuels, and prevailing winds.

Landscape fire models were modified from LANDFIRE 2014 data to include all FACTS and NFPORS fuel treatments and fires from 2014-2018. Surface fuel, canopy cover, canopy base height, and canopy bulk density changes are based on the Pyrologics landscape updater rules for the western U.S.

Fire modeling inputs were drawn from the most recent WFDSS NTFB runs, and winds were based on the 3-day weather forecast from September 21, 2018. Tabular output is displayed on attached maps (p54). SDI uses FlamMap outputs (flame length and heat per unit area) to characterize potential fire hazard, and a summarized index of road and trail density, terrain steepness and exposure, and fireline production rates to characterize suppression opportunities. The generalized equation for SDI is (Fire Hazard/Suppression Opportunity). Model inputs can be found in Rodriquez y Silva et al. (2014).

The PCL atlas uses a boosted regression machine learning algorithm to assess relationships between historical fire perimeters and fire interiors to a suite of physical landscape attributes, modeled fire behavior outputs, and indices of suppression effort. These relationships are then projected onto the current landscape condition. For PCL methods see O'Connor, et al. (2017).

Model Results

The boosted regression tree assessed relationships between fire and landscape predictor variables at 74,607 point locations sampled from the 103 historical fires. The model reached optimal improvement at 10,900 regression trees. Below are summary statistics for the final model.

mean total deviance = 0.85
mean residual deviance = 0.663
estimated cv deviance = 0.706 ; se = 0.002
training data correlation = 0.494
cv correlation = 0.425 ; se = 0.003
training data ROC score = 0.804
cv ROC score = 0.759 ; se = 0.002

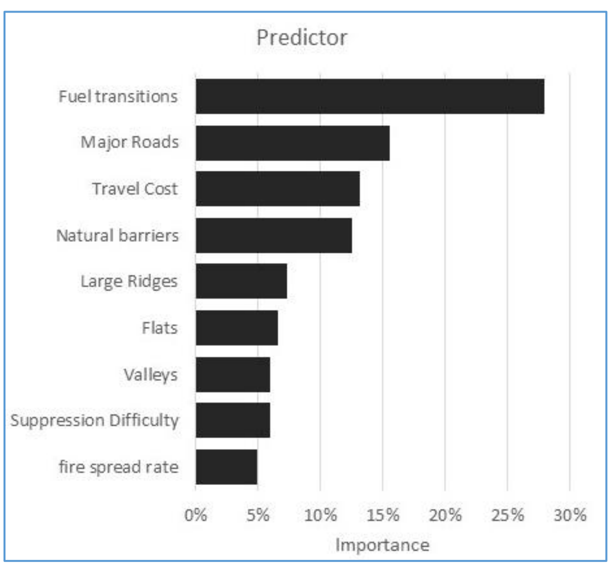


***Figure F1** – This shows the relative importance of factors associated with the historical fire perimeter analysis.*

The training data ROC score of 0.804 translates to the modeled relationships correctly classifying 80% fire perimeters and interiors. The cross-validated ROC score (cvROC) refers to the predictive power of the model that correctly classified 76% of new data left out of the training dataset.

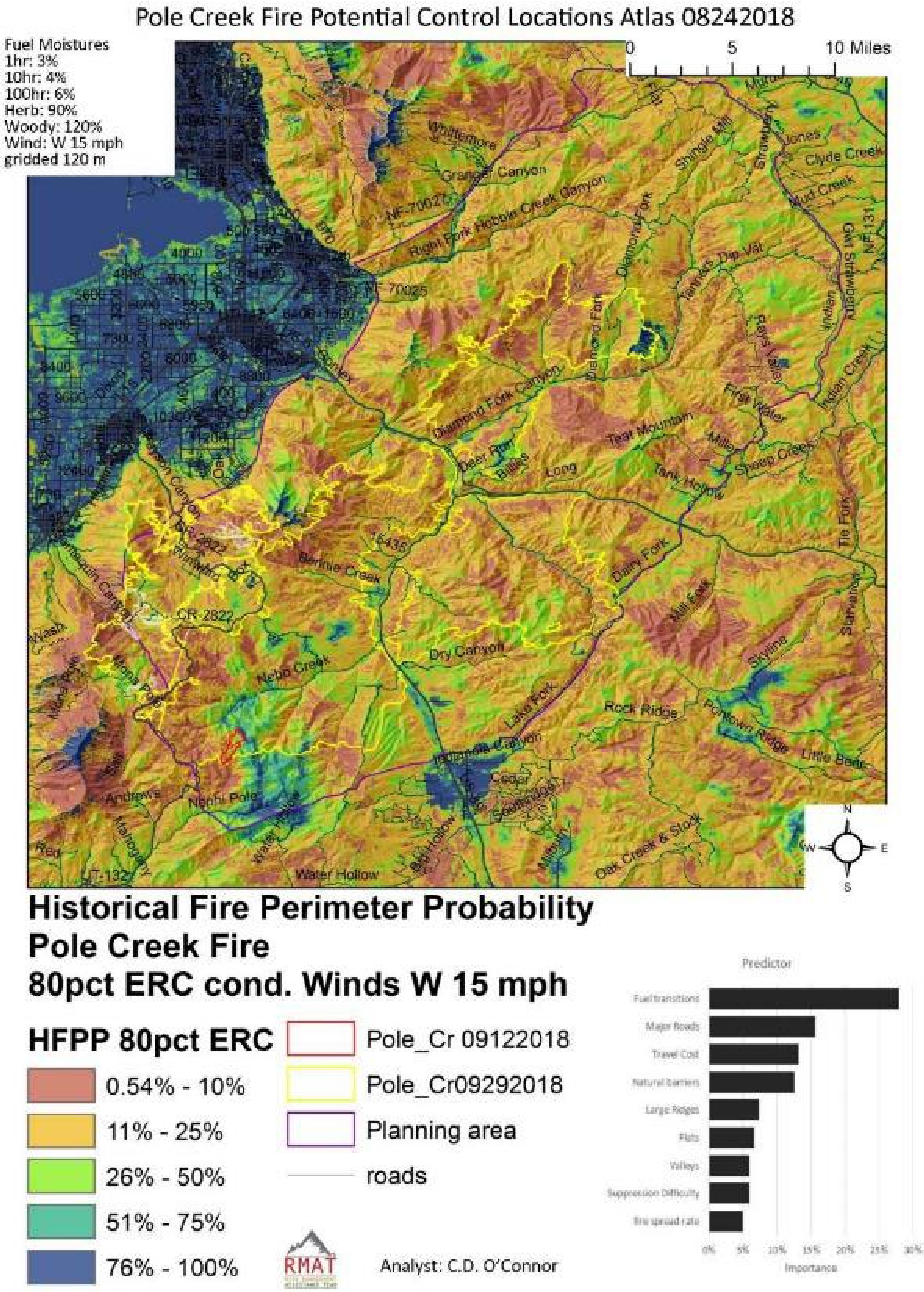
Fuel transitions were the primary drivers of historical fire perimeter formation, followed by major roads, ease of access on foot, and natural barriers (rock and water). Topographic features – ridges, flats, and valleys – were moderately important for stopping fires, and suppression effort and rate of fire spread were poorly correlated with fire perimeter formation.

For questions regarding product interpretation, please contact Christopher (Kit) O'Connor at christopheroconnor@fs.fed.us.

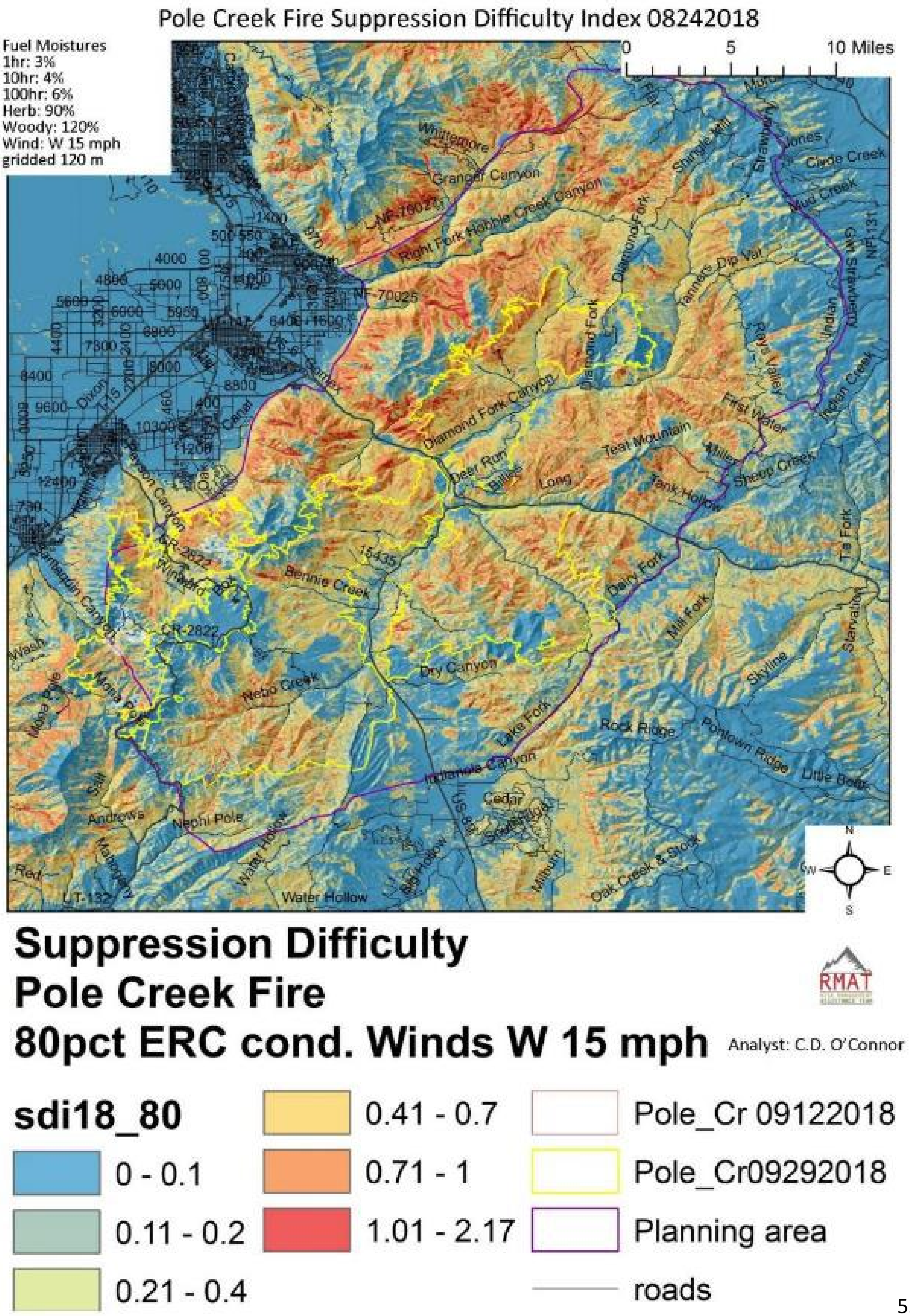
References

O'Connor, C.D., Thompson, M.P., Calkin, D.E. (2017). An empirical machine learning method for predicting potential fire control locations for pre-fire planning and operational fire management. *International Journal of Wildland Fire*, 26: 587-597.

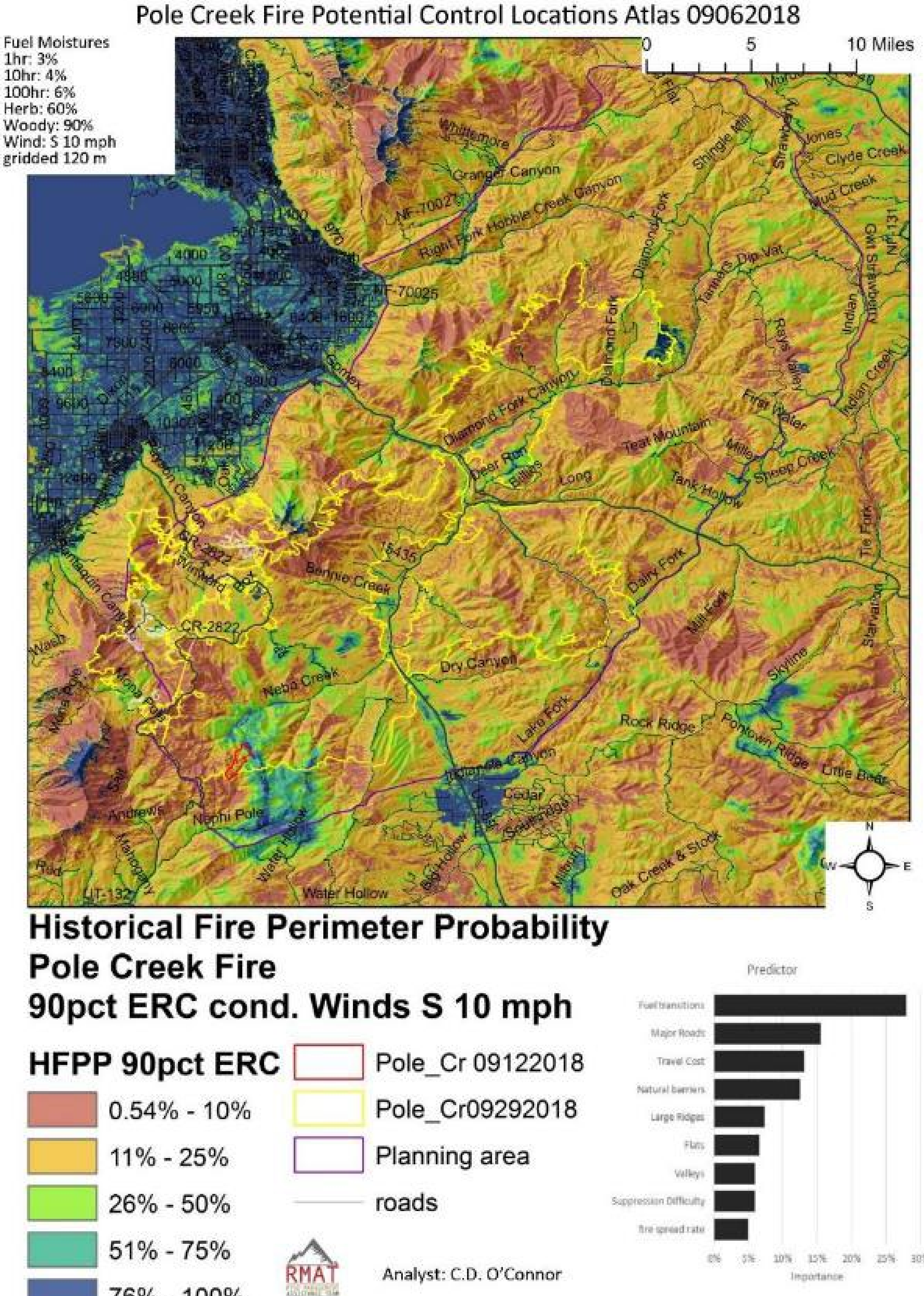
Rodriguez y Silva, F., Martinez, J.R.M, Gonzalez-Caban, A. (2014). A methodology for determining operational priorities for prevention and suppression of wildland fires. *International Journal of Wildland Fire*, 23(4), 544-554.



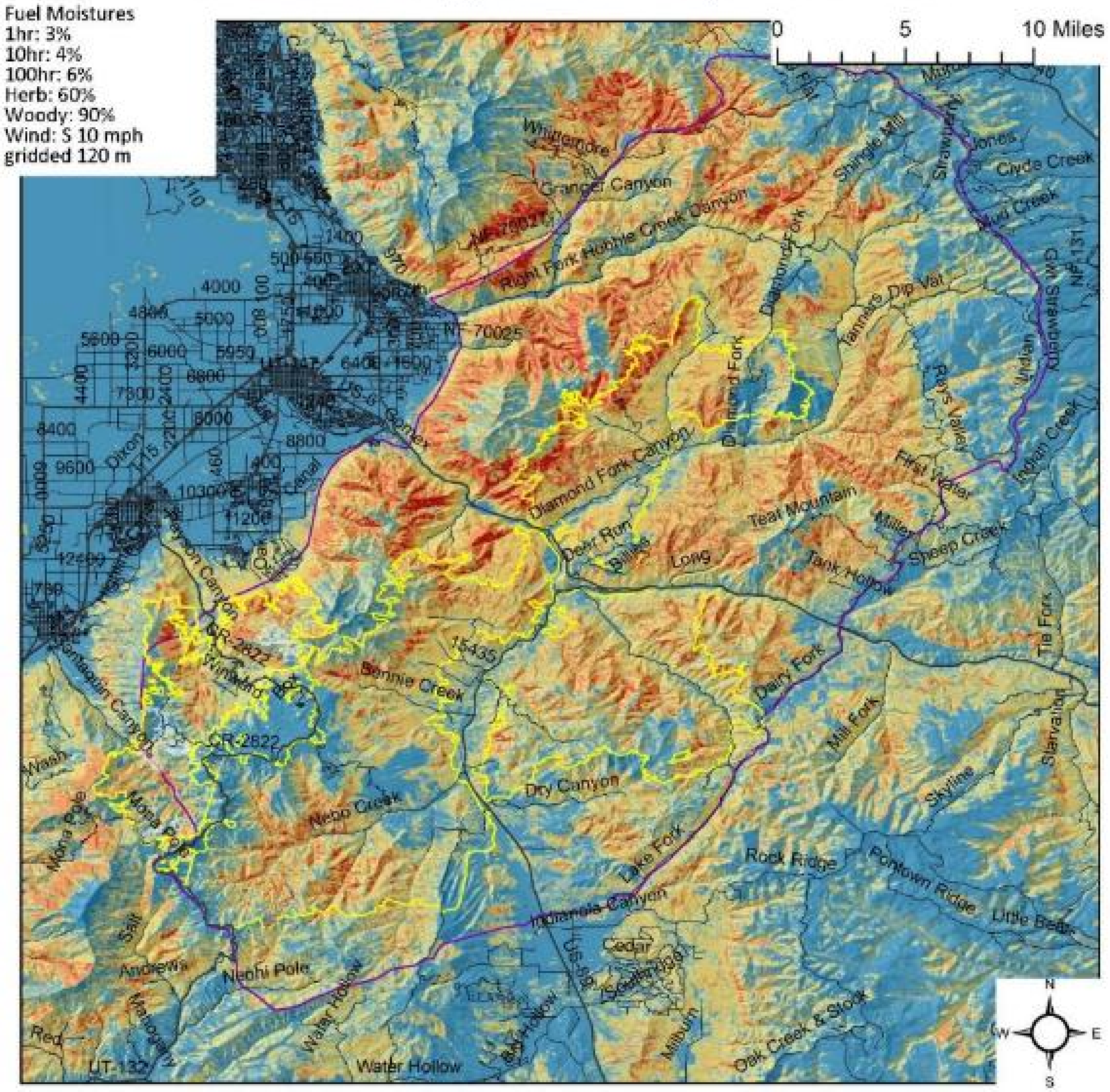
Pole Creek Fire Potential Control Locations Atlas 08242018
Fuel Moistures
1hr: 3%
10hr: 4%
100hr: 6%
Herb: 90%
Woody: 120%
Wind: W 15 mph
gridded 120 m
0
5
10 Miles
N
E
S
Historical Fire Perimeter Probability
Pole Creek Fire
80pct ERC cond. Winds W 15 mph
HFPP 80pct ERC
0.54% - 10%
11% - 25%
26% - 50%
51% - 75%
76% - 100%
Pole_Cr 09122018
Pole_Cr09292018
Planning area
roads
RMAT
Analyst: C.D. O'Connor
Predictor
Fuel transitions
Major Roads
Travel Cost
Natural barriers
Large Ridges
Flats
Valleys
Suppression Difficulty
Fire spread rate
0%
5%
10%
15%
20%
25%
30%
Importance



Pole Creek Fire Suppression Difficulty Index 08242018
Fuel Moistures
1hr: 3%
10hr: 4%
100hr: 6%
Herb: 90%
Woody: 120%
Wind: W 15 mph
gridded 120 m
0
5
10 Miles
N
W
E
S
Whittemore
Granger Canyon
Right Fork Hobble Creek Canyon
Diamond Fork Canyon
Teat Mountain
Tank Hollow
Sheep Creek
First Water
Deer Run
Bennie Creek
Dry Canyon
Nebo Creek
Lake Fork
Dairy Fork
Mill Fork
Skyline
Rock Ridge
Pontown Ridge
Little Bottle
Indianola Canyon
Nephi Pole
Andrews
Mona Pole
Water Hollow
Oak Creek & Stock
Tie Fork
Starvation
Clyde Creek
Mud Creek
Strawberry
Payson Canyon
CR-2822
NF-70025
US-89
UT-132
Suppression Difficulty
Pole Creek Fire
80pct ERC cond. Winds W 15 mph
Analyst: C.D. O'Connor
RMAT
sdi18_80
0 - 0.1
0.11 - 0.2
0.21 - 0.4
0.41 - 0.7
0.71 - 1
1.01 - 2.17
Pole_Cr 09122018
Pole_Cr09292018
Planning area
roads


Pole Creek Fire Potential Control Locations Atlas 09062018
Fuel Moistures
1hr: 3%
10hr: 4%
100hr: 6%
Herb: 60%
Woody: 90%
Wind: S 10 mph
gridded 120 m
0
5
10 Miles
Whittemore
Granger Canyon
Right Fork Hobble Creek Canyon
NF-70025
Diamond Fork
Diamond Fork Canyon
Teat Mountain
Tank Hollow
Sheep Creek
First Water
Clyde Creek
Mud Creek
Indian Creek
Tie Fork
Bennie Creek
Dry Canyon
Nebo Creek
Dairy Fork
Mill Fork
Skyline
Rock Ridge
Pontown Ridge
Little Bear
Lake Fork
Cedar
Nephi Pole
Andrews
Water Hollow
Oak Creek & Stock
CR-2822
N
E
S
W
Historical Fire Perimeter Probability
Pole Creek Fire
90pct ERC cond. Winds S 10 mph
HFPP 90pct ERC
0.54% - 10%
11% - 25%
26% - 50%
51% - 75%
76% - 100%
Pole_Cr 09122018
Pole_Cr09292018
Planning area
roads
RMAT
Analyst: C.D. O'Connor
Predictor
Fuel transitions
Major Roads
Travel Cost
Natural barriers
Large Ridges
Flats
Valleys
Suppression Difficulty
fire spread rate
0%
5%
10%
15%
20%
25%
30%
Importance

Pole Creek Fire Suppression Difficulty Index 09062018

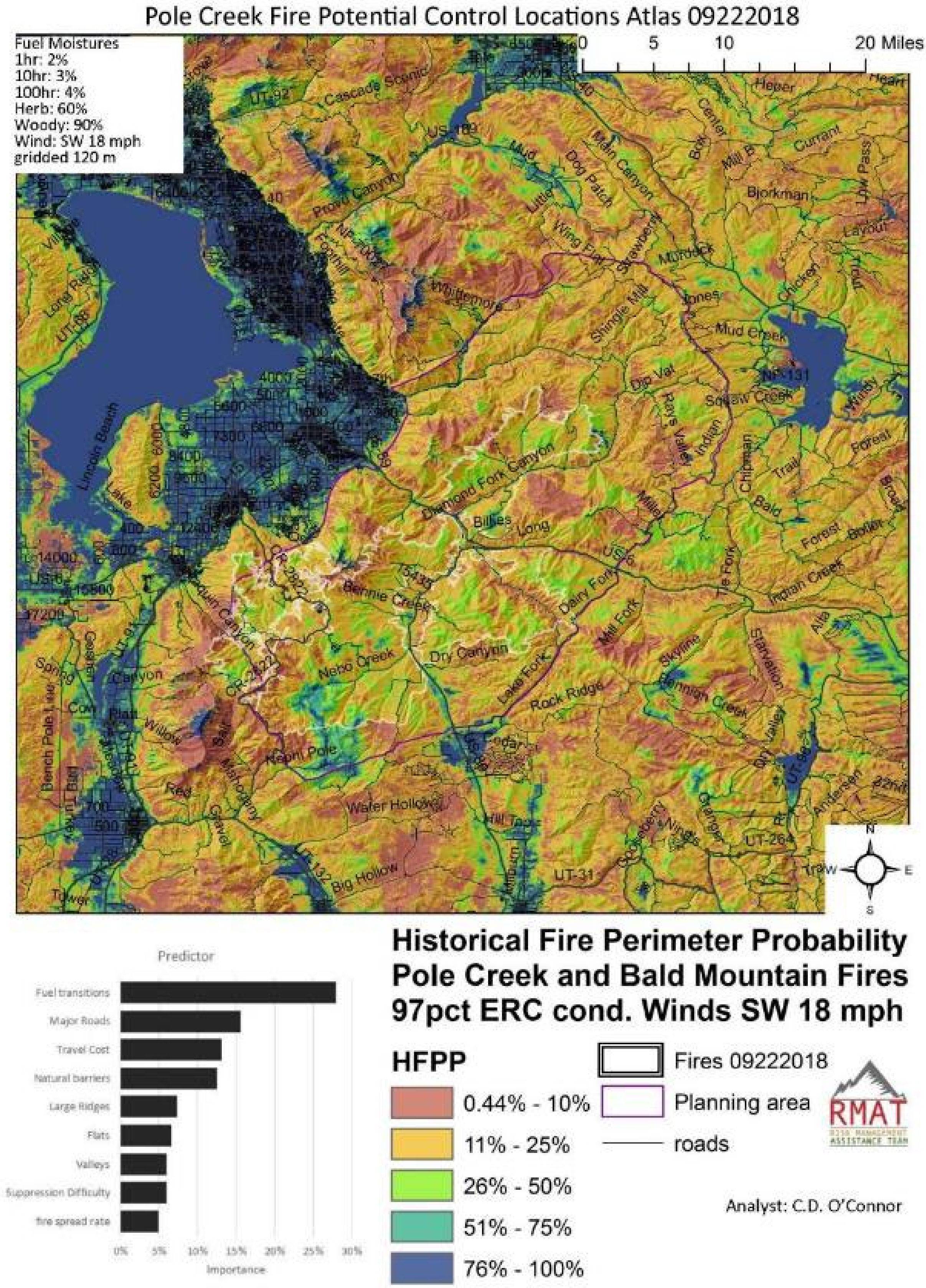


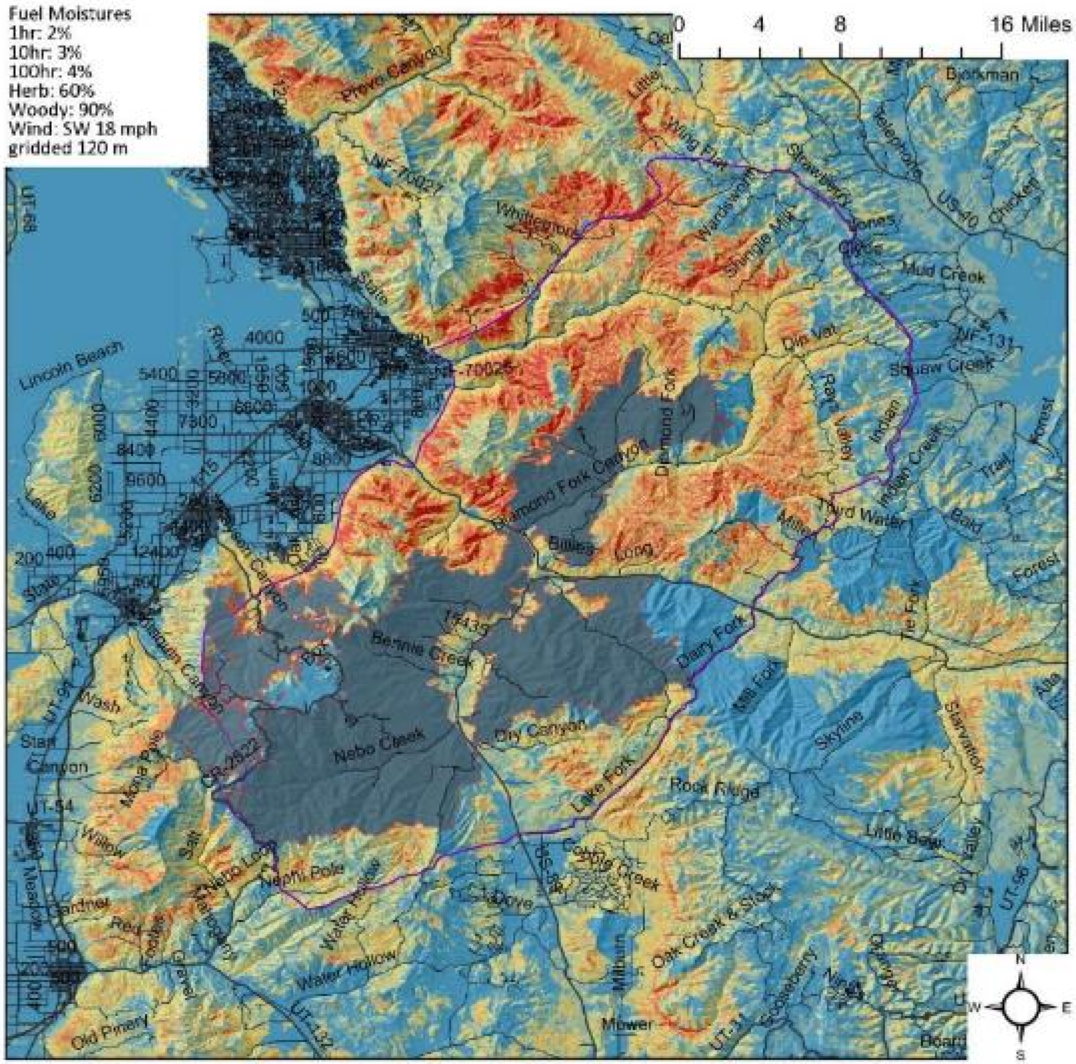
Suppression Difficulty
Pole Creek Fire
90pct ERC cond. Winds S 10 mph

Analyst: C.D. O'Connor

sdi18_90

- 0 - 0.1
- 0.11 - 0.2
- 0.21 - 0.4
- 0.41 - 0.7
- 0.71 - 1
- 1.01 - 2.17
- roads
- Pole_Cr 09122018
- Pole_Cr09292018
- Planning area


Pole Creek Fire Potential Control Locations Atlas 09222018
Fuel Moistures
1hr: 2%
10hr: 3%
100hr: 4%
Herb: 60%
Woody: 90%
Wind: SW 18 mph
gridded 120 m
0 5 10 20 Miles
N
E
S
W
Predictor
Fuel transitions
Major Roads
Travel Cost
Natural barriers
Large Ridges
Flats
Valleys
Suppression Difficulty
fire spread rate
0% 5% 10% 15% 20% 25% 30%
Importance
Historical Fire Perimeter Probability
Pole Creek and Bald Mountain Fires
97pct ERC cond. Winds SW 18 mph
HFPP
0.44% - 10%
11% - 25%
26% - 50%
51% - 75%
76% - 100%
Fires 09222018
Planning area
roads
RMAT
RISK MANAGEMENT ASSISTANCE TEAM
Analyst: C.D. O'Connor



Suppression Difficulty (Relative Responder Exposure)
Pole Creek and Bald Mountain Fires 09212018
97pct ERC conditions Winds SW 18 mph

0 - 0.1	0.41 - 0.7	Fires 09212018
0.11 - 0.2	0.71 - 1	Planning area
0.21 - 0.4	1.01 - 2.17	roads

RMAT RISK MANAGEMENT ASSISTANCE TEAM

Analyst: C.D. O'Connor

Appendix G: Fire Behavior

The figure below gives an overview of the fire discovery, growth, decision publication, fuel advisories, and significant weather events. It is shown here to give context and to be used as a reference as needed when going through the narrative on fire behavior, as well as the narrative on fuels, weather, and climate.

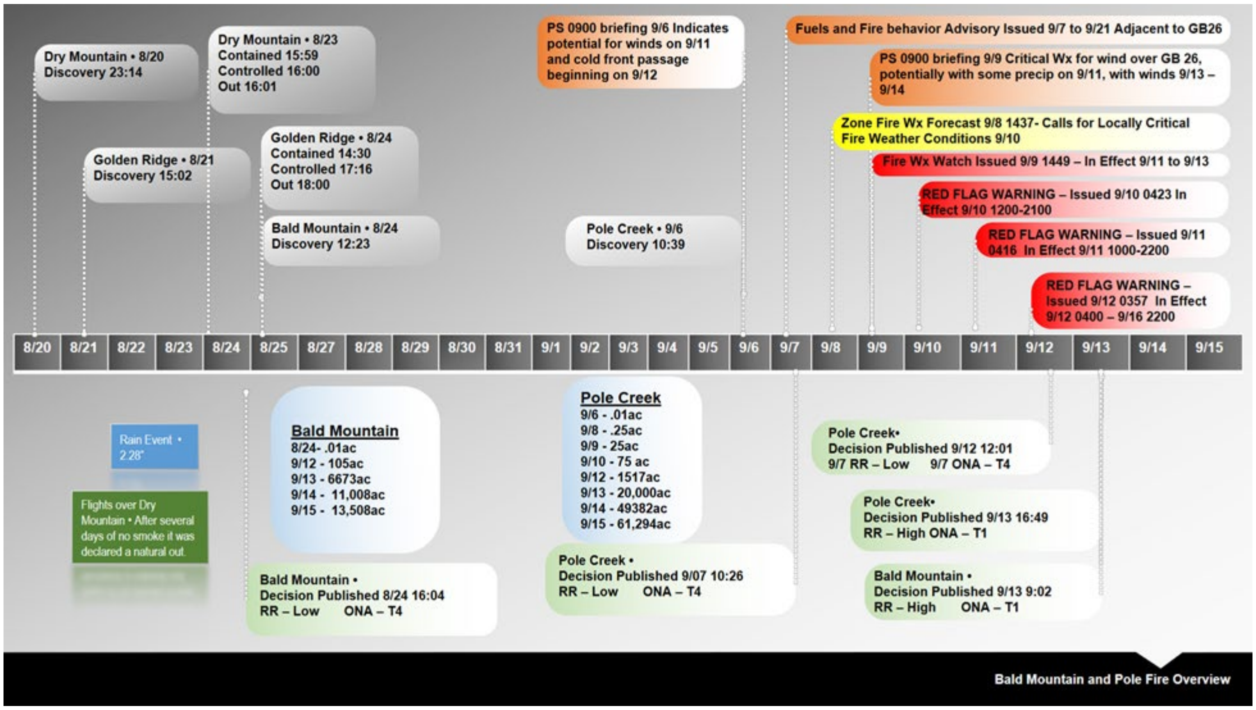


Figure G1 *– Timeline for incidents, showing initial discovery, growth, decision publication, and fuel and weather advisories.*

Bald Mountain – Projected and Observed Fire Behavior

The Bald Mountain Fire was reported on August 24, shortly after precipitation events on August 21 and 22. After it was apparent the fire wouldn't self-extinguish, an FSPro run was done on August 26 to inform the initial decision that was published on August 27. The FSPro from August 27 – "Initial 14 day calibration from 8/24 spotting," – used three days of forecast weather starting from August 25 and going through September 7. The analysis shows not only the effect of the weather for August 25-27, but also the climatology this time of year. During this period, the fire did not really grow beyond creeping and smoldering with some roll out (see Figure G2).

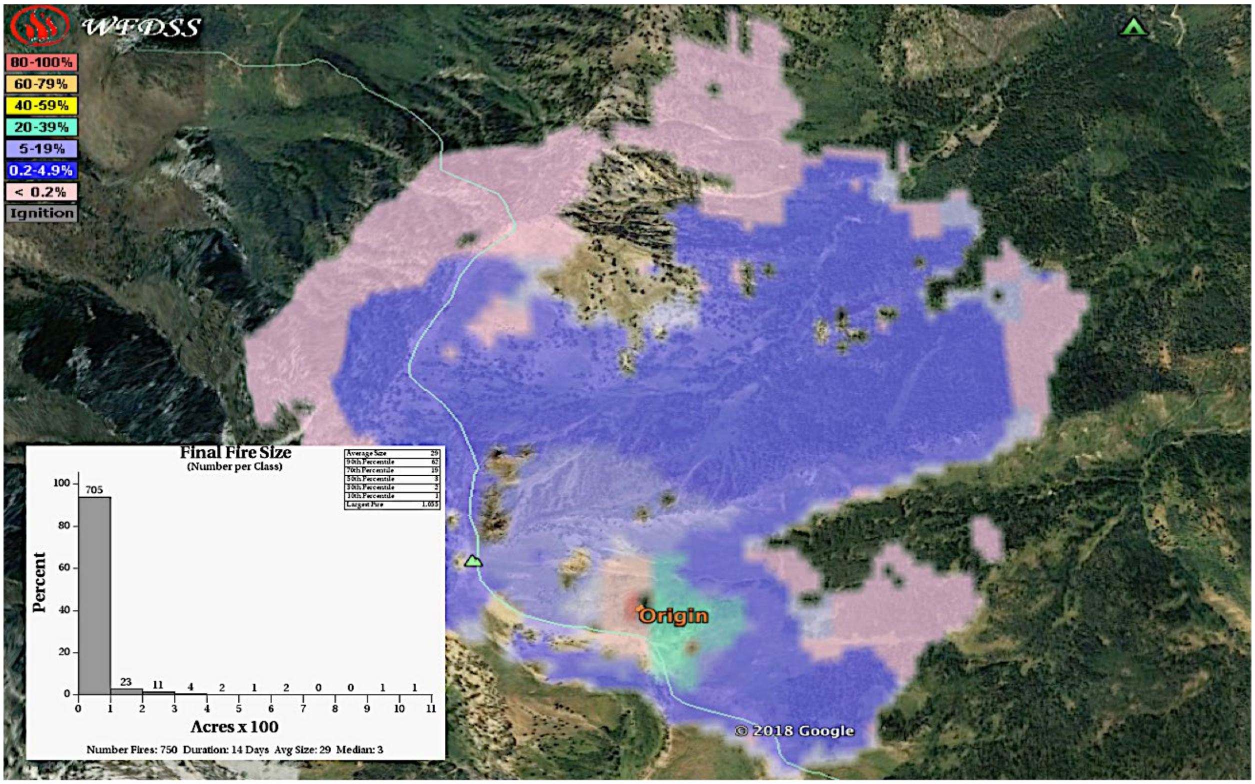


Figure G2 – *Bald Mountain FSPro run August 26 "Initial 14 day calibration from 8/24 spotting" for 14 days (August 25-September 7). North is to the top of the image. The fire size histogram is inset.*

As the weather began to warm and dry toward the end of August and the frontal passage of September 10 approached, no new FSPro (or other fire behavior analyses) was done. In an effort to assess the driving factors behind the September 10 fire growth, a Short Term Fire Behavior (STFB) run was done in WFDSS to utilize the gridded wind output and the Major Flow Paths (MFPs).

The run shown in Figure G3 was modeled on September 10 using a 13 mph wind from 281 degrees. The colored arrows shown on the image are the outputs of WindNinja and show the wind direction and speed, as modified by the topography. The perimeter from 1245 on September 12 is shown in red and the perimeter from 1045 September 13 is shown in orange. From September 10-13, the daily prevailing winds from ~1100-1900 were from the west, with some minor variations. The wind vectors from the west explain the growth through September 12. The prevailing wind kept the fire on the SSE facing slope, in effect causing a downslope wind.

Once the fire crested the ridge to the north on the 12 and became exposed to the wind, the Major Flow Paths (MFPs) show the combined effect of fuels and wind and track fairly well with the actual growth based on the perimeter of the 13. Wind was instrumental in the spread of this fire as is apparent when examining the perimeter from September 13. The fire perimeter's frequent intersection with the blue wind vectors indicate that the fire spread slowed significantly due to sheltered winds. The dependence on the wind for spread can again be seen in Figure G4, which shows the gridded winds from the 12 at 1400, and again demonstrates sheltering from the wind along the eastern perimeter of the 13.

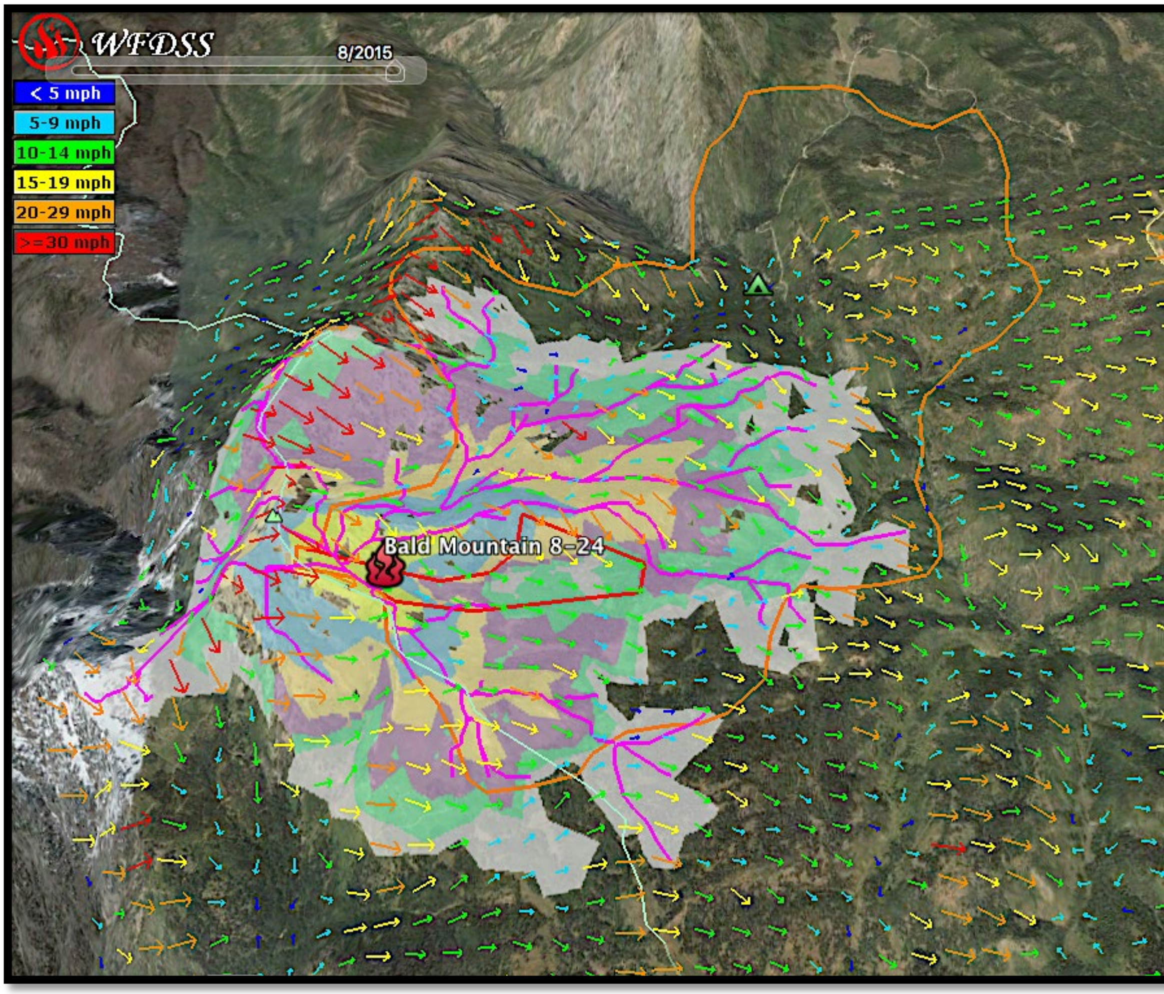


Figure G3 – *STFB "FLA 4-5 Bald 9-10 18hr" Major Flow Paths in purple. September 12 perimeter in red and September 13 perimeter shown in orange. This analysis assumes no suppression and was run for September 10 at 1400 for 18 hours of burning with a 14 mph wind at 291 degree. North is to the top of the image.*

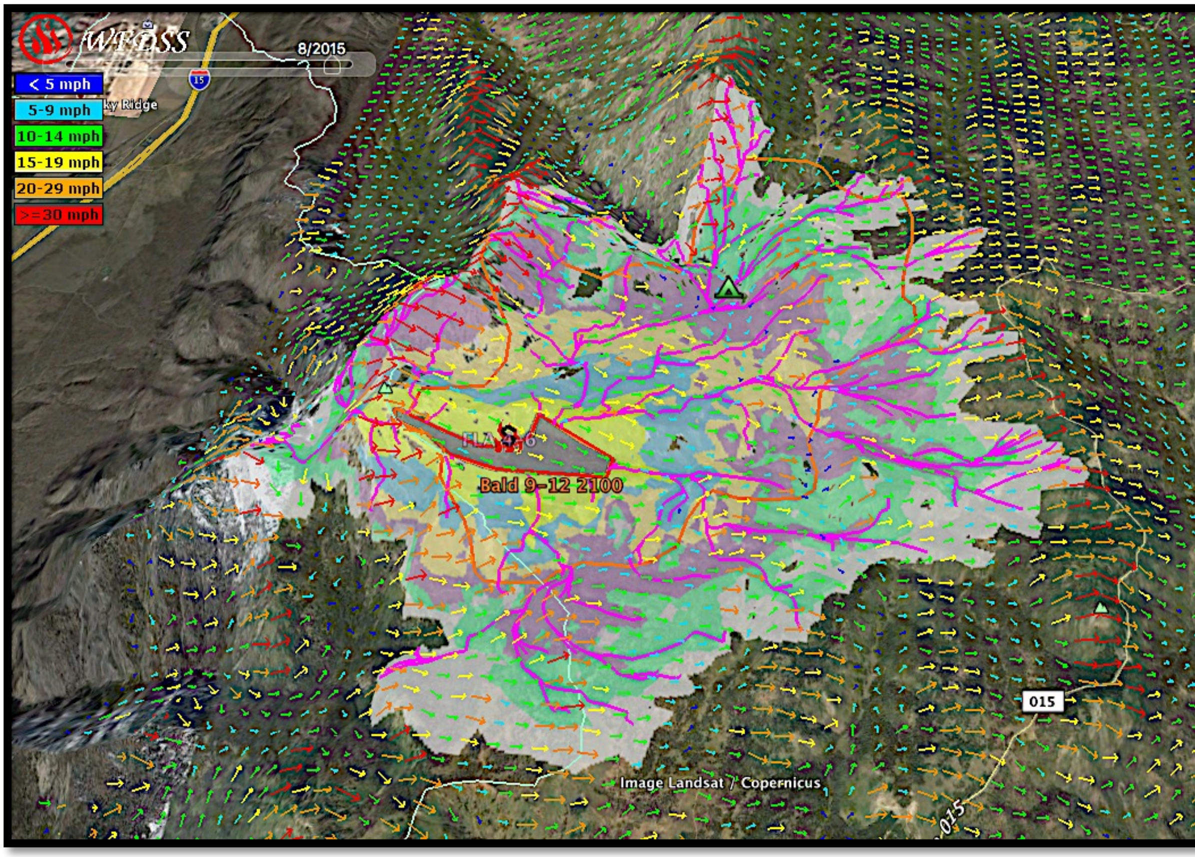


Figure G4 *– STFB "FLA 4-6 Bald September 12 18hr". Major Flow Paths in purple. September 12 perimeter in red and September 13 perimeter shown in orange. This analysis assumes no suppression and was run for September 2 at 1400 for 18hrs of burning with a 15mph wind at 261 degrees. North is to the top of the image.*

Figure G6 shows the FSPro run that was done on the 13 for the Bald Mountain Fire. It again demonstrates not only the effect of the wind but also the rarity of the fuel conditions that propagated the fire spread. The purple line in Figure G6 shows the IR perimeter from 0445 on September 15. Notice the wind-driven shape that runs out to the .2-4.9% probability radii. This is mostly due to the extremely dry nature of the fuels, and in part due to the wind. During this time, a rare event occurred from September 10-16 with the combination of ERC near the 97th percentile, Red Flag conditions for high winds, and low RH.

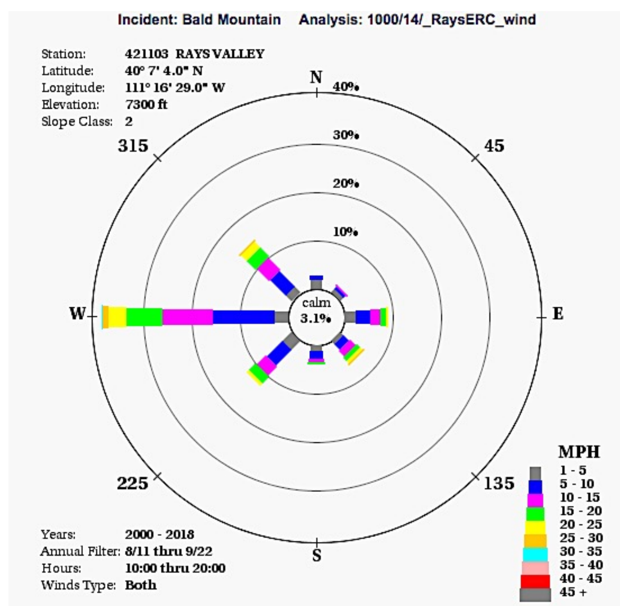


Figure G5 *– Wind rose for 9-13 FSPro run. Rays Valley RAWS 1000-2000, August 11 to September 22 from 2000 to 2018.*

Figure G5 shows the predominant wind directions and speed for the Rays Valley RAWS for the September 13 FSPro run. It is evident from this wind rose that 5-15 mph west winds are the most prevalent winds during this time of year. It stands to reason the higher wind speeds from the west and southwest with very low RHs would push the fire into the lower probability radii, since the combination of these conditions is less represented in the climatology.

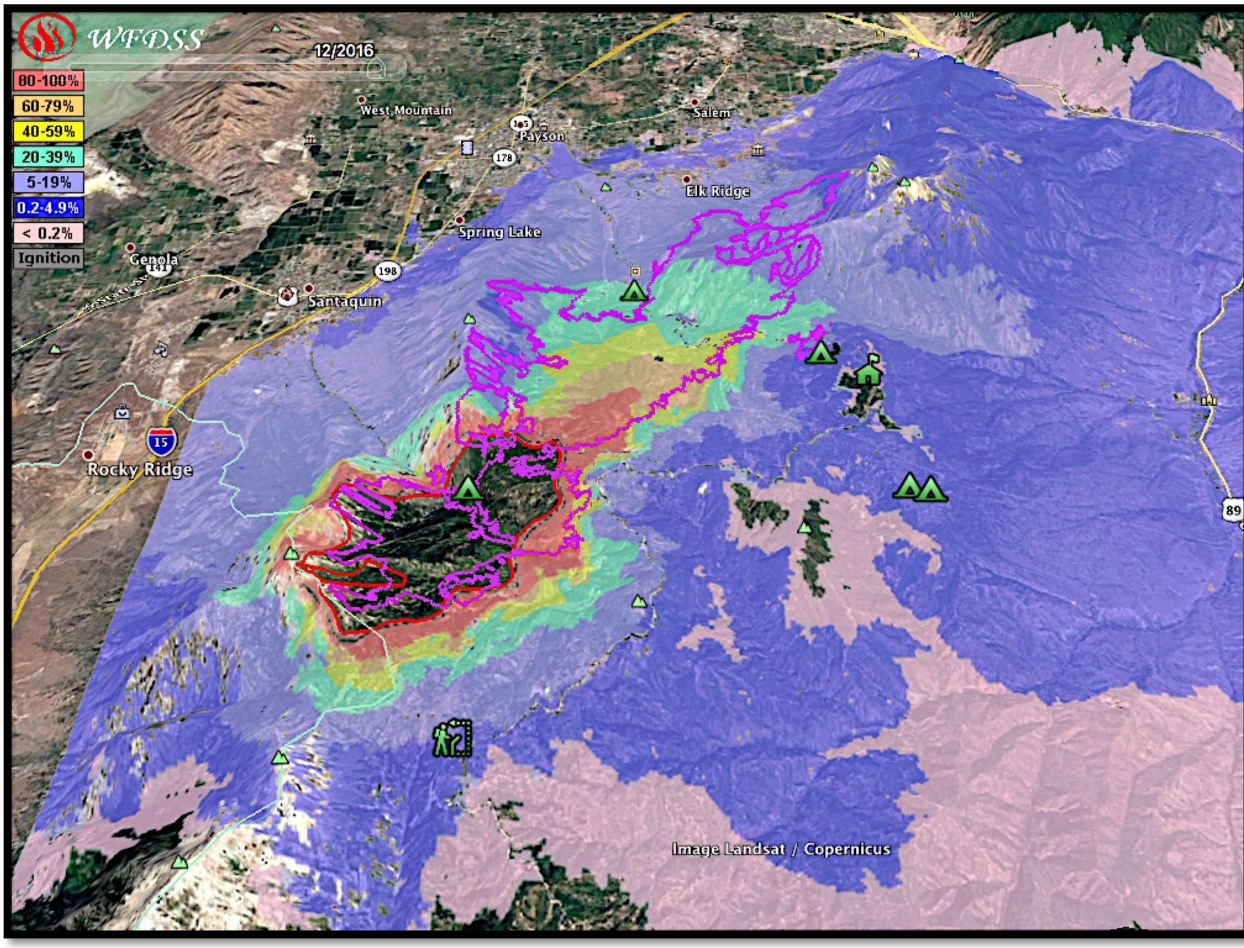


Figure G6 – *FSPro run "1000/14/_Rays ERC wind" that was run on September 13 with the September 13 1245 perimeter for 14 days with three days of forecast weather assuming no suppression. The September 15 0445 IR perimeter is shown in purple. North is to the top of the image.*

Bald Mountain – Expected Fire Behavior

The FLA Team asked an analyst to create an STFB run that reflected the expectations of the local unit. This enabled a comparison of what actually happened to their expectations regarding fire behavior on north slopes. Nothing was changed between the runs except the fuel model to a 181 (very slow spreading timber litter) on the north slopes between 315 and 45 degrees.

Figure G7 shows the dramatic effect of north slopes being less receptive to fire spread in the changing of MFP location and distance traveled over the 18 hours for the initial projection starting on August 25. This analysis shows MFP and potential that seem to be more in line with the local unit's initial expectations of fire behavior. This does of course assume that even at the 97th percentile of ERCs that the north slopes would still exhibit fire behavior that would be associated with the 80th percentile and below, which would be more typical for late August and early September on the UWF.

Both analyses over-predict potential growth on August 26 probably due to shorter burn periods caused by high RH recovery, comparatively high minimum RH values, and afternoon cloud cover. The non-calibrated analysis of the growth on September 12 is only slightly over predicted due to the length of the burn periods. When looking at the 12 hours of spread (dark purple in Figure G4), predicted spread is close to observed. In contrast, the north-slope calibration under predicts by about half. The difference between the north-slope calibration run and the no-calibration run helps to explain the local personnel's surprise as the north slopes became involved, adding to the rapid fire growth.

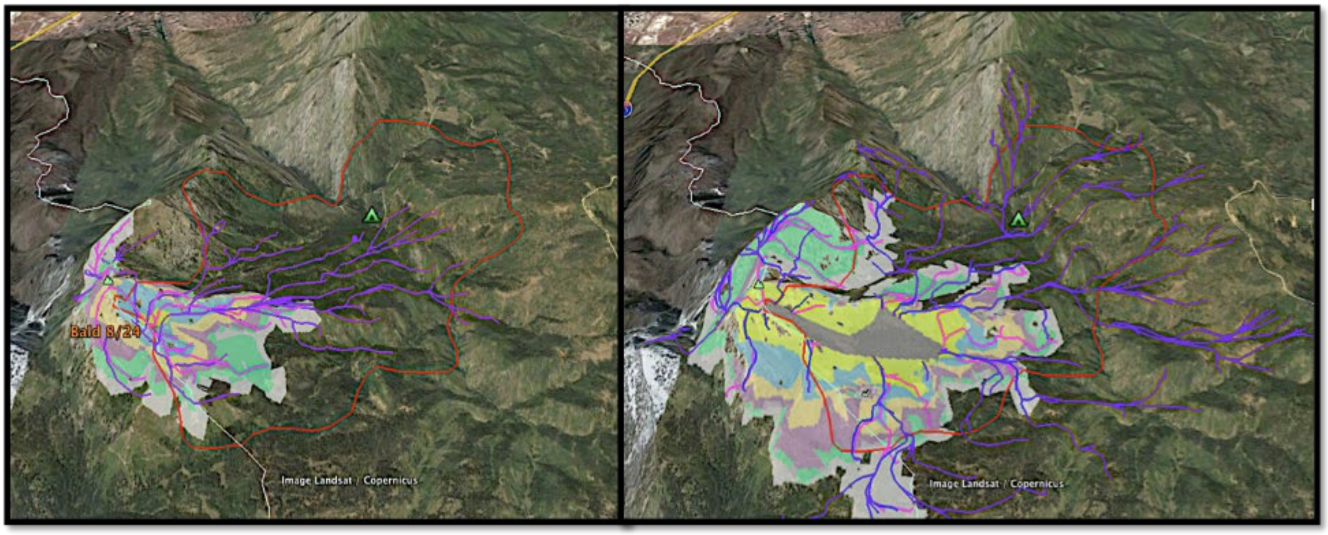


Figure G7 – *Comparison of STFB from August 25 and September 13 showing north-slope slowing effect. North-slope effect shown in pink with arrival time and no north-slope effect in dark purple, with the September 13 perimeter in red. The left image shows the August 26 STFB. The right image shows the September 12 STFB. Both analysis are for 18 hours with gridded winds.*

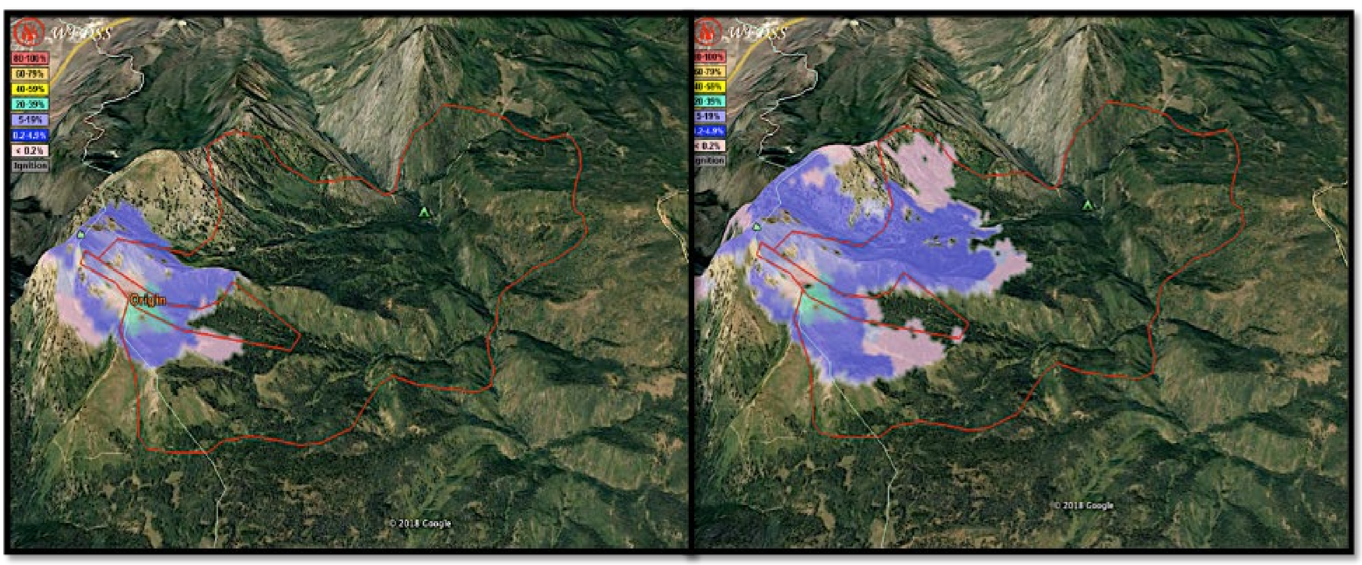


Figure G8 – *Comparison between the north-slope effect calibration on the left and the original FSPro run done on August 26 on the right. The September 12 and 13 perimeters are shown in red.*

Both Figures G8 and G9 show comparisons of the north-slope calibration effect on FSPro analyses. Figure G8 shows a comparison between the original run done on August 26 on the right and the north-slope calibrated run on the left. Had there been time to calibrate based on past experience with north slopes, the original analysis would have looked very similar to the image on the left of Figure G8. It is also important to note that the fire did not start growing out of either analyses probability radii until September 11, which was past the 14-day analysis period, so both analyses would have been valid for the initial period.

Figure G9 shows the north-slope calibration effect on the left and the original analysis on the right. By the time the next FSPro analysis was done on September 13, it would have been apparent that the north slopes were burning, so the assumption that the north slopes would not burn would have been disproved by observed fire behavior.

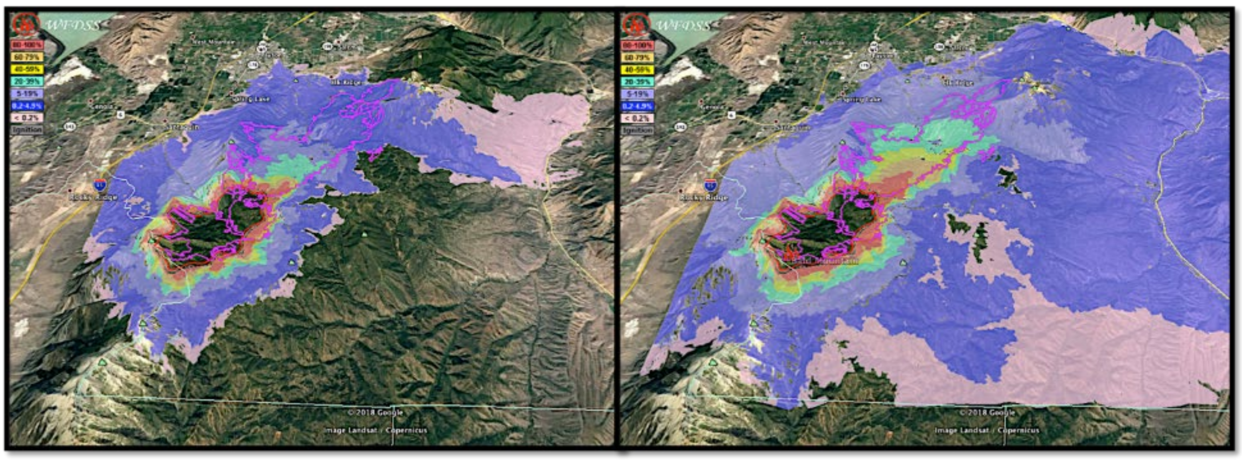


Figure G9 *– Comparison between the north-slope effect calibration on the left and the original FSPro run done on September 13 on the right. The September 13 perimeter was the ignition for this run and the September 15 perimeter is shown in purple.*

Pole Creek – Projected and Observed Fire Behavior

The Pole Creek fire was reported on September 6 after several wet thunderstorms and lightning events. An indirect control strategy was implemented on September 7. None of the fire behavior analyses in this section incorporates these actions.

The initial FSPro run (Figure G13 left) shows the fire having a low probability of spread, due to the current, and forecast ERCs and the higher dead fuel moistures associated with those ERC bins. To give context to the observed fire behavior, an STFB analysis was run in retrospect to show the effect of the gridded winds and major flow paths. Figure G10 shows an STFB run done for September 7 at 1300, using west winds (273 degrees) at 9 mph (at 20 feet). Based on the MFP orientation along the ridge to the north and south of the origin – which is perpendicular to the general and topographically adjusted wind directions – we can infer that fire spread would primarily be influenced by fuels and topography. This pattern was fairly representative through September 9, with primarily west winds ranging between 8 and 15 mph through the burn period (1100-1700). Also not included in this analysis is the effect of rollout, which contributed to the run to the north on September 10. Even with the effect of rollout excluded, the model is predicting a MFP moving downslope to the northeast, towards the base of the box canyon below the ridge between DP 20 and DP 30. Winds are shown to accelerate across the north/south ridge below DP 20 in alignment with the fire origin. The WindNinja output also indicates less sheltering than might be expected in the bottom of the draw to the east of the fire origin. More sheltering from the west wind can be seen in the draw to the west of the fire origin, which was within their initial proposed containment area.

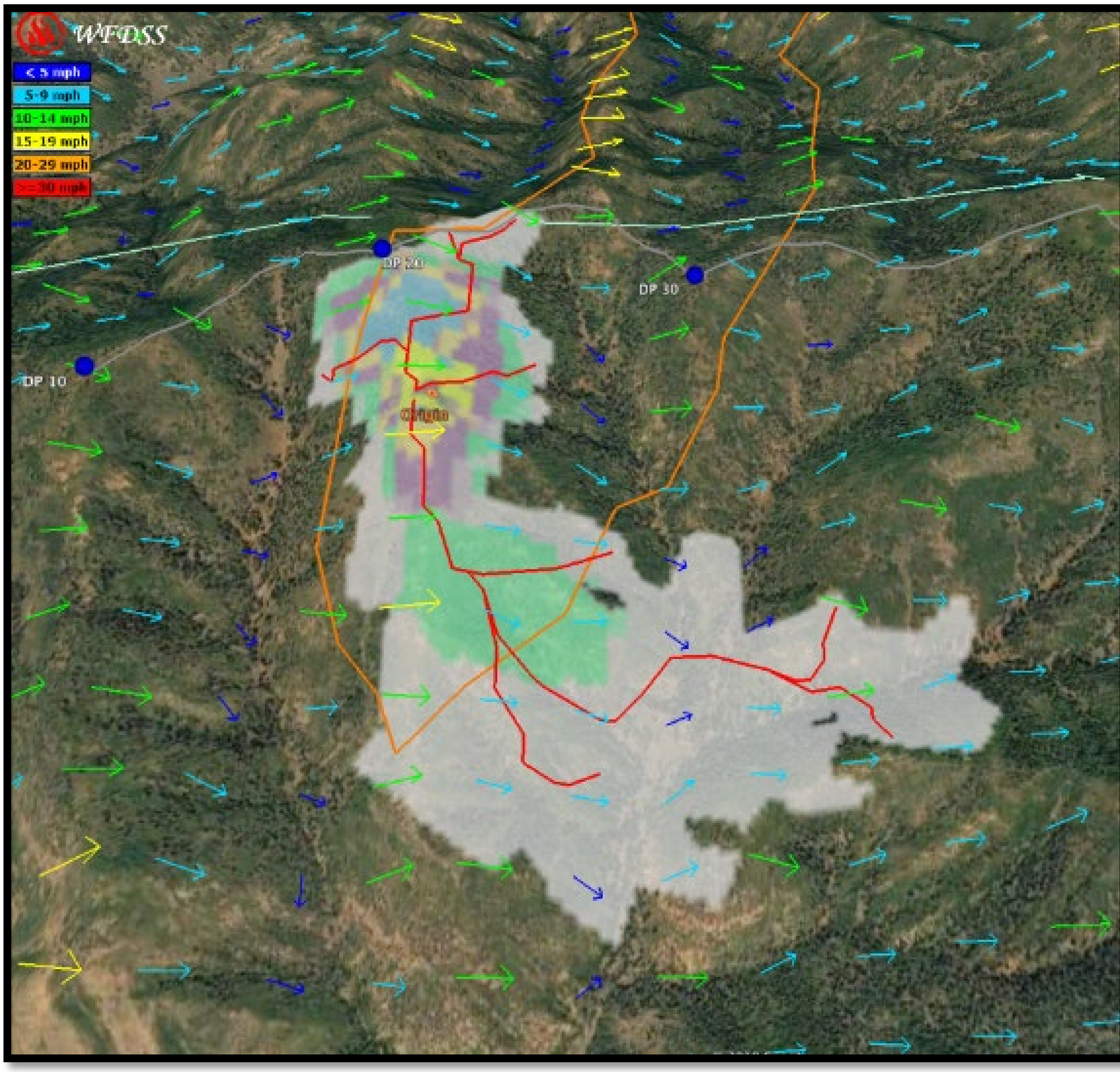


Figure G10 – *STFB run on September 7 1300 for 18hrs, using winds at 273 degrees at 9 mph. The perimeter from September 12 at 2100 shown in orange and Major Flow Paths (MFP) shown in red. The grey line indicates the approximate location of the summit trail. Drop point locations shown in blue are also approximate.*

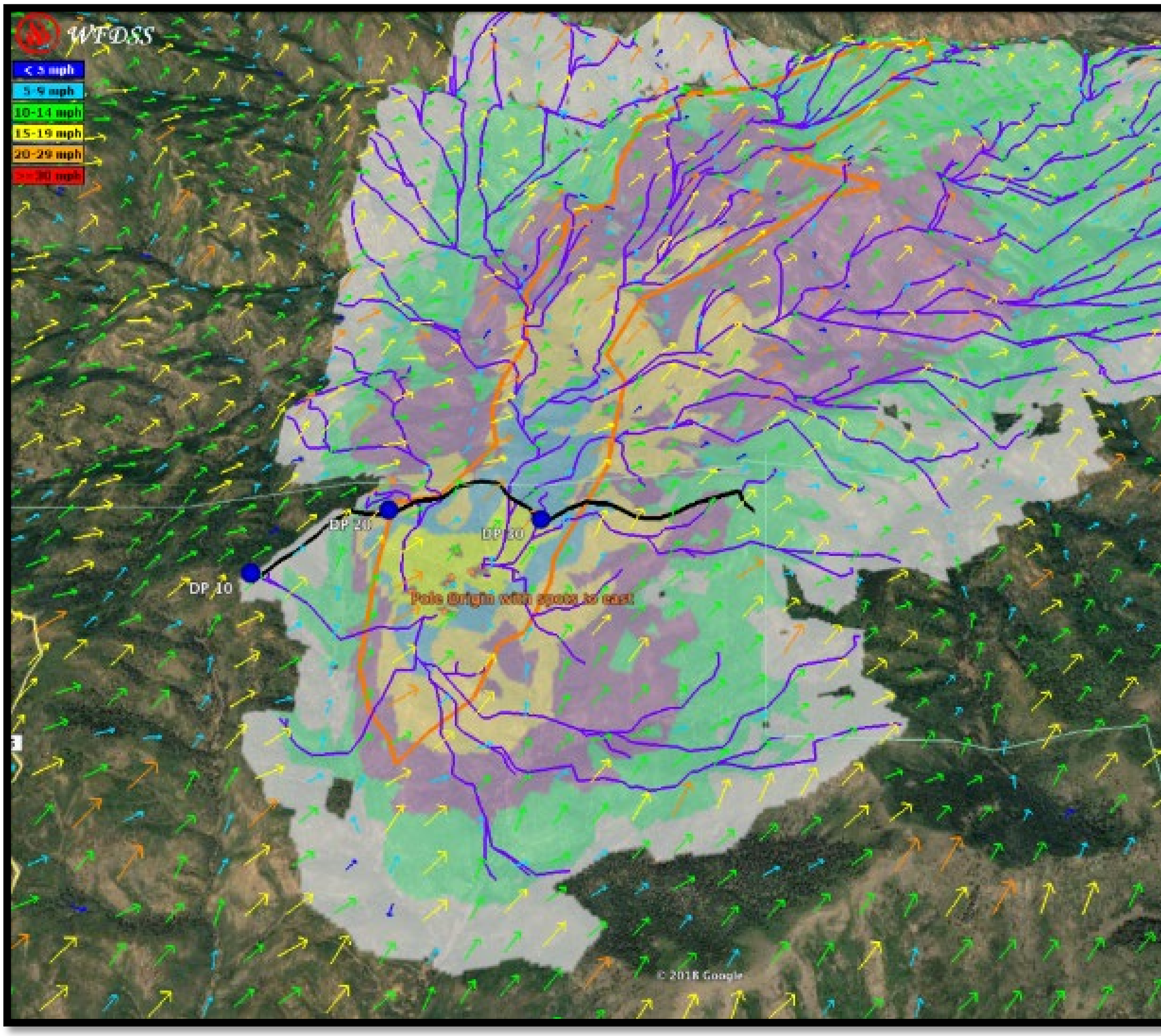


Figure G11 – *STFB run on September 10 1400 for 18hrs, using winds at 225 degrees at 14mph. The perimeter from 9/12 at 2100 shown in orange and Major Flow Paths (MFP) shown in purple. The grey line indicates the approximate location of the summit trail. Drop point locations shown in blue are also approximate. Reported spots and rollout ignitions to the east of the origin were estimated for this analysis.*

The STFB analysis shown in Figure G11 was run for September 10 at 1400. There was about 25 acres of fire on the ground when the Red Flag winds arrived on September 10. Interviews indicated the spots to the east were the most significant fire behavior. The origin and scattered spots to the east were used as ignition sources in this analysis. The spots to the east were based partially on the MFP for September 7. The output seems to be representative based on eyewitness accounts of fire behavior on September 10-12. Using the perimeter from 2100 on September 12, it is clear that most of the actual fire growth occurred along the main branch of the MFP, originating from the roll out. Lateral MFPs that are perpendicular to the wind vectors do not represent observed fire behavior, indicating that the growth event from September 10-12 was primarily wind driven. Although fuels were obviously available and promoted fire growth, they were not the primary driver.

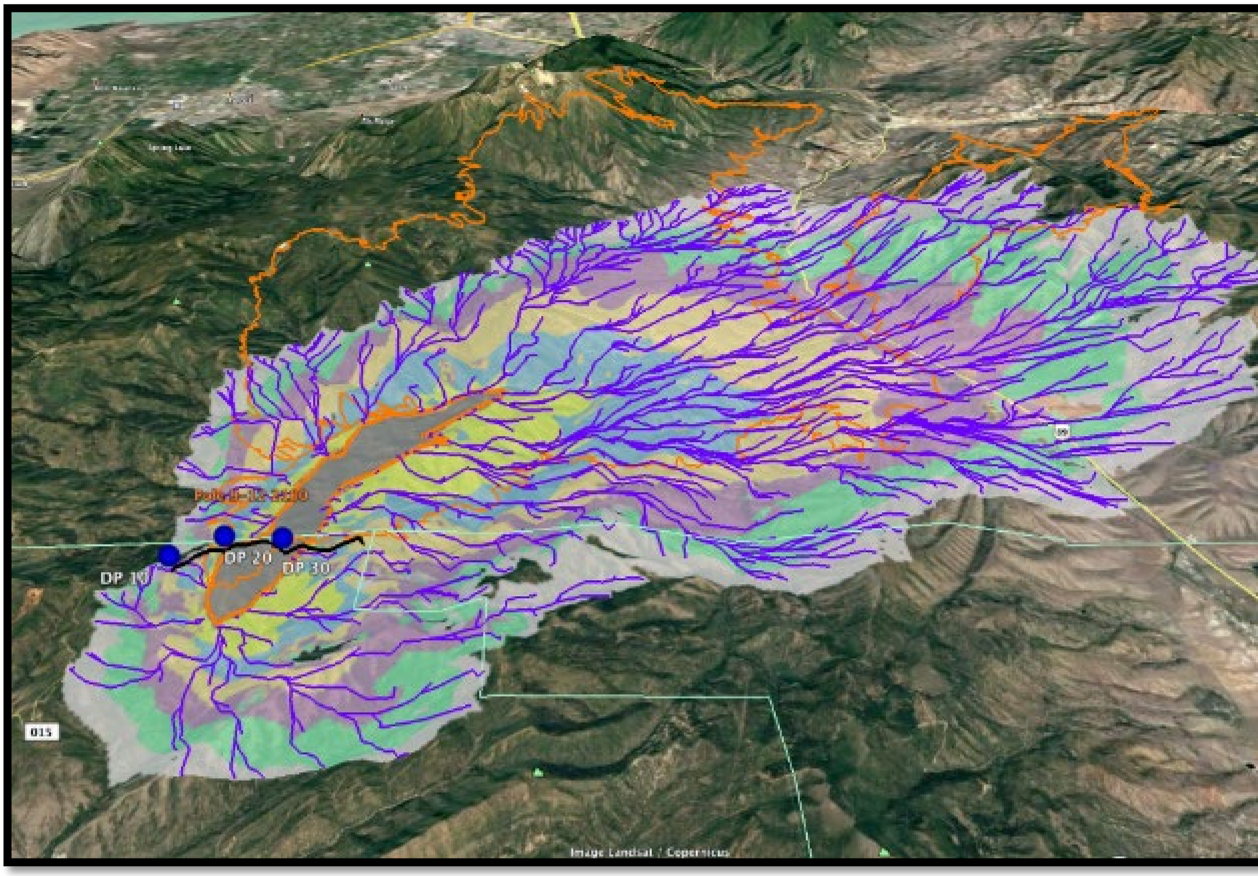


***Figure G12** – STFB run on September 13 1400 for 18hrs, using winds at 245 degrees at 15 mph. The perimeter from September 15 at 0445 shown in orange and Major Flow Paths (MFP) shown in purple. The black line indicates the approximate location of the Summit Trail. Drop point locations shown in blue are also approximate.*

Figure G12 shows a STFB analysis for the 1400 September 13. Due to the very low RHs during this period, the fire was burning actively day and night, so it experienced a variety of winds. The strongest winds were west and southwest, so that is what was used for this analysis. Much of the north and northwesterly growth was likely due to spotting and fuels-driven fire spread during low wind speed and low relative humidity periods. Existing fire behavior models are not complex enough to incorporate the effect that indrafts and short distance spotting have on fire growth. The areas where this type of fire behavior might have been more prevalent – such as on the north and northeast portion of the fire – are not reflected in this analysis. However, STFB analyses effectively represents areas where the fire behavior was driven by topography, fuels, wind, or a combination of those factors. The MFP accurately models fire spread influenced by the alignment of fuels, topography, and wind, including fire spread over the ridge between DP 20 and DP 30 on September 10 (Figure G11), as well as where the fire crossed Highway 89 (Figure G12) .

By September 13, the spread probability radii (Figure G13 right) were much larger as a result of the forecasted ERCs in the 97th percentile and the 20+ mph SW winds. Southwest winds are less frequent at the Rays Valley RAWS during the period from August 25 to October 6. When totaling the weights for the forecasted winds, they fall into bins that total ~4%. The relative infrequency of 20+ mph SW winds can also be seen by looking at the yellow band of the SW wind direction in the wind rose in Figure G14. This reinforces the assertion of local resources and Predictive Services that the consecutive days of Red Flag Warnings, due to high speed SW winds and low RHs that occurred from September 10-16, are an infrequent occurrence (see the fuels, weather and climate section for more details).

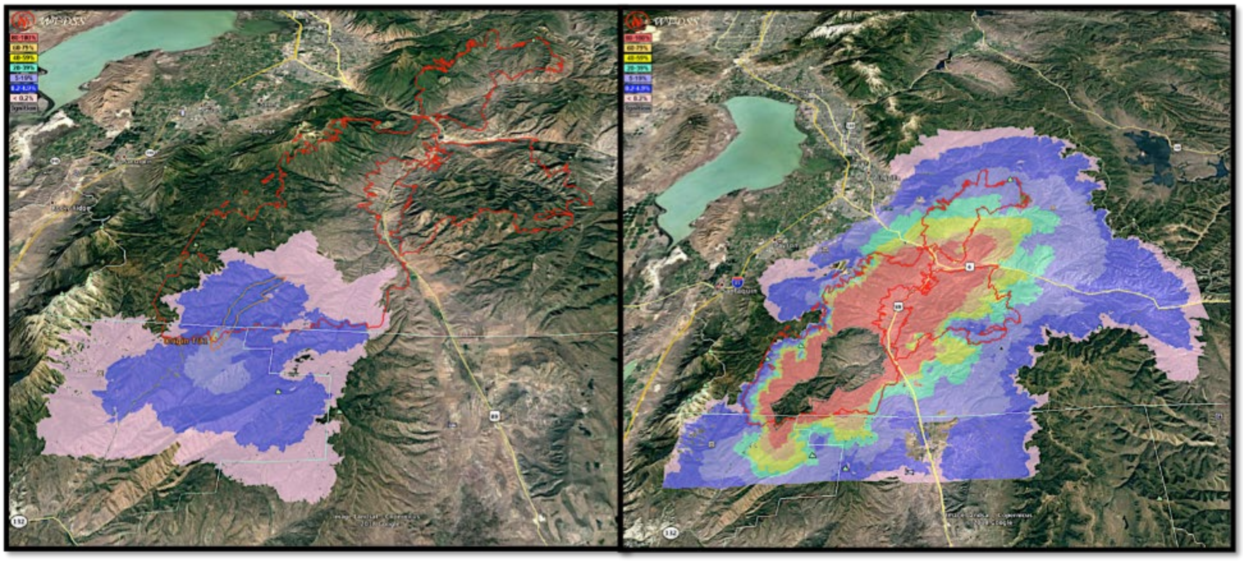
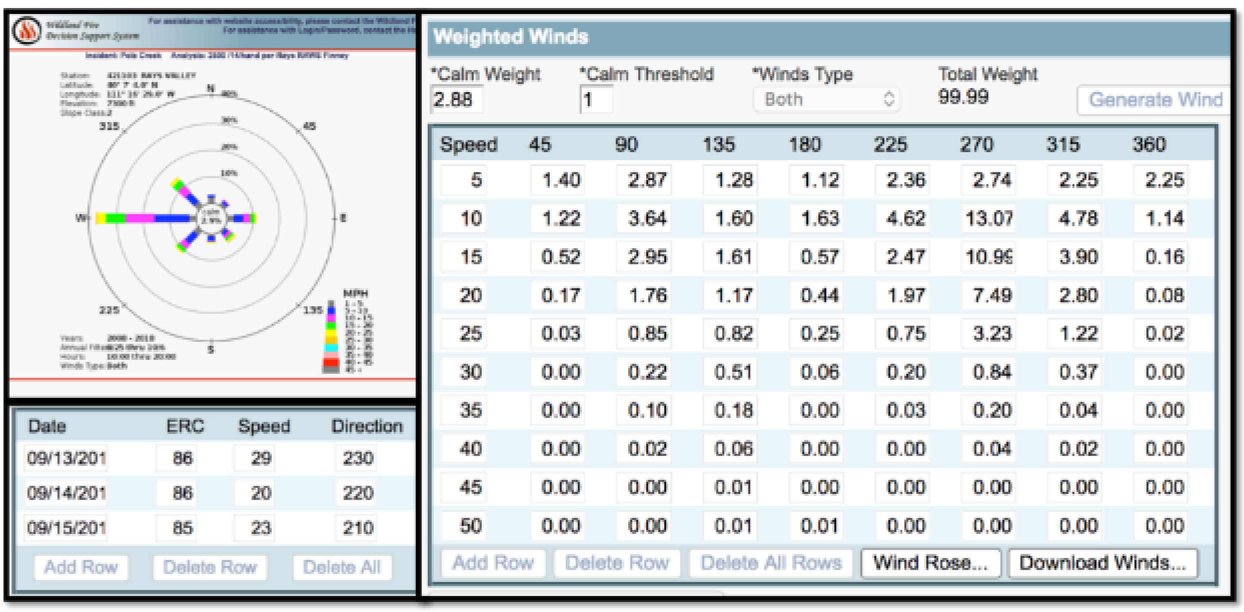


Figure G13 – This figure shows the original FSPro analyses done on September 8 on the left and September 13 on the right, with the September 15 0445 IR perimeter shown in red.



Speed	45	90	135	180	225	270	315	360
5	1.40	2.87	1.28	1.12	2.36	2.74	2.25	2.25
10	1.22	3.64	1.60	1.63	4.62	13.07	4.78	1.14
15	0.52	2.95	1.61	0.57	2.47	10.9	3.90	0.16
20	0.17	1.76	1.17	0.44	1.97	7.49	2.80	0.08
25	0.03	0.85	0.82	0.25	0.75	3.23	1.22	0.02
30	0.00	0.22	0.51	0.06	0.20	0.84	0.37	0.00
35	0.00	0.10	0.18	0.00	0.03	0.20	0.04	0.00
40	0.00	0.02	0.06	0.00	0.00	0.04	0.02	0.00
45	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00

Date	ERC	Speed	Direction
09/13/201	86	29	230
09/14/201	86	20	220
09/15/201	85	23	210

Figure G14 – Wind elements from the September 13 FSPro run. Upper left shows the wind rose for Rays Valley RAWS for 2008-2018, August 25-October 6 from 1000-2000 hours for both gusts and 10 min average wind. The image on the right shows the binned data that is also represented in the wind rose. The lower left image shows the forecasted ERC, wind direction, and wind speed.

Pole Creek – Expected Fire Behavior

As with the Bald Mountain fire, the FLA Team asked an analyst to create an STFB run that reflected the expectations of the local unit. This enabled a comparison of what actually happened to their expectations regarding fire behavior on north slopes. Nothing was changed between the runs except the fuel model to a 181 (very slow spreading timber litter) on the north slopes between 315 and 45 degrees.

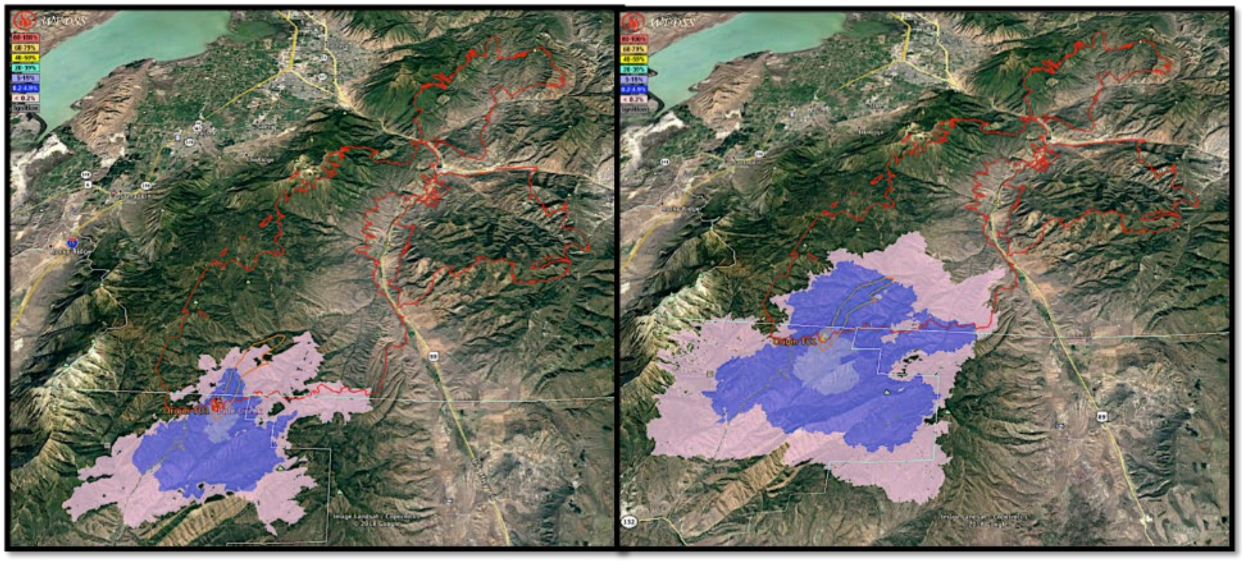


Figure G15 – *Comparison between the north-slope effect calibration on the left and the original FSPro run done on September 8 on the right. The September 22 perimeter is shown in red.*

Figure G15 shows the initial FSPro run done on September 8 (right) and the north-slope calibration (left). Both analyses have large radii of low probability of spread. The uncalibrated run shows the larger radii, and indicates the greater potential size of spread events. The large size of the lower probability radii reflects a potential for large fire growth due to relatively few days of 90th and 97th percentile ERCs in conjunction with high-speed wind events in the climatology.

Adding to the small high probability radii were the three days of forecasted ERCs that fell into the 70th and 80th percentile. Essentially what Figure G15 illustrates is 1) local managers imagined that the landscape would act more like the left side, with very, very low likelihood of significant movement to the north; and 2) actual conditions were really more like those depicted in the frame to the right because the north slopes were not acting as barriers to fire spread.

These are still very rare events that would cause a significant north push. Even though this model shows a higher potential for north spread than what managers imagined, it still does not indicate that such spread is a certainty.

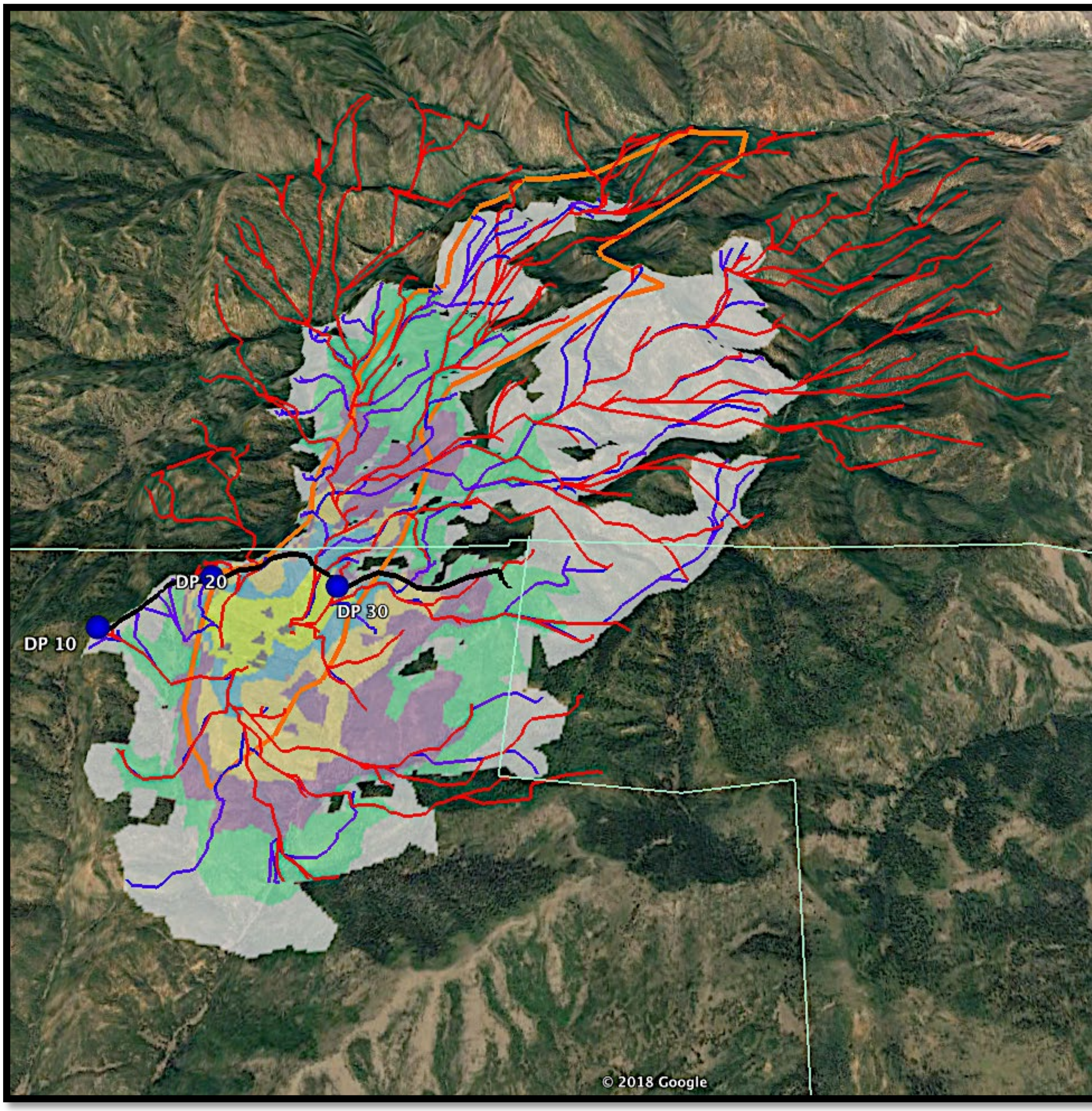


Figure G16 *– STFB analysis for September 10 with the north-slope calibration MFP shown in purple and the uncalibrated analysis shown in red. The September 12 2100 perimeter is shown in orange.*

September 10 saw the first of seven consecutive Red Flag Warnings for high winds and low RH. Figure G16 shows a comparison of MFP for an uncalibrated landscape in red, and a landscape that is calibrated to minimize fire growth on north slopes (MFPs are shown in purple). This comparison shows that fuels are somewhat important in fire spread with regard to spread on north slopes. This is depicted in the deviation where purple can be seen outside of the red. The purple and red MFPs overlap shows areas more driven by winds and topography, and north slopes was not a factor. The area between DP 30 and DP 20, where the fire crossed the ridge and the Summit Trail, is an example where the effects of wind and topography were overriding factors for fire spread. In that area and beyond, the model favors fire spread regardless of whether the north-slope fuels were modeled as having a slowing effect or receptive effect on fire spread to the north and northeast.

The next FSPro analysis was done on September 13 (Figure G17), and by that time the ERC value had recovered to 86, which is in the 97th percentile. This increase in the observed and forecasted ERC values from September 8 resulted in significantly larger spread probability radii. There was a noticeable difference between the north-slope calibration (left) and the original analysis (right), but both analyses were valid for the analysis period. In both cases the fire spread to lower probability radii, partially the result of the ERCs (fuels) being in the 97th percentile. It is clear that winds heavily influenced the fire behavior and growth. The SW winds that pushed the fire occurred with low frequency in the wind bins (Figure G14) but were present in the forecast. This had an effect on the fire spread probability, both with and without the north-slope calibrations.

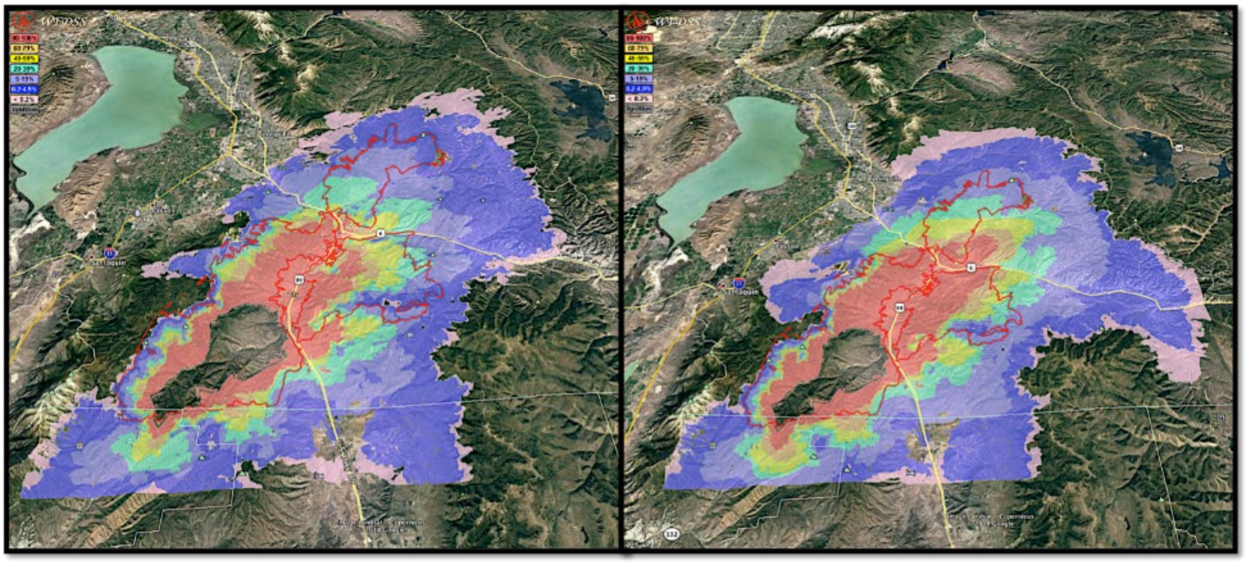


Figure G17 – *Comparison between the north-slope effect calibration on the left and the original FSPro run done on September 13 on the right. The September 22 perimeter is shown in red.*

Research Fire Products and Analysis

Suppression Difficulty Index (SDI) is an experimental product that Risk Management Assistance Teams have been testing to determine utility for fire managers. The SDI product shown in Figure G18 with proposed containment areas for the Pole Creek Fire, shows where it is relatively easy versus relatively difficult to perform fire control work based on slope/topography, fuels, expected fire behavior, fireline production rates, and accessibility (distance from roads/trails). The 80th percentile SDI shows that in the immediate area of the fire, suppression difficulty was relatively low. However north of the Summit Trail there is a large area where it is more difficult to work. Considering the initial goal to allow this fire to affect a 200-300 acre area, it is apparent that the selected containment boundaries have merit. It is also apparent that holding the Summit Trail is critical to the success of the control plan. The importance of holding the Summit Trail seemed to be more evident to the firefighters on scene on September 10-11 than to managers back at the office.

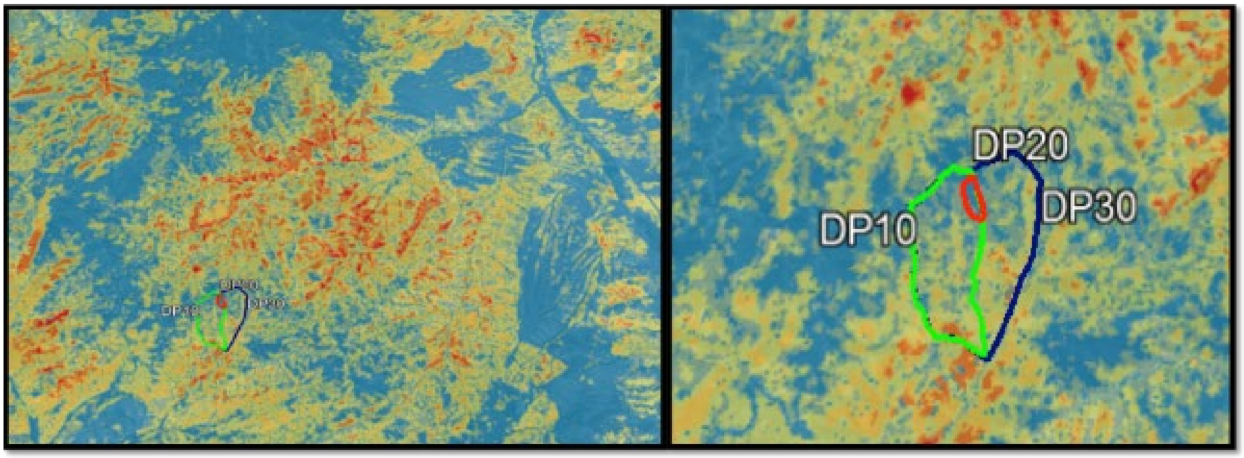


Figure G18 – 80th percentile SDI, with landscape view on left and the zoomed in view on the right. The Pole Creek Fire initially proposed containment is shown in green.

Potential Control Locations (PCL) is another experimental RMAT product that operates much like experienced firefighters' decision process to assess potential control points. It looks at past fire perimeters and estimates probability of a control location's success based on where those historic perimeters intersect with natural barriers, fuel changes, slope, topographic features, and the SDI roads and trails. According to the PCL model, fuel transitions (which are often associated with changes in aspect/topography in this area) were the primary driver for historical fire perimeter formation, with road/foot access and natural barriers also showing strong association with past perimeters (Figure G19).

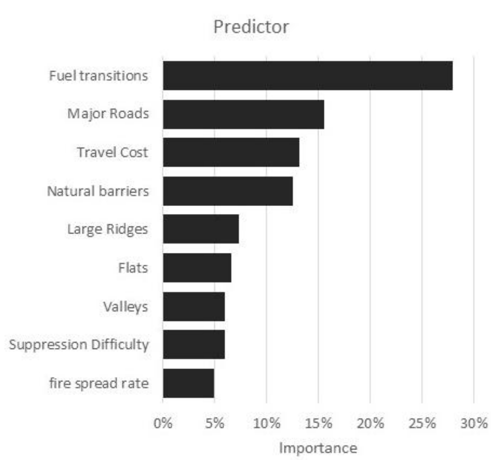


***Figure G19** – This shows the relative importance of factors associated with the historical fire perimeter analysis.*

When taken in context with the goal to allow this fire to affect a 200-300 acre area, Figure G20 shows that the initially selected containment boundaries have merit. The Summit Trail is shown to be the kind of feature that is effective for creating fire edges (look closely at the narrow green bands between DP10 & DP30). However as you move downhill to the south, there are fewer fuel transitions. Fewer natural barriers and lack of access reduces the likelihood of establishing a fire edge. This model does not mean that a fire cannot be stopped in these orange or red areas, it simply means that the probability of success is lower there than in the green and blue areas.

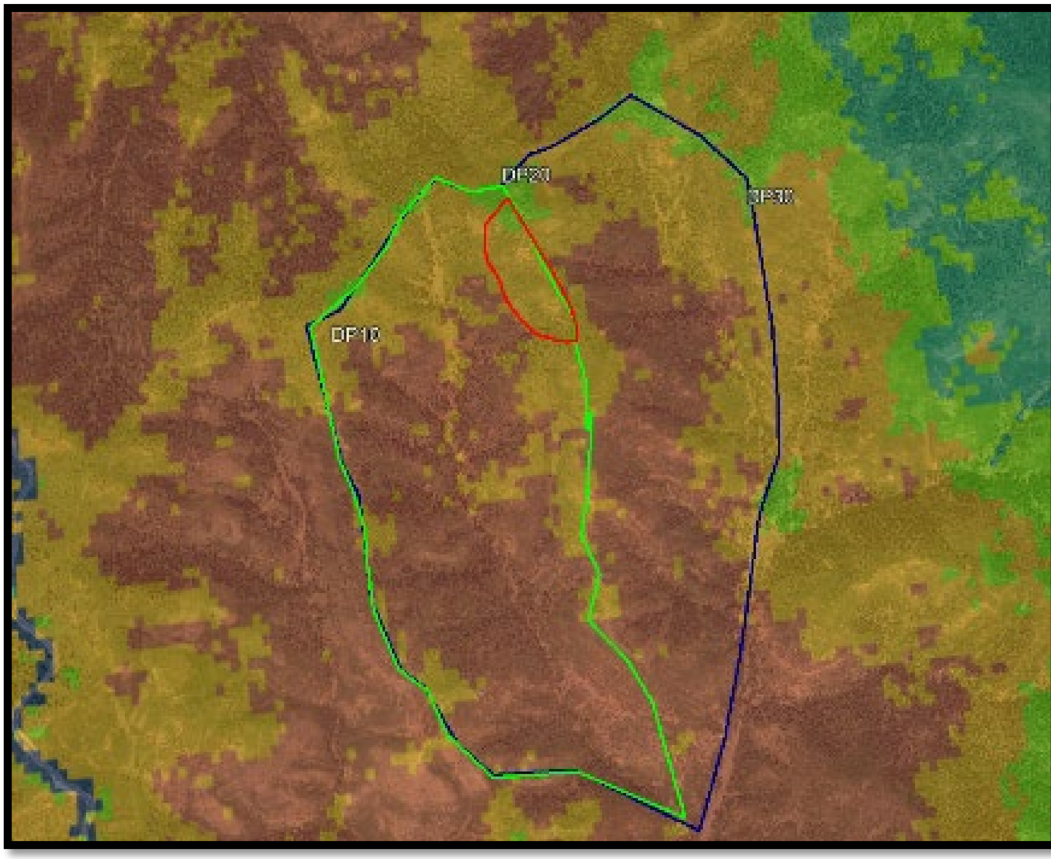


Figure G20 – *Close-in view of the Pole Creek Fire and initial proposed containment on the PCL map. Initial containment shown in green, with contingency in blue.*

When examining Figure G20, it becomes evident that the area to the east of the 25-acre fire on September 9 is not a place where the model predicts formation of fire edge. This indicates fires tend to spread through this type of landscape. In fact this is where initial control problems developed on September 10, with the fire first spotting east and then north across the trail between DP20 and DP30 and establishing in another red area north.

The PCL predicted there was a good chance this fire would form an edge to the north and east of where the fire perimeter was on September 10. This is consistent with what local managers and the IMT3 expected. But the weather and fuel conditions that were actually experienced pushed the fire through a potential control feature that both the PCL indicated and some firefighters believed would hold.
The PCL, which is based on a "machine learning algorithm," was equally "surprised" that this fire did not form an edge before reaching Highway 89. This speaks to the uniqueness of the weather and fuels scenario that resulted in fire behavior unlike that experienced by either firefighters or the historical data set used to train the PCL model.

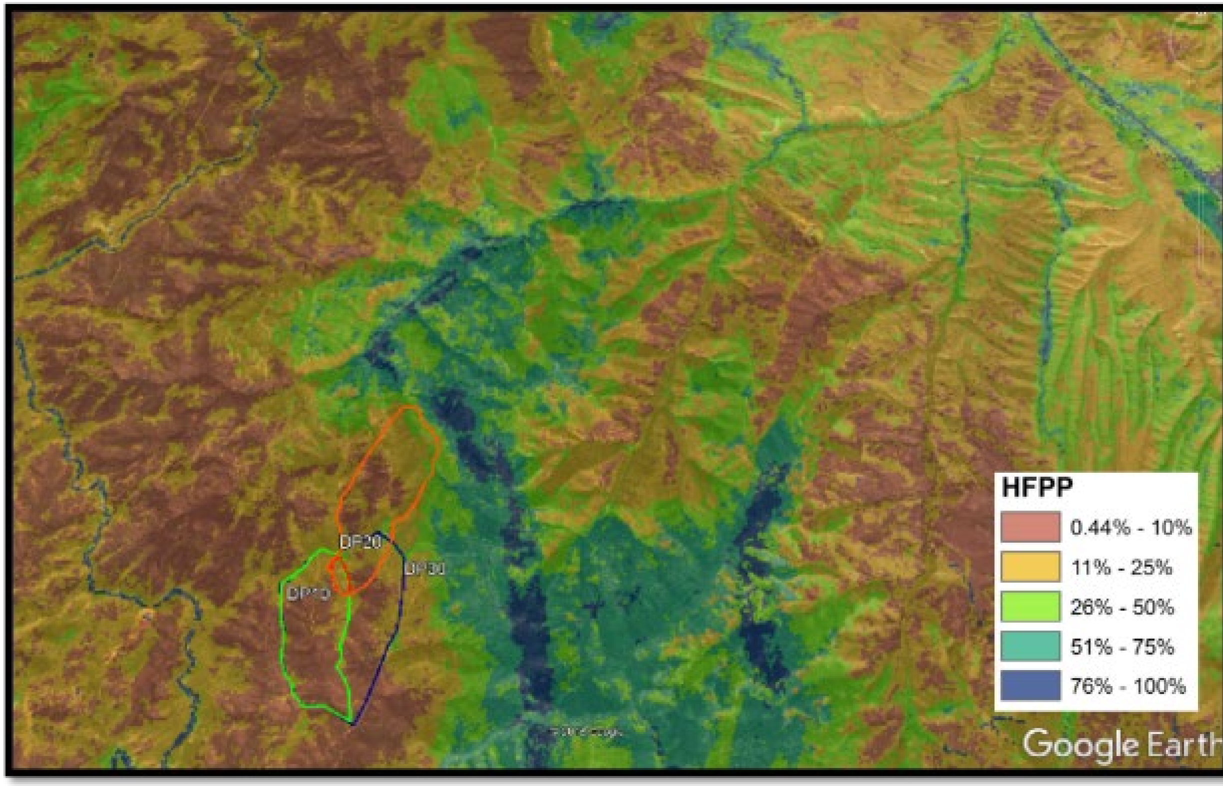


Figure G21 *– PCL with the fire perimeter from September 12 in orange, primary containment in green, and contingency in dark blue. Notice the high probability of containment where the fire paused on the 12th.*