info@fpinnovations.ca
www.fpinnovations.ca

Area-Based Water Delivery Systems

Exploratory research on logistics, water delivery, and its localized impacts

PROJECT NUMBER: 301014417

Razim Refai, Research Scientist

Rex Hsieh, Research Scientist

January 2021

The aim of this study was to capture data on area-based water delivery systems, specifically in the context of logistics, systems differentiation, water delivery, and its localized effects. FPInnovations successfully collaborated with Fire & Flood to obtain this data. A two-day test was executed during which Fire & Flood set up their 4- and 12-inch systems and carried out sprinkler operations.

Project Number: 301014417

Technical Report TR 2021 N1

ACKNOWLEDGEMENTS

This project was financially supported by Fire & Flood Emergency Services Ltd.

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

REVIEWERS
Ray Ault,
Executive Director, FireSmart Canada

Stephen Paskaluk,
Research Engineer, University of Alberta

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

Table of contents

List of figures

List of tables

BACKGROUND

Area-based water delivery systems involve the movement of water from a bulk water source such as a river or lake, to an area of critical importance where water can be effectively distributed to fuels. The addition of water to fuels can offer temporary resistance to ignition by raising the short-term moisture content of the fuels.

Area-based water delivery systems utilize high-pressure, high-volume pumps, irrigation sprinklers, and large-diameter hose. This equipment is typically larger than what wildfire practitioners have historically use on the fireline. A consequence of using equipment that is scaled up to move large quantities of water are the logistical considerations associated with these systems.

Currently, there is limited documentation on the logistics requirements of area-based water delivery systems, which are system specific. Quantitative information on logistics offers wildfire operations personnel specific data that can inform decisions on when and where these systems can be deployed on a fire. In addition, knowing the potential impact of these systems in modifying localized fuel moisture conditions can help understand their effectiveness.

In this study, exploratory research was conducted on the logistics requirements for area-based water delivery systems as well as their water delivery efficacy. To execute this study, Fire & Flood, a service provider of area-based water delivery solutions, collaborated with FPInnovations to trial multiple systems and facilitated data collection practices. This work will contribute to the development of test methods for potential future testing of area-based water delivery systems.

OBJECTIVES

The objective of this study is to collect information in the following key areas:

1. **Systems differentiation –** Document logistics/water delivery of at least two different types of systems.
2. **Logistics** – Document set-up time, tear-down time, start/stop time, instrumentation, staging requirement, manpower, etc.
3. **Water delivery** – Document pressure, flow rates, time-bound rainfall equivalent, and estimated coverage area.
4. **Localized effects of water delivery -** Document two-dimensional localized surface impact of water delivery from sprinklers (weather permitting).

SITE

The site selected for this study was on the north shore of Abraham Lake in Clearwater Country, Alberta. The site was located 4 km off Highway 11. The site selection criteria were the following:

1. Minimum 1-km distance from water source to the first sprinkler.
2. Relatively open test area with few trees for sprinkler operations and data collection.
3. Availability of staging area.

Figure 1 presents the locations of the water source, staging area, and test area as well as the path taken by the supply lines. Water withdrawal permits were obtained by Fire & Flood and capped at a withdrawal rate of 28 cubic metres per minute. The entire site and test area had fairly dry and firm ground.

Figure 1. Locations of water source, staging area, and test area. Path of supply line presented in blue.

Figures 2 to 4 present images of the key locations shown in Figure 1.

Figure 2. Abraham Lake served as the water source for this study.

Figure 3. Overview of the staging area used in this study.

Figure 4. Open and relatively flat test area.

METHODS

To facilitate documentation of two area-based water delivery systems, 4-inch and 12-inch water delivery systems were selected for this study. The methods used to document logistics and water delivery as well as system set-up are presented in this section.

Logistics

To document logistics of the water delivery systems, Fire & Flood was asked to set up their systems for a series of water delivery trials over a span of two days. The following chronological sequence of events was followed:

Table 1. Chronological sequence of events on the two days of testing

<table>
<tr><th>Day</th><th>System</th><th>Event</th><th>Documentation</th></tr>
<tr><td colspan="4">Start of Day 1</td></tr>
<tr><td rowspan="4">#1</td><td>4- and 12-inch systems</td><td>Arrive at the site and unload all equipment</td><td>▪ Unloading time
▪ Staging requirement
▪ Time to set up road crossing</td></tr>
<tr><td rowspan="3">4-inch system</td><td>Set up 4-inch system</td><td>▪ Time to set up 4-inch system
▪ Manpower requirement
▪ Equipment requirement
▪ Instrumentation used</td></tr>
<tr><td>Sprinkler operations with 4-inch system (multiple iterations)</td><td>▪ Start/stop time (average time for a minimum of three iterations)</td></tr>
<tr><td>Tear down 4-inch system</td><td>▪ Time to tear-down 4-inch system</td></tr>
<tr><td colspan="4">End of Day 1 / Start of Day 2</td></tr>
<tr><td rowspan="4">#2</td><td rowspan="3">12-inch system</td><td>Set up 12-inch system</td><td>▪ Time to set up 12-inch system
▪ Manpower requirement
▪ Equipment requirement
▪ Instrumentation used</td></tr>
<tr><td>Sprinkler operations with 12-inch system (multiple iterations)</td><td>▪ Start/stop time (average time for a minimum of three iterations)</td></tr>
<tr><td>Tear down 12-inch system</td><td>▪ Time to tear-down 12-inch system</td></tr>
<tr><td>4- and 12-inch systems</td><td>Demob entire operation</td><td>▪ Time to wrap up entire operation
▪ Equipment required for demob</td></tr>
<tr><td colspan="4">End of Day 2</td></tr>
</table>

System set-up

Fire & Flood was asked to set up sprinklers for each system at specific locations in the test area for sprinkler operations. This involved running a 1.1-km supply line from the water source to the sprinklers for the 4-inch system, and a 2.2-km supply line (inclusive of meander) for the 12-inch system along the path shown in Figure 1. The approximate elevation gain/loss for the supply line in the direction of flow of water was 85.8 ft / -37.5 ft, and average slope of 3% / -3.6%. The set-up of the supply lines also involved one road crossing on a public road that had to be appropriately managed.

Details about the sprinkler placement, type and lengths of hose required, pumps, etc. are presented later in this report.

Figure 5. Supply line running from water source to sprinklers for 1.1 km.

Figure 6. A road crossing was set up to manage supply lines that crossed roads.

Water delivery and its localized effects

1.1 Pressure and flow rates

To document pressure and flow rates, flowmeters and pressure gauges were placed in-line to assist with recording this data. A flowmeter was placed immediately after the pump to record flow rate data while pressure gauges were placed on the pump as well as on the nozzles. Figure 7 presents one of the flowmeters used in this study while Figure 8 presents a sprinkler head with a pressure gauge attached to it.

Figure 7. Flowmeter used to capture flow rate data in this study.

Figure 8. Pressure gauge mounted near a sprinkler head.

1.2 Rainfall equivalent, coverage area, temperature, and relative humidity data

To capture rainfall equivalent, temperature, and relative humidity data, two sprinklers for each system were set up at specific locations in the test area. The limitation to two sprinklers was due to the finite test area available for data capture. The following subsection outlines the set-up of sprinklers, sensor placement, and the rationale used for the set-up.

Sprinkler set-up

Figures 9 and 10 present the set-up used for the sprinkler trials to assess water delivery for the 4-inch and 12-inch systems, respectively.

Sprinklers in both systems were spaced apart at a distance equal to the estimated casting distance provided by the sprinklers' manufacturer (assuming sufficient pressure and flow rate supplied to the sprinkler). The 4-inch system had an estimated casting distance of 100 ft while the 12-inch system had an estimated casting distance of 280 ft. Sprinklers can be set up in several different ways; the authors found a set-up based on estimated casting distance easily replicable and therefore proceeded with this set-up in this study.

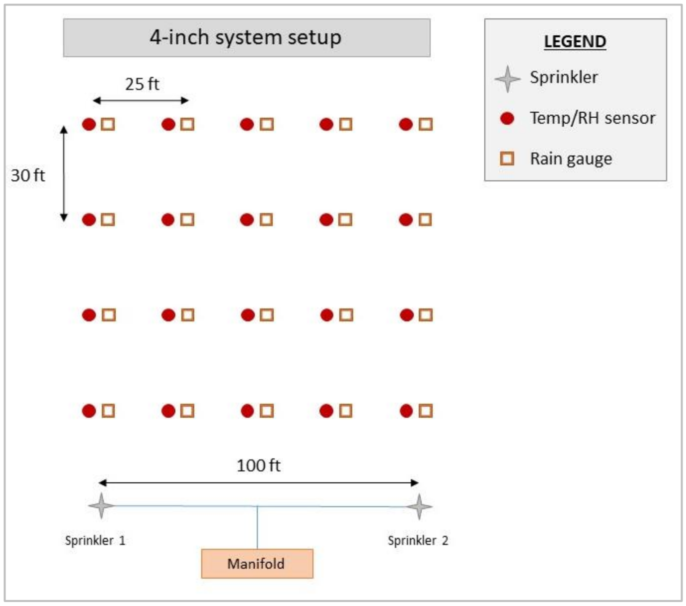


Figure 9. Four-inch system set-up for water delivery measurements.

Both systems had sprinklers set up with 24-degree casting angles as per Fire & Flood recommendations. Each sprinkler was allowed 180 degrees of rotation. With a 180-degree rotation, only the overlapping 90 degrees was considered as the area of interest, as indicated by the locations of rain gauges and sensors. This area of interest allowed a reasonable data resolution over a significant area with limited quantities of sensors and rain gauges.

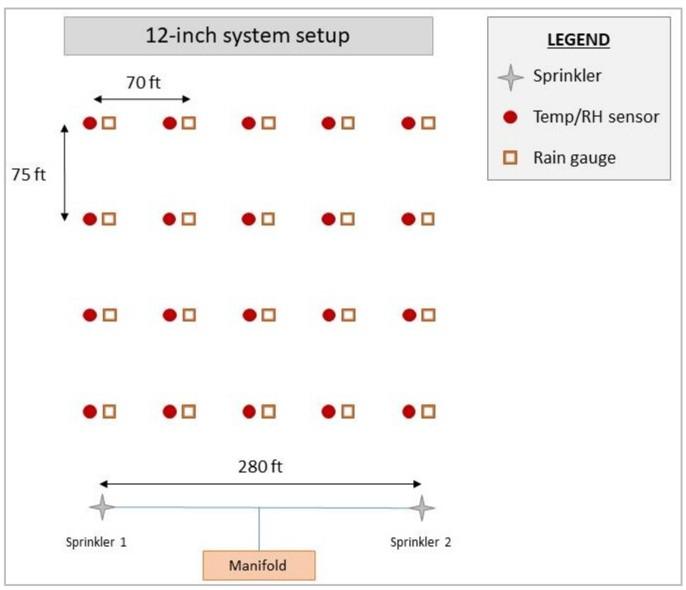


Figure 10. Twelve-inch system set-up for water delivery measurements.

With the 90-degree overlap of two sprinklers, it was estimated that six rain gauges and sensors would receive 100% overlap of water delivery. Therefore, rainfall equivalent data collected for those six rain gauges will be halved when reviewing the data to obtain median rainfall amounts per sprinkler. The six gauges receiving 100% overlap are illustrated in Figure 11.

Sprinkler operations for both systems were done for a period of 15 minutes per iteration. Therefore, a multiplier would have to be applied to the data sets to obtain hourly rainfall equivalent amounts.

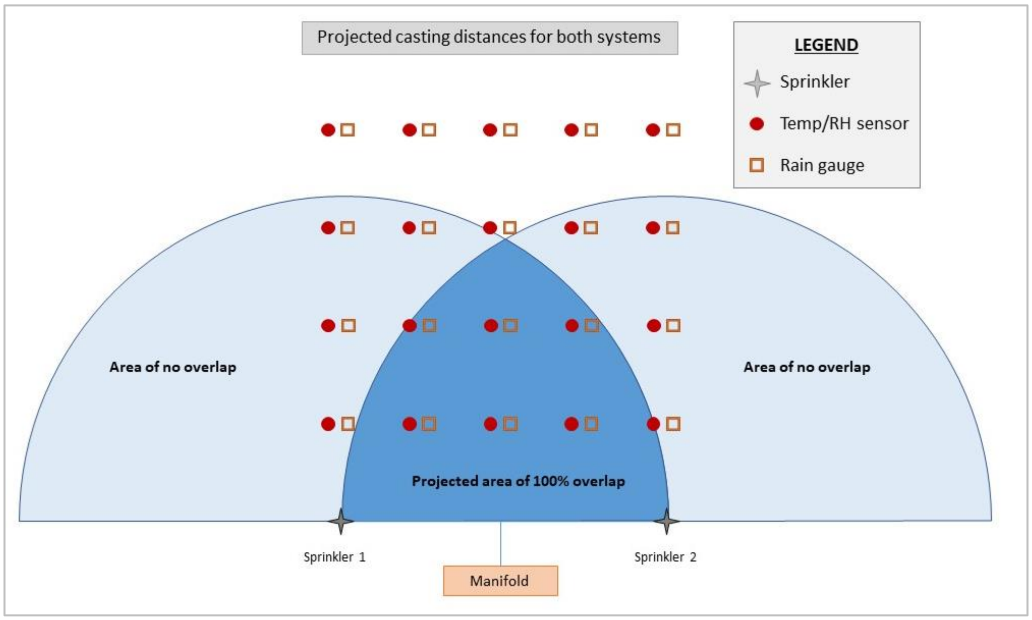


Figure 11. Projected areas of 100% overlap in the area of interest in sprinkler trials.

Grid set-up

The set-up employed a grid format of five columns and four rows within the defined area of interest in which rain gauges (rainfall equivalent) along with temperature/relative humidity sensors were placed, as shown in Figures 9, 10, and 11. Figure 12 presents an instance of a node on the grid where a rain gauge and temperature/relative humidity sensor are placed adjacent to each other.

Figure 12. Rain gauge and temperature/relative humidity sensor on a stake with an inverted cup for shelter against direct water contact.

The estimated casting distance for a sprinkler was used as a guide to decide the spacing between rows. For example, if the 4-inch system had an estimated casting distance of 100 ft, then the total distance of interest was considered as the estimated casting distance plus 10 to 20% of additional distance as tolerance. In the set-up for the 4-inch system, the total distance of interest was 120 ft, resulting in 30-ft spacing between rows. The distance between columns was based on the spacing between the two sprinklers since that offered the boundary for where sensors would be placed.

Sensors

The temperature and relative humidity sensors selected for this study were REED R6020 sensors. A total of 20 sensors were used in the area of interest, each set to a logging frequency of 30 seconds. Two control sensors were placed away from the area of interest to avoid the impact of any potential humidity influence created by sprinkler operations. Each sensor was attached to a metal stake that was placed in the ground. An inverted cup, as shown in Figure 12, was used to shield the sensors from direct water contact to avoid incorrect humidity readings.

It is worth noting that collecting temperature and humidity data was not the main focus of this study. This study offered an opportunity to collect data that could result in usable data for other purposes and therefore the rationale behind laying out these sensors.

Weather station

A weather station (ATMOS 41) was placed in the vicinity of the test area to capture wind speed and direction during sprinkler operations. The site selected for this study was in a valley, and historically has had relatively high wind speeds. Therefore, any interference due specifically to wind was deemed worth documenting if wind affected sprinkler operations.

FINDINGS

Logistics

This section details the logistics findings from this study. Most details related to logistics do not have multiple replicates due to time and cost constraints. Therefore, while this logistics data is only a singular data point, it offers insight to what may be expected when using these systems.

Transportation requirements

A total of seven semi-trucks with flat-bed trailers were used to transport all equipment, including a crane and a Sea-Can containing spare parts. Six of the seven semi-trucks were rented for this study; therefore, their task involved exclusively the transportation and unloading of all equipment (inclusive of Sea-Can) at the site. The six semi-trucks left the site immediately after unloading equipment, thereby reducing the staging footprint requirement. The semi-trucks returned to the site after the trials were completed to assist with demobilization of all equipment on site.

Figure 13. Equipment being unloaded from the semi-trucks at the staging area by using a crane.

Figure 14. Sea-Can containing spare parts. The Sea-Can was on site for the duration of the study.

Figure 15. A variety of spare parts inside the Sea-Can.

Figure 16. Equipment offloaded from the semi-trucks was placed in the staging area.

Manpower requirements

Eight personnel, inclusive of field staff and field supervisors, were on site for this set-up. All eight personnel were involved in unloading equipment at the site, set-up of different systems, operation of different systems, and demobilization of equipment from the site. A total of seven pickup trucks were also on site and used to transport personnel to the site. One of the seven pickup trucks towed a flatbed trailer.

Figure 17. Instance of personnel participating in equipment set-up.

System set-up details

Two skid steers and eight personnel were involved in the set-up of both 4- and 12-inch systems. The skid steers were used to carry a spooling mechanism (Figure 18) to lay out the hose, while field personnel were tasked with connecting lengths of hose (Figure 16).

Figure 18. A skid steer carrying the spooling mechanism that laid 4-inch hose.

The following table outlines specific details on the two systems that were set up as well as corresponding figures for visual presentation.

Table 2. Specifics of the 4- and 12-inch systems

System segments	Particulars	4-inch system	12-inch system	Figure No.
Set-up	Manpower required	8 personnel*	8 personnel*	-
	Machinery required	2 skid steers	2 skid steers + pickup with flatbed[#]	18
Pump	Pump	PP86C17 Pioneer	MX 6822 Cornell	19, 20
	Pump power	325 HP	644 HP	-
	Number of pumps used	1	1	-
Hose	Length of supply line	1.1 km	2.2 km (inclusive of meander)	-
	Type of hose	4” forestry	12” layflat	-
	Length of each hose	50 ft	656 ft	-
	Hose lengths per spool	33-37	1	21, 22
	No. of lengths used	72	7	-
	Hose connection type	Quick-couple fitting	Victaulic coupling	23, 24
	Whip check	Not used	Used	24
	Compressor required for pigging the line[+]	Yes	Yes	-
Sprinkler	Number of sprinklers	2	2	25, 26
	Nozzle size	0.5”	1.77”	-

** Not all eight personnel were necessarily involved in the set-up at the same time. Involvement varied throughout the set-up.*

 # Flatbed carried additional spools to assist with faster installation for the 12-inch system.

+ Only required when near freezing conditions.

Figure 19. Mobile PP86C17 Pioneer pump used for the 4-inch system.

Figure 20. Mobile MX 6822 Cornell pump used for the 12-inch system.

Figure 21. Four-inch hose in spool in the foreground housing 33 lengths of hose.

Figure 22. Twelve-inch hose on a spool.

Figure 23. Four-inch quick-couple forestry fitting.

Figure 24. Whip checks used for 12-inch hose. Victaulic fittings used to connect two lengths of hose.

Figure 25. Sprinkler used in the 4-inch system.

Figure 26. Sprinkler used in the 12-inch system.

Timed logistics

Table 3 presents approximate times for the key activities during this study.

Table 3. Data on timed sections of system set-up

Activity	Time	
Unloading equipment	1 hour	
Road crossing set-up*	20 minutes	
	4-inch system	**12-inch system**
Set-up time (excluding unloading equipment, road crossing set-up)	2 hours	2 hours
Priming the line	5 minutes	10 minutes
Start-up time (*n = 3*)	5 minutes	2 minutes
Turn-off time (*n = 3*)	2 minutes	2 minutes
Tear-down time	1 hour	2 hours
Demobilization from site	1 hour	

** A gravel truck was used to transport gravel for the road crossing. Surplus gravel was used to pack down any uneven areas in the vicinity once the trials were complete.*

It is worth noting that this study cannot comment on the impact of soil conditions due to the heavy machinery on site, given the limited data available from this trial. Visually, no obvious impacts were caused to the surface soil. Different soil types and conditions may result in different impacts that may require soil remediation practices.

Water delivery

Pressure and flow rates

Table 4 presents the pressure and flow rates observed during sprinkler operations.

Table 4. Pressure and flow rate for the 4- and 12-inch systems

Parameter (*n = 3*)	4-inch system	12-inch system
Pressure at pump	140 psi	130 psi
Pressure at sprinklers	100 psi	105 psi
Flow rate	680 L/min	7100 L/min

Rainfall equivalent and coverage area

Figures 27 and 28 provide a map of estimated average ($n = 3$) rainfall equivalent amounts observed during sprinkler operations. Data sets for both the 4- and 12-inch systems were adjusted to present hourly rainfall equivalent amounts since sprinkler operations lasted only 15 minutes per iteration.

Note that the colour gradients presented in Figures 27 and 28 are relative within the data set and not relative across data sets. In addition, Figures 27 and 28 are of the same pictorial size but represent different physical scales.

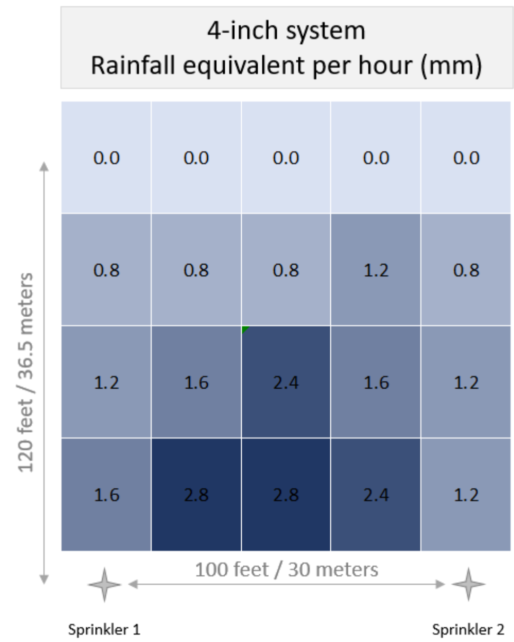


Figure 27. Average rainfall equivalent amount per hour for the 4-inch system.

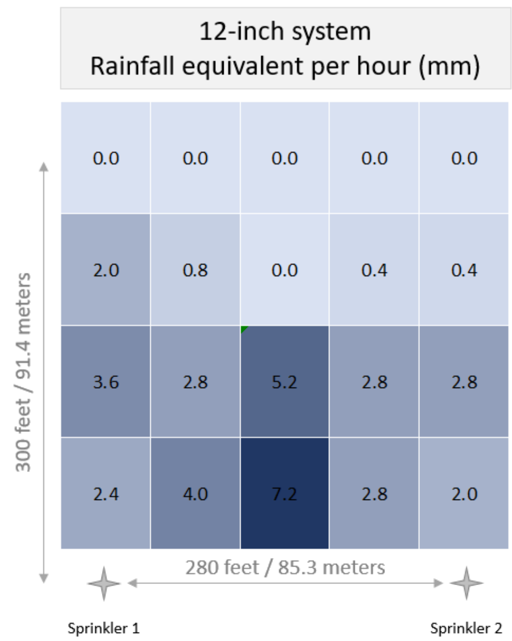


Figure 28. Average rainfall equivalent amount per hour for the 12-inch system.

Figure 28 suggests that the rain gauge located in the third row and third column (starting bottom-left) shows no rainfall amounts received. This is due to obstruction from trees located in the immediate vicinity of the rain gauge.

Sprinkler systems are often set up such that they can produce a wet area of consistent length and width. This is achieved by having sprinklers overlap in their coverage area, not dissimilar to the set-up used in this study. Based on the two-sprinkler set-up presented in this study, the 4-inch system is capable to producing a coverage area of 100 ft x 90 ft (0.08 ha) of relatively consistent wet area. Likewise, the 12-inch system can produce a coverage area of 280 ft by 225 ft (0.59 ha acres) of relatively consistent wet area. These area measurements can be further refined with greater resolution in rain gauge grid set-up. Furthermore, the areas presented here offer a measurement exclusively for a two-sprinkler set-up. The area covered can be scaled up with additional sprinklers if appropriate pressure and flow rates are delivered to the sprinklers.

Average rainfall amounts per sprinkler

Rainfall equivalent data was adjusted to compensate for the six gauges that received 100% overlap from two sprinklers. This adjusted data was used to calculate the average rainfall equivalent amount offered per sprinkler for an hour's worth of run-time within their casting area. The 4-inch system averaged 1.1 mm of rainfall equivalent per sprinkler (standard deviation of 0.3), while the 12-inch system averaged 1.8 mm of rainfall equivalent per sprinkler (standard deviation of 1.1). Note that these values were calculated for two different area sizes with two different rain gauge grid resolutions.

A question that arises from large rainfall equivalent amounts from area-based water delivery systems is soil erosion. This current study cannot state with confidence the impact of large rainfall equivalent quantities on the various soil types and conditions that exist. However, average rainfall amounts per sprinkler can be used to simulate soil erosion from run-off water, which may provide more useful information.

Implications for localized fuel moisture

Wildfire practitioners in Canada use the Fire Weather Index (FWI) System to predict fire behaviour [1]. This system is based on various weather inputs such as rainfall, relative humidity, wind conditions, etc. Two publications by Lawson titled *Weather Guide for the Canadian Forest Fire Danger Rating System* and *Predicting Forest Floor Moisture Contents from Duff Moisture Code Values* discusses the sensitivity of the FWI System to weather elements quantitatively [2, 3]. It has been documented that rainfall has the largest impact among the various weather inputs on FWI indices.

In the context of area-based water delivery systems, the ability to supply rainfall equivalent to assist with impacting localized fuel moisture conditions is certainly important. However, rainfall equivalent should not be taken at face value. The FWI System and associated impacts from rainfall equivalent have nuances such as time lag constants, drying rates, seasonal drought, fuel characteristics, solar radiation (or lack thereof), etc. that have to be considered. Given the breath of variables involved, the implications for localized fuel moisture due to rainfall equivalent can be considered qualitatively positive, but quantitatively yet to be determined.

It is worth noting that increased rates of delivery of rainfall or rainfall equivalent do not necessarily mean that the wetting phase of fuels is reached more quickly. Higher rates of delivery of rainfall or rainfall equivalent can lead to surface run-off. The ideal quantity of rainfall equivalent required to have a tangential impact on localized fuel moisture conditions while simultaneously limiting any ecological impacts can be challenging to determine and will require attention on a case-by-case basis.

Temperature and relative humidity data

Table 5 presents weather conditions logged by the weather station on the day of sprinkler operations:

Table 5. Weather conditions during sprinkler operations

Weather	4-inch system	12-inch system
Temperature range	1.6 to 4.6 °C	0.6 to 4 °C
Relative humidity range	70.7 to 84.1%	69.1 to 77.6%
Average wind speed	6.5 km/h	6.2 km/h
Average wind direction	186°	179°

Temperature and relative humidity data within the grid were collected using REED R6020 sensors. In addition, control sensors as well as a weather station were placed away from the test area. Table 6 presents the accuracy of the sensors (sourced from the manufacturer):

Table 6. REED R6020 specifications [4]

Temperature	
Measuring Range	-40 to 158°F (-40 to 70°C)
Accuracy	±1.8°F (1.0°C)
Resolution	0.1°F/°C
Humidity	
Measuring Range	0 to 100% RH
Accuracy	0 to 20% and 80 to 100%: ±5% 20 to 40% and 60 to 80%: ±3.5% 40 to 60%: ±3%
Resolution	0.1% RH

Figures 29 and 30 present the average temperature and RH data logged by the sensors during sprinkler operations. The light-red vertical bars indicate the time periods when sprinklers were switched on. Note that control sensors for the 4-inch system trial were found faulty and did not log data. Therefore, weather station temperature and RH data were used as a backup control. The authors acknowledge that the error tolerances between the two data logging devices are different, and therefore should be considered when interpreting the data. To keep data presentation consistent, weather station data was also used as a control for the 12-inch system.

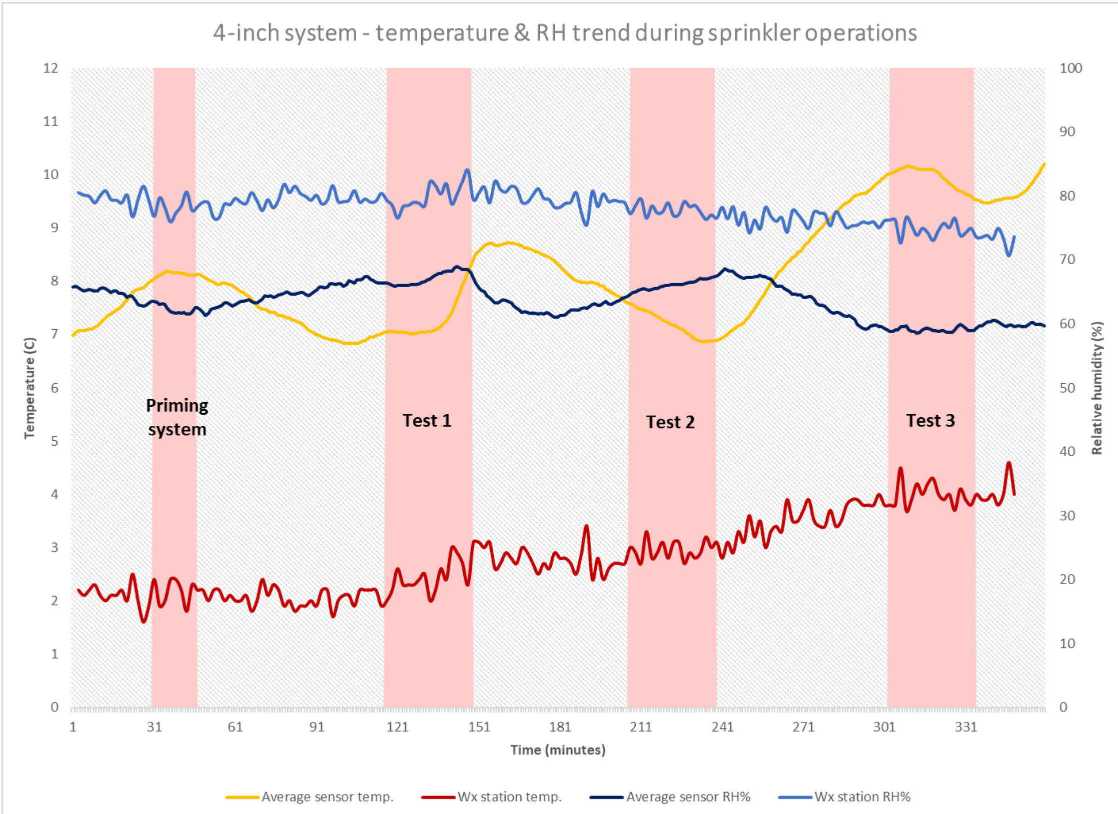


Figure 29. Temperature and RH trends during sprinkler operations with the 4-inch system.

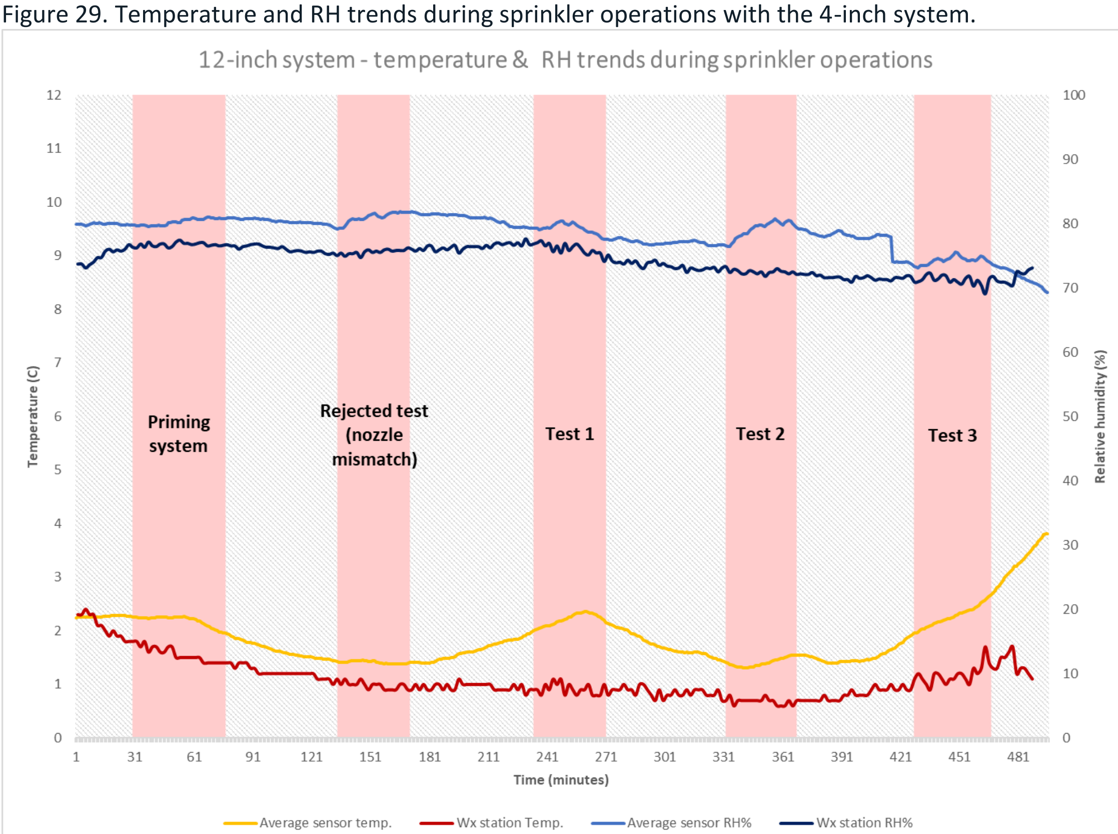


Figure 30. Temperature and RH trends during sprinkler operations with the 12-inch system.

The following interpretations can be made from the data presented in Tables 5 and 6 as well as Figures 29 and 30.

1. The weather conditions were not ideal for sprinkler operations. The tests were done on days with near-freezing temperatures and high relative humidity. Therefore, from the outset, it was presumed that noticeable localized weather changes resulting from sprinkler use would have a minimal effect. To fully capture the impact that these mass water delivery systems can have on temperature and relative humidity, sprinkler operations will be conducted once again in the summer. The ideal weather sought after will be hot and dry conditions, representative of weather that wildfires are likely to occur in. it is expected that the impacts to temperature and relative humidity would be more pronounced under realistic wildfire conditions.
2. For both the 4- and 12-inch systems, the temperature changes observed are not drastic enough to draw meaningful conclusions. This can likely be partially attributed to the temperature of the water source as well as the weather conditions on the day of testing.
3. For both the 4- and 12-inch systems, the RH changes observed are not drastic enough to draw meaningful conclusions. This can likely be partially attributed to high RH conditions on test days.

From these trials, the following are suggestions for test design improvements:

1. **Site selection:** The site selected in this study is known to have high wind conditions. For future tests, seasonal wind conditions should be factored into site selection to mitigate the risk of winds impacting sprinkler operations.
2. **Temperature and RH data:** To effectively capture the sprinklers' impact on temperature and RH, hot days with low ambient relative humidity conditions are preferred. Further, such conditions would better replicate realistic wildfire burning conditions.
3. **Recovery time:** It may be worth exploring the impact of increased recovery time between sprinkler operations to see the extent to which temperature and RH recover after sprinkler operations. This way, the impact of one set of sprinkler operations does not spill into the next.
4. **Equipment improvement:** Figure 12 shows the placement of the sensors very close to the ground. This can potentially cause incorrect readings on hot days where evaporation of water from the ground may cause false readings. Placing sensors higher up may be more helpful but comes with an increased cost and time for set-up.

CONCLUSION

The objective of this study was to capture data on area-based water delivery systems, specifically in the context of logistics, systems differentiation, water delivery, and its localized effects. FPInnovations successfully collaborated with Fire & Flood to obtain this data. A two-day test was executed during which the 4- and 12-inch systems were set up and sprinkler operations were carried out.

Key timed metrics such as set-up time, tear-down time, start/stop time, and demob time were recorded for both systems. In addition, instrumentation, equipment transportation, and manpower requirements were documented. Water delivery metrics such as pressure and flow rates, as well as time-bound rainfall equivalent and estimated coverage area were recorded. Rainfall equivalent data was processed to provide linkage to the FWI System and the associated localized impacts that sprinkler operations may have.

Lastly, localized two-dimensional temperature and relative humidity data was collected during sprinkler operations. While the data gathered was unable to provide any meaningful conclusions due to less-than-ideal weather conditions, the exercise produced learnings on how to improve the design of tests for area-based water delivery systems. Sprinkler operations will be repeated in the near future under more realistic wildfire weather conditions to understand the impact that these systems can have on temperature and relative humidity.

REFERENCES

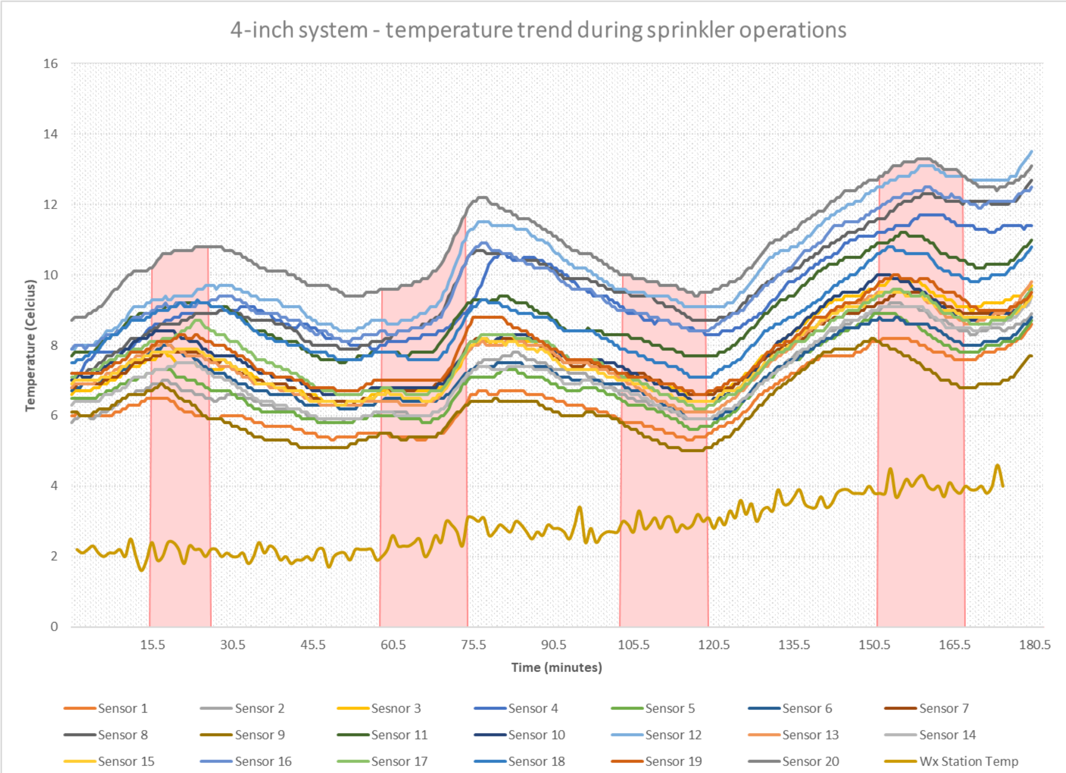
[1] "Canadian Forest Fire Weather Index (FWI) System". Background Information. Natural Resources Canada. 2009.

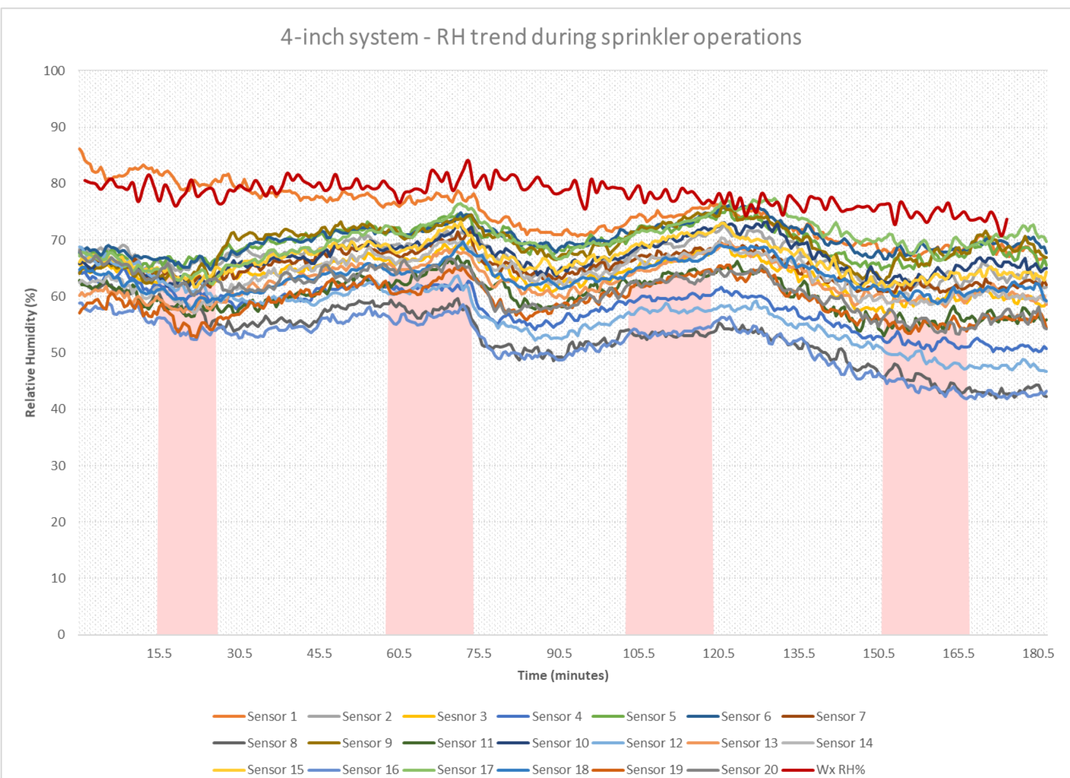
[2] Lawson B.D., 2008 Weather Guide for the Canadian Forest Fire Danger Rating System. Northern Forestry Centre, Canadian Forest Service.

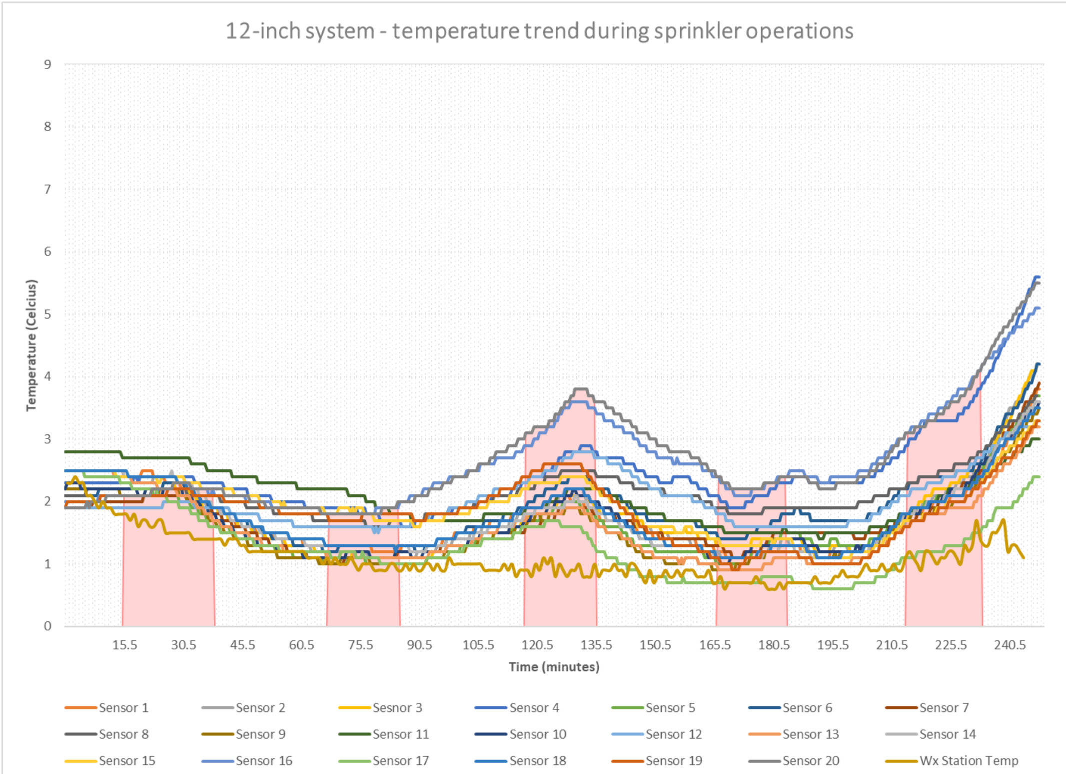
[3] Lawson B.D., G.N. Dalrymple, and B.C. Hawkes. 1997a. Predicting Forest Floor Moisture Contents from Duff Moisture Code Values. Technology Transfer, Forestry Research Applications, Pacific Forestry Centre, No. 6, October.

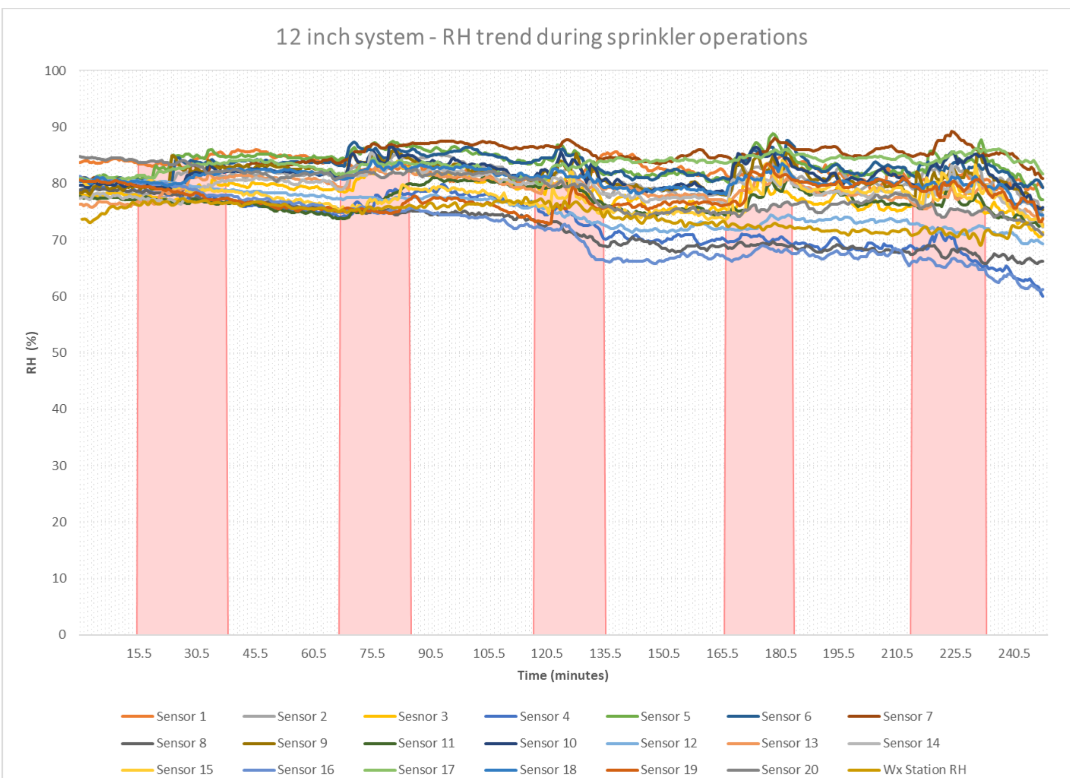
[4] Reed Instruments, https://www.reedinstruments.com/product/reed-r6020-temperature-humidity-data-logger, accessed on November 9, 2020.

APPENDIX


4-inch system - temperature trend during sprinkler operations
Temperature (Celcius)
16
14
12
10
8
6
4
2
0
15.5
30.5
45.5
60.5
75.5
90.5
105.5
120.5
135.5
150.5
165.5
180.5
Time (minutes)
Sensor 1
Sensor 2
Sesnor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7
Sensor 8
Sensor 9
Sensor 11
Sensor 10
Sensor 12
Sensor 13
Sensor 14
Sensor 15
Sensor 16
Sensor 17
Sensor 18
Sensor 19
Sensor 20
Wx Station Temp


4-inch system - RH trend during sprinkler operations
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
15.5
30.5
45.5
60.5
75.5
90.5
105.5
120.5
135.5
150.5
165.5
180.5
Time (minutes)
Sensor 1
Sensor 2
Sesnor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7
Sensor 8
Sensor 9
Sensor 11
Sensor 10
Sensor 12
Sensor 13
Sensor 14
Sensor 15
Sensor 16
Sensor 17
Sensor 18
Sensor 19
Sensor 20
Wx RH%


12-inch system - temperature trend during sprinkler operations
Temperature (Celcius)
Time (minutes)
Sensor 1
Sensor 2
Sesnor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7
Sensor 8
Sensor 9
Sensor 11
Sensor 10
Sensor 12
Sensor 13
Sensor 14
Sensor 15
Sensor 16
Sensor 17
Sensor 18
Sensor 19
Sensor 20
Wx Station Temp


12 inch system - RH trend during sprinkler operations
RH (%)
Time (minutes)
Sensor 1
Sensor 2
Sesnor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7
Sensor 8
Sensor 9
Sensor 11
Sensor 10
Sensor 12
Sensor 13
Sensor 14
Sensor 15
Sensor 16
Sensor 17
Sensor 18
Sensor 19
Sensor 20
Wx Station RH

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