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Hügelkultur as a debris management technique in forest fuel reduction treatments

Developing a research plan to evaluate the flammability of constructed debris piles (hugels)

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Disposal of woody debris and vegetative matter from forest fuel reduction treatments is a challenge and alternatives to conventional methods of pile burning and chipping are being considered. The construction of hugels is proposed as a debris management technique that would configure debris on site in a less flammable state. This research design presents considerations for development of an experimental burn site, test methods, and data collection methods that can be applied in evaluating and comparing the flammability of hugels constructed with different fuel components and construction methods.

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1 BACKGROUND

Forest fuel treatments in the wildland-urban interface typically require the strategic removal of large volumes of vegetative fuel and woody debris to achieve the objectives and measurable fuel reduction standards defined in a fuel treatment prescription. The final disposal of removed fuel is often achieved through a pile and burn tactic.

Chipping and mulching are becoming more commonly applied techniques to convert fuel treatment residue to a less combustible state but these are not universally appropriate or acceptable practices.

While a pile and burn tactic can typically be applied safely during winter months with snow cover, several negative consequences occur when using this approach. In winter months, when the potential for escaped fire is low, poor atmospheric venting conditions often limit smoke dispersion and air quality can be compromised. With any debris burning operation, green house gas emissions are a concern.

2 INTRODUCTION

Disposal of woody debris and vegetative matter from fuel treatments is a challenge and alternatives to conventional methods of pile burning and chipping are being considered. Hügelkultur is proposed as a debris management technique that would configure woody debris, branches, and other vegetative residue on site in a less flammable state (hugels). Objectives and desirable long-term outcomes of a hügelkultur technique are to:

1. Reduce the regrowth of flammable fine fuels in zones of created hugels. A patchwork of surface fuels created by hugels can interrupt the horizontal continuity of fine fuels such as grasses and shrubs that occurs in conventional fuel reduction treatments.
2. Create rings of beneficial habitat around each hugel that encourage or "push" the forest structure towards more fire-resistant broadleaf species.
3. Reduce the labour and equipment expense of the original fuel treatment.
4. Reduce the long-term maintenance requirements in a fuel reduction treatment.

'Hügelkultur – "mound-culture" pioneered by an Austrian ecological farmer Sepp Holzer – aerobically decomposes woody debris into humus over years to decades' (Bennett 2020). This technique has been recently applied in innovative agricultural settings to store excess woody debris and allow it to slowly rot in a fuel matrix including branches, logs, and finer mulches, which are typically covered with either soil or more mulch and then seeded or planted.

Hügelkulturs (hugels) are not composts. Composts are rich in nutrients and bacteria, so decompose in a matter of weeks or months and quickly off-gas a large proportion of their carbon. By contrast, nutrient-poor hugels decompose slowly over many years, and more carbon remains sequestered for much longer. Other benefits of hugels include habitat creation, and humus development for increased water retention and slow nutrient release.

The City of Rossland has contracted FPInnovations Wildfire Operations group to develop research protocols that explore the viability of applying hügelkultur as a debris management technique in forest fuel reduction treatments. To initiate this project, general research questions were proposed that would focus the research process.

3 RESEARCH QUESTION

3.1 Flammability of hugels

Two primary goals of forest fuel management and wildfire mitigation practices are to:

1. Reduce surface fuel loading and potential surface fire intensity
2. Increase crown base height to lessen the probability of crown fire initiation.

To accomplish this strategy, a large volume of surface debris, overstory stems, understory vegetation and prunings must be removed from a treatment area. Construction of hugels in the fuel treatment area is proposed as an alternative means of managing debris by concentrating debris in isolated pile structures.

Technically speaking, constructing hugels is not a form of fuel removal; however, it may reduce piled debris to a less flammable state and reduce the potential for spread to surrounding fuels by concentrating debris in isolated parcels. Fuel conversion and isolation may be more appropriate terms to categorize this debris management process. Regardless of terminology, two key fire behaviour related research questions put forward are:

- How likely will hugels ignite from different ignition mechanisms – airborne firebrands[1] (burning embers) or approaching surface fire
- What is the spread potential from burning hugels and what impact will this have on surrounding fuels (surface vegetation and surrounding forest)

To address these questions, it will be necessary to evaluate the probability of ignition, sustained burning and the potential fire behaviour in hugels. Experimental burn trials are considered a relevant and realistic research mechanism to assess the flammability of hugels. Empirical data collected from these trials can provide the most compelling documentation of hugel flammability.

[1] The terms firebrand and burning ember are often used synonymously. The authors have chosen to use firebrand in this document.

4 OBJECTIVES

Hugels will be constructed in various configurations of different sized fuels combined with other added fuel treatment by-products including mulch. Ignition probability tests and experimental burns will be applied to each hugel configuration to evaluate and compare the following fire behaviour characteristics in the constructed hugels:

1. Probability of ignition
2. Sustained burning
3. Fire intensity and firebrand production

5 METHODS

5.1 Research design – a background to experimental burns

'There is no opportunity to conduct experimental crown fire work in the dry forests of western North America. So possibilities of experimentally treating stands and then purposely subjecting them to a worst case wildfire are non-existent' (Agee and Skinner 2005).

This constraint to documenting the efficacy of fuel treatments applies to specific fuels in a geographic area with a high concentration of values at risk. In other parts of North America, fire behaviour research project sites such as the International Crown Fire Modelling Experiment[2] and the Pelican Mountain FireSmart Vegetation Management site[3] have been established to conduct experimental crown fires to evaluate the efficacy of fuel treatments. A list of documented experimental crown fires to evaluate the efficacy of fuel treatments can be found in Appendix A.

The majority of these experimental burns have been conducted under extreme fire weather and low fuel moisture conditions to achieve an objective of evaluating the capacity of a fuel treatment to moderate continuous crown fire to a reduced intensity that would permit safe and successful fire suppression activities. The crown fires in these experimental burns are initiated in areas of untreated forest stands and allowed to spread freely towards treated areas. (Figure 1). The major fuel components that drive fire behaviour in these experimental burns is live crown fuels and surface fuel.

[2] Overview of the International Crown Fire Modelling Experiment (ICFME)
[3] Pelican Mountain FireSmart Fuel Management Research Site

Figure 1. Experimental crown fire conducted at Red Earth Creek, Alberta. (photo courtesy of Alberta Agriculture and Forestry).

In contrast, burn trials in a hugel fuel environment would primarily involve compacted dead fuels in the constructed hugels with grass and minor amounts of dispersed woody debris and branches in the ignition zone and in areas separating the hugels. Hence, modifications to the crown fire research design are required to study flammability of hugels. A modified approach has been applied in burn trials to assess the flammability of roadside harvest residue configured in different arrangements. These modifications will be applicable to studying flammability of hugels.

A recent experimental burn trial in roadside harvest residue (Spencer, Hvenegaard and MacKinnon 2021) provided insights into fire behaviour that can result in large volumes of oriented piles (tops aligned in a parallel orientation). Under conditions of low fuel moisture content in all debris sizes, ignition in elevated pockets of fine fuel was easily achieved at the peak of the burning day and sustained ignitions grew to high intensity fire in the large woody debris (Figure 2).


Figure 2. Varying stages of fire development and fire intensity in an oriented pile burn trial.

These observations and documentation of fire behaviour in oriented debris piles were conducted at the extremes of fire weather and fine fuel moisture content. Further documentation of fire behaviour in the middle ground of fuel moisture content and fire behaviour indices is required to close this knowledge gap. Continued experimental burns under high fire hazard conditions will provide the most representative data to evaluate potential fire behaviour and assess fuel hazard in these unique fuel environments.

It is important that burn trials to test the flammability of hugels are conducted under the "worst case scenario" of an extreme drought year with a high fire hazard. To ensure that precipitation doesn't wet the piles and reduce their flammability prior to the burn trials, tarps to cover all the trial hugels will be kept on site, ready to deploy over the piles quickly should a rain event threatens. When the rain has passed, the tarps must be removed quickly (within a day) to avoid condensation effects inside the tarp wetting the hugels' outer surfaces.

5.2 Assessing flammability of hugels

5.2.1 Terminology

Flammability – The relative ease with which a substance ignites and sustains combustion.

Fire behaviour – The manner in which fuel ignites, flame develops, and fire spreads and exhibits other related phenomena as determined by the interaction of fuels, weather, and topography.

Fuel – Any organic material that can ignite and burn; it can be divided into three broad levels: ground, surface, and aerial.

(CIFFC Canadian Wildland Fire Glossary[4])

[4]Canadian Interagency Forest Fire Centre Inc. - Canadian Wildland Fire Glossary

Hugels are a constructed fuel source of which there are no known representative fuel types in current fire behaviour models. Without observations or documentation of burning hugels, the flammability of this fuel and resultant fire behaviour is unknown.

The research hypothesis for this project proposes that hügelkultur can be applied in forest fuel treatments to dispose of woody debris and vegetative matter without creating an unacceptable fire hazard.

Fire hazard means (a) the risk of fire starting, and (b) the hazard associated with an industrial activity; and (c) if a fire were to start, (i) the volatility of the fire's behaviour, (ii) the difficulty of controlling the fire, and (iii) the potential threat to values at risk.

Fuel hazard means the potential fire behaviour, without regard to the state of weather or topography, based on the physical fuel characteristics, including fuel arrangement, fuel load, condition of herbaceous vegetation and the presence of ladder fuel. (Province of British Columbia 2012)

Experimental burns in a simulated fuel environment with constructed hugels can provide insights into the fire hazard and fuel hazard that this debris management technique presents. A research site will be designed to support a realistic simulation of the key ignition mechanisms that would be present in a wildfire environment to observe the interaction between these mechanisms and the constructed fuel environment.

5.2.2 Ignition mechanisms in a hügelkultur fuel environment

The two key ignition mechanisms that would ignite debris piles or hugels are airborne firebrands or an encroaching surface fire. The research plan and research site will be developed to:

1. Compare and evaluate the probability of ignition and sustained burning in different hugel configurations and
2. Allow ignitions in the hugels to spread unimpeded to compare and evaluate the sustained burning, fire spread, and potential fire intensity within the hugels.

Observing the flammability of hugels and the resulting potential fire behaviour can lend to a better assessment of fuel hazard, spread potential and threat to values at risk.

Ignition of the hugels will be initiated in one of two ways. The ignition patterns will be dependent on fire hazard conditions and at the discretion of the incident commander (prescribed fire burn boss)[5]. Firstly, ignition probability tests will be conducted to simulate firebrand transfer and document the ease of ignition and sustained burning in the hugels. Ideally, comparative ignition trials in the hugels of various construction designs should be conducted simultaneously but this may need to be reconsidered under higher fire hazard conditions or if there are limited suppression resources available. These tests can occur under higher fire hazard conditions by testing each hugel individually and ensuring sufficient suppression resources are deployed to extinguish the ignitions at a small size before growing to an unmanageable intensity.

[5]Further explanation of prescribed fire operations and terminology can be found in the BCWS S-235 Ignition Operations training manual.

Secondly, a line ignition will be initiated on the upwind or downslope side of each hugel to simulate an encroaching wildfire engaging the constructed hugels. A progressive ignition process will be applied by using drip torches to consistently simulate varied intensities of approaching wildfire. As the hugels are engaged by the fire, they will be allowed to burn to collect data on fire behaviour characteristics and consumption rates.

Successful comparative ignition trials in the hugels will depend on low fuel moisture content in the fine fuels and this can be achieved by tarping the hugels in the week(s) prior to the ignition trials if rain is forecast for the area. However, the tarps should be removed at other times to permit the natural processes of moisture transfer with the atmosphere and allow drying through the influence of wind and solar radiation.

Tarping of the hugels will permit ignition trials at a low fuel moisture content in the hugels while the surrounding forest fuels are still at a higher moisture content; thus, provide a safety margin to reduce the chance of escaped fire.

When comparative trials are conducted by igniting each hugel independently at different times, that time between ignitions should be minimized to reduce the variation in flammability due to diurnal moisture loss through the burning day. A randomized selection and ordering of hugel ignitions should be adopted across the trial plots.

5.2.2.1 Ease of fire spread from encroaching surface fire to hugels

During an experimental burn to assess the flammability of oriented piles (Spencer, Hvenegaard and MacKinnon 2021) a methodology was tested to simulate a wildfire encroaching on the oriented pile. Essentially, a line ignition was initiated in woody debris upwind of the oriented pile and intervening fuels were allowed to burn toward the pile. The compacted surface fuels close to the ground had absorbed moisture and burned with low intensity and rate of spread but eventually engaged the oriented piles and ignited the piles. One observation from these trials was that to achieve sustained burning in the different oriented piles, more than one line with a drip torch was often required to sustain burning in these fuels.

A progressive ignition test process is proposed to simulate encroaching wildfire of increasing intensity. In order to maintain consistency in the ignition process, we propose that the number of lines (simultaneous passes with one or more drip torches) will be used as an indicator of intensity or energy applied in the ignition. For example, the progressive ignition testing will start with a single line with one drip torch. If ignition is not successful or burning is not sustained, a second attempt will be made with a double line produced with two torches. If sustained burning is not achieved, a final attempt will be made with three drip torches.

If these ignition attempts are not successful on that hugel, the same test will be applied on the next hugel. If the remaining hugels in the plot will not ignite, it will be necessary to attempt ignition during times of lower fine fuel moisture content (later in the day or with extra days of drying).

During the comparative trials, it will be important to apply the same amount of drip torch fuel during each pass across the different hugels that are being ignited. To achieve this, an ignition specialist would need to apply fuel for the same duration on each pass. If there is an indication that different drip torches have different flow rates, the same torch should be used for the initial passes while the second and third passes should be applied by the same respective drip torches.

Another factor to consider during this ignition trial is how the volume of surface fuel across a trial site might influence fire intensity in the ignition zones of each individual hugel. The impact of this variable can be reduced by creating a consistent surface fuel environment in each ignition zone. This can be achieved by cutting the surface fuels in the ignition zone (1 meter width) using a grass mower or brush saw with removal of the cut fuel with a rake.

5.2.2.2 Probability of ignition and sustained burning from firebrands

Probability of ignition test methods have been developed and applied in fine fuels of various fuel environments to assess the potential for sustained ignition. The match drop test method (Paul 1969) has been used to model the probability of sustained ignition in mulch fuels (Schiks and Hvenegaard 2013) and in thinned lodgepole stands (Schroeder et al. 2006).

The match drop test may be a viable test method in hugels if there is a large presence of fine fuels such as needles, grass, or mulch. Other devices or materials that produce a more robust ignition source of longer duration may be required to more realistically simulate firebrands generated by wildfire in forest fuels and achieve ignition of hugels with fewer fine fuels.

Firebrand generators[6] have been developed to simulate firebrand production from wildfires and evaluate vulnerabilities of structures subjected to firebrand storms. Currently, these devices have only been developed for laboratory testing and are not available for field use. However, the desired outcome of generating 'a controlled and repeatable size and mass distribution of glowing firebrands' (Suzuki et al. 2013) can also be achieved by selecting other combustible materials that can produce an ignition source of consistent intensity (flaming or glowing combustion) and duration. These materials may include barbecue starters and charcoal briquettes.

Hand-held plastic sphere dispensers[7] are commercially available ignition devices that dispense ping pong ball sized incendiaries that generate sustained and consistent flame intensity for approximately two minutes. While these devices are designed primarily for supplementing ignition operations with drip torches on prescribed fires, they may also have application on ignition probability tests.

A relative assessment of ignition and sustained burning can be documented using a vigour code presented in Paul (1969) (Appendix B). This vigour code has been adapted to ignition and sustained burning trials in the larger fuels of hugels. As part of the overall flammability test, successful ignitions can be allowed to burn the hugels to compare fire behaviour characteristics in the hugels (flame length, fire spread rate, firebrand production, and consumption rate).

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[6] National Institute of Standards and Technology Standard Firebrand Generator

[7] Dragon egg dispensers

5.3 Research site design

5.3.1 Site description

The site proposed for these experimental burn trials is approximately 4 km north of Rossland and adjacent to the Ophir Reservoir (elevation 1148 m) and Black Jack ski club and nordic ski trails. Forest fuel reduction treatments are planned for forested areas east of the reservoir.

An open area (approximately 1.0 ha in size) southeast of the treatment area is available to be developed as the hügelkultur experimental burn project site (Figure 3).

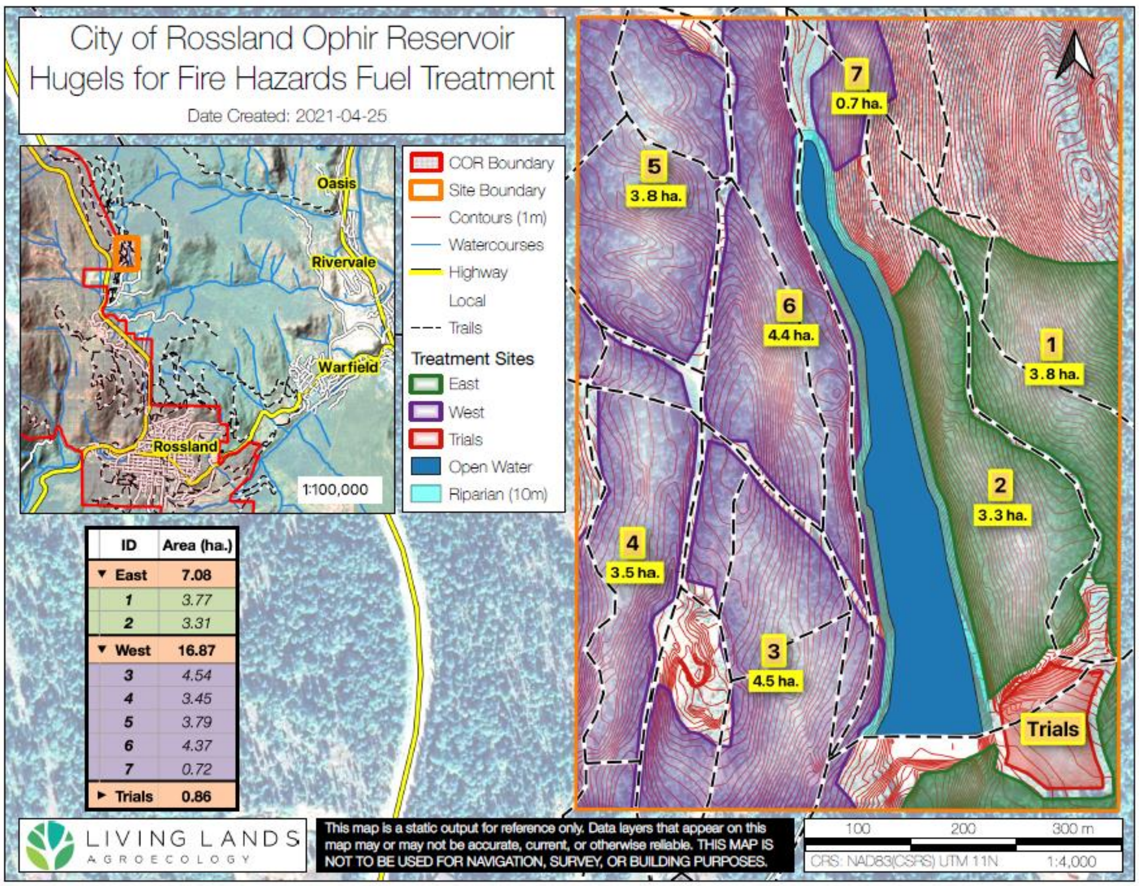

Figure 3. Ophir reservoir with treatment area (east) and experimental burn site (southeast) of reservoir.

The site has a southwest aspect with a general slope less than 10%. The northern edge of the site has a slope of approximately 40% (Figure 4). This site has good access to the reservoir to supply water to a sprinkler system.

Figure 4. Experimental burn site (looking northeast toward fuel treatment area).

5.3.2 Principles of hugel construction

The size and shape of residue piles can influence potential fire behaviour. Burn piles that are constructed to dispose of residue from harvest operations or fuel treatments are designed to ignite easily, sustain burning and consume debris. Conversely, constructed hugels will be designed to be less flammable with reduced ignition potential and lower potential fire intensity. 'Haystack' burn piles in harvest blocks are constructed to allow for burning at lower fire hazard levels, promote fire spread in the pile, and to optimize fuel consumption. A taller vertical structure with good vertical continuity allows for greater fire spread with greater volume of fuel consumed on a smaller footprint.

Relative to constructed 'haystack' burn piles, oriented harvest residue piles with fuel particles aligned horizontally and reduced vertical structure are more difficult to ignite with reduced sustained burning and potential fire intensity (Hvenegaard et al. 2019). Applying these preliminary findings, a low-profile shape is proposed for the constructed hugels with branches and stems aligned to increase density and reduce air flow through the hugel.

Hugel construction variables including fuel components, arrangement of fuels and orientation of fuels can influence the flammability and potential fire intensity of the hugels. This research plan proposes to evaluate and compare the flammability and fire behaviour of hugels constructed using two varying design principles. These design principles are size of hugels and composition of fuels. The experimental burn site will be designed to allow for multiple trials that can evaluate and compare the flammability of the various configurations.

It is anticipated that the contractor conducting the fuel treatment will be using a mulcher; hence, mulch will be one of the fuel by-products of the fuel treatment. The remaining fuel component produced in the treatment will be woody debris (stems and branches). To incorporate the design variable of fuel component, we propose that hugels be created with a varying mulch to woody debris ratio.

5.3.3 Site design

The experimental burn site can be divided into 4 plots, and each can be burned as an independent burn trial. Plot 1 can be established on the upper slope with three plots on the lower and flatter area. (Figure 5). Plot 1 would be the first area to be burned. This blackened area from the burn will reinforce the fuel break (sprinklers and handline if constructed) and allow for burning of subsequent trials at higher fire hazard levels. Once plot 1 has been burned the next downhill plot can be burned. On the upper slopes of the site, space has been dedicated to experimenting with different hugel configurations (labelled Expt on Figure 5) to determine optimum sizes and construction methods.

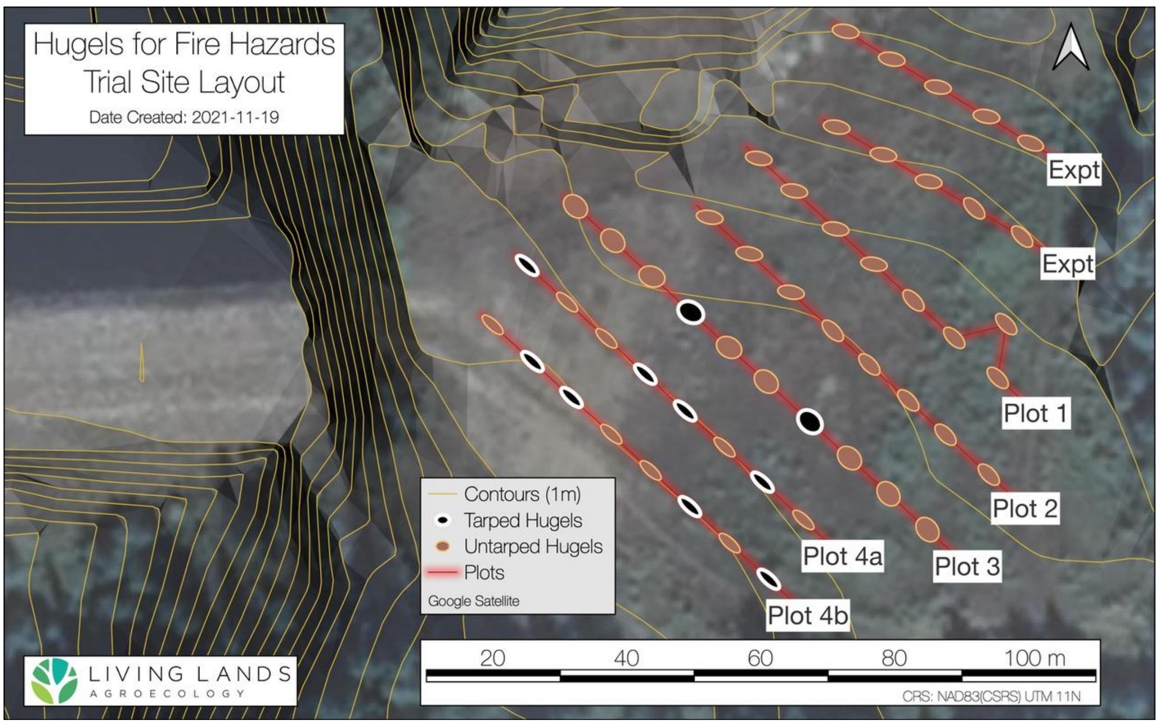

Figure 5. Burn trial plot layout in the hugel experimental burn site.

Plot 1 – The northern edge of the site has a moderate slope (up to 40%) which can be utilized to place hugels in a cross-slope orientation to trap moisture from rain and snowmelt. In plot 1 the hugels will be of the same size but the mulch to woody debris ratio will be varied.

Plot 2, on flatter ground, will use the same hugel configurations and same size of hugels.

In plots 3 and 4, the hugel dimensions (width and height) will be varied to evaluate how adjusting the volume to surface area ratio of the hugel would affect flammability.

5.3.4 Proposed hugel configurations and sizes

Six hugel configurations are proposed for replication through the four plots. The proposed fuel compositions for these piles are:

1. Matrix (67% mulch/33% woody debris)
2. Core (67% woody debris covered by 33% mulch)
3. 0% mulch
4. 100% mulch
5. Matrix (33% mulch/67% woody debris)
6. Core (33% woody debris covered by 67% mulch)

The proposed configurations will be trialed in an area above the burn site (plots marked ‘expt’ in Figure 5) before committing to specific designs that will be applied in the burn site.

Matrix configuration – woody debris and mulch will be combined in varied ratios to create an ‘oriented matrix’ of larger branches and stems combined with mulched smaller branches. These stems and larger branches can be aligned in an oriented fashion.

Core configuration – A ‘core’ of woody debris (stems and branches) will be placed along the central axis of the hugel and covered with a varied mix of mulch and debris to create a cap on the hugels to insulate the inner fuels and retain moisture.

0% mulch configuration - (minimal extent of pile preparation) This configuration is representative of piles created as part of a pile and burn tactic and is considered a control by which other hugel configurations are compared to. Composition is 100% woody debris and there is the least attention to orientation of debris in the pile.

Mulch configuration – Piling mulch in a fuel treatment area is not a typical debris management technique but this configuration is being explored to compare fire behaviour in a full range of woody debris and mulch combinations. This configuration may be more labor intensive and time consuming but that will be captured in the comparative productivity study.

During the creation of hugels in the fuel treatment and in the experimental burn site there will need to be a determination of size thresholds for chipping branches and stems. The lower stems of some species may be limb free and easy to compact in the pile in an oriented fashion. However, a decision will need to be made whether to delimb branches from the tops before placing these in the pile. Delimbing and mulching small branches (less than 3 cm) will reduce the volume of fine fuels in the hugels but will be time consuming.

In preparing the hugels, overlying considerations should include:

- can these construction methods be implemented in a fuel treatment area?
- how much time or supplemental material is required to construct a hugel of a specific design?

5.3.4.1 Ignition test procedures with pile dimensions

Plot 1: (6 piles) – Probability of ignition from firebrands

- Pile size: 2 x 4 x 1.5 (width X length X height) (meters)

Plot 2: (6 piles) – Line ignition with drip torches

- Pile size: 2 x 4 x 1.5

Plot 3 (6 piles) – Line ignition with drip torches

- Pile size: 3 x 4 x 2 (double the volume)

Plot 4a and 4b (12 piles) — Line ignition with drip torches

- Pile size: 1.5 x 4 x 1

Plot 4a and Plot 4b are identical replicates with each pair of identical hugels assigned randomly for a tarp versus no-tarp trial.

5.3.5 Tarping to reduce hugel fire hazard

While the burn trials would use tarps for very short periods during rain events to keep the piles as dry as possible (as a means to simulate drought and highest possible fire hazard conditions prior to the burn tests) tarps might also be used as a management tool to achieve the exact opposite result, and actually increase hugel moisture and reduce the fire hazard.

Tarps can be pulled over hugels when they are first created and left in place until fall rains and cool weather arrive. Used like this, tarps are likely to have three main impacts:

1. Evaporation is reduced, retaining moisture in the woody debris and in the soil under the hugel.
2. Condensation on the inside of the tarp from trapped evaporation transports moisture to the outside layer of the hugel, where it has the greatest impact on hugel fire risk.
3. Decomposition is increased from the additional moisture, but also from increased hugel temperatures due to both reduced convection and the “tent effect” of captured infrared radiation.

Taken together, these three impacts could significantly reduce hugel fire hazard, particularly in the first season when un-decomposed fine woody debris dries out quickly and presents the greatest risk. Whether the benefits of the practice justify the cost of the tarp and the labour required to remove them in the fall, however, is not known.

To test the impact of tarping a hugel for it’s first season, plots 4a and 4b are made as identical replicates of “small” hugels. For each pair of identical hugels in Plot 4, either the “a” or “b” version will be randomly assigned to be tarped continuously. The other will only be tarped in rain events, and immediately untarped, to simulate drought as in Plots 1, 2, and 3.

Winter snow and spring melt after the first season should substantially reduce hugel flammability, so tarping in the second and subsequent seasons is unlikely to be cost-effective for the additional material and labour required. Nevertheless, a longer-term study would be required to test this proposition, with burn trials compared across multiple seasons.

5.3.6 Containment requirements

The research site will be assessed to determine the potential for fire escape beyond containment lines. Features such as natural barriers, topography, proximity to continuous fuels and access to water sources will be evaluated to determine appropriate containment measures. A containment strategy will be developed in consultation with the burn boss as part of the prescribed burn plan. A sprinkler deployment will be a required and straightforward containment measure while construction of a fuel break may be considered.

5.4 Determining an appropriate burn prescription

One of the challenges of planning an experimental burn is defining appropriate weather and fuel moisture parameters that will generate active and challenging fire behaviour to achieve the research objectives. At the same time, it is critical that an upper limit on these parameters be established to ensure that fire intensity and rate of spread are limited to a controllable state to prevent fire escape.

In the planning stages of the prescribed burn, it will be important to communicate to the burn boss the research goals and the desired fire behaviour. Ultimately, the burn boss will need to determine appropriate burn window (FWI values and weather conditions) to achieve the appropriate fire behaviour and reduce the potential for escaped fire.

5.4.1 FWI values and weather conditions

FWI values and weather conditions are the key factors that are considered and applied in a burn prescription. These factors are adjusted based on other static environmental conditions such as slope and aspect and adjacent fuels.

The experimental burn site is well-drained. Especially on the steeper upper slope, the southwest aspect will enhance drying of fine fuels and increase the slope equivalent wind speed (Taylor et al. 1997) which will effectively increase ignition potential and rate of spread.

Previous ignition probability tests have determined hourly FFMC thresholds for ignition in different fine fuel environments. Figure 6 illustrates probability of ignition in four fine fuel types and indicates an FFMC in the range of 78 to 83 is necessary achieve to a 50% probability of ignition in fine fuels. This range of FFMC values serves as a good starting point for ignition probability testing and there is little value in conducting tests below this range.

If the hugels are tarped to reduce moisture absorption prior to the comparative trials, the FFMC from a nearby weather station may not be a reliable indicator of moisture content in the fine fuels of the hugels. In this case, tactical cues provide some indication of fuel moisture and test ignitions can be conducted to determine if ignition probability testing is feasible. Fuel moisture sampling in fine fuels will be essential to documentation.

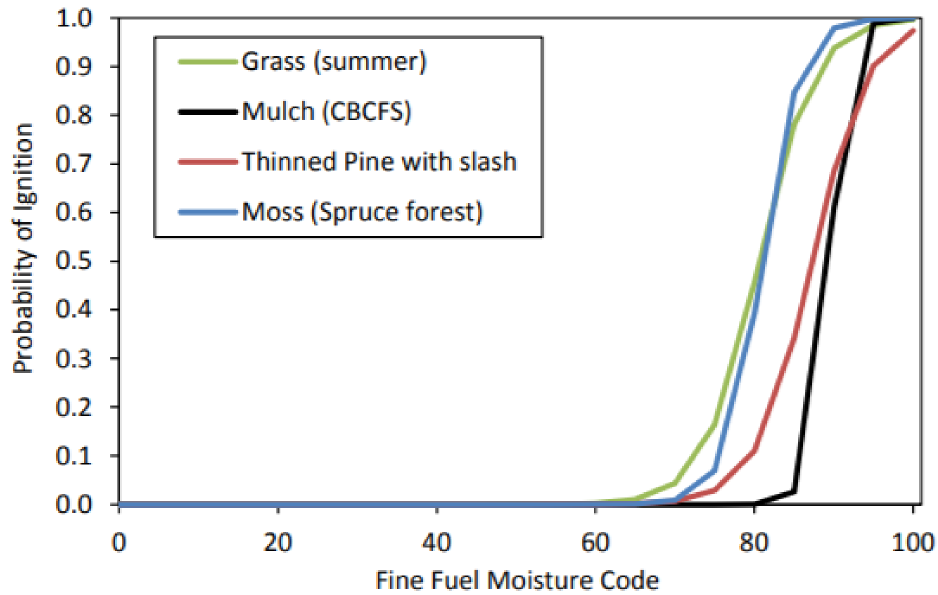

Figure 6. Probability of ignition vs. hourly FFMC for summer grass, mulch (CBCFS site), thinned pine with slash, and moss in a spruce forest. (Schiks and Hvenegaard 2013)

5.4.2 Scheduling experimental burns

Constructing hugels in the experimental burn site will be dependent on availability of debris from the fuel treatment site. Fuel treatment work may proceed in the spring of 2022. This would allow for hugel construction as debris is accumulated and, potentially, set the stage for a burn trial in fall 2022.

Multiple burn trials would be beneficial to better understand the flammability of hugels under a wider range of moisture and weather conditions. However, given the time requirements for planning a prescribed burn and logistics of acquiring and deploying containment operations, it may be simpler to limit to the number of burn trials to two. The availability of fire suppression crews and equipment will be an important consideration in scheduling burn trials.

Developing a burn plan should be done under the direction of a certified burn boss. BCWS has a wealth of knowledge and experience in prescribed burning and early engagement with the Southeast Fire Centre prevention section or the Fire Zone will be essential.

5.5 Documentation

5.5.1 Environmental conditions

Weather and FWI values

Long-term weather data and Fire Weather Index values will be retrieved from the nearest BCWS weather station (Nancy Green). During the burn trials, FFMC will be adjusted diurnally with hourly ISI calculated based on current wind speed. Data from the Environment Canada weather station in Warfield will also be collected.

Long-term localized weather data preceding the experimental burns can be recorded by establishing a weather station at the experimental burn site.

A Kestrel 5500 weather meter[8] with datalogging capability will be used during the experimental burns to monitor and log on-site weather conditions including temperature, relative humidity, and wind speed and direction.

Fuel Moisture Content

Fuel moisture content (FMC) will be a good indicator of how different construction methods influence moisture retention and the potential for ignition and sustained burning. Collecting fuel samples during the construction phase and measuring fuel moisture can provide a good baseline for moisture change in different size class fuels over time. Measuring FMC of woody debris typically involves collecting and processing fuel samples from defined size class categories (McRae et al. 1979):

- SC 1- less than 0.49 cm,
- SC 2 – 0.5 to 0.99 cm
- SC 3 – 1 to 2.99 cm
- SC 4 – 3 to 4.99 cm
- SC 5 – 5 to 6.99 cm
- Coarse woody debris – greater than 7 cm

Prior to the burn trials, fuel samples should be collected as close to the burn time as possible and stored in sealed containers (metal tins or ziplock bags) to prevent moisture loss during transportation to a drying oven. An additional measure to ensure accurate moisture content assessment is to weigh and record fuel sample weights (in fine fuels) immediately after collection. Fuel samples are oven dried until no loss in fuel weight can be measured. A commonly applied drying temperature and time is 100 C for 24 hours (McRae et al. 1979). Oven drying larger fuel components is difficult and a Protimeter moisture meter[9] can be used to measure moisture content in these fuels.

Calculation of fuel moisture content

Fuel moisture content (%) = ((green weight – oven dry weight)/oven dry weight) X 100

FMC in size classes 1 and 2 is an indicator of the ignition potential of the hugels while FMC in larger debris indicates the potential for sustained burning and potential fire intensity.

[8] Kestrel weather meters
[9] https://www.protimeter.com/timbermaster

Collecting fuel samples and oven drying to measure FMC is time consuming, and this process can be streamlined to assess the most influential fuel components. As an alternative to rigorous fuel sample collection with oven drying and FMC calculations, a simple approach to assessing fuel moisture content will be to use Fine Fuel Moisture Code (FFMC) as an indicator of moisture content in SC 1 and 2 with measurement of FMC using a Protimeter moisture meter for larger size classes greater than 3 cm in diameter (Zahn and Henson 2011).

5.5.2 Fire behaviour

Fire behaviour observations are a qualitative approach to assessing flammability of hugels. Ease of ignition, sustained burning, fire behaviour characteristics and consumption rate can be evaluated using tools including video capture (ground-based and aerial), infrared imagery, and timing devices.

Video capture

- Rate of spread
    - In hugels – time required for a sustained ignition to spread through the hugel
- Flame length – flame length can be used as an indicator of fire intensity
- Spot fire ignitions in adjacent surface fuels are the most practical indicator of firebrand production. Spot fires should be marked with flagging tape or pins so that the number of ignitions can be counted and distance from the hugel can be measured. Firebrand production can also be assessed using infrared imagery to detect airborne firebrands generated by the burning hugels.

- Aerial imaging with drone will be captured of overall ignition and burn trials
- Video cameras will be set up to record progression of ignition, sustained burning and consumption of each hugel. In plots with 6 or 8 piles, one camera can cover 2 hugels.

Consumption rate – Record the time to achieve:

- Sustained flaming in each hugel. Fire spread continues without the influence of an ignition source.
- Full involvement of flaming in the hugel. In previous studies, a pile was considered to be fully involved when 80% of the pile material was estimated to be engulfed in flames (Hvenegaard et al. 2019).
- Self-extinguishment - if sustained burning is established in a hugel but later stops spreading in the hugel and fire self- extinguishes.

Overall hugel consumption – how much of the hugel is consumed in the burn trial. This can be estimated as a percentage of initial pile size.

5.5.3 Data collection summary

At time of hugel construction:

- FMC of larger debris (SC3+) by protimeter.

- FMC of fine fuel (SC1, SC2) by oven-dry: weigh by scale immediately, bag, dry in oven, and reweigh. [Drying ovens may be available at Selkirk College]

- Fuel size compositions

- Height, length, and width of pile
- Signpost staked at hugel with details of construction
- Photographs of all sides to use 3D modelling software — include meter stick for scale and signpost.

During season:

- Long term weather station on a data logger [AB to investigate tools. e.g. Kestrel Drop - (temp, rev humidity, wind (no rain)]
- Dates and times tarps applied and removed.

Data collection immediately before trials:

- FMC of larger debris by protimeter and finer debris (SC1, SC2) by oven-dry.
- Additional weather monitoring (e.g. Kestrel 5500 on 15 second intervals)

During burn:

- Number & intensity of ignition attempts
- Fire behaviour: Time to complete engagement, rate of spread, flame length, firebrand and spot fire production, suppression requirements.
- Video (tripod and drone)
- Optional: infrared imagery for firebrand production

After burn:

- Percent consumption (ocular estimate)
- Height, length, and width of pile

Photographs of all sides to use 3D modelling software — include meter stick for scale and signpost.

5.5.4 Ongoing modifications to this research

This research design is a preliminary proposal based on methods and documentation applied in experimental burn trials in crown fires and harvest residue. The proposed research methods in this research design have been discussed and revised in collaboration with the project champion, Andrew Bennett. The research design attempts to account for specific site attributes and perceived burning potential in the hugel fuel environment. Further modifications may be required to address unknown variables in the future.

Successful execution of an experimental burn is dependent on several factors including collaboration with a wildfire management agency or contractor with a certified burn boss in prescribed burn planning and support in igntion and containment operations.

6 REFERENCES

Agee, J. K., & Skinner, C. N. (2005). Basic principles of fuel reduction treatments. Forest Ecology and Management, 211, 83–96.

Bennett, A. (2020). (unpublished). Hugels for Fire Hazards. Project summary, proposal, and action plan.

Hvenegaard, S., Spencer, S., Baxter, G., & Strimbu, V. (2019). Evaluating the relative fire hazard of oriented debris piles and constructed burn piles. FPInnovations Technical Report No. 15.

Paul, P.M. (1969). Field practice in Forest Fire Danger Rating. Canadian Forest Service, Forest Fire Research Institute. Report FF-X-20. Ottawa, ON.

McRae, D.J., Alexander, M.E., and Stocks, B.J. 1979. Measurement and description of fuels and fire behavior on prescribed burns: a handbook. Can. For. Serv. Inf. Rep. O-X-287.

Province of British Columbia. (2012). A guide to fuel hazard assessment and abatement in British Columbia.

Schroeder, D., Russo, G.; Beck, J., Hawkes, B.C. & Dalrymple, G.N. (2006). Modelling ignition probability of thinned lodgepole pine stands. FPInnovations, FERIC Advantage Report, Volume 7, No. 12.

Schiks, T. & Hvenegaard, S. (2013). Modelling the probability of sustained igntion in mulch fuelbeds. FPInnovations Project Report.

Spencer, S., Hvenegaard, S., & MacKinnon, B. (2021). Oriented pile flammability burn trial October 2020: Collaborations with Mosaic Forest Management and British Columbia Wildfire Service. FPInnovations Technical Report No. 8.

Stocks, B. J., Alexander, M. E., & Lanoville, R. A. (2004). Overview of the International Crown Fire Modelling Experiment (ICFME). Canadian Journal of Forest Research. Volume 34.

Suzuki, S., Manzello, S. L., & Hayashi, Y. (2013). The size and mass distribution of firebrands collected from ignited building components exposed to wind. *Proceedings of the Combustion Institute*, *34*(2), 2479-2485.

Taylor, S.W.; Pike, R.G.; Alexander, M.E. 1997. Field guide to the Canadian Forest Fire Behavior Prediction (FBP) System. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta. Special Report 11.

Van Wagner, C. E.: 1987, 'The development and structure of the Canadian forest fire weather index system', Canadian Forest Service, Forest Technical Report 35, Ottawa, Canada.

Zahn, S., and Henson, C. 2011. A Synthesis of Fuel Moisture Collection Methods and Equipment—A Desk Guide, USDA Forest Service, San Dimas Technology and Development Center, San Dimas, CA.

APPENDIX A: EXPERIMENTAL CROWN FIRES TO EVALUATE THE EFFICACY OF FUEL TREATMENTS

Hvenegaard, S. (2017). Fire behaviour in jack pine/black spruce forest fuels following mulch fuel treatments: a case study at the Canadian Boreal Community FireSmart Project. FPInnovations Technical Report. Number 24.

Hvenegaard, S., Schroeder, D., & Thompson, D. (2016). Fire behaviour in black spruce forest fuels following mulch fuel treatments: A case study at Red Earth Creek, Alberta. FP Innovations Technical Report Number 42

Mooney, C. (2013). Can light stand thinning weaken advancing crown fire? A case study in black spruce (Picea Mariana). FPInnovations Technical Report.

Schroeder, D. (2010). Fire behaviour in thinned jack pine: two case studies of FireSmart treatments in Canada's Northwest Territories. FPInnovations Advantage Report Volume 12. Number 7.

Thompson, D. K., Schroeder, D., Wilkinson, S. L., Barber, Q., Baxter, G., Cameron, H., Hsieh, R. Marshall, G., Moore, B., Refai, R., Rodell, C., Schiks, T., Verkaik, G. & Zerb, J. (2020). Recent crown thinning in a boreal black spruce forest does not reduce spread rate nor total fuel consumption: Results from an experimental crown fire in Alberta, Canada. *Fire*, *3*(3), 28.

APPENDIX B: SUSTAINED BURNING VIGOUR CODES

VIGOUR (Match-set fires)

0. Fire goes out before two minutes.
1. At two minutes fire is burning very weakly on one front only and goes out by itself.
2. At 2 minutes fire is burning slowly and poorly on two or more fronts and seems likely to go out on its own accord rather than continue indefinitely.
3. At two minutes no sign of fire going out by itself, burning fairly briskly, but not on all fronts.
4. Fire burning briskly at two minutes on all fronts with tendency to become progressively stronger, but no difficulty in putting it out with the feet.
5. As for No. 4 but difficult or impossible to put out fire with feet after two minutes.

From Paul (1969)

Vigour codes for ignition and sustained burning trials in hugels (based on vigour codes in Paul 1969)

Due to the expected differences in fuel size in hugels with reduced volumes of fine fuels, the match drop may not generate sufficient heat intensity to ignite the fuels. A more robust ignition source may be required (as discussed in the text of this plan). A longer duration of observation may be required to assess sustained burning and assign a vigour code.

1. Ignition source does not ignite any surrounding fuels and ignition source self-extinguishes within 5 minutes.
2. At 5 minutes, some surrounding fuels have ignited burning very weakly on one front and any flaming eventually self-extinguishes.
3. At 5 minutes, fire in surrounding fuels is self-sustaining, burning fairly briskly, but not on all fronts.
4. Fire is self-sustaining in surrounding fuels and burning briskly on all fronts with tendency to become progressively stronger, but no difficulty in putting out the fire with feet or backpack pump.
5. Same as for No. 4 but difficult or impossible to put out fire with feet or backpack pump after five minutes.

Observers should have at least two backpack pumps at the site to extinguish the ignition before the entire hugel is engaged. If the ignition is intended to progress to observations of sustained burning and consumption of the hugel, a water delivery system (pump and hose) should be tested prior to and running during the observation.

APPENDIX C: BURN TRIAL OBSERVATIONS AND DOCUMENTATION: IGNITION TEST AND FIRE BEHAVIOUR

<table>
<tr><td>DATE</td><td colspan="10"></td></tr>
<tr><td>LOCATION</td><td colspan="10"></td></tr>
<tr><td rowspan="2">FORECAST FWI VALUES</td><td>FFMC</td><td>DMC</td><td>DC</td><td>BUI</td><td>ISI</td><td>FWI</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="11"></td></tr>
<tr><td>IGNITION #</td><td></td><td>TIME</td><td colspan="8"></td></tr>
<tr><td rowspan="2">WEATHER VALUES AT TIME OF IGNITION</td><td>TEMP</td><td>RH</td><td>WS</td><td>WD</td><td>ADJUSTED FFMC</td><td>ADJUSTED ISI</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CWD moisture content (10 stems > 5 cm)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>IGNITION DEVICE</td><td>VIGOUR CODE</td><td>HUGEL TYPE</td></tr>
<tr><td>SUSTAINED BURNING</td><td>Y/N</td><td></td><td></td><td></td></tr>
<tr><td>FLAME LENGTH AT 10 MINUTES (cm)</td><td>FLAME LENGTH AT 20 MINUTES (cm)</td><td>SELF-EXTINGUISHING?</td></tr>
<tr><td></td><td></td><td>YES/NO</td></tr>
<tr><td>IF FIRE SELF-EXTINGUISHES - OVERALL PILE CONSUMPTION (%)</td><td>TIME TO COMPLETE CONSUMPTION</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Firebrand generation</td><td>YES/NO</td><td>Spot fire initiation – distance from hugel (m)</td><td></td></tr>
<tr><td>COMMENTS</td><td colspan="10"></td></tr>
</table>

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