On the Use of Fire Behavior Models for Decision Support
Part III (Final): Table-top Application and Evaluation of WFDSS Results

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1. INTRODUCTION

In the fall of 2010, a presentation was given to the Gateway Interagency Fire Front (GIFF), a multi-agency wildland fire mutual aid response group based in Pocatello, Idaho. The presentation focused on the use of the Wildland Fire Decision Support System (WFDSS) (see Wildland Fire Decision Support System) for producing timely fire behavior modeling information which might be used to support the aggressive fire suppression actions taken by the first responders arriving at a wildfire, actions typically referred to as *initial attack* (Glossary of Wildland Fire Terminology, 2006). The presentation highlighted results from several local wildfires to show the potential for producing skillful forecasts of fire spread. At the time, the newly fielded system was being used intermittently by wildland fire specialists to model fire behavior on incidents generally two or more days following discovery (Fig. 1) while a much smaller percentage of model runs were conducted to support fire management activities during initial attack (Day 1). That part of each 24-hour period when fires spread most rapidly, typically 1000 LT to sundown, is commonly referred to as a *burning period* (Glossary of Wildland Fire Terminology, 2006). Critical fire management decisions which occur within the *initial* burn period can have significant ramifications on the resulting size and cost of the incident. The main thrust of the presentation was geared toward exploring the concept of using this new tool to generate preliminary fire behavior and decision support guidance for use during this critical period in an effort to help improve the outcome and safety of fire management actions. One local Incident Commander associated with the GIFF was intrigued by the idea and was willing to explore the concept further.

In the spring of 2011, a post-analysis of the Howard Fire, located approximately 4 km east-southeast of the Pocatello Regional Airport in southeast Idaho, was used as a back-drop for further exploration into the application and use of the WFDSS results during initial attack. The table-top exercise began with a sketch of the fire management activities that likely occurred on the incident starting with the initial dispatch and ending at the conclusion of the first burn period. The discussion then concentrated on fire management decision support needs and the potential application and usefulness of the WFDSS results throughout the process. Based on this initial discussion, follow-up work was conducted to further illuminate some of the unanswered questions that arose during the dialogue. The results of this discussion and follow-up work are presented below.

2. WILDLAND FIRE DECISION SUPPORT SYSTEM BACKGROUND

a. General Overview

In June of 2005, the National Fire and Aviation Executive Board chartered the Wildland Fire Decision Support System (WFDSS) to replace the Wildland Fire Situation Analysis (WFSA) system. At the time, WFSA had been utilized for over 30 years and had become cumbersome to use and was not meeting the complex needs of the fire management community. In the spring of 2009, the WFDSS was fielded by the US Forest Service with the remaining federal fire agencies (BLM, USFWS, NPS, BIA) following in 2010. The WFDSS was designed to provide the following advantages over the WFSA system:

- Combined numerous fire modeling applications into a single web-based system for easier data acquisition.
- Streamlined the analysis, decision-support, and documentation processes needed for incident reports.
- Provided one decision process and documentation system for all types/scales of wildland fires.
- Allowed timely reporting of critical information across all levels of the federal wildland fire organization using a web-based interface.
- Introduced economic principles into the fire decision process.

b. System Access

Access to the WFDSS is accomplished through a web portal. *Production* and *training* applications are available through an assigned user account, although privileges may vary between either application based upon fire management experience and/or established need.

Federal fire agency employees must provide a government email address with one of the following domains in order to obtain a user account: *bia.gov; *blm.gov; *fs.fed.us; *fws.gov; *nifc.gov; *nps.gov. Non-federal and National Weather Service (NWS) employees are approved, as needed, to support the interagency fire management mission.

c. User Roles

Each user is assigned system level privileges or *roles* within WFDSS. These roles are tied to fire specific functions with increasing levels of complexity. These roles, categorized from least to greatest complexity, consist of Viewer, Dispatcher, Author, Data Manager, Geographic Area Editor, National Editor, Fire Behavior Specialist, Rapid Assessment of Values-At-Risk (RAVAR) Analyst, Super Analyst, Help Desk, and Administrator. A detailed description of each role can be found within the WFDSS Help menu. The Viewer, Fire Behavior Specialist, and/or Super Analyst are currently the three roles available to NWS employees based on experience, fire behavior training, and application access (*production* or *training*).

In production mode, NWS employees are restricted to the Viewer role. Viewers can examine incident information for all WFDSS incidents and groups as well as completed analyses and reports but they are restricted from making any changes to the WFDSS data unless they have incident- or analysis-specific privileges. Access to higher privileges would require specific training in Advanced Fire Behavior Calculations (S490) and Geospatial Fire Analysis, Interpretation, and Application (S495) (Seli, 2010) as well as approval from associated Geographic Area Coordination Centers and/or the National Wildfire Coordination Group.

In training mode, NWS employees can request access to the Super Analyst role. Super Analysts have the greatest authority and implicit ownership of all analyses in the WFDSS. They can provide coaching and training to other analysts and they can run, edit, and accept all types of analyses as well as view all analyses within the WFDSS training application.

d. Training

Distance learning modules, PowerPoint presentations, and training documents are available through the training page on the WFDSS website. Page-level, context-sensitive help is also available within the application and is updated frequently.

e. Fire Behavior Models

A number of powerful fire behavior modeling tools have been incorporated into the WFDSS. These tools provide predictive capabilities that can be used to support fire management decisions. Dispatchers, Authors, Editors, and Incident Owners can run automated Basic Fire Behavior (BFB) and Short Term Fire Behavior (STFB) models on incidents within their geographic area of responsibility. FlamMap and the FlamMap-Minimum Travel Time algorithms (Finney, 2006) are the desktop equivalents to the WFDSS BFB and STFB modules, respectively. These automated analyses allow limited manipulation of the input parameters and are intended to provide a quick view of the potential fire situation.

The Near Term Fire Behavior (NTFB) and Fire Spread Probability (FSPro) modules are more complex fire behavior modeling tools which require the expertise of a Fire Behavior Specialist and/or a Super Analyst. FARSITE (Finney, 2004) is the desktop equivalent to the WFDSS NTFB module. Based upon the flexibility and performance exhibited in previous work (Huston, 2010 and 2011), the WFDSS NTFB (FARSITE) module was used as the model of choice for initial attack modeling in this study.

3. HOWARD FIRE REVISITED - JUNE 17, 2007

The following information was presented in previous work (Huston, 2011) and is partly repeated here for the convenience of the reader.

a. General Description of Event

On the afternoon of June 17, 2007, a wildland fire started approximately 4 km east-southeast of the Pocatello Regional Airport in the northwest foothills of the northern extent of the Bannock Range at approximately 1402 m MSL (Fig. 2). Strong west winds drove the fire east across the ridge (1770 m MSL) and into the western periphery of the city of Pocatello consuming over 650 hec in a little over 9 hours. Little further growth was observed the following day and the fire was declared contained on June 19, 2007.

b. Geospatial Fuel Distribution and Fuel Moisture Conditions

The fuel distribution was predominantly a mix of grass and sage (see Scott and Burgan, 2005; fuel models GR2, GS2, and SH2) with low to moderate fuel loading, typical of the northern Great Basin. Fuel moisture conditions were characterized as *transitioning* from spring green-up into early summer curing as discussed in Huston (2011). Of particular interest were the live fuel moisture readings of 145-160 percent for Basin Big Sagebrush located near Pocatello and 10-hour dead fuel moisture readings near 6 percent, both of which were approaching levels that would normally support high fire behavior (Pollet and Brown, 2007).

c. Synoptic Developments

During the afternoon of June 16, 2007, one day prior to the fire ignition, a vigorous low pressure system advanced east across northern Washington and into northwest Montana by 0600 MDT the following morning. The progression of the low was typical of many late spring storm systems which make landfall in the Pacific Northwest and shift east along the Canadian border. As the low pressure system progressed east across Washington, an associated surface cold front pushed southeast through southern Idaho and into northern Utah by 0600 MDT on June 17 (Fig. 3). A strong postfrontal surface pressure gradient remained across southern Idaho throughout the day resulting in sustained west-southwest winds in excess of 25 mph with frequent gusts greater than 35 mph.

4. INITIAL ATTACK DEPICTION

As previously stated, the actions taken by the first responders arriving at a wildfire to protect lives and property and to suppress fire growth are commonly referred to as initial attack (Glossary of Wildland Fire Terminology, 2006). Initial attack actions are commonly a planned response to potential and/or observed fire behavior. The kind and number of resources responding to wildfires during initial attack varies from event to event depending upon existing fire danger, predicted weather, fuel type, values threatened, and the availability of resources, among other factors (Fireline Handbook, 2004). Initial attack typically involves a small number of resources unless the initial assessment suggests otherwise.

a. Initial Assessment

Wildland fire managers routinely begin their initial assessment or size-up *prior* to departing for an incident. Information concerning fire location, terrain, access, fuels involved, fire behavior, and fire weather, all play a critical role in shaping expectations and ensuring firefighter and public safety (Wildland Fire Suppression Tactics Reference Guide, 1996).

b. Risk Management Process

Upon arriving at the incident, a formal *Risk Management Process* is initiated by fire management personnel *before* taking any on-scene action (Fireline Handbook, 2004). In short, the process involves building situational awareness, assessing hazards, establishing hazard controls, developing a plan of attack, and instituting an iterative process of incident re-evaluation. At the completion of this process, specific tactical instructions are assigned to on-scene forces with an emphasis on maintaining fire fighter safety.

c. Howard Fire Initial Attack Depiction

Documentation of actions taken by land management resources responding to the Howard Fire was not available for this study. However, a plausible depiction of the initial response activities could be inferred from the observed weather, fire behavior, and the operational experience of the incident commander participating in the table-top exercise. This narrative was then used as a back-drop for further exploration into the application and use of the WFDSS during initial attack. The portrayal was by no means meant to replicate the actual actions taken on the incident nor was it intended to be exhaustive in nature.

The first Incident Command Officer would have likely arrived on-scene within approximately 30 minutes of discovery based upon the close proximity of the fire to Pocatello and Interstate 86 (Fig. 2). High fire behavior with flame lengths on the order of 1.2-1.5 m (4-5 ft) and fire spread rates of approximately 600 m/hr (30 chains/hr) would have been expected given the steep terrain, dry fuel conditions, and strong gusty winds. In addition, the morning Fire Weather Planning Forecast (Fig. 4) called for strong gusty winds continuing into the evening with low afternoon humidity, both of which would have supported the expectation that high fire behavior would continue into the early evening hours.

Given the expectation of high fire behavior and the initial lack of timely resources, responding forces would have been directed to employ *indirect* tactics starting from an anchor point at the flank of the fire and proceeding along established roads and jeep trails conducting burnout operations to secure the flank of the fire (Fig. 5, black line). These indirect tactics would continue to be employed into the evening until the fire behavior diminished, allowing forces to utilize *direct* tactical methods.

Of primary concern was the Facer Mountain subdivision (Fig. 2) which lay 4.5 km (2.5 mi) downwind of the fire on the east side of the Bannock Range. Given the initial rate and direction of spread, residents would have been forewarned that an evacuation order might be forthcoming and that it would be advisable to begin moving livestock out of the region as soon as possible.

d. Howard Fire Decision Support Needs

Following the assignment of resources and the initiation of indirect operational tactics, three pressing fire management questions emerged:

1. How far would the fire spread by the end of the first operational burn period? The primary concern here was the potential evacuation of the Facer Mountain subdivision as well as organizing and pre-positioning limited structural protection resources.
2. Would there be any tactical and/or strategic opportunities available within the first burn period to mitigate the impact of the fire? A prominent access road positioned along the main ridge axis appeared to be a potential area from which a control line might be constructed (Fig. 2, tan line) given adequate resources and time to complete the operation. The main concern here would be firefighter safety, timing of the arrival of the flaming front, and fire intensity.
3. What were the fire behavior expectations for the second operational burn period and would additional resources need to be ordered to ensure the success of management objectives? The resource concern here is rather straight forward and primarily connected to securing adequate resources for use during the next operational burn period.

5. WFDSS NEAR TERM FIRE BEHAVIOR MODEL RESULTS

a. WFDSS NTFB Initial Simulation

Using the results from Huston (2011) as a guide, two modest input adjustments were made before initializing the WFDSS NTFB model. First, the broad scale wind was forced to 290 deg, which better aligned with the major axis of the observed fire spread perimeter and was a close approximation to the average of the two best performing wind direction results (270 deg and 300 deg) used in the previous study. Second, the Live Herbaceous Fuel Moisture level of 65 percent used in the *Custom Fuel* scenario of the previous work was nudged slightly lower to 60 percent to allow a greater component of the grass and sage fuels to be consumed in the fire modeling process (Scott and Burgan, 2005). Based on these modest adjustments, the NTFB simulation was initiated producing an acceptable *calibration* run (not shown).

b. Secondary Timing Simulation

A secondary simulation was quickly completed with the main emphasis focused on replicating two *rough* timing observations noted on the actual fire progression. First, the head of the fire appeared to reach the main ridge axis around 1900 MDT (Fig. 6, solid black line) from a vantage point of nearly 7 km (4.3 mi) away at the National Weather Service forecast office. Second, the northeast portion of the fire was observed at about mid-slope backing downhill at midnight (Fig. 6, solid blue line). In an effort to conform to these rough observations, the wind speed was reduced slightly (3-5 MPH) from the input used in the calibration run. The simulation was initiated at 1500 MDT on June 17, 2010 and allowed to continue until 0200 MDT on June 18, 2010 when it was arbitrarily terminated. The resulting simulation exhibited improved timing results while the total modeled fire perimeter (Fig. 6, red shading) compared reasonably well with the final observed perimeter (note: see Huston, 2011 for more detail on the observed differences).

c. **Additional Fire Behavior Outputs**

In addition to the fire spread projections provided above, additional WFDSS outputs were collected in an effort to address the decision support needs expressed in section 4.d above. These outputs follow:

i. **Simulated Impact of Fire Suppression Tactics**

The implementation of indirect fire suppression tactics is clearly visible when examining fire perimeter maps alongside Google Earth imagery. In the present case, the final fire perimeter paralleled many of the nearby jeep trails and roads that flanked the ignition point which is typically a clear indication of anchoring and burnout tactics used in indirect attack. In an effort to simulate these tactics, a model barrier was established along the flank of the fire following well established roads and jeep trails visible within the Google Earth imagery. The simulation was then reinitialized with the results presented in figure 7.

ii. **Flame Length**

Flame length (Fig. 8) is the length of the flames in the propagating fire front measured along the slant of the flame from the midpoint of its base to its tip (Paysen et. al., 2000). Flame length is a common metric used to guide safety considerations as well as fire suppression decisions (Fire Line Handbook, Appendix B – Fire Behavior, 2006). Generally speaking, when flame lengths reach 1.2-2.4 m (4-8 ft), the fire is considered too intense for direct attack on the head of the fire by persons using hand tools, although equipment such as engines and retardant aircraft may prove effective. When flame lengths reach 2.4-3.4 m (8-11 ft), control efforts at the head of the fire are typically ineffective.

iii. **Rate of Spread**

Rate of spread (Fig. 9) is the relative activity of a fire in extending its horizontal dimensions. It is expressed as the rate of increase of the total perimeter of the fire, the rate of forward spread of the fire front, or as the rate of increase in area, depending on the intended use of the information. Usually it is expressed in chains (ch) or acres per hour for a specific period in the fire's history (Glossary of Wildland Fire Terminology, 2006). Generally when the rate of spread reaches 100-400 m/hr (5-20 ch/hr or 5.5-22 ft/min), fire behavior is classified as moderate. When the rate of spread reaches 400-1005 m/hr (20-50 ch/hr or 22-55 ft/min), the fire behavior is classified as high (Scott and Burgan, 2005).

iv. **Fireline Intensity**

Fireline intensity (Fig. 10) is the rate of energy released per unit length of the fire front expressed as BTU per foot of fire line per second (Paysen et. al., 2000). Fireline intensity is another common metric used to guide safety considerations and fire suppression decisions (Fire Line Handbook, Appendix B – Fire Behavior, 2006). When fireline intensity reaches 346-1730 kw/m (100-500 BTU/ft-s), the fire is generally too intense for direct attack on the head of the fire by persons using hand tools, although engines and retardant aircraft may still be effective. When fireline intensity reaches 1730-3460 kw/m (500-1000 BTU/ft-s), control efforts at the head of the fire are typically ineffective.

v. **Fire Spread Projections for the Second Burn Period June 18, 2010**

One final simulation was completed for the second operational burn period on the afternoon of June 18, 2010 (Fig 11). The simulation was initiated using the perimeter from the previous days simulated fire activity (Fig. 7). The model run was initiated at 1200 MDT on June 18, 2010 and allowed to continue through 2000 MDT when it was arbitrarily terminated. Observed wind, temperature, and humidity conditions were used for the weather inputs. The previous day's fuel moisture variables were left unchanged due to the self-calibrating function (conditioning) of fuel moisture routine found within the WFDSS software.

6. APPLICATION AND DISCUSSION OF WFDSS RESULTS

a. **Disclaimer –** Rothermel (1983) stated, "It should be clear to anyone who has observed wildland fires that there is considerable variability in the fuels, the wind speed, and other influences that rule out the ability to make *absolute* predictions" (italics mine). This statement still rings true today. However, advancements in the meteorological and wildland fire sciences over the last three decades have provided substantial advantages that did not exist in the early 1980's. The fact of the matter is, given reasonable fuel and weather inputs, today's fire behavior models are capable of reproducing many of the details observed on wildfires. That said, model output should *never* be used to dictate tactical or strategic actions on a fire but rather should be used to inform human reason within the full scope of the fire management decision making process.

b. Fire Progression

Without a doubt, the primary question following the deployment of forces on nearly every wildfire is where the fire is going to be at the end of the day. A great deal of qualitative information regarding the expected progression of the fire throughout the first burn period can be garnered from the secondary timing results (Fig. 6 and 7) presented in section 5.b and c. By 0200 MDT, the simulation indicated that the fire would have burned to within 0.4 km (0.25 mi) of the Facer Mountain subdivision. Given a prompt request for modeling, results of the fires simulated progression and threat to the Facer Mountain subdivision might have been available to fire management personnel as early as 9 hours prior to the arrival of the flaming front. These model results not only confirm the anticipated threat but also provide necessary information needed to accomplish evacuation of the subdivision in a timely manner along with activation and pre-positioning of structural protection forces.

A strong sense of the speed of the flaming front can also be inferred from the gradients found on the hourly fire progression map (Fig. 7). In areas where the gradient is tightly packed, the fire progression is slow. In areas where the gradient is widely-spaced, the fire progression is fast. For example, earlier in the day, as the flaming front was progressing up the west side of the Bannock Range and across the ridge axis, the gradient was widely-spaced indicating that the fire was progressing rapidly across the terrain. Later in the evening on the east slopes of the range, the gradient tightened indicating that the fire progression was slowing. This notion is readily confirmed by a cursory examination of the Rate of Spread map (Fig. 9) which shows high rates of spread (30-45 ch/hr, yellow and orange colors) early in the day followed by much slower rates (6-18 ch/hr, green colors) later in the evening.

c. Potential Tactical and/or Strategic Opportunities

As part of the risk management process implemented on every fire, incident commanders are expected to employ an iterative process of re-evaluation which is intended to keep fire managers engaged and responsive to observed and expected fire developments which in turn maximizes safety and enhances fire management outcomes. This process should be based upon experience and supported by the best available science (Fireline Handbook, 2004). In addition, the full range of strategic and tactical options should be considered in response to *every* wildland fire (Guidance for Implementation of Federal Wildland Fire Management Policy, 2009; italics mine).

A natural requirement of this process then is the need for quantitative decision support information which allows fire managers to envision and frame the most likely outcome of current fire activity. Output from the NTFB model would likely prove useful in this regard particularly as it pertains to evaluating future fire suppression opportunities and/or potential conflagrations.

i. **Indirect Backfiring Opportunity**

A tactic commonly associated with indirect attack is backfiring. Backfiring involves intentionally setting fire to fuels within a control line. Most often the tactic is used to contain rapidly spreading fires where control lines can be located to maximize firefighter safety and effectiveness (Wildland Fire Suppression Tactics Reference Guide, 1996). Because timing and location of fireline construction and the establishment of adequate escape routes and safety zones are critical to the safety and success of backfiring operations, the tactic is, with rare exception, executed on a command decision made through appropriate lines of authority.

From the initial assignment of forces, the main spur road (Fig. 2, tan line) was identified as a natural barrier from which a potential backfiring operation might commence. One primary concern was whether the operation could be completed successfully and safely prior to the arrival of the flaming front. Without the aid of fire modeling, this question would likely have gone unanswered. In this case, based upon the arrival of the simulated flaming front (1900 MDT, Fig. 6, black line) and the high degree of fire behavior (Figs. 8 through 10) expected at the spur road, a backfiring operation would have been quickly discounted as a viable tactic due to the unnecessary risk to firefighter safety. In addition, a line production rate of 24 ch/hr for a 3-person engine crew working in a short-grass fuel model (Fireline Handbook, 2004) was applied to the construction of a 2.5 km barrier along the spur road. Based on this rate, it would have taken approximately five 3-person engine crews on-scene and in position on the spur road to complete and hold the operation in a 1-hour period, an unrealistic scenario for initial attack.

Although the current case did not meet the minimum threshold for a safe backfiring operation, one can imagine a number of scenarios where the ability to model such a tactic might prove useful (e.g. earlier onset of lighter winds in the evening). Despite the fact that specific backfiring tools are not yet available within WFDSS, the process can be artfully conducted using a combination of the *barrier* and *ignition* source tools found within the system.

In the current case, a mock backfiring operation was performed simply to explore the non-traditional use of the NTFB model. In preparation, a barrier 2.5 km (1.5 mi or 120 ch) long was constructed within the model which paralleled the spur road from south to north. To complete the backfire simulation, an area ignition source was created on the west side of this spur road barrier and used to initiate a secondary model run. The backfire was started at 1700 MDT and allowed to burn until 1900 MDT when the flaming front was originally timed to reach the spur road. Since the simulated barrier prevented the model backfire from burning downwind to the east, the fire backed slowly westward into the wind, creating a modest 164 m (540 ft or 8 ch) buffer west of the spur road control line. These results were then incorporated into a tertiary model run that integrated the modest backfired buffer zone created along the spur road and line construction completed from the anchor point along the western flank of the fire (Fig. 12, black line/area). In this simulation the advancing fire was stopped at the spur road fire line, whereas in supplemental experiments with greater spotting probability and a smaller backfire line (not shown) the simulated fire was able to advance beyond the constructed barrier. Again, this exercise was intended to show a non-traditional use of the NTFB. Many of the elements necessary to conduct a successful backfire operation were either not present or were considered dangerous.

ii. Direct Attack Opportunity

Upon closer examination of the hourly fire progression map (Fig. 7), there was a notable increase in the fire spread gradient after 2200 MDT. As previously mentioned, this phenomenon is the direct result of a diminishing rate of fire spread associated with decreasing wind speed. A concomitant drop in fire intensity (Fig. 10) and flame length (Fig. 8) were also depicted in the associated fire behavior output. In fact, the decreasing rate of spread (6-8 ch/hr) (Fig. 9) and flame length (1-2 ft) reached levels which would allow direct attack at the head of the fire by persons using hand tools (Fireline Handbook, Appendix B, 2006). Ideally, several engine crews could have been staged near the spur road at the south and north flanks of the advancing fire prior to 2200 MDT in anticipation of the decreasing fire behavior. When fire conditions permitted, they could have used the spur road to advance into the black and begin directly attacking hot or rapidly spreading portions of the fire, a technique commonly referred to as hotspotting (Wildland Fire Suppression Tactics Reference Guide, 1996). The process would have allowed firefighters more time to construct fireline and/or cool portions of the fire preventing it from advancing closer to the Facer Mountain subdivision. Another important aspect here would have been to keep the fire from gaining a foothold in areas on the east side of the Bannock Range where heavier fuel loads existed in the deeper ravines and canyons.

d. Resource Management

In addition to the pressing concerns associated with fire management activities during the initial burn period, managers are required to anticipate the potential resource needs of expanding fire management forces during subsequent burn periods. The prominent question here is whether adequate resources will have been mobilized and made available to the expanding command structure in order to meet the potential fire management demands during the upcoming burn period.

In an effort to anticipate complex resource management needs, early fire spread projections extending into the second burn period might prove beneficial in securing necessary resources. To this end, a fire spread projection was completed for the second burn period (Fig. 11) as detailed in section 5.c.v. Two important caveats need to be kept in mind when utilizing such projections. First, early projections for the second burn period, such as the one provided in this case study, are based upon a projection of the first period fire perimeter. Second, and perhaps more importantly, it is assumed that none of the previous day's fire perimeter is *secured* prior to the start of the second burn period projection. In nearly every instance, the combination of these two assumptions will invariably lead to an over-prediction of fire spread when compared to observations. The primary benefit of such projections is to gain a sense of the scope and potential impact of unabated fire activity within successive burn periods. In the present case, the output stresses the potential loss of the Facer Mountain subdivision, doubling the acreage burned, and escalating threats to additional subdivisions positioned within the wildland-urban interface situated along the east slope of the Bannock Range. In addition, these projections clearly provide supporting documentation for the completion of the Incident Complexity Analysis (Fireline Handbook, 2004) which is used to determine fire management team assignments.

7. CONCLUSION

Previous work (Huston, 2010 and 2011) was primarily focused on the mechanics of whether National Weather Service (NWS) personnel could deliver timely and accurate fire behavior model output to Initial Attack forces in support of critical fire management decisions. It was shown that rapidly evolving technological advances in wireless communications and numerical meteorological and fire behavior prediction had created an opportunity for land managers to make more effective use of NWS decision support expertise. In turn, it was suggested that timely decision support information generated during the early stages of an incident could allow fire managers to objectively assess potential fire outcomes, reduce uncertainty, evaluate risk, and formulate strategic and/or tactical plans and alternatives quickly and efficiently.

The thrust of the current effort was to demonstrate these concepts through the use of the WFDSS fire behavior model in a supportive fire management role. Quantitative output from the NTFB model was used in a table-top exercise to support and discount contingent operational strategies and tactics as well as reinforce firefighter safety measures. It was also demonstrated that the application of such output could be used to support timelier requests for resources which directly impacts the ability of fireline officers to accomplish mission objectives. Model output could also be used to improve situational awareness during the risk management process especially if projections showed the potential for extreme fire behavior. Finally, the evidence provided in this study strongly supports the conjecture that timely and accurate fire behavior output in the hands of experienced fire managers can be used to inform the decision making process potentially helping to improve fire management outcomes and safety.

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9. REFERENCES

Finney, Mark A. 2004. FARSITE: Fire Area Simulator – model development and evaluation. Res. Pap. RMRS-RP-4 Revised. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 47p.
http://www.firemodels.org/downloads/farsite/publications/fireareaall.pdf

Finney, Mark A. 2006. An overview of FlamMap modeling capabilities. In: Andrews, Patricia L.; Butler, Bret W., comps. 2006 Fuels Management – How to Measure Success: Conference Proceedings. 28-30 March 2006; Portland, OR. Proceedings RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 213-220.
http://www.treesearch.fs.fed.us/pubs/25948

Fireline Handbook. NWCG Handbook 3. March, 2004. PMS 410-1. NFES 0065.

http://www.wildfirelessons.net/documents/flhb_410-1.pdf

Fireline Handbook, Appendix B - Fire Behavior. NWCG Handbook. April, 2006. PMS 410-2. NFES 2165.
http://www.nwcg.gov/pms/pubs/410-2/appendixB.pdf

Glossary of Wildland Fire Terminology. NWCG Publication. October, 2006. PMS 205.
http://www.wildlandfire.com/docs/2006/NWCGglossaryPMS205.pdf

Guidance for Implementation of Federal Wildland Fire Management Policy. February, 2009.
http://www.nifc.gov/policies/guidance/GIFWFMP.pdf

Huston, Mike 2010. On the Use of Fire Behavior Models for Decision Support, Part I: Model Survey and NWS Capabilities**.** WR-Technical Attachment 10-06.
http://www.wrh.noaa.gov/wrh/TA1006.pdf

Huston, Mike 2011. On the Use of Fire Behavior Models for Decision Support, Part II: Additional FARSITE Operational Considerations. WR-Technical Attachment 11-02.
http://www.wrh.noaa.gov/wrh/TA1102.pdf

Paysen, Timothy, R.J. Ansley, J. Brown, G. Gottfried, S. Haase, M. Harrington, M. Narog, S. Sackett, R. Wilson. 2000. Fire in Western Shrubland, Woodland, and Grassland Ecosystems. Chapter 6. USDA Forest Service Gen. Tech. Rep. RMRS-GTR-42-vol. 2.
http://www.fs.fed.us/rm/pubs/rmrs_gtr042_2.pdf

Pollet, J. and Brown, A. 2007: Fuel Moisture Sampling Guide. Bureau of Land Management. Utah State Office. Salt Lake City, Utah.
http://72.32.186.224/nfmd/references/fmg.pdf

Rothermel, Richard C. 1983. How to predict the spread and intensity of forest and range fires. Gen. Tech. Rep. INT-143. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 161 p.
http://www.treesearch.fs.fed.us/pubs/24635

Scott, Joe H.; Burgan, Robert E. 2005: Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model. Gen. Tech. Rep. RMRS-GTR-153. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 72 p.
http://www.fs.fed.us/rm/pubs/rmrs_gtr153.pdf

Seli, Robert. July 1, 2010. WFDSS System Administrator. Personal communication.

Wildland Fire Decision Support System (WFDSS).
https://wfdss.usgs.gov/wfdss/WFDSS_Home.shtml

Wildland Fire Suppression Tactics Reference Guide. NWCG. April 1996. PMS 465. NFES 1256.
http://www.coloradofirecamp.com/suppression-tactics/suppression-tactics-guide.pdf

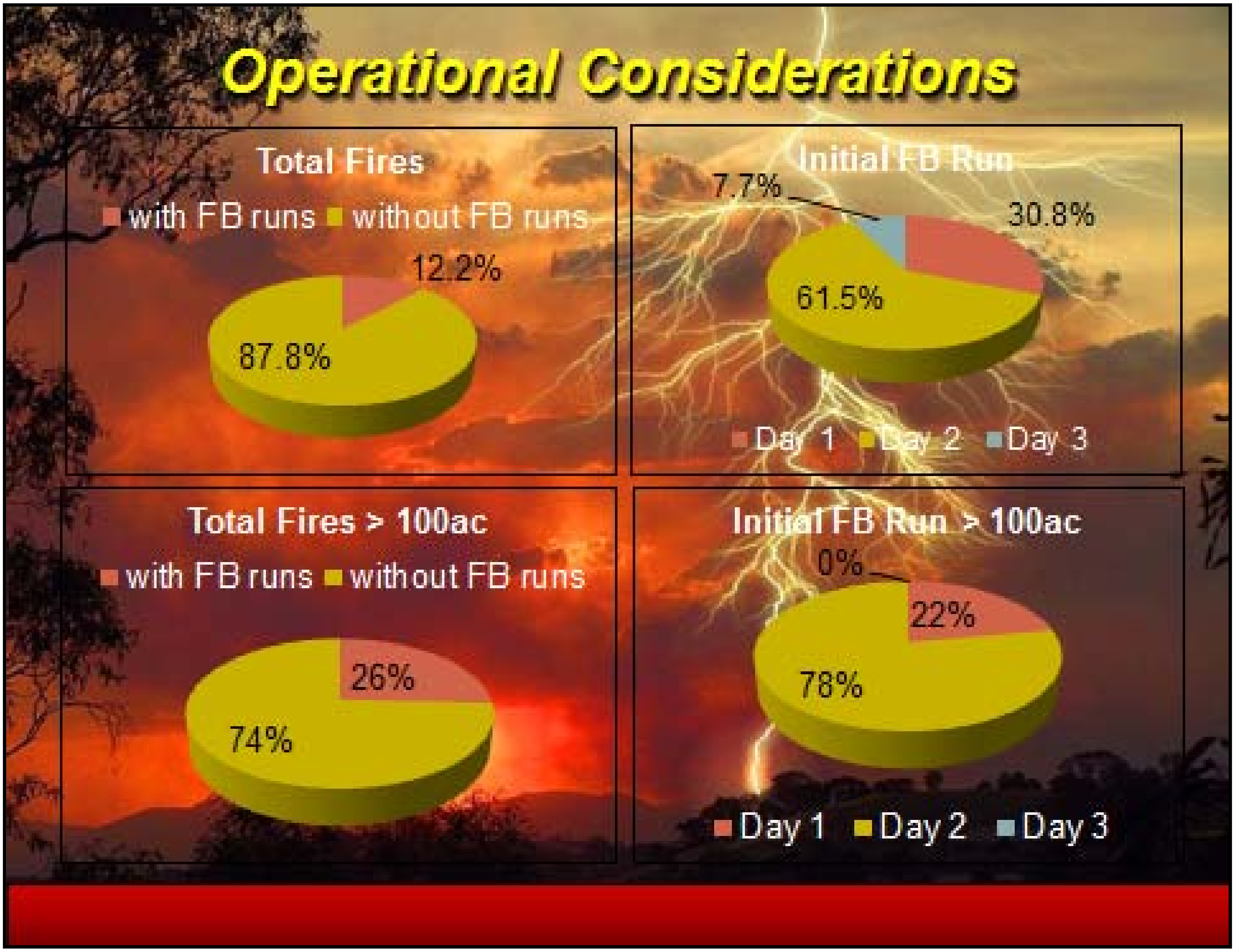

Figure 1. Percentage of the Total WFDSS Fire Behavior (FB) runs performed during the 2010 fire season (left two panels) and percentage of FB runs performed within one, two, or three days of discovery (right two panels) across southeast Idaho.

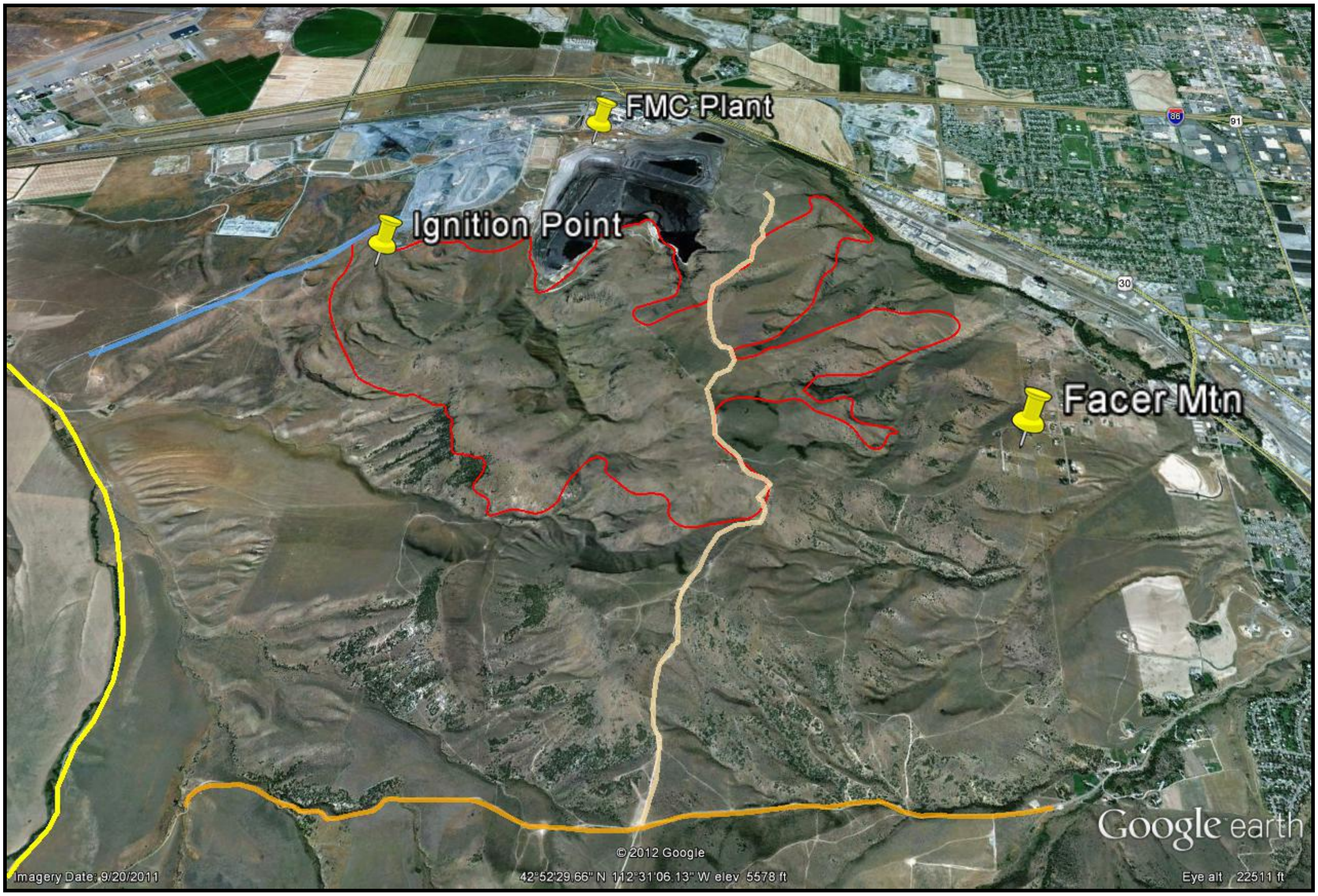

Figure 2. Google Earth image looking north with the perimeter of the Howard Fire overlaid in red. The Michaud Creek Road is overlaid in yellow, the Trail Creek Road is overlaid in orange, the Spur Road is overlaid in tan, and the FMC Tailings Road is overlaid in blue.

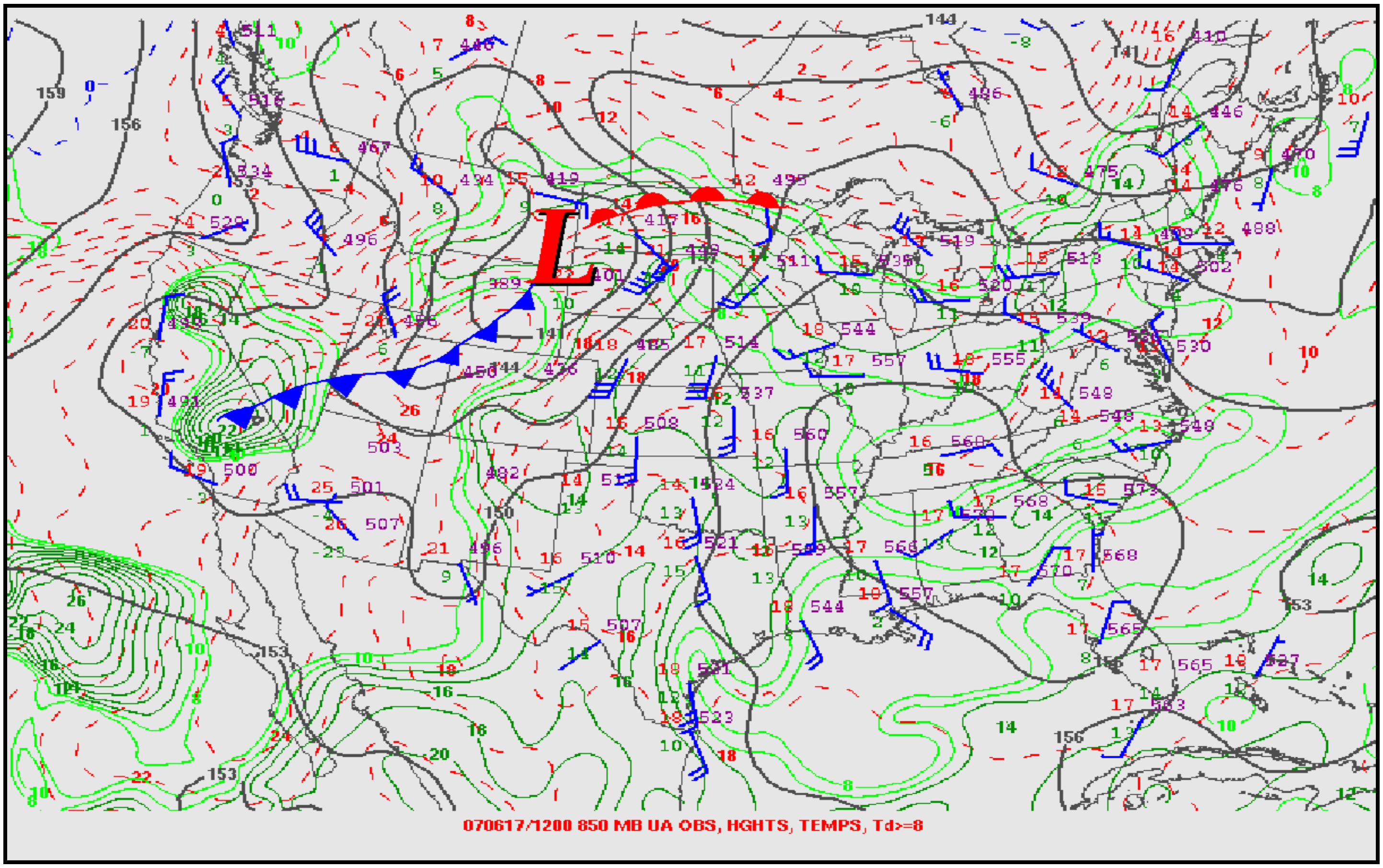

Figure 3. Observed 850 hPa height (purple, solid black line with contour interval 30 meters), wind (blue wind barbs in knots), and temperature (red, dashed red line with contour interval 2 ^{o}C) for June 17, 2007 at 0600 MDT.

FIRE WEATHER PLANNING FORECAST FOR IDAHO
NATIONAL WEATHER SERVICE POCATELLO ID
551 AM MDT SUN JUN 17 2007

.DISCUSSION...
WINDS TODAY WILL BE RATHER STRONG...PARTICULARLY THROUGH THE SNAKE RIVER VALLEY AND ACROSS RIDGE TOP. A STRONG BUT DRY PACIFIC LOW WILL PUSH ACROSS THE EAST IDAHO FIRE DISTRICT TODAY. THE COLD FRONT HAS ALREADY PASSED THROUGH MUCH OF THE DISTRICT...AND TEMPERATURES WILL BE SIGNIFICANTLY COOLER TODAY. SINCE THE SYSTEM
WAS DRY...ONLY SLIGHT MODERATION IN HUMIDITIES IS EXPECTED. HOWEVER...THE HUMIDITIES WILL BE HIGH ENOUGH TO KEEP CONDITIONS FROM REACHING CRITICAL THRESHOLDS DESPITE THE STRONG WINDS. GRADUALLY WARMING CONDITIONS ARE FORECAST THROUGH THE REST OF THE WEEK.

IDZ413-180200-
CARIBOU RANGE/CARIBOU NF-
551 AM MDT SUN JUN 17 2007

.TODAY...
SKY/WEATHER................SUNNY.
MAX TEMPERATURE.....65-74 VALLEYS AND 58-67 RIDGES.
  24 HR TREND.................DOWN 17.
MIN HUMIDITY...............15-23 PERCENT VALLEYS AND 17-25 PERCENT RIDGES.
  24 HR TREND.................LITTLE CHANGE.
20FT/10MIN AVG WIND.
  VALLEYS.......................WEST 10 TO 20 MPH WITH GUSTS TO AROUND 35 MPH.
  RIDGES...........................WEST 10 TO 15 MPH WITH GUSTS TO AROUND 30 MPH.
CHC WETTING RAIN…...0 PERCENT.
LAL.....................................1.
HAINES INDEX................3 VERY LOW.
MIXING HEIGHT.............7250-8250 FT AGL.
TRANSPORT WINDS......WEST AROUND 25 MPH.

.TONIGHT...
SKY/WEATHER...............CLEAR.
MIN TEMPERATURE......37-47 VALLEYS AND 36-45 RIDGES.
  24 HR TREND................DOWN 11.
MAX HUMIDITY.............63-73 PERCENT VALLEYS AND 62-72 PERCENT RIDGES.
  24 HR TREND................UP 8.
20FT/10MIN AVG WIND.
  VALLEYS.......................NORTHWEST 10 TO 15 MPH. GUSTS UP TO 30 MPH IN THE EVENING.
  RIDGES..........................WEST 10 TO 15 MPH. GUSTS UP TO 30 MPH IN THE EVENING.
CHC WETTING RAIN…..0 PERCENT.
LAL.....................................1.
HAINES INDEX................3 VERY LOW.
MIXING HEIGHT.............700-1200 FT AGL.
TRANSPORT WINDS…...LIGHT AND VARIABLE WINDS.

.MONDAY...
SKY/WEATHER................SUNNY.
MAX TEMPERATURE... .68-78 VALLEYS AND 61-70 RIDGES.
  24 HR TREND................UP 4.
MIN HUMIDITY...............21-31 PERCENT VALLEYS AND 26-36 PERCENT RIDGES.
  24 HR TREND................UP 7.
20FT/10MIN AVG WIND.
  VALLEYS.......................UPSLOPE/UPVALLEY 2 TO 4 MPH BECOMING SOUTHWEST UP TO 10 MPH IN THE AFTERNOON.
  RIDGES..........................VARIABLE 4 TO 8 MPH BECOMING SOUTHWEST UP TO 10 MPH IN THE AFTERNOON.
CHC WETTING RAIN......0 PERCENT.
LAL.....................................1.
HAINES INDEX................4 LOW.
MIXING HEIGHT.............8000-9000 FT AGL.
TRANSPORT WINDS......WEST AROUND 10 MPH.

Figure 4. Morning issuance of the Fire Weather Planning Forecast for the impacted zone.

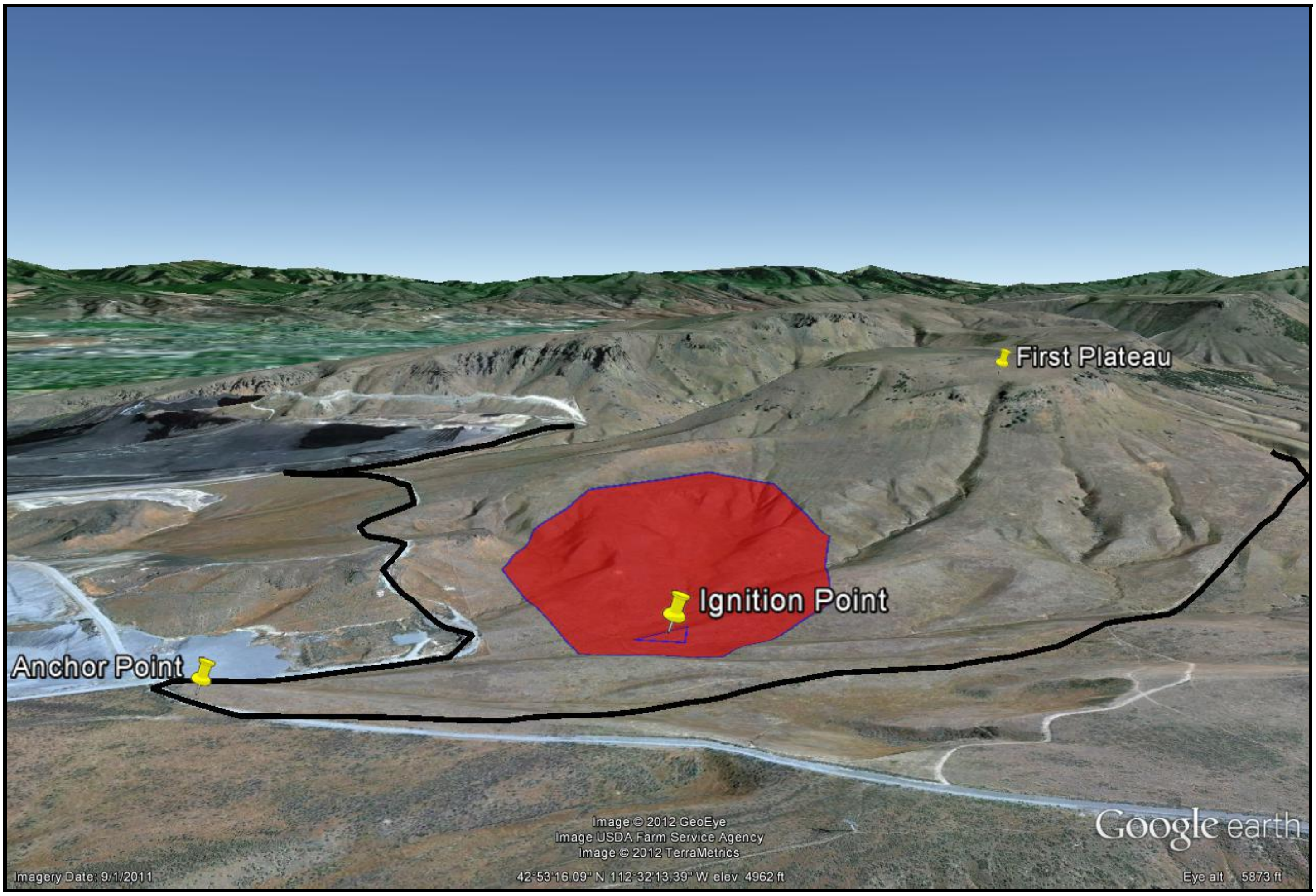

Figure 5. Google Earth image looking downwind (east-southeast) across the FMC Tailings Road (blue line) and the Ignition Point toward the first plateau. The black line highlights the proposed northern and southwestern flanks from which the fireline would be anchored. The red shaded area represents the modeled fire growth through 1600 MDT.

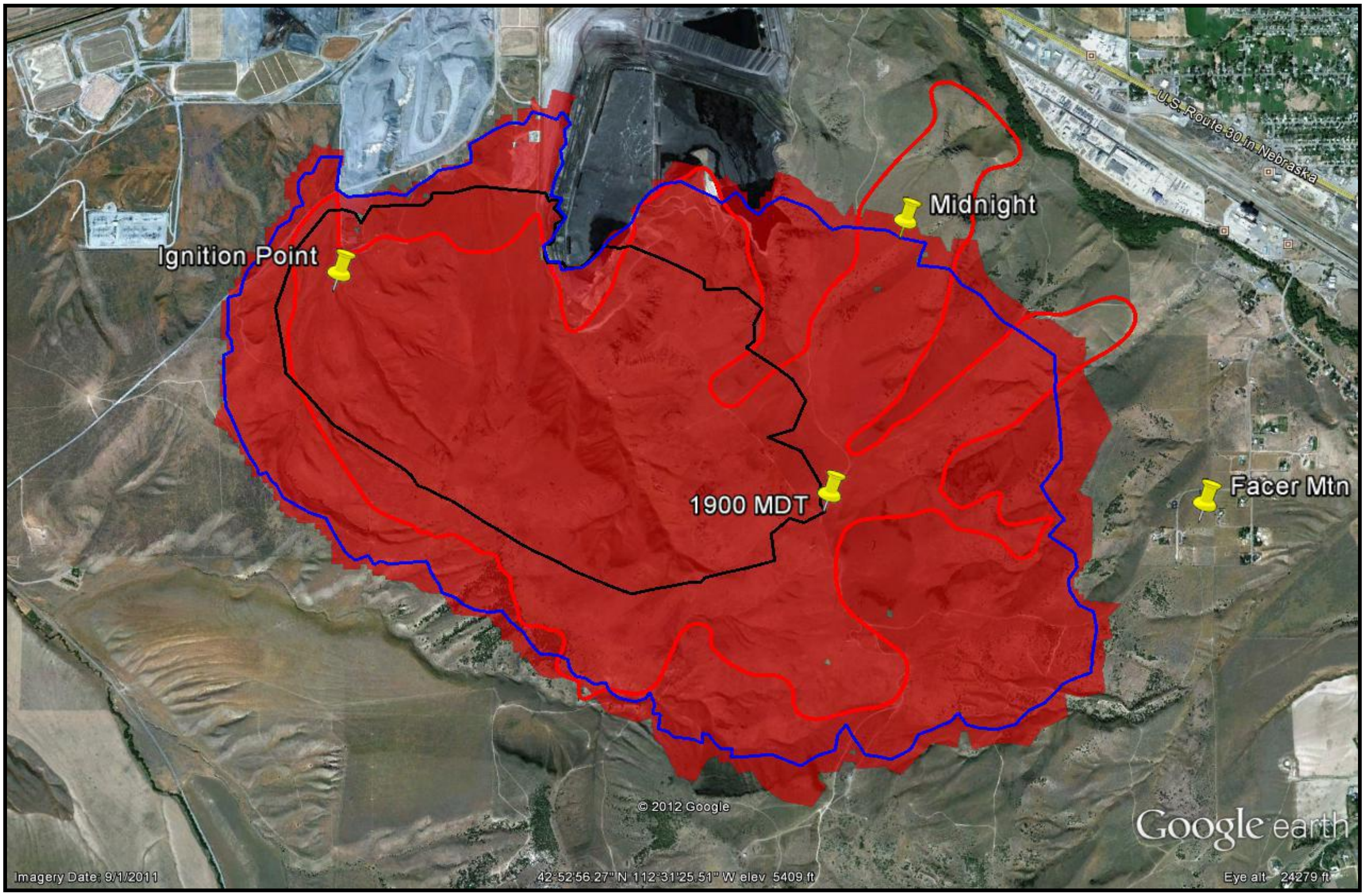

Figure 6. Google Earth image of the observed fire perimeter (solid red line), WFDSS NTFB simulation at 1900 MDT (solid black line), the NTFB simulation at midnight (solid blue line), and the total simulated fire perimeter through 0200 MDT (red shading) without any adjustments for suppression activities.

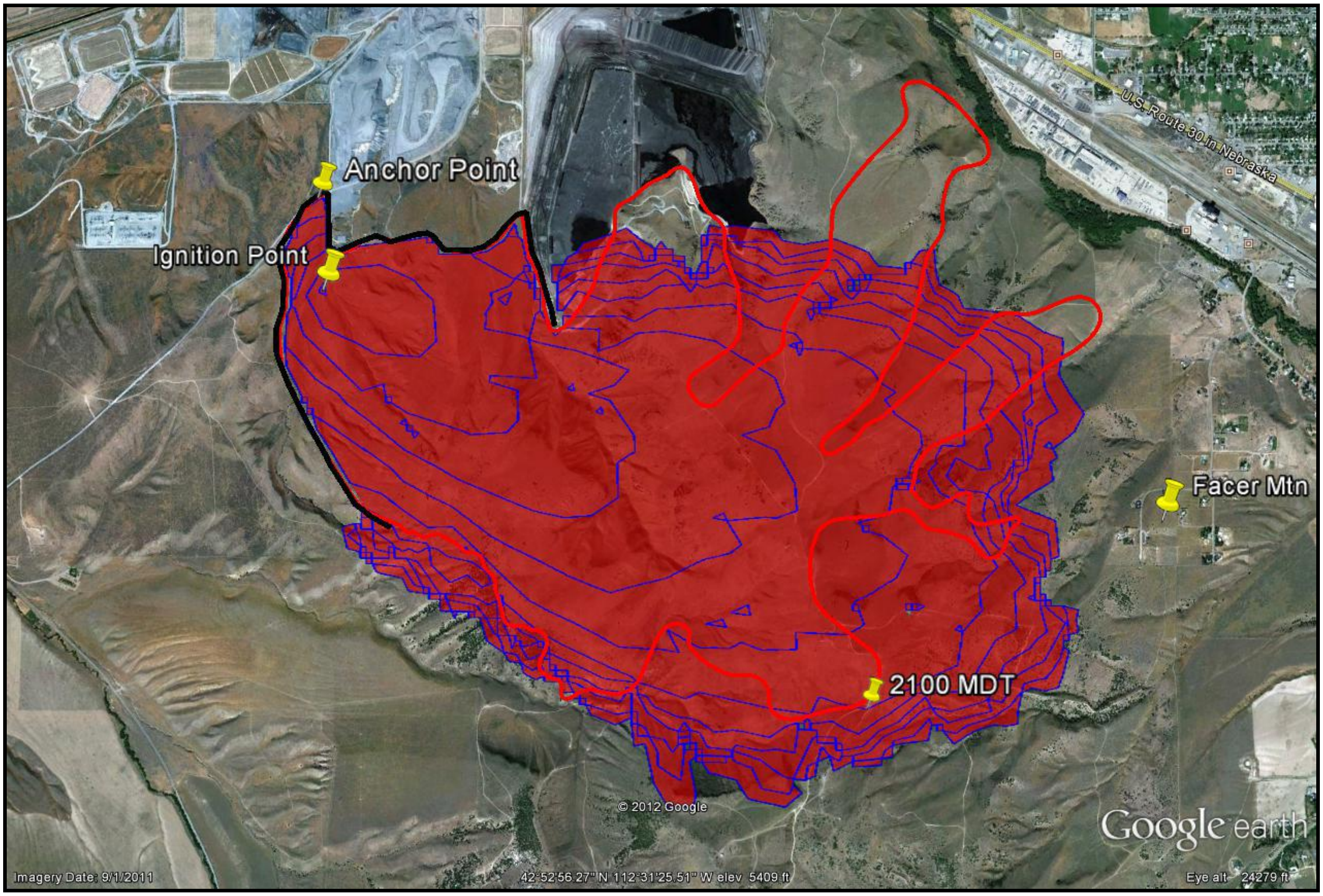

Figure 7. Google Earth image comparing the observed fire perimeter (solid red line) and the total simulated fire perimeter through 0200 MDT (red shading). Simulation incorporates indirect fireline construction (black line) from the designated anchor point. Hourly simulated fire spread progression is denoted by thin blue lines.

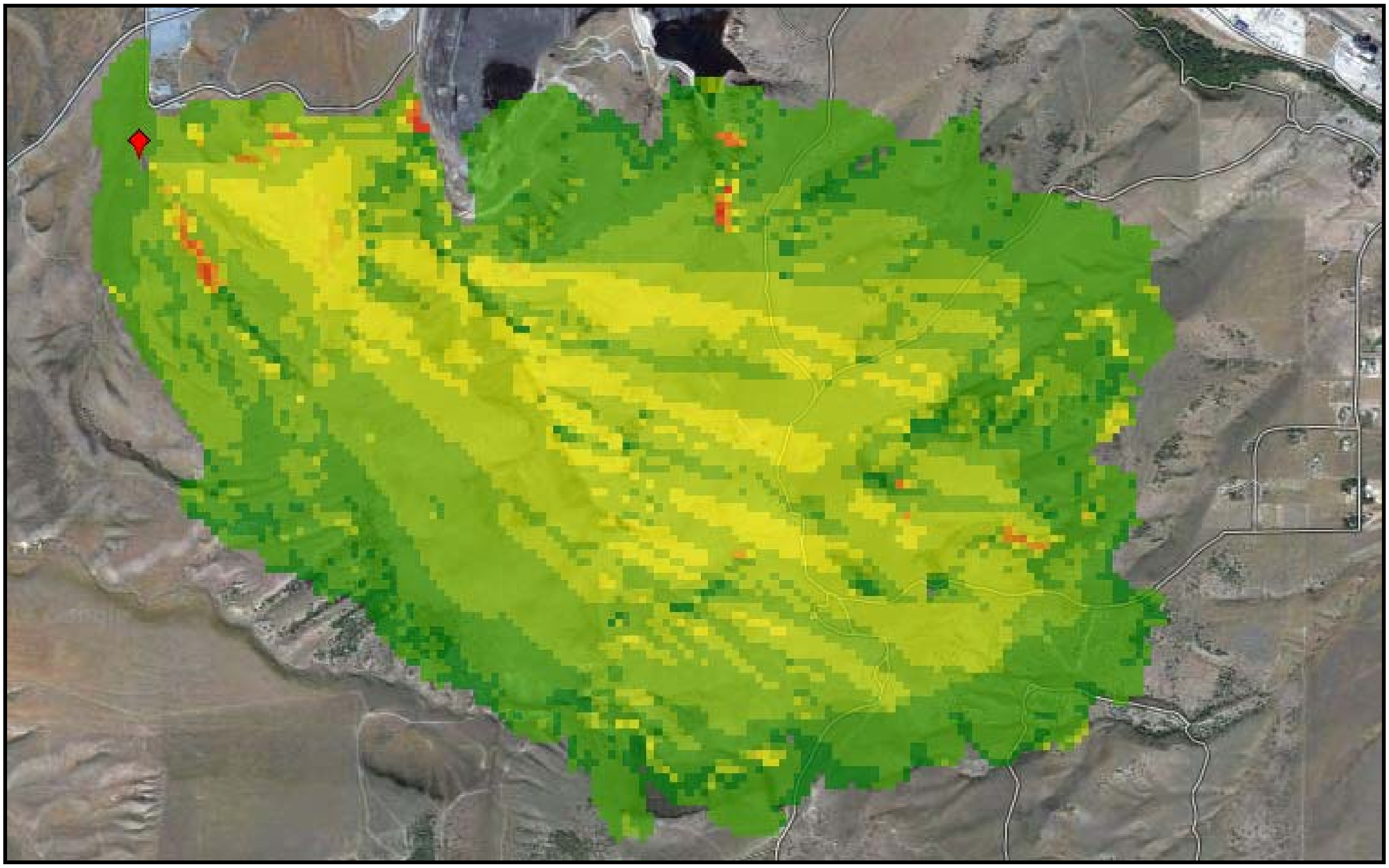

Figure 8. WFDSS Flame Length.

Flame Length Legend

Resolution: 30 meters   Units: feet

Value	Freq
0.00 - 1.09	553
1.09 - 2.19	3,255
2.19 - 3.28	2,532
3.28 - 4.37	2,476
4.37 - 5.47	958
5.47 - 6.56	43
6.56 - 7.66	8
7.66 - 8.75	14
8.75 - 9.84	12
9.84 - 11.48	8
11.48 - 13.12	15
13.12 - 16.40	5
16.40 - 19.69	4
19.69 - 32.81	5
No Data	214,953

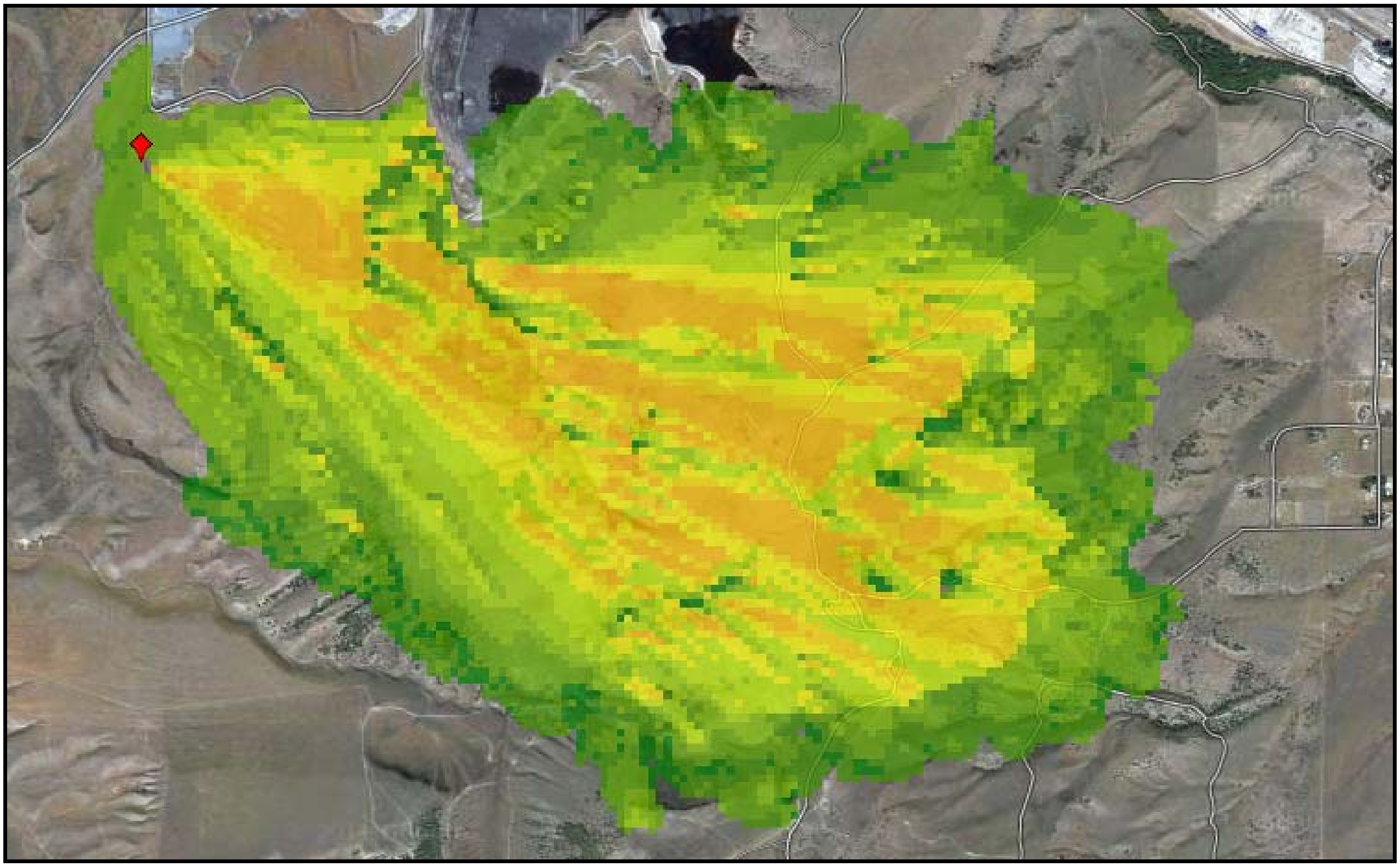

Figure 9. WFDSS Rate of Spread.

Rate of Spread Legend

Resolution: 30 meters   Units: chains per hour

Value	Freq
0.0 - 1.5	331
1.5 - 3.0	1,115
3.0 - 6.0	1,844
6.0 - 8.9	1,206
8.9 - 11.9	785
11.9 - 17.9	1,331
17.9 - 23.9	1,149
23.9 - 29.8	996
29.8 - 44.7	1,077
44.7 - 59.7	53
59.7 - 74.6	1
No Data	214,953

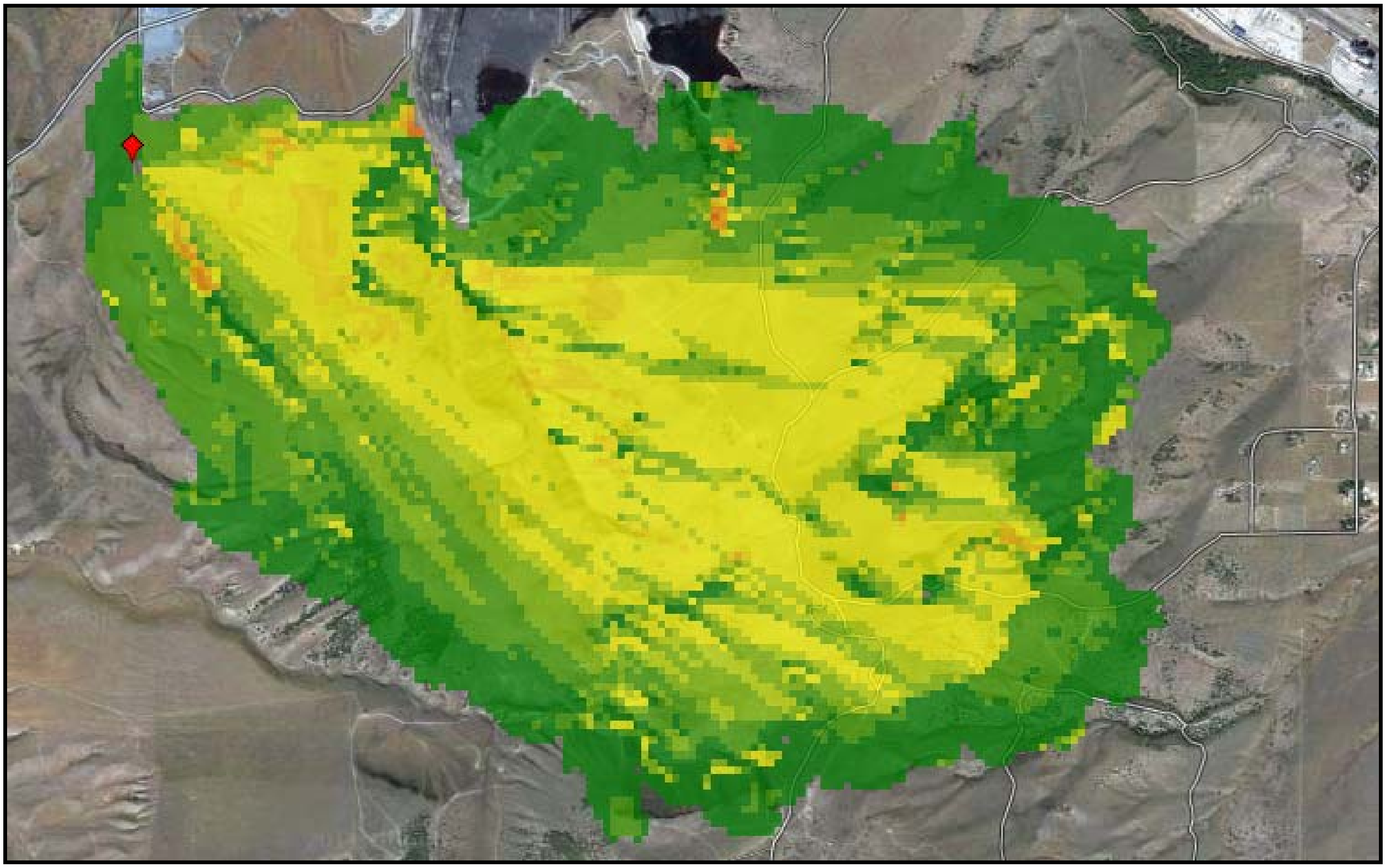

Figure 10. WFDSS Fireline Intensity.

Fireline Intensity Legend

Resolution: 30 meters   Units: BTUs per foot-second

Value	Freq
0.0 - 21.7	2,795
21.7 - 43.4	1,906
43.4 - 65.0	1,196
65.0 - 86.7	971
86.7 - 173.5	2,695
173.5 - 289.1	263
289.1 - 433.7	20
433.7 - 578.2	21
578.2 - 867.3	15
867.3 - 1,156.4	1
1,156.4 - 2,023.7	5
No Data	214,953

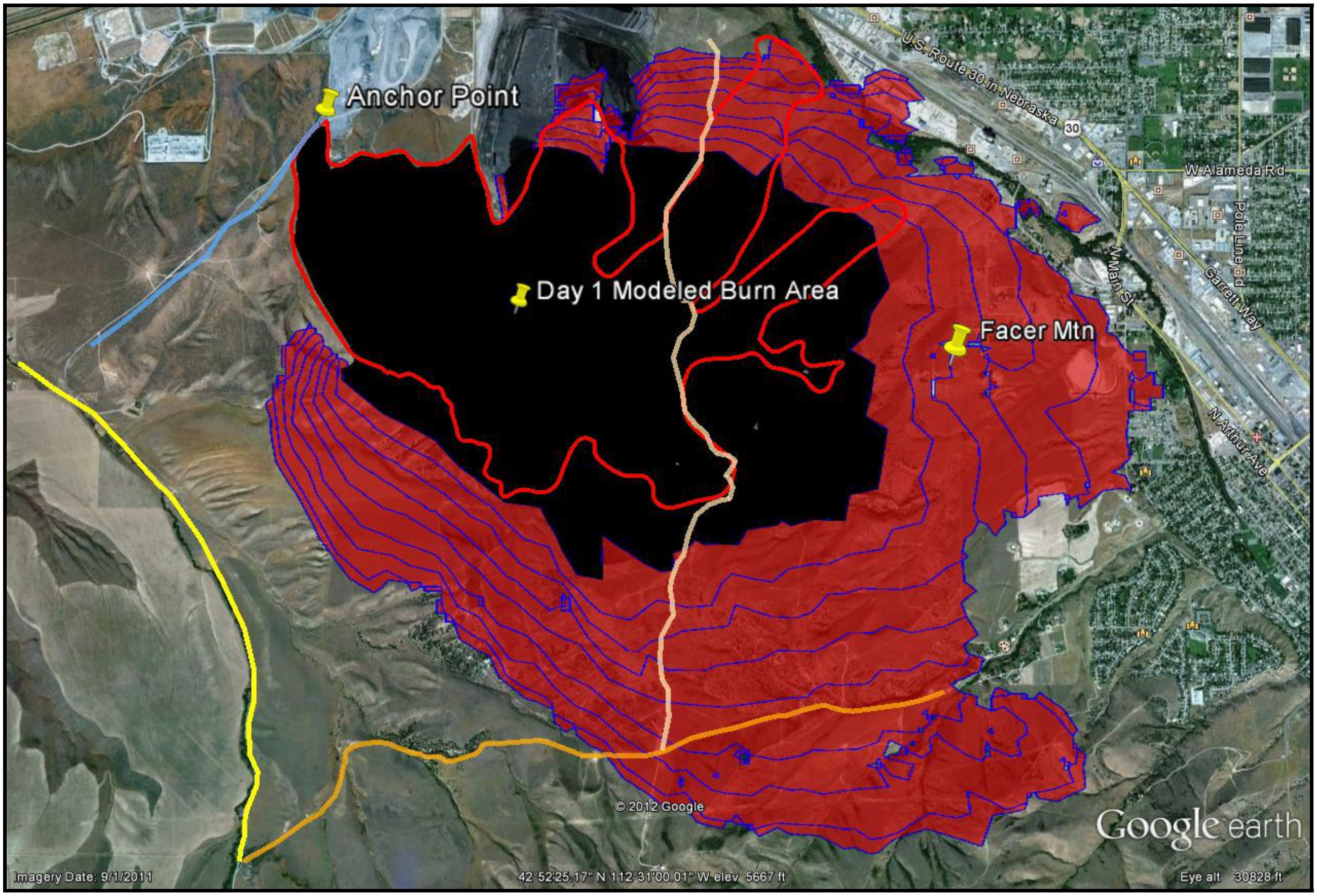

Figure 11. Google Earth image of the projected day-2 burn potential (red shading) utilizing the day-1 projected burn area (black shading) as the ignition file. Hourly simulated fire progression is denoted by the thin blue lines from noon to 2000 MDT. Final observed fire perimeter depicted by the solid red line for reference. The blue, yellow, orange and tan reference lines remain as depicted from Fig. 2.

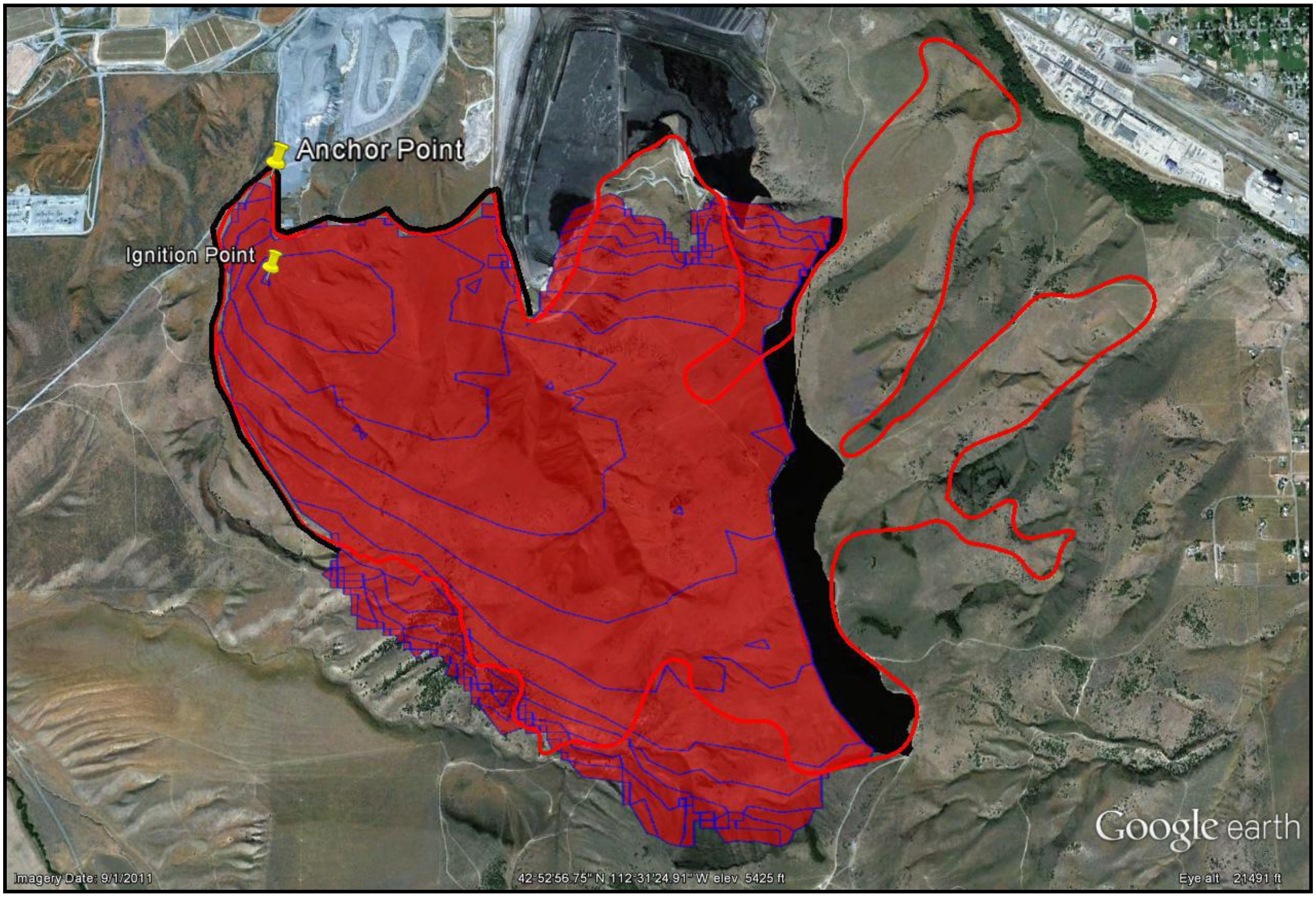

Figure 12. Google Earth image comparing the observed fire perimeter (solid red line) and the total simulated fire perimeter through 0200 MDT (red shading) incorporating indirect fireline construction from the designated anchor point (black line) and backfiring (black shaded area) along the Spur Road. Hourly simulated fire progression is denoted by thin blue lines.