FPInnovations
Wildfire Operations Research
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Survival zones for wildland firefighters: data collection in one experimental opening in timber

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Data Collection

Location:	Canadian Boreal Community FireSmart Project Site (near Fort Providence, NT)
Date:	June 23, 2012
Fuel:	Jack Pine
Opening:	one circular opening 50 m in diameter

This was our first test in standing timber. We constructed the opening by removing and burning vegetation. A 50 m opening is about the size in which a medium helicopter could land.

Heat Flux

Heat flux sensors were placed 5 m apart in straight lines across the opening. We used two types of heat flux sensors: flat sensors were placed on the ground, and cube sensors were placed on 0.9 m posts. The two types of sensors each have a different field of view; flat sensors only sense radiation directly above it, whereas elevated cube sensors sense radiation from five directions.

Figure 1. A cube sensor and a flat sensor.

Mechanical engineers from the University of Alberta had placed some prototype sensors in the opening. Their sensors were placed on wooden cubes approximately 1m^3. These boxes were placed 10 and 30 m from the block edge.

Carbon Monoxide

The carbon monoxide sensors—located in four of the camera boxes—were distributed throughout the opening.

Nine in-fire cameras were placed in the opening and four were placed on the edge of the opening looking across it. One camera was placed in the timber at the back of the opening looking in.

Temperature data-loggers were buried in ground in the timber and in the opening to record temperature at ground level during the passage of fire. This is used to calculate rate of spread.

Ignition

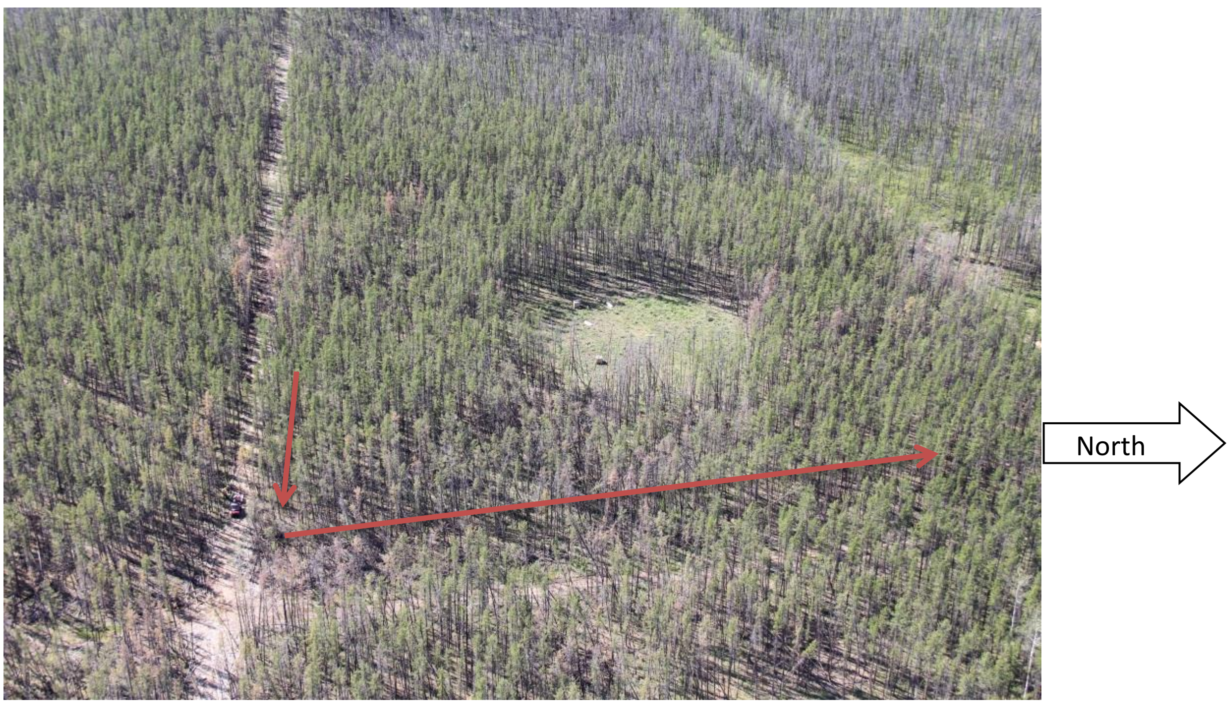

Figure 2. The opening from the air. The red arrows indicate the ignition line.

The fire ran for 40 m in standing timber before it hit the opening.

FINDINGS

Fuels

The opening was surrounded by mature stand of Jack Pine (FBP fuel type C-3). Trees averaged 16 m in height. There was an area of blowdown and dead standing timber in the SE corner of the opening where ignition took place. The opening was covered in grass, small shrubs, and aspen saplings. This less flammable vegetation is likely what a firefighter might find in a natural opening. The site was flat, and some some damp microsites did exist.

Fire Weather

Table 1. On-site weather conditions and FWI values (Williamson 2012).

Date	Time	Temp	RH	WS	WD	P	FFMC	DMC	DC	ISI	BUI	FWI
23-Jun	12:00	23.1	32	7.7	113	0	92.9	135.4	394.9	9.5	145.8	35.2
	16:00						93.0			9.7		35.7

Fire Behaviour

The recorded wind speed was 12–25 km/h; the average rate of spread was calculated at 13 m/min.

We estimated fire intensity and flame length from the in-fire video footage. We estimated that the average flame length was 5–7 m, with maximum flame lengths of 10–12 m (Figure 2)

Figure 3. A screen capture of the fire as it hit the SE corner of the opening.

This photograph was sent to fire behavior specialists and they categorized the fire as Class 5 Intermittent Crown Fire with an intensity of approximately 8000 kW/m.

Using the equation below with a 5 m flame length, we get a fire intensity of roughly 8500 kW/m.

$$I = 259.833\ (L)^{2.174}$$

where, L = flame length (m)
I = intensity (kW/m)

Heat Flux

Figure 4 shows that the highest heat flux values were recorded on the SE side of the opening, where the fire first entered. Levels above 7 kW/m^2 were recorded in this area. A value of 32.8 kW/m^2 was measured 2.5 m from the opening edge on the south side, this dropped to 7.3 kW/m^2 7.5 m from the edge. A value of 19.3 kW/m^2 was recorded 3 m from opening edge in the NE corner of the opening, this dropped to 5.5 kW/m^2 8.5 m from that edge. Heat flux values decrease to survivable levels as one moves away from the front edge of the opening. The sensors that recorded the highest values were eventually burned over. When readings did cross the threshold for survival (7 kW/m^2), they remained so for only 30 seconds. However, at higher heat flux values this would be fatal. Where the elevated cube sensors were in close to the flat sensors, the cube sensors recorded higher heat flux values. Sensors in the back half of the opening recorded values that were below the critical threshold of 7 kW/m^2. Spikes in heat flux did occur, but these values were still low.

The prototype sensors tested by the U of A mechanical engineers recorded similar peak values as our sensors located nearby. At 10 m from opening edge their sensor peaked at 16 kW/m^2, whereas 30 m from the edge 5 kW/m^2 was their peak value. However, there was a difference in how long their heat flux values stayed above the threshold value. The engineers think that the insulation block they used held the heat longer (McDonald and Sullivan 2012).

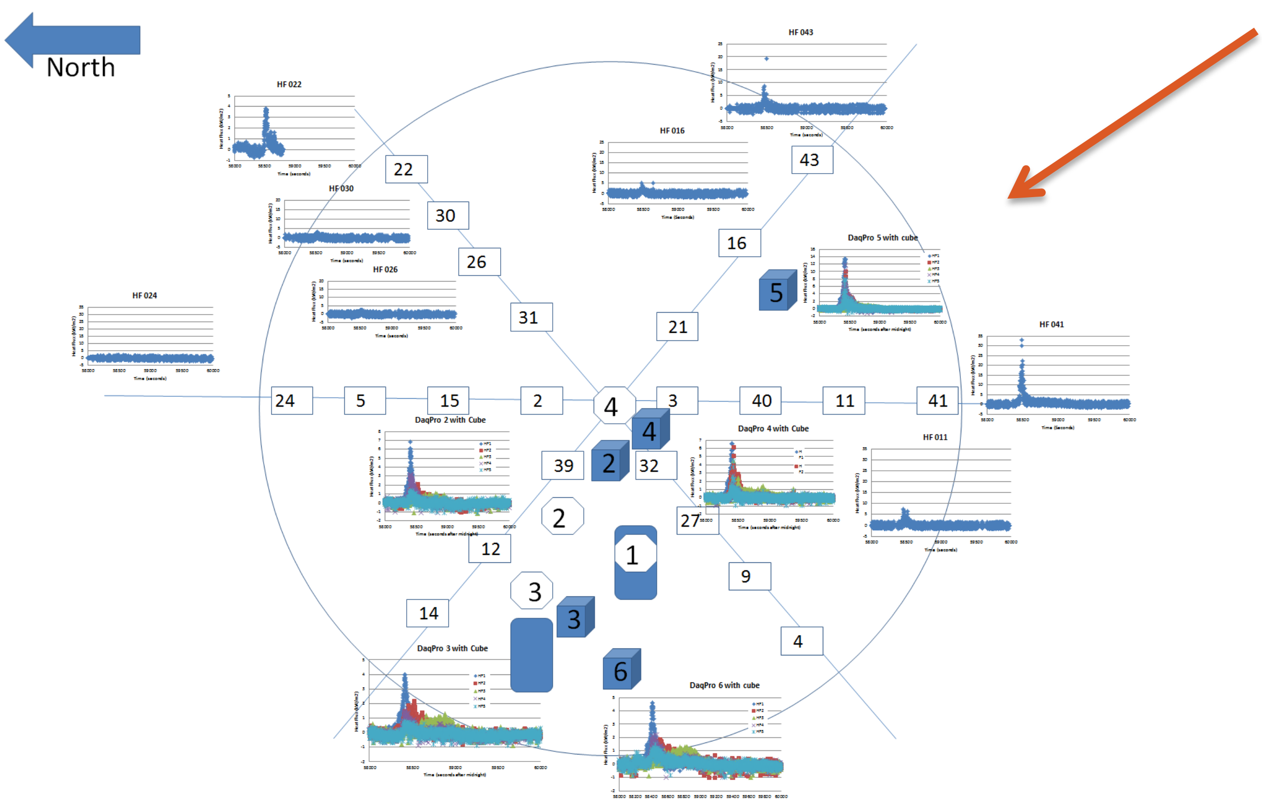

Figure 4. An example of the data collected inside the opening. The red arrow indicates the fire direction.

Temperature

The temperature in the middle of the opening was 61^{o}C; the temperature 30 m from the edge was 52^{o}C. These values were similar to those recorded by the U of A engineers. They recorded values between 40^{o}C and 70^{o}C.

Carbon Monoxide

The length of time the CO was above the 2000 ppm varied slightly between sensors. The times were as follows:

- 40 minutes for Camera 27
- 44 minutes for Camera 30
- 26 minutes for Camera 28
- no data for the fourth sensor

Unfortunately, the sensors are not set up to provide readings above 2000 ppm, but the length of time it was above this threshold does show that breathing may become difficult over an extended period of time. Concentrations of 1000 ppm for 30 minutes has been reported to cause severe headaches, so more than doubling this over a slightly longer period of time could have some effects.

Preliminary Conclusions

The heat flux recorded at the front of the opening was lethal to humans, but these values decreased as you moved into the opening and at the back end of the opening the level was survivable for humans. Unfortunately, an area of blowdown and light winds did not allow the fire to become as intense as we would have been liked, but it was still a dangerous fire. Our data showed that under these fire weather conditions and in this stand type a 50 m opening is sufficient for the survival of firefighters

Peak heat flux values lasted only a short time (20–30 seconds). Even with PPE, this exposure to these levels can cause second-degree burns in 10 seconds (Ackerman 2010). Although the fire wrapped around the back half of the opening, heat flux values at the back of the opening only reached 5 kW/m^2 partly due to the fire pulling the 'air' away from the sensors instead of rolling over the sensors. Video shows the flames leaning away from the opening, following the fire past the opening.

Three sensors recorded values above 2000 ppm for extended periods of time. The sensors' alarms were set off when clouds of smoke blew over the sensors. Our video footage showed that pockets of clean air are common and thus the period of time above the 2000 ppm is not continuous and therefore effects may be reduced.

References

Ackerman, M. 2010. *Burn injuries and their relation to wild land firefighting*.

McDonald, A.; Sullivan, E. 2012. *Mathematical model development for energy interaction between wildland/urban interface fires and building structures*. Progress Report 2.