info@fpinnovations.ca
www.fpinnovations.ca

Log-deck fire suppression using high volume water delivery systems

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Razim Refai, Researcher

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Multiple log-deck fires at mill sites and log yards in Western Canada in the past year resulted in the loss of merchantable timber. These fires showcased how existing equipment and suppression efforts from wildfire agencies are heavily challenged when asked to handle the thermal output from burning log-decks.

In an effort to explore alternate solutions, FPInnovations collaborated with West Fraser and the High Level Forest Management Area to understand the efficacy of high-volume water delivery systems in log-deck fire suppression. Over the course of three days, water-penetration tests as well as suppression tests were carried out to better understand the utility and resource requirements of high-volume water delivery systems.

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APPROVER CONTACT INFORMATION
Michael Benson
Manager, Wildfire Operations
michael.benson@fpinnovations.ca

AUTHOR CONTACT INFORMATION
Razim Refai
Researcher, Wildfire Operations
razim.refai@fpinnovations.ca
(780) 817-1840

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BACKGROUND

In 2021, multiple instances of log-deck fires occurred at mill sites and log yards in Western Canada – High Level (Alberta), Chetwynd (British Columbia), and Quesnel (British Columbia). Each instance resulted in the loss of notable quantities of merchantable timber. Suppression efforts from wildfire agencies proved to be challenging – on-site water sources (if any) were scarce, ground-based suppression efforts lacked sufficient water throughput, and aviation suppression efforts lacked adequate log-deck penetration.

In an effort to explore alternate solutions, FPInnovations' Wildfire Operations group was approached by High Level's Forest Management Area (Alberta Agriculture and Forestry, Government of Alberta) to participate in a research study that looked to understand how high-volume water delivery systems can play a role in log-deck fire suppression. Log-deck fires, once partially or fully engulfed, often output large quantities of thermal energy that can over-power traditional sprinkler systems used by fire departments and wildfire agencies. These traditional water delivery systems often range 1.5-inch to 4-inch main lines and are unable to supply enough volume of water effectively suppress a log-deck fire. High-volume water delivery systems use larger diameter hose primarily used in water hauling operations over long distances. With main lines using 6, 8, 10, or 12-inch hose, it is theorized that the combination of a low friction coefficient of larger diameter hose and greater suppressant volume delivery may be suitable to rapidly manage log-deck fires.

This field study aimed to understand the interaction of log-deck fires and high-volume water delivery systems, with the goal of determining their efficacy in log-deck fire suppression. Several competing factors influence the efficacy of a suppression effort - availability of water on-site, time taken for suppression, access to heavy machinery such as butt-n-tops, and most importantly, safety of personnel and protection of existing merchantable timber. This study looks to provide insight into some of these variables that influence success of log-deck fire suppression. In collaboration with West Fraser, the High Level Forest Management Area conducted prescribed burns on several log-decks at West Fraser's OSB mill site at High Level. These prescribed burns offered an opportunity to collect valuable data on the subject matter.

OBJECTIVE

The objectives of this study were:

1. Understand how high-volume water is able to penetrate log-decks.
2. Assess the efficacy of high-volume water-delivery systems to effectively suppress a log-deck fire.
3. Understand how much water is required to suppress a fully engulfed log-deck fire.

SITE

The site chosen for this field study was the storage yard at West Fraser's OSB mill at High Level. The site was composed of an on-site water source (Figure 1), several aspen log-decks dedicated for the prescribed burn (Figure 2), several aspen debris piles (Figure 2), and a large set of merchantable timber that required protection from the prescribed burn (Figure 3). The linear distance between the water source and the merchantable timber was approximately 500-meters, with the log-decks and debris piles at varying locations in between.

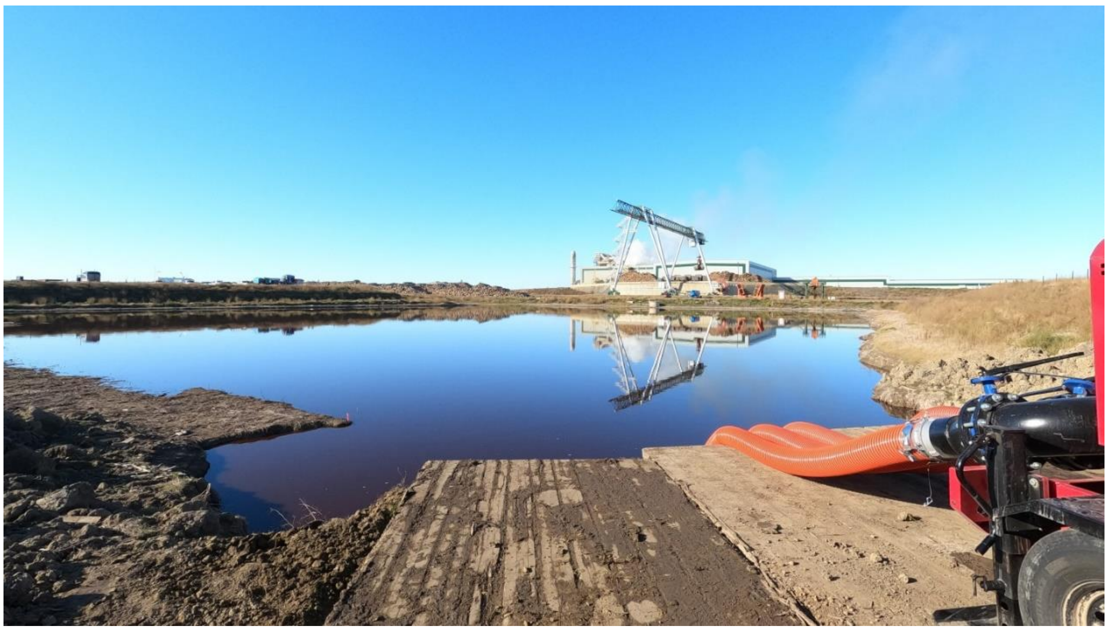

Figure 1. On site water source at the West Fraser mill site.

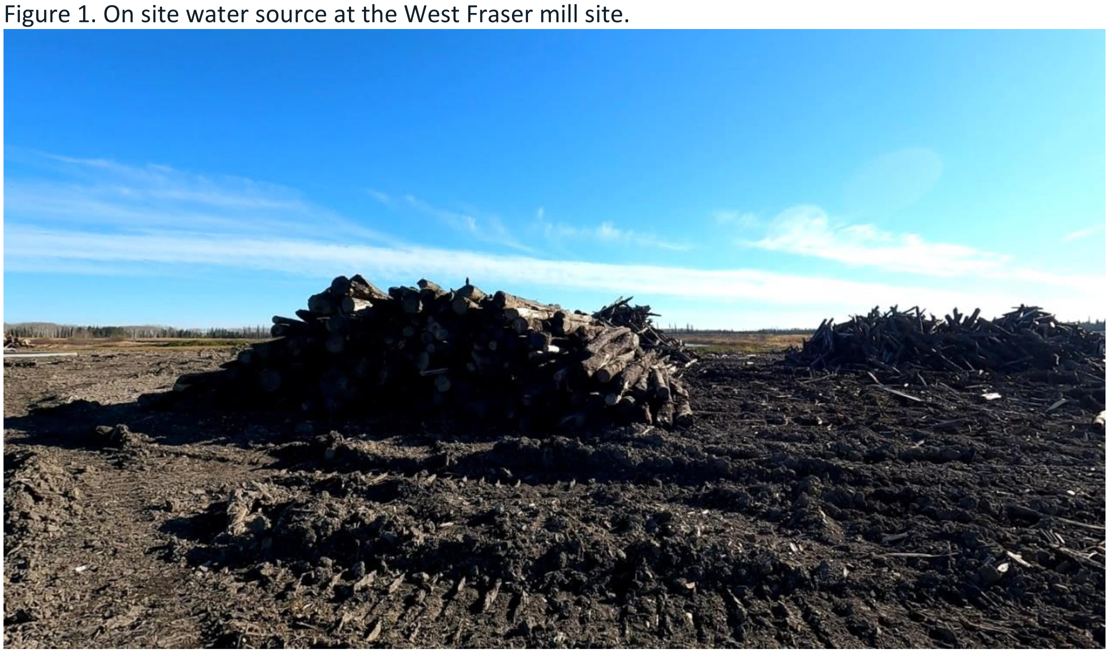

Figure 2. Aspen log-decks in the foreground with debris piles in the background.

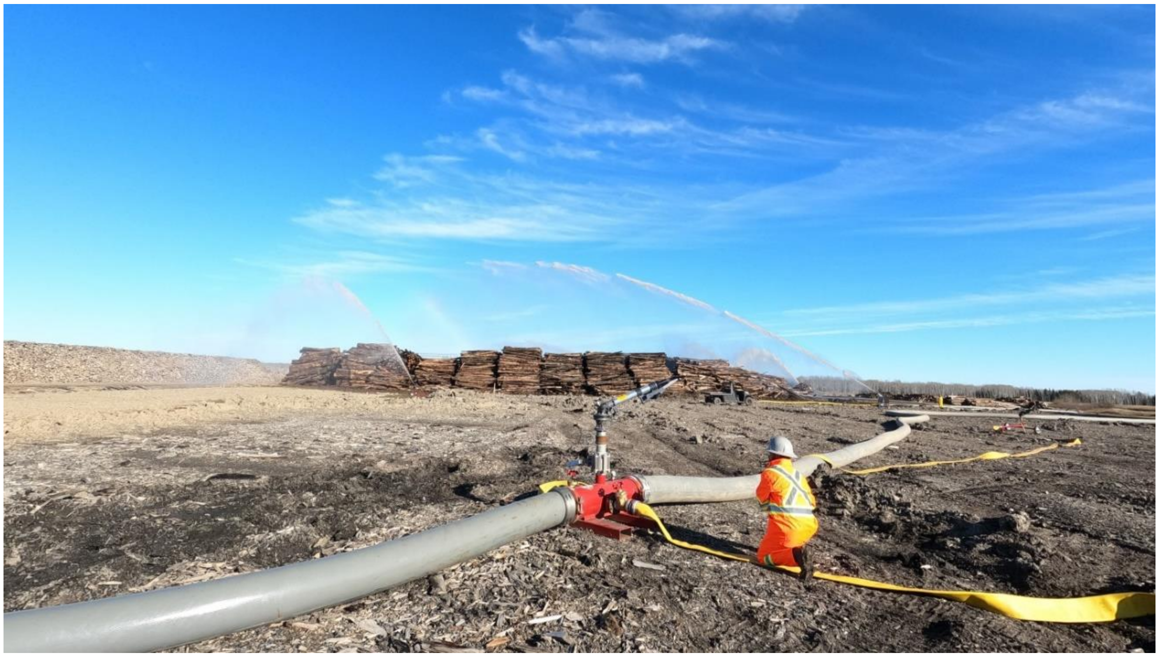

Figure 3. Merchantable timber on site that required risk mitigation from the prescribed burn.

Equipment setup

Two 600 HP Duetz engine 8”x6” high-volume pumps (Fluid end model, Cornell 6822MX) were placed at the water source to supply water for log-deck suppression (Figure 4). The outputs from the two pumps were merged to form one 12-inch main supply line. A flowmeter was attached at this manifold to provide a flowrate estimate during operations (Figure 5). The main 12-inch supply line ran from the water source, through the field with the log-decks and debris piles and ended at the far end of the merchantable timber pile – approximately 1 km in total length. At 200-meter increments, a manifold was placed that supported three water cannons (Figures 6 and 7). The technical details of the water cannons are presented in Table 1. For brevity, the two types of water cannons are referred to by their nozzle size in this report.

Table 1. Technical details for the two types of water cannons attached to each manifold.

Water cannons per manifold					
Supply line size (inch)	Nozzle size (inch)	Max. flow Rate* (m^3/min)	Operating pressure (psi)	Quantity	Portable
4	1.1	1.4	110	2	Yes, on wheels
12	1.78	3.9	130	1	No, on manifold

** Max. flow rate data obtained from manufacturer’s website.*

Figure 4. High-volume pumps used in the water delivery system.

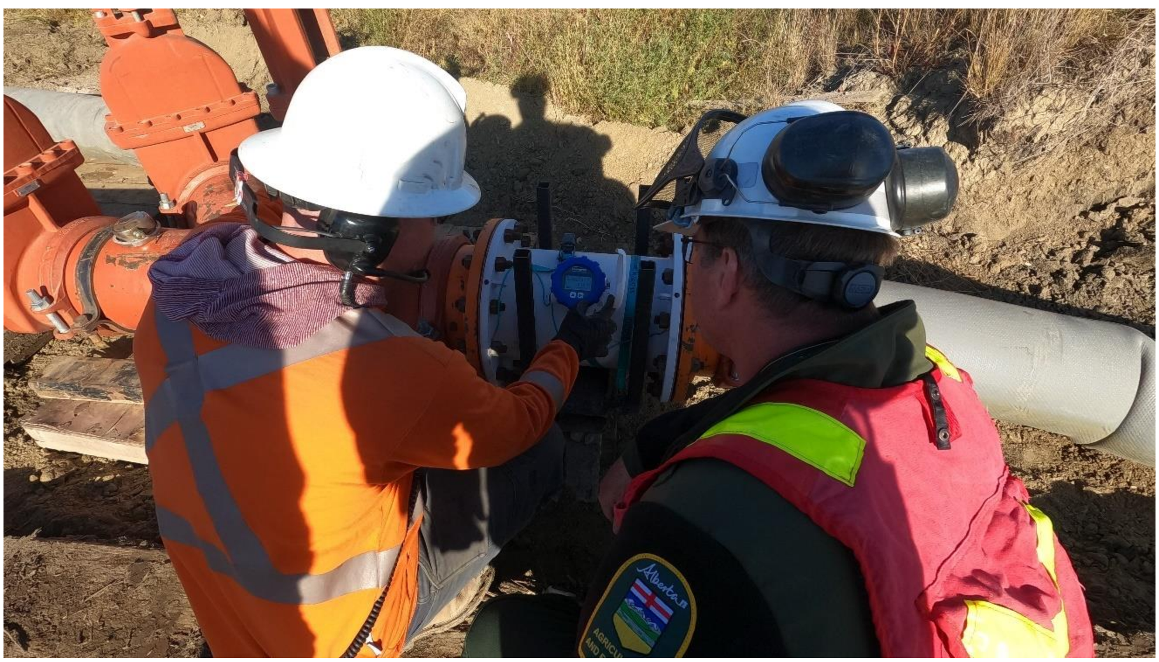

Figure 5. A flowmeter was used to estimate flowrate during suppression operations.

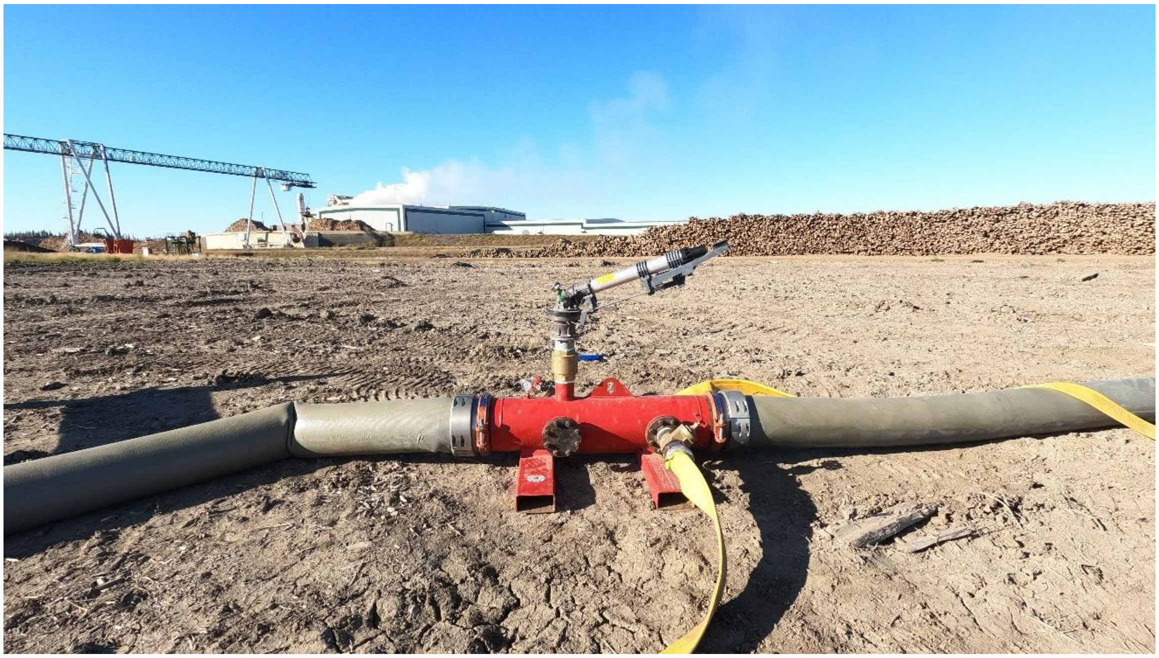

Figure 6. A manifold with one 1.78-inch water cannon and two outlets for 50-foot long, 4-inch hose.

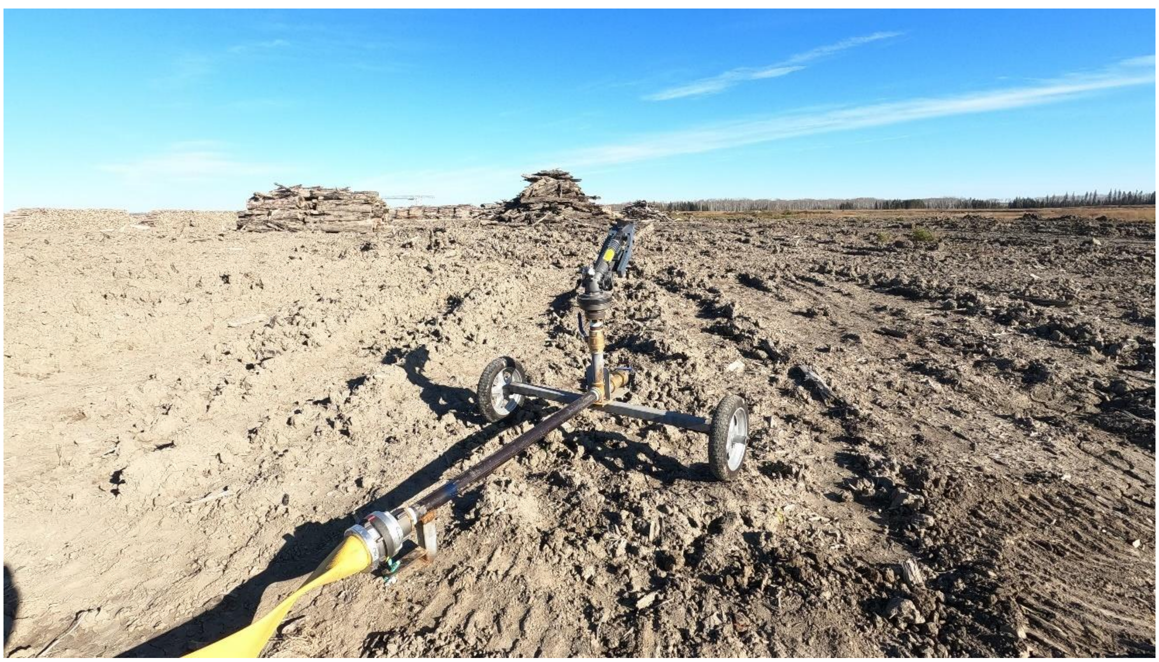

Figure 7. A 1.1-inch water cannon at the end of a 4-inch hose.

Log-decks

Six log-decks were dedicated to the prescribed burn and high-volume water suppression tests. The log-decks were approximately 45 feet in length (2 bolts), with variation in height and width ranging from 9-12 feet and 20-32 feet respectively. All log-decks had individual log cross-sections ranging from 1.5-2.5 feet. The range of moisture content across all six log-decks was estimated to be 10-15% using a protimeter.

METHODS

Water penetration test

A key issue in suppressing log-deck fires is the lack of suppressant penetration into the deck. With high-volume water delivery systems, it was speculated that despite the penetration resistance put up by the log-deck, the use of greater water volumes may lead to more water entering the core of the log-deck. Therefore, the decks were 'treated' with water from these high-volume systems for a pre-defined amount of time and then assessed for water penetration.

Given the resources available, it was deemed opportunistic to use the merchantable timber for the water penetration tests. Based on its proximity to log-decks dedicated for the prescribed burn, it was necessary to protect the merchantable timber from spotting/ember transfer during the burn. This risk mitigation was done in the form of wetting down the merchantable timber using the high-volume water delivery systems (Figure 8). This task of wetting down the timber presented the opportunity to collect water penetration data. Three water cannons were utilized in this task – one 1.78-inch water cannon and two 1.1-inch water cannons with overlapping coverage areas.

To better estimate water penetration in a log-deck, it requires the deck to be taken apart and inspected. In this field study, the use of a butt-n-top to take apart the deck was not an available option. Therefore, a non-disruptive test method was required. This non-disruptive method of measurement was done in two forms: (1) the use of 10-hour fuel-moisture sticks placed at varying heights within the log-deck (Figure 9), and (2) the use of protimeters to measure fuel moisture at varying heights within the log-deck.

A total of 6 moisture sticks were placed in three rows of varying heights along the edge of the merchantable timber (Figure 10). An 8-foot pole was used to place the fuel moisture sticks approximately 7 feet from the edge of the log-deck. Fuel moisture sticks were weighed before and after the wetting down process. Changes in fuel moisture measured by the fuel moisture sticks served as a proxy to assess locally and qualitatively the consistency of water penetration. To compensate for the limited quantity and local applicability of fuel moisture stick measurements, a protimeter was used to take several random readings throughout the height and width of the log-deck. Protimeter readings were limited to external reachable areas of the deck.

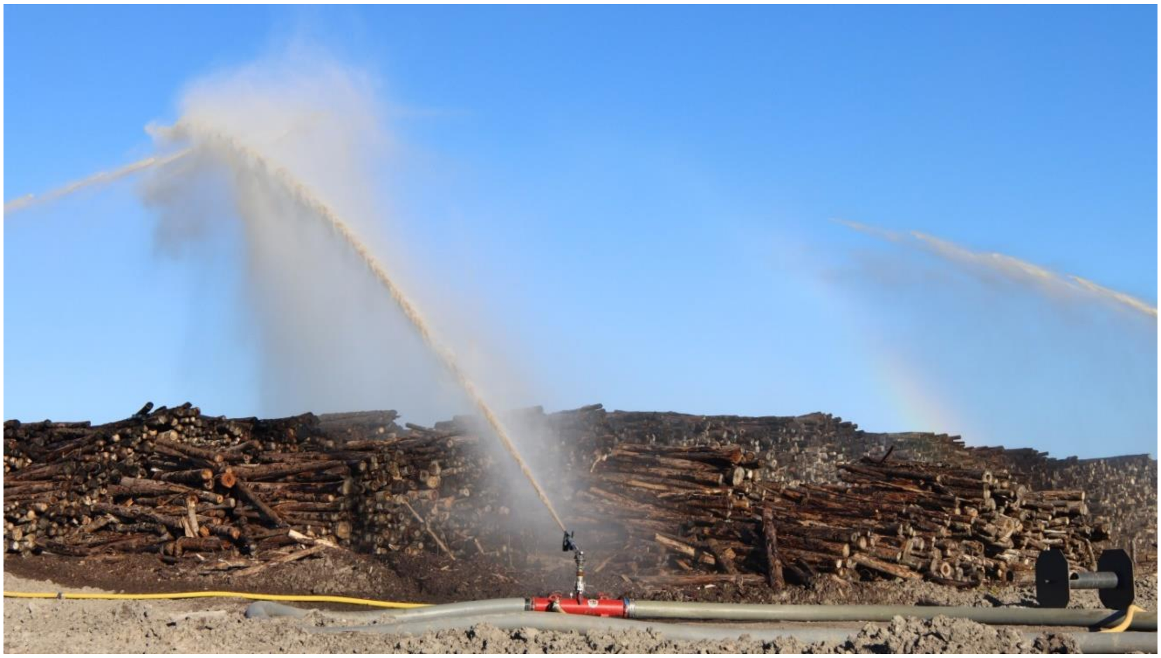

Figure 8. Merchantable timber being wetted down as part of the water penetration tests.

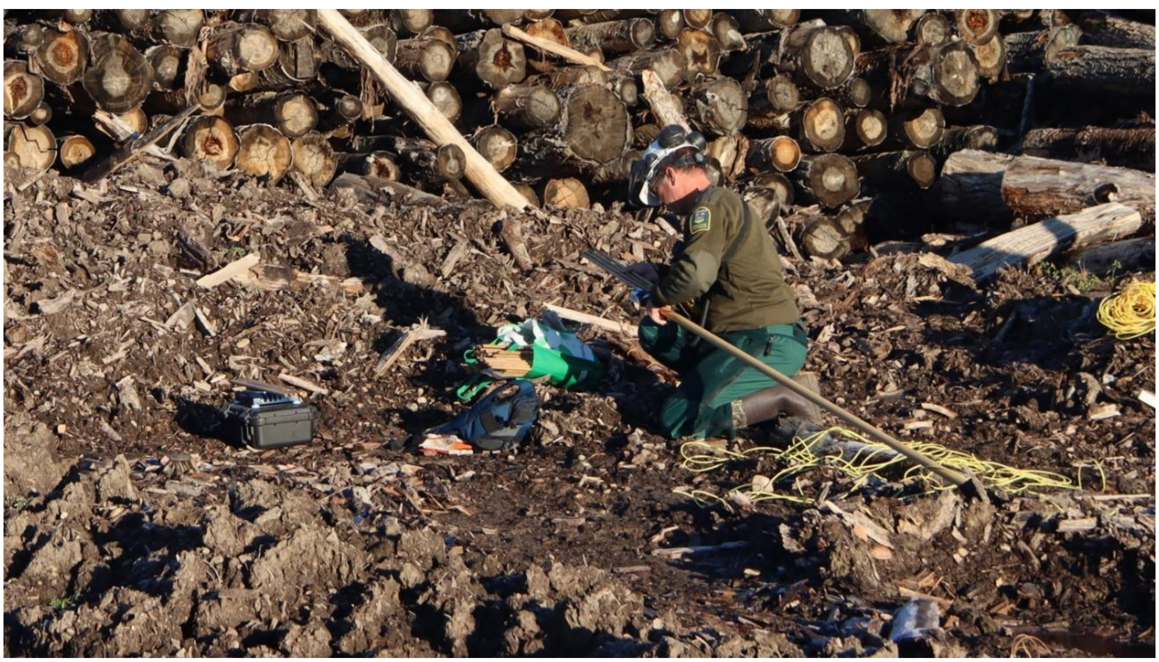

Figure 9. 10-hour fuel moisture sticks being setup.

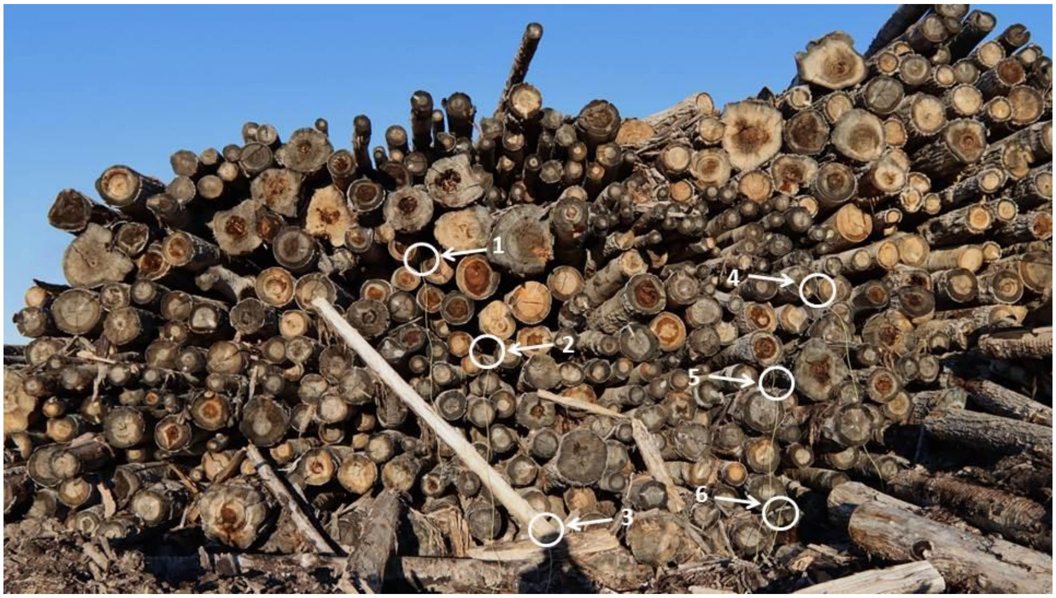

Figure 10. Fuel moisture sticks placed at varying heights in the merchantable timber.

Log-deck suppression test

Six log-decks were burned as part of the log-deck suppression tests which involved the suppression of fully engulfed log-decks using high-volume water delivery systems. A fully engulfed log-deck fire was defined as a log-deck wherein the entire pile (i.e., both bolts) was in the process of being consumed (Figure 11). Ignition of log-decks was carried out using Flash 21 and drip-torches. Once log-decks were at the desired state of engulfment, suppression operations using high-volume water delivery systems occurred.

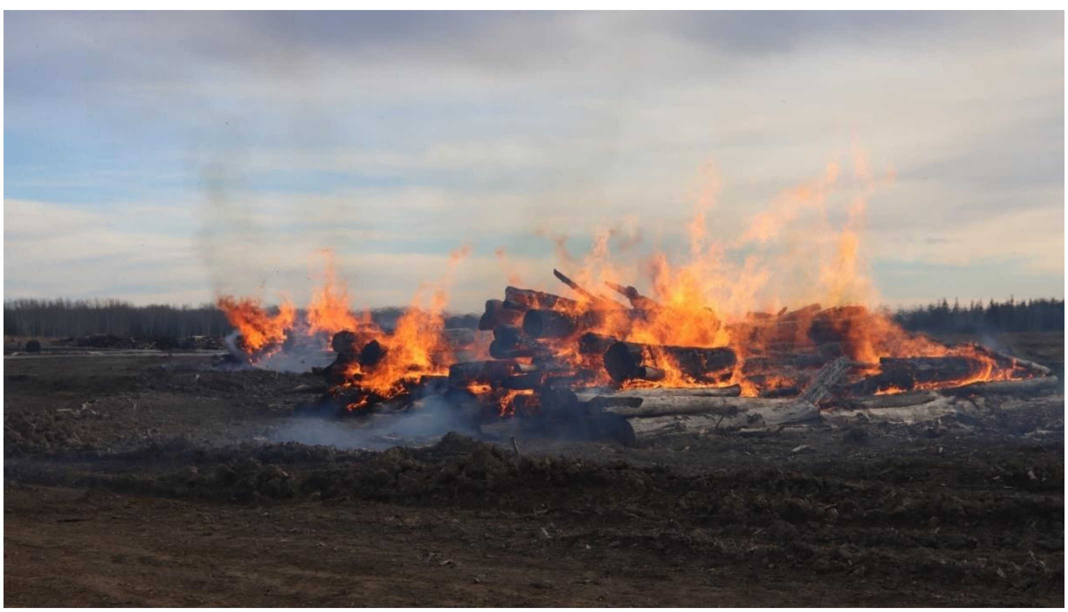

Figure 11. An instance of a state of fully engulfed log-deck fire.

To better understand the efficacy of a water cannon type as well as the water volume/flow rate required to suppress a fully engulfed log-deck, each log-deck was suppressed using different water cannon combinations. Table 2 outlines the suppression efforts received by each log-deck.

Table 2. Suppression efforts utilized for different log-decks.

Log-deck	Suppression from water cannons		Expected water delivery (m^3/min)
	1.1-inch	1.78-inch	
1	2	1	6.7
2	1	1	5.3
3	-	2	7.8
4	2	-	2.8
5	1	-	1.4
6	-	1	3.9

Suppression efforts were timed so that the total water required to extinguish a fire could be estimated from the flowrate. Knowing complete extinguishment is unlikely to occur due to a combination of thermal output from the burning log-decks and/or lack of suppressant penetration, suppression in this exercise was defined as the moment when no visible flames existed on exterior of the log-decks (Figure 12). Interior glowing combustion and flame re-growth over time on the exterior of the log-deck did not constitute a failure in suppression (Figure 13).

Figure 12. An instance of a log-deck fire that has been suppressed, as per the definition of suppression used in this study.

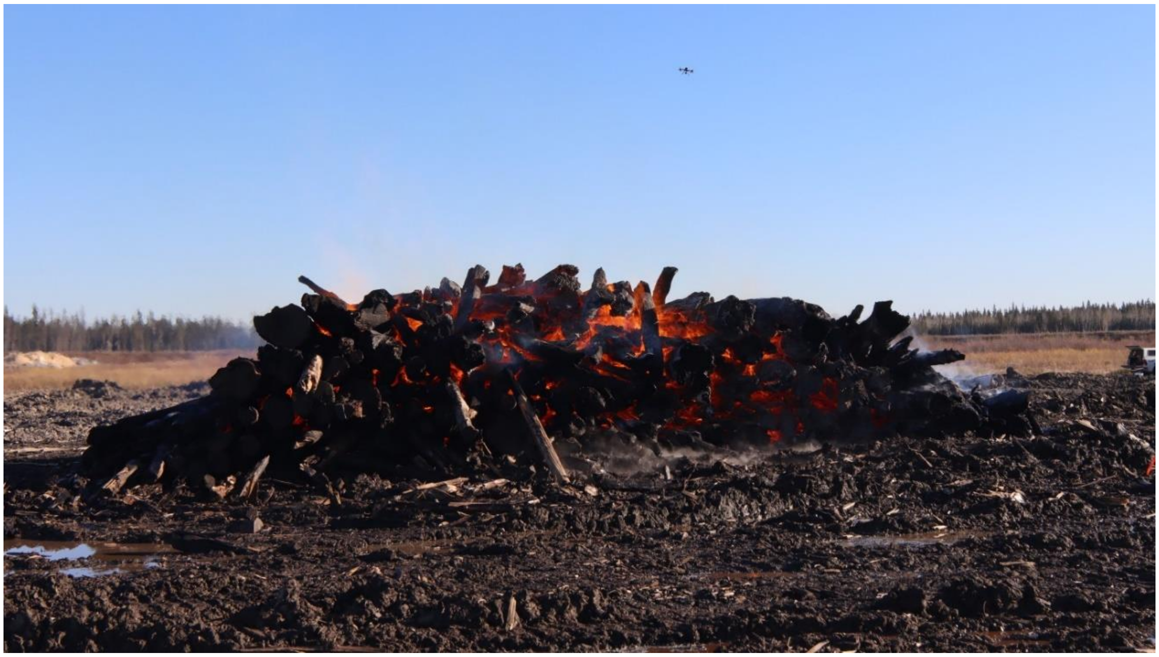

Figure 13. An instance of a log-deck fire after suppression. Glowing combustion at the core of the log-deck did not constitute suppression failure, as per the definition presented in this study.

FINDINGS

Water penetration test

A combination of one 1.78-inch water cannon and two 1.1-inch water cannons were run for a period of ten minutes, applying water to the merchantable timber. The total amount of water delivered during this duration was 61 cubic meters. The water cannons were set to function normally – i.e., set to ensure areas of overlap as they rotated around their pivots. Regular casting trajectory and direction was maintained such that the location of the fuel moisture sticks was not intentionally preferred. Therefore, only a portion of the water delivered to the merchantable timber was expected to be received by the fuel moisture sticks. Table 3 presents the change in weight of fuel moisture sticks before and after the water application.

The change in weight of fuel moisture sticks, which directly correlates to a change in moisture content (%), suggest that high-volume water delivery systems was able to deliver water that penetrated the log-decks. Percentage estimates of surface wetting of the fuel moisture sticks suggest that while notable quantities of water were able to reach the fuel moisture sticks, its coverage was uneven. This was further supported by minimal consistency in moisture content change at varying height categories in the log-decks. This uneven coverage is expected due to the influence of log-deck arrangements on water penetration.

Table 3. Fuel moisture stick weights before and after water application.

Fuel moisture stick	Location above ground (feet)	Before (g)	After (g)	Increase in moisture content (%)	Estimated surface wetting of fuel moisture stick
1	8	104.6	N/A*	N/A	N/A
4	8	105.0	109.7	4.7	25%
2	6	104.2	107.7	3.5	10%
5	6	104.6	112.7	8.1	50%
3	2	104.0	105.2	1.2	5%
6	2	103.4	123.0	19.6	90%

** Unable to retrieve fuel moisture stick*

Protimeter readings from the merchantable timber in varying locations suggested that the moisture content of the log-deck ranged from 10-15% prior to water application. Measurements obtained after the water application resulted moisture content estimates between 30-35% in the wetted areas. These wetted areas were observed to have directionality based on log-deck arrangement. Despite the relatively large volume of water delivered, water can only penetrate and wet certain areas of the log-deck. Therefore, complete extinguishment of a log-deck may not be possible without altering the arrangement of the log-deck.

Log-deck suppression test

Log-deck suppression tests occurred over two days. Log-decks 1 and 2 were burned on Day 1 while log-decks 3-6 were burned on Day 2. Of the six-log decks, one log-deck was found unsuitable for use in this test due to wetting that occurred while nearby log-decks were being suppressed. Table 4 presents data on the suppression effort, flow rate, time taken for suppression, and estimated total volume required for suppression required for each of the six log-decks. Similar sized log-decks are grouped by colour wherein the blue group had dimensions closer to the upper end of the dimension range specified earlier while the green group had dimensions closer to the lower end of the dimension range. Note that all results presented are exclusive to the characteristics (available biomass, shape, size, arrangement, etc.) of log-decks in this study. Log-decks found at mill sites are often larger in size (and consequently differ in available biomass and shape).

In general, all five variations of water cannon combinations tested were found to be effective at suppressing log-deck fires within the suppression definition outlined earlier in this report. Suppression effectiveness was found to improve with a greater flow rate when casting distances are approximately the same. This is showcased when comparing log-decks 1 and 2 wherein, despite using approximately the same water volume, log-deck 1's suppression time was reduced due to a greater flow rate.

Table 4. Log-deck suppression effort data. Colour grouping indicates similar log-deck sizes among group.

Log-deck No.	Suppression from water cannons		Flow rate (m^3/min)	Suppression time (min)	Total water volume delivered (m^3)	Average casting distance (feet)	Comments
	1.1-inch	1.78-inch					
1	2	1	6.7	6	40.2	75	Regular suppression.
2	1	1	5.3	8	42.4	75	Regular suppression.
3*	-	-	-	-	-	-	-
4	2	-	2.8	8	22.4	120	Increased casting distance.
5	1	-	1.4	3	4.2	50	Reduced casting distance.
6	-	1	3.9	5	19.5	75	Water directed at log-deck cross – section.

** Log-deck compromised due to wetting that occurred when neighboring log-decks were being suppressed.*

Data from log-decks 4 and 5 suggest casting distance plays a role in suppression effectiveness. Log-deck 4 was approximately 120 feet from the water cannons while log-deck 5 was approximately 50 feet from the water cannons. Despite having twice the flowrate as log-deck 5, log-deck 4 was found to take notably longer to suppress. This may be attributed to increased evaporation and atomization from the water cannons as the trajectory of casting is increased. The differences in water delivery between log-decks 4 and 5 are pictorially presented in Figure 14 and 15.

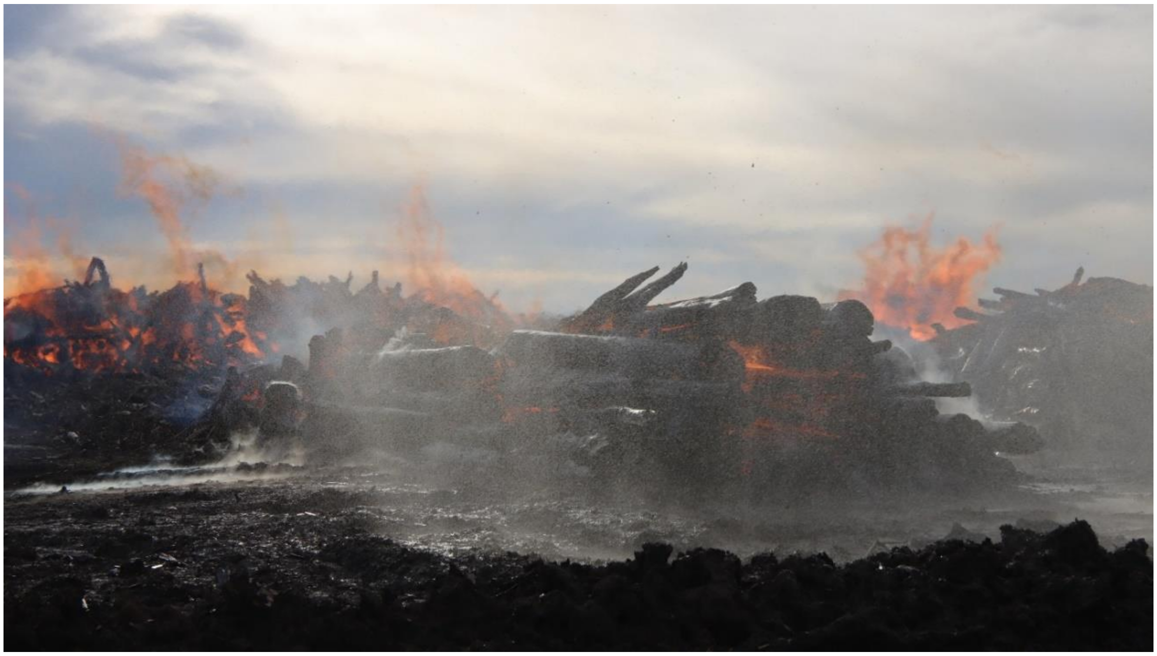

Figure 14. Log-deck 4 - greater casting distances resulted in more evaporation and atomization of water stream.

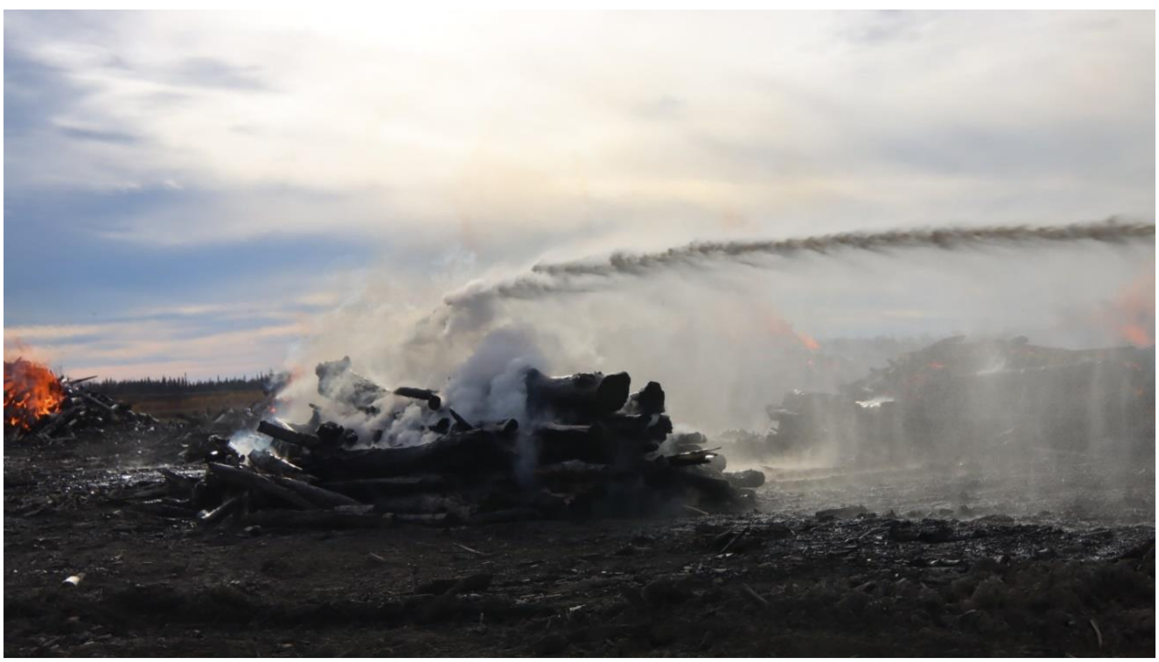

Figure 15. Log-deck 5 - reduced casting distances resulted in less evaporation loss and atomization when water reaches the log-deck.

A different suppression tactic was used in log-deck 6 – water was aimed directly at the cross-section of the log-deck as opposed to having water rain down like a regular sprinkler. This tactic was found to be more useful at quickly knocking down the flames – however, was limited by cross-sectional penetration into the deck (Figure 16).

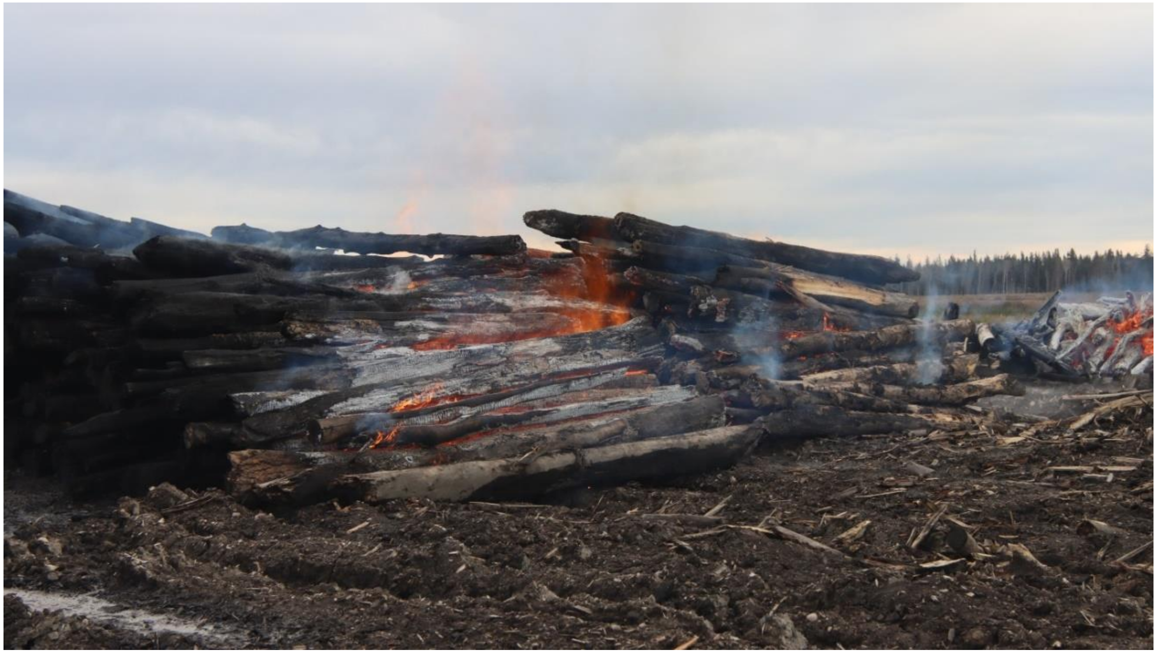

Figure 16. Log-deck 6 - the left side of the log-deck shows the effect of water delivery on the cross-sectional area of the log-deck. While suppression was effective in that local area, water penetration deeper into the deck was less effective, showcased by the middle of the log-deck still in the combustion process.

DISCUSSION

1. **Water penetration of log-decks** – The water penetration test carried out in this study was highly localized, with a limited quantity of data to produce definitive statements or inferences. Based on the collected data, it was found that water application using high-volume water delivery systems are able to penetrate log-decks to a certain degree – however, any biomass surface coverage limitations are likely due to log-deck arrangements. Fuel moisture sticks suggested that while notable increases of moisture may result in areas where water can penetrate, the resultant coverage may be uneven. Despite the physical resistance offered by the log-deck arrangement, high-volume water delivery systems are likely to be more beneficial than traditional water delivery systems used by wildfire agencies owning to their greater casting distance, coverage areas, and water-volumes being supplies.
2. **Improved water penetration tests** – A better way of assessing water penetration that can be explored in future studies is the use of a dye in water. This offers the ability to temporarily stain the log-decks, providing a longer-lasting visual estimate of water penetration in a log-deck. Resistance to penetration offered by the log-deck arrangement can also be better visualized. This method may require the use of a butt-n-top to break up a log-deck for inspection.
3. **Suppression efficacy** – Suppression tests suggested that high-volume water delivery systems were effective at suppressing log-deck fires based on the definition of suppression presented in this report as well as the specific characteristics of log-decks

(size, quantity, species, moisture content, etc.) in this study. Data suggested that a log-deck can be suppressed with a lower flowrate water delivery system, albeit at the expense of time. The distance between the log-decks and the water delivery system can also influence suppression efficacy. The thermal output from log-deck fires may be sufficient enough to minimize the effectiveness of water delivery systems when the water being delivered is atomized. Atomized water (or even water with larger droplet size) is more prone to evaporation than bulk fluids due to greater available surface area for inbound heat transfer. Therefore, it may be advantageous to direct the water stream from water cannons directly at the log-deck instead of aiming for a 'rain-effect'. This tactic may help address the thermal inertia of the log-deck fire.

4. **Improved safety for heavy machinery** – The thermal output from log-deck fires without suppression results in an unsuitable environment for heavy machinery to operate, such as butt-n-top loaders. Such heavy machinery is necessary in managing log-deck fires to break apart the burning fuel. The use of high-volume water delivery systems was found capable of reducing the thermal output of log-deck fires temporarily such that heavy machinery may access the log-deck and break the deck apart. Operationally, the use of heavy machinery in conjunction with high-volume water delivery systems may be the most effective strategy to deal with log-deck fires – addressing thermal suppression, isolation of fuels, and greater surface area exposure for water application.
5. **Water requirements** – The total water requirements for the water penetration test and the suppression test was approximately 190 cubic meters (~50,000 gallons) of water. Given the relatively small scale of biomass that was protected/suppressed in this field study, it is advisable to have a sufficiently large water source on site or nearby. The log-decks at mill sites are significantly larger (Figure 17) and will require enough water to manage the thermal output of the corresponding quantity of biomass.

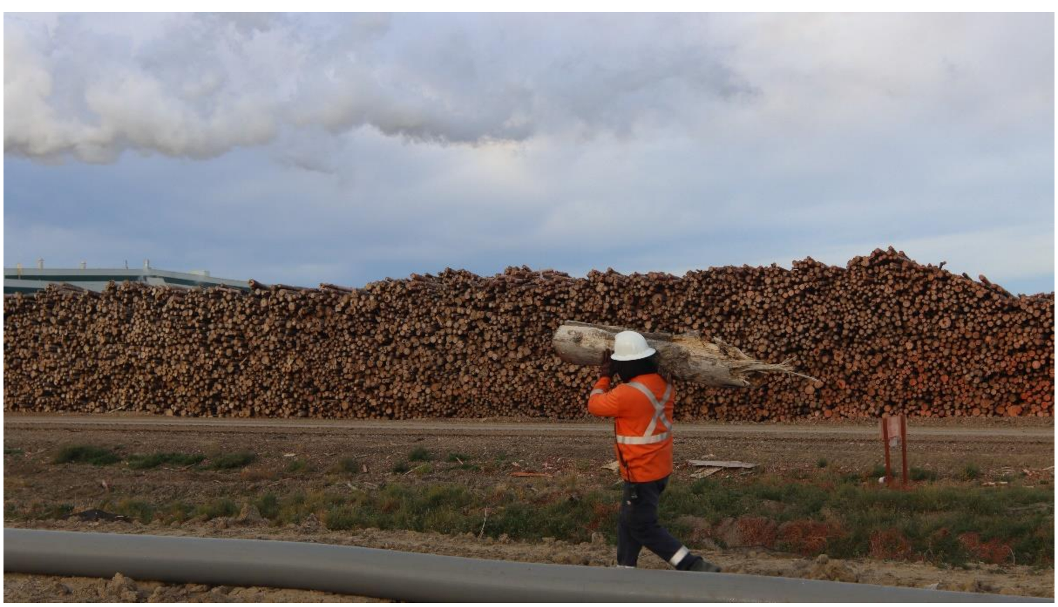

Figure 17. Mill sites generally stack their merchantable timber in significantly larger decks than ones used in this study.

6. **Scaling up findings** – Findings from this report (water requirements, suppression time, etc.) should not be scaled-up linearly with increase in biomass. The thermal inertia and output of biomass being consumed does not scale linearly with size. Therefore, all data from this report applies exclusively to log-decks used in this report. Scaling up findings is not advisable. Empirical tests with representative log-decks and biomass quantities will be required.

CONCLUSION

This field study was undertaken with the intent of understanding how high-volume water delivery systems can be used in log-deck fire suppression. In collaboration with West Fraser and the High Level Forest Management Area, water penetration tests and log-deck fire suppressions tests were conducted at a mill site in High Level.

The findings from the tests suggested that high-volume water delivery systems are capable of log-deck penetration. This suppressant penetration may be restricted based on log-deck arrangement and geometry, resulting in uneven coverage. Suppression tests suggested that these water delivery systems are capable of suppressing log-deck fires, with flow rate and casting distance influencing the time taken to suppress a fire. High-volume water delivery systems are also capable of creating a temporary safe operational environment for heavy machinery to approach and work on disrupting the combustion process in a log-deck fire. Water requirements for these high-volume systems are not small – therefore, proactive resource management may be necessary to have sufficient quantities of water readily accessible.

info@fpinnovations.ca
www.fpinnovations.ca

OUR OFFICES

Pointe-Claire
570 Saint-Jean Blvd.
Pointe-Claire, QC
Canada H9R 3J9
(514) 630-4100

Vancouver
2665 East Mall
Vancouver, BC
Canada V6T 1Z4
(604) 224-3221

Québec
1055 rue du P.E.P.S.
Québec, QC
Canada G1V 4C7
(418) 659-2647