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Hemlock Drying in Coastal BC: 2015-2016

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Abstract

Based on the data from this study and a literature review, there are two distinct trajectories for hemlock wood moisture content, depending on if the tree was felled before or after May. Hemlock trees felled before May gain the full benefit of spring drying according to the ambient conditions of their local micro-climate. Trees felled after May suffer from a physiological spike in moisture content that the tree generates to promote its growth and survive the summer soil drought.

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Executive summary

The findings of this study suggest that if western hemlock (Hw) requires drying it should be felled before May, unless it can wait for watering until the following summer. After Hw has been felled for two months, it can be watered at anytime that it's moisture content (MC) is 51% or less at time of watering.

Based on the data from this study and a literature review, this study concludes that there are two distinct trajectories for hemlock wood moisture content, depending on if the wood was felled before or after May. Hemlock felled before May gain the full benefit of spring drying according to the ambient conditions of their local micro-climate. Wood felled after May suffers from a physiological spike in tree MC that the tree generates to promote its growth and survive the summer soil drought. Hemlock felled after May may be up to 15-20% higher in MC than Hw felled before May when both are measured in August or later. Analysis showed that there was no advantage in reduced MC from falling in July versus September or November.

Study data showed that felled Hw may gain up to 15-20% MC during the fall months and MC will likely remain constant during the winter months. Interpolating from the data shows that spring and summer drying may be 20% or more, provided the trees were felled before May. FPInnovations does not have data on Hw drying during April to July.

The study also showed that there was no difference in MC between shavings or cookies as a sampling method. It showed there is no difference in MC between bark and white wood, shortly after felling. The study confirmed that log tops have higher MC than log butts. The study was inconclusive in determining if ecotype affected wood MC.

The "General guidelines for timber managers" section can serve as a rough prediction tool for knowing if western hemlock will sink or float when watered and what are the best management strategies to control Hw moisture content. In general, Hw felled before May can be watered after August and throughout the following fall and winter. For safety, hemlock felled after May should be watered after August but before October. Any hemlock may be watered if its MC is 51% or less at the time of the watering, providing it was felled at least two months earlier. It is always best to check the MC at time of watering to ensure Hw will float. Samples taken from log butts will likely show 5-8% lower MC than their top logs. Frequent MC monitoring provides empowering information for timber managers, and may be especially useful when dealing with younger logs or wetter ecotypes.

A streamlined moisture content sampling method was presented. In brief, separate sample sets should be taken from each distinct stratum, and may be as few as 10 samples per set (more are desirable). Each sample can be a small wedge taken at least 10 cm from the cut log end, and should be weighed or stored in a sealed plastic bag immediately. After wet weights are taken, drying should occur, and then wet and dry weights can be used to determine moisture content. Detail on sample specifications and MC calculation is in the report.

Introduction

There have been many recent instances along the British Columbia (B.C.) coast of western hemlock (*Tsuga heterophylla*) sinking or ‘floating-low’ when transported in water. The direct cause of low flotation in western hemlock (Hw) is high moisture content (MC). Hw is especially prone to high moisture content because within the wood structure it has relatively large pits between its lumens (compared to other softwood species). Lumens are the large hollow tubes that make up wood – like a handful of drinking straws, only smaller. Pits are structures (like holes or valves) that allow material to pass from one lumen to another. Large pits allow water to easily penetrate deep into Hw wood and then remain there through surface tension on the walls of the lumens.

FPInnovations has looked at ways to increase flotation of Hw through physical means like lashing it with buoys or lighter logs like cedar (Jokai, 2016). However, the present report focuses on increasing flotation by reducing the moisture content of hemlock through drying.

Over the last three years, FPInnovations has looked at a variety of drying regimes for Hw. They are summarized here. Methods for testing moisture content have been refined during the course of this study and are presented. Anecdotal reports that young trees are more likely to sink than older trees are confronted. Strategies for managing Hw harvest and fibre flow to prevent sinking, gleaned from literature review and the last three years of studies are summarized. Lastly, an attempt is made to summarize and consolidate all the findings of the last three years into a coherent whole that may lead to a prediction tool to assist industry in knowing in advance if particular Hw logs are likely to sink or float.

Background

Western hemlock has an average wood density of 0.450 kilograms/litre (kg/L) (Josza et al., 1998). Josza et al. list 0.426 as the overall mean for Hw stemwood density. In their study, average densities range from 0.40 to 0.45, with a normal range of 0.34 to 0.50. Here, the upper value of the average range is used for safety, 0.45.

Using this value as its average density, Hw will float in fresh water at moisture contents up to 55% and in seawater (average density of 1.027 kg/L) at MC up to 58%. This is because seawater contains dissolved salts, making it heavier than freshwater.

For the purposes of this study, the ‘low floating’ threshold has been established at 0.96 kg/L to provide a safety margin that accounts for variations in wood density between different Hw logs and between different parts of the log, as well as possible uptake of water during flotation. This equates to a MC of 51% for Hw when floated in seawater. This information was summarized in a previous FPInnovations’ report “Flotation of western hemlock” (Friesen, 2015) but has been refined and is shown in Table 1.

Table 1. Important moisture content thresholds for Hw

Limiting factor	Density (g/cm^3)	Equivalent MC for Hw average (%)
Seawater	1.027	58
Fresh water	1.000	55
Low-floating	0.960	51

In an FPInnovations study on wood density in hemlock, Blackburn (2016b) conducted a trial to assess variability of timber characteristics related to sinking along the length of second-growth Hw logs. He found that moisture content generally increases from butt to top in second-growth Hw, while wood density (oven-dried density, which implies 0% MC) generally decreases along the same axis.

This makes sense considering that there are typically more tightly spaced rings at the bottom of logs than at the top. This means that there is more woody material at the butt (the tight rings) and relatively more lumen space at the top where the rings are generally wider. More lumen space means there is greater opportunity for higher moisture content at the top of the log where more water can be held, and tighter rings at the butt means that there is more woody material there that, when oven-dried, shows as greater wood density at the butt.

Putting these two together produces a banana-shaped graph to describe the green density of Hw logs. Since logs are shipped with some level of green density (and not oven-dried density), this knowledge can be used to facilitate water transport.

A summary of the graphs from Blackburn (2016b) is presented in Figure 1.

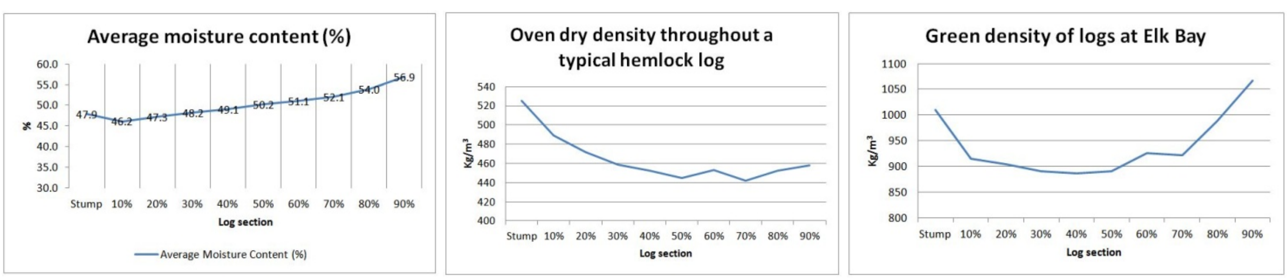

Figure 1. Hw density characteristcs from Blackburn (2016a).

The information from Blackburn (2016b) is an excellent starting point for understanding Hw flotation along different parts of the log. However, questions remain about time of year in relation to hemlock flotation.

Clark and Gibbs (1957) found that the water content of eastern hemlock (*Tsuga canadensis*) varies greatly from tree to tree but that there are nevertheless averages that indicate a seasonal pattern with minima in May and August-September. They also find that there is a vertical gradient in the trees with highest average values in tops and lowest average values in butts. This is confirmed by Blackburn's study for western hemlock, and is also confirmed for most tree species generally, by Ovington (1956).

Clark and Gibbs also note that this distinct seasonal pattern applies to the MC of the sapwood, but this is not reflected in the heartwood. This may be a noteworthy finding in relation to the anecdotal evidence from B.C. coast loggers that young trees, which are mostly sapwood, are more likely to sink than older trees.

In an analogous study on Douglas-fir (*Pseudotsuga menziesii*) by Beedlow et al. (2007) found that there was only ~5% seasonal variation in bole relative water content in Douglas-fir. They also cite Wullschleger et al. (1996), Irvine and Grace (1997), and Irvine et al. (1998) in claiming that hardwoods and Scots pine (*Pinus sylvestris*) similarly show little variation throughout the year in tissue water content. Similarly, Shottafer and Brackley (1982) showed there was little variation in seasonal MC for eastern spruce and balsam fir.

Taking all these studies together would seem to confirm that the seasonal variation in moisture content is likely to be more prominent in western hemlock on the B.C. coast than in other species. This would seem to confirm that hemlock's large pits between lumens are the likely culprits in facilitating seasonal high moisture content in Hw, since they allow the easy transport of water into and out of the log.

Clark and Gibbs (1957) found that there was a seasonal dip in hemlock moisture content in early May followed by a spike, then a dip in August-September. Beedlow et al. (2007) found a similar (albeit smaller magnitude) pattern in Douglas-fir, noting there was a maximum reached during earlywood production in late spring and early summer, followed by a gradual decrease in MC during fall coinciding with latewood formation. According to Waring and Running (1978) and Waring and Franklin (1979) in studies on large trees in the Pacific Northwest, bole water then recharges to maximum values in the winter. It seems then that trees spike their MC to allow for the rapid growth of the early growing season and to protect against summer drought in spite of decreasing soil moisture content. This is also reflected by Tyree et al. (1978) who found an annual maximum MC for hemlock in winter and minimum in summer, although that study focused on foliage.

Turning to drying regimes, FPInnovations conducted studies on the efficacy of sour-felling in *Populus spp*. hardwoods in northern Alberta but found that it was ineffective, (Forrester 1989; 1991). Sour-felling, also known as 'wicking', is the practise of leaving the limbs on the log after felling in hopes that water demand of the leaves will reduce moisture content of the stemwood if left long enough.

Because the previous studies were conducted on hardwoods, another wicking trial was performed by FPInnovations on western hemlock on Vancouver Island. It found there was no difference in the MC of wicked or un-wicked Hw logs over a period of three months, negating the idea that leaving the branches on assisted drying (Friesen, 2014). This study also observed that after three months of drying, there was no uptake of water by Hw logs during the time in which they were watered – a period of two months.

Specifically, the study observed that as time passed, Hw logs showed less and less variation in their moisture content. The volatility of their response to environmental humidity decreased over time to the point that they did not uptake any moisture when watered after three months of drying. The results of the study are summarized in Figure 2.

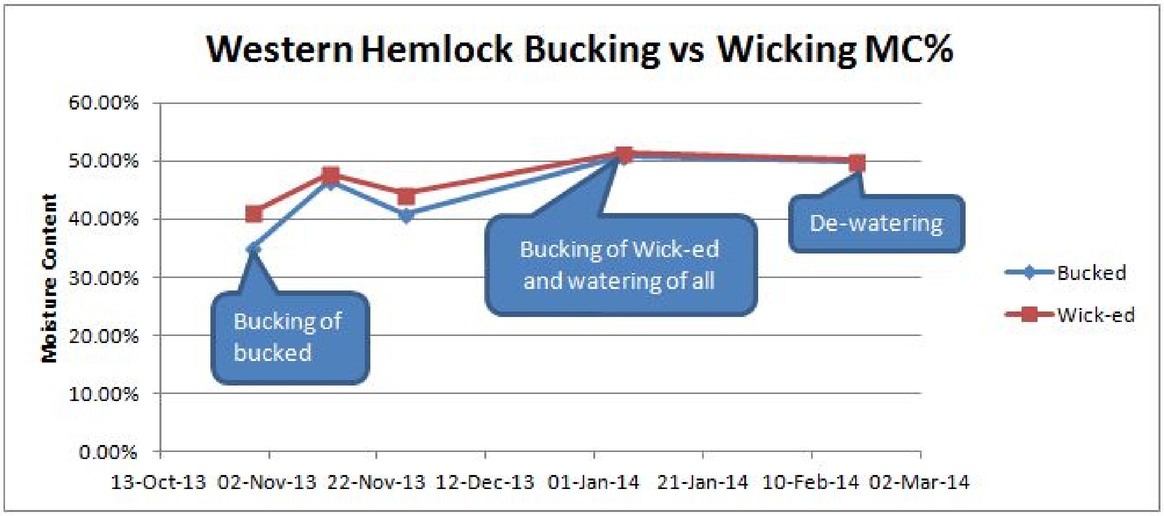

Figure 2. Results of 2014 wicking study on Vancouver Island.

Based on these findings and the need to uncover the drying behaviour of Hw, FPInnovations undertook another study tracking the moisture content of felled Hw logs over time to observe if drying occurred during winter months on coastal B.C. The study found that no drying occurred at three different sites during winter, in periods varying from 4 to 111 days (1-16 weeks) after felling, (Friesen, 2015).

Wanting to know if drying was more effective at other times and if long term drying could be expected, the study was extended into and beyond summer and is the basis for the material presented here. Additionally, there was a call from industry to develop a prediction tool that would help loggers know in advance if hemlock logs were likely to sink or float low. Anecdotal evidence suggested that young hemlock were more likely to sink than older trees, and that wetter micro-sites produced more sinkers than better-drained ecosystems. Partially to this end, a simplified field method for collecting MC from Hw was developed for adoption by industry.

Method

Sites were selected near Southeast Bay on mid-Vancouver Island's east side on the Lower Adams Mainline. Additionally, block 2-700 from West Cracroft Island was revisited. Unless otherwise noted, each sample collection was of 30 samples from each block/date combination.

Block 49279 on the Lower Adams was sampled starting 7 August 2015 using both chainsaw shavings and chainsaw-cut discs (cookies) to see if these differed. The block also was the subject of samples taken from bark and white wood of the same logs to see if these varied in MC. Additionally, right-of-way (ROW) wood from this block was sampled along with felled timber. The ROW wood was felled in January, and the block timber was felled in July. Since these were from the same stand and the same ecosystem – the two locations were adjacent – differences in MC could be attributed to the time that the ROW wood had to dry or cure during the January to July period.

A nearby stand, block 45035, was felled in September and it was sampled starting 24 September 2015. Comparisons were made between this block and block 49279 felled two months earlier. Another block, block 50027 was felled in late November and it was sampled on 17 December 2015. It was compared to the two previously felled blocks. Finally, block 2-700 on West Cracroft, which was the subject of the previous year's study, was sampled again on 5 February 2016, to see if any changes had occurred from the previous year, to see if there were differences between the MC of tops and bottoms of logs, and to test preliminarily if ecotype affected wood MC.

Samples were collected in sealable plastic bags, were weighed (wet weight) and then dried in 195-200 °F oven for 24 hours, to determine dry weights. From this data, MC of the samples was determined. All moisture contents in this report were determined on a 'wet basis' with the basic formula: MC_{wet} = ((wet weight – dry weight) / wet weight) x 100.

Comparisons were made between the different samples, noting variations in block, time since cutting, and collection method. Additionally, a refined sample collection method was developed for use by industry as part of an early prediction tool of impending Hw flotation problems.

Results and discussion

Block 49279

Right-of-way vs block wood

The first samples were taken from Block 49279 and focused on the differences between the recently felled block wood and the ROW wood that had been felled six months earlier. It also looked at the differences between using chainsaw shavings or chainsaw cookies as a sampling method, as well as the differences in MC between bark and white wood from the same log.

There was a dramatic difference between the recently felled block wood and the ROW wood felled six months earlier. In the four measurements taken in August 2015, the ROW wood had a consistently lower MC, varying between 12 and 20% lower (Figure 3).

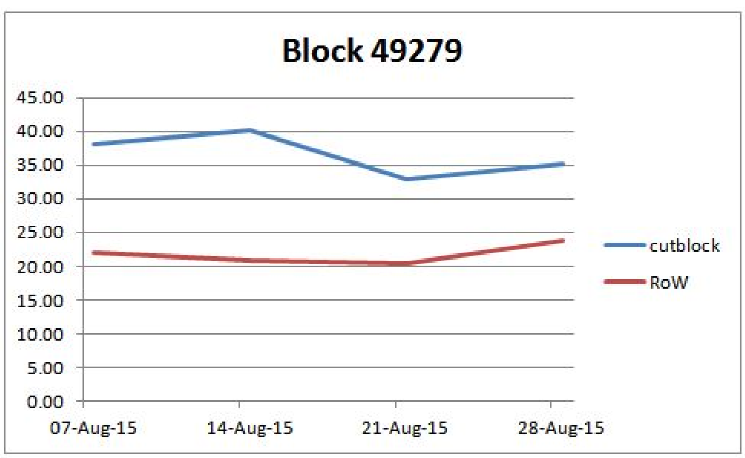

Figure 3. MC of ROW vs cutblock wood felled six months later.

The ROW wood was felled six months earlier than the cutblock wood but was immediately adjacent to the cutblock wood and from the same ecotype. The differences in MC can be attributed to the drying time that the ROW wood experienced during the January to July period.

Standard deviation ranged between 4.0 and 6.3 for all samples except for the final cutblock wood sample which had a standard deviation of 9.0. Regardless, there was a significant difference between the ROW and cutblock wood at each time step.

It would have been interesting to see if the difference between ROW and block would have persisted as time passed or if (or when) eventually the two MCs would become the same. However, at the beginning of September the two wood types were mixed together for processing and removal from the block. Sampling of this block for comparison to other blocks continued through December.

Shavings vs discs

To see if there was a significant difference in moisture content based on collection method, ten randomly selected trees had chainsaw discs (cookies) collected in addition to the chainsaw shavings that were collected from every tree. The results are shown in Figure 4.

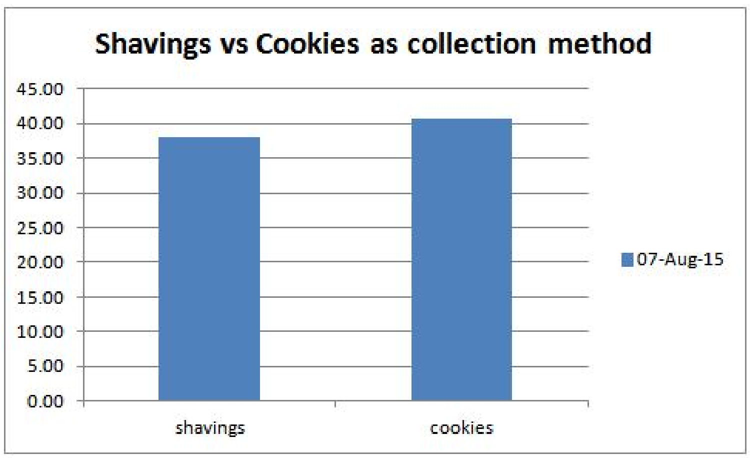

Figure 4. MC of shavings and cookies from the same ten trees.

Although the cookies displayed a slightly higher average MC of 40.8% this was found to not be significantly different (alpha = 0.05) from the shavings MC collected from the same ten trees which averaged 38.1% MC. The significance of this finding is that either shavings or cookies can readily be collected as reliable predictors of MC. If one method or the other is particularly easy for a sample collector, it may chosen without fear of contaminating the results. This may encourage industry to sample their own Hw more frequently.

Bark vs wood

FPInnovations was asked by industry if bark was more likely to be a flotation problem than white wood. The behaviour of bark in drying and when submerged in water was thought to be outside the scope of this study but as an initial answer, samples were taken from Block 49279. A fuller study on Hw bark was later conducted by FPInnovations made by Blackburn (2016a).

For the present study, there were 26 logs sampled for shavings that were also sampled for bark. The results are shown in Figure 5.

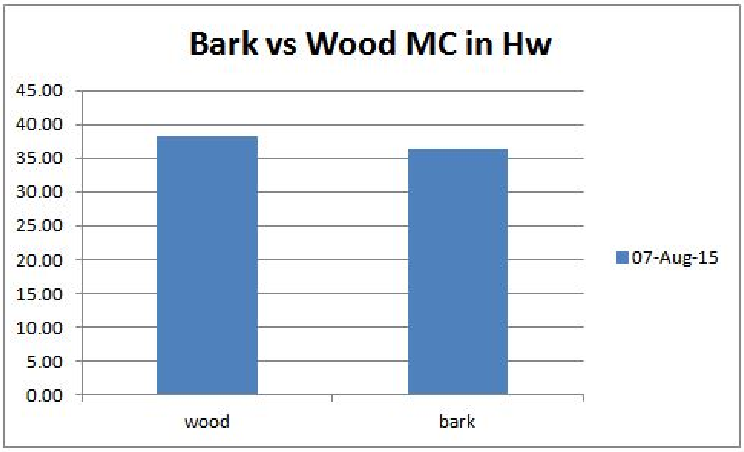

Figure 5. MC of wood and bark from the same 26 trees.

The wood shavings had a slightly higher moisture content than the bark: 38.1% vs 36.3%, respectively. However there was no significant difference between the two numbers (alpha = 0.05). This means that the bark carried the same moisture content at the time of cutting.

This does not indicate whether the bark will dry more or less quickly if left to cure with the log, or if the bark is more or less likely (than wood) to take on water when floated. It may mean that the bark makes little difference in the buoyancy of Hw logs, however anecdotal evidence (which may be wrong) is that Hw bark is more likely to take on water and sink than the log it accompanies, when the log is watered (placed in water for transport).

Blackburn (2016a) observed a slight increase in buoyancy for logs with bark removed but ultimately was not able to state so conclusively. More study on this question is needed.

Overall drying trend

White wood samples were taken from this block each week for the first month and then once a month through December. There was a drop in MC from 40% to 33% during the hot weather of August, but then MC rose to ~43% in September and stayed there until very wet weather in December drove it up to 49%. This is shown in Figure 6.

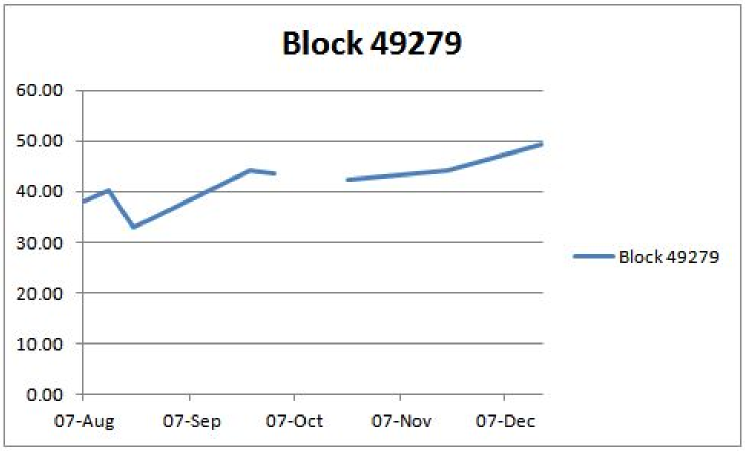

Figure 6. MC of block 49279.

Hopes that the drying that occurred in August would prevent re-uptake of moisture during the fall were disappointed. In fact, as the data from Block 45035 shows, there appeared to be no benefit to falling in July vs falling in September.

Block 45035

Block 45035 was felled in September and the first MC readings were taken on 24 September. These were repeatedly weekly for the first month and then monthly thru December. Adding the MC results to the Block 49279 results shows that they moved very much in parallel, as shown in Figure 7.

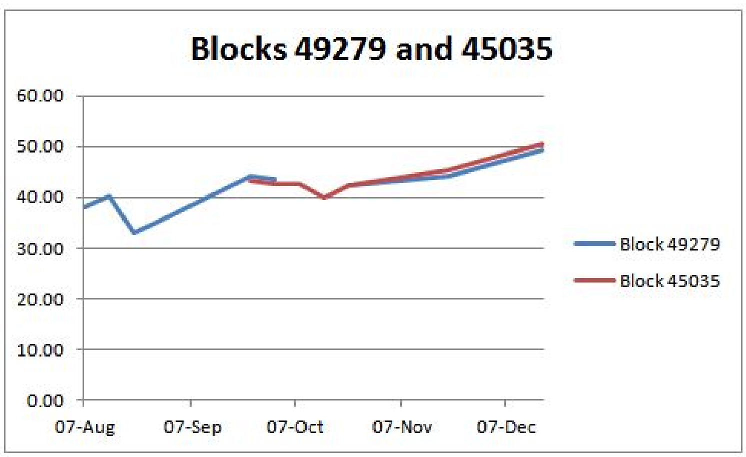

Figure 7. MC of blocks 49279 and 45035.

This indicates that the earlier felling of Block 49279 did not assist in keeping its moisture content lower than a freshly felled block (45035) even though it had two extra months of drying in the late summer. Unfortunately, both blocks seemed very responsive to ambient weather conditions, even 3 and 5 months after falling, respectively. These two blocks did come in 2-3% lower in MC than Block 50027 which was not felled until November, but that difference was not statistically significant (alpha = 0.05).

Block 50027

Block 50027 was felled in November and only one date (in December) was sampled with a set of 30 samples. Overall, the MC of block 50027 was not significantly different from blocks 49279 and 45035 which had already dried for several months. Block 50027 results are added to the graph, shown in Figure 8.

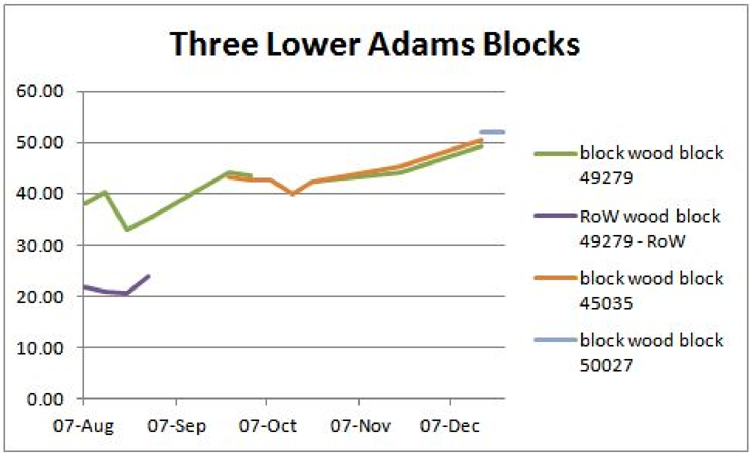

Figure 8. MC of the three Lower Adams blocks.

Also added to this graph are the results from the ROW wood of Block 49279 from August (felled in January). Even though the July-felled wood mimicked the MC of the more recent September-felled (45035) and November-felled wood (50027), the ROW wood seemed on course to remain 15-20% lower in MC despite starting to rise with the onset of wetter weather in early September.

Unfortunately, the ROW was mixed with the rest of block 49279 and it was not possible to track it any longer. However, unexpected help in understanding what might occur to it, and data, came from an extension of the previous year's project (2014-15).

Lessons from West Cracroft block 2-700

West Cracroft Block 2-700 was felled in November 2014 and monitored and sampled for moisture content between January and March 2015. Along with other blocks monitored that year, the conclusion of its study was that drying was not efficacious during winter months, since MC did not change during the course of the study, (Friesen, 2015).

The wood from Block 2-700 was extremely wet and did not reach a low enough moisture content to be watered and transported during the window of operation in 2015. So the wood was left to dry over the summer and re-uptake MC in the fall, come what may. It was sampled again in early Februay 2016, nearly a year since it had last been sampled.

Tops vs butts

In addition to comparison with other blocks, samples were taken from both tops and butts of logs. Analysis confirmed the findings of Blackburn's study: tops had significantly higher MC than butts, (alpha = 0.05). In this case, tops had 4.3% higher MC than butts.

The influence of wetter ecotypes and elevation

This study also sought to explore the question of wether or not differences in ecotype or soil drainage affects Hw moisture content. The block extends across several hundred metres of elevation with the base of the block in more of a drainage-receiving position than the top. Samples were taken from the top, middle, and bottom of the elevation range for the block, but analysis showed no significant difference in the MC between any of the locations (alpha = 0.05). Given the limitation of only one sample site, this result cannot be taken as conclusive proof at this time.

Overall drying trend

Moving to comparisons with the other blocks of this study, the micro-climate of the West Cracroft site may not be identical to Lower Adams, but they are fairly close geographically, only about 20 km as the crow flies. Therefore their climates can be considered roughly analogous.

The last samples taken from Lower Adams in mid-December were about 50-52% MC. The sample taken from West Cracroft 1.5 months later came in at ~42% MC. This is about 10% lower than the three Lower Adams blocks. Given the wet winter weather in the intervening period, the West Cracroft samples might be expected to have been below 42% MC in mid-December.

This 10% (or more) difference should be a good analog for the ROW wood from Lower Adams. The results are shown in Figure 9.

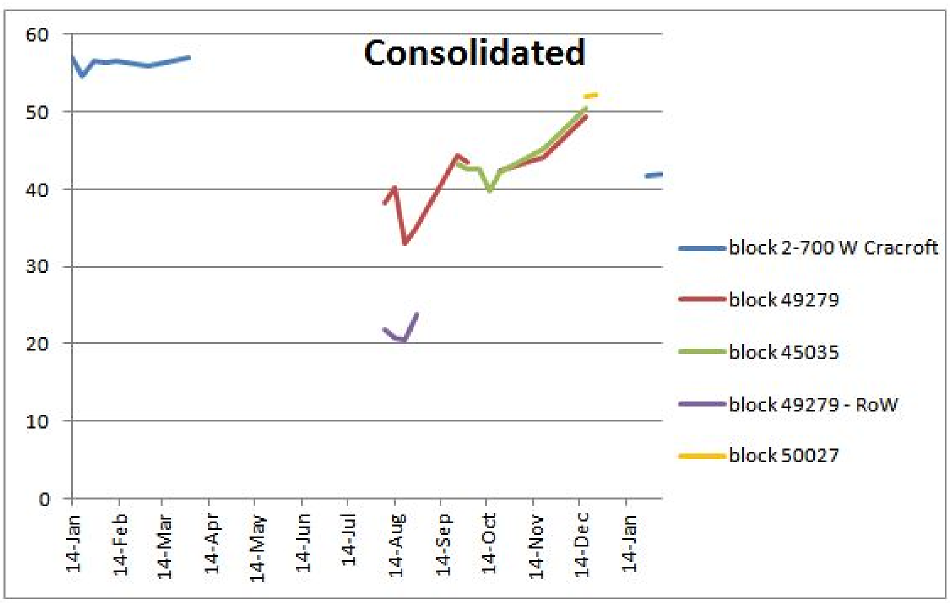

Figure 9. Consolidated graph of Lower Adams and West Cracroft, with projections.

In this graph it appears that the wood felled before spring (West Cracroft and the ROW wood) follows a different trajectory than the wood felled after May. There are two basic trends present.

The first is of the mid-2015 blocks (49279, 45035, and 50027). Although varying in harvest date by up to five months, they all followed the same basic trend in in MC. Their trend is the black dashed line in

Figure 10. The other trend is of the wood felled in winter 2014-15. This is shown as the red dashed line in Figure 10.

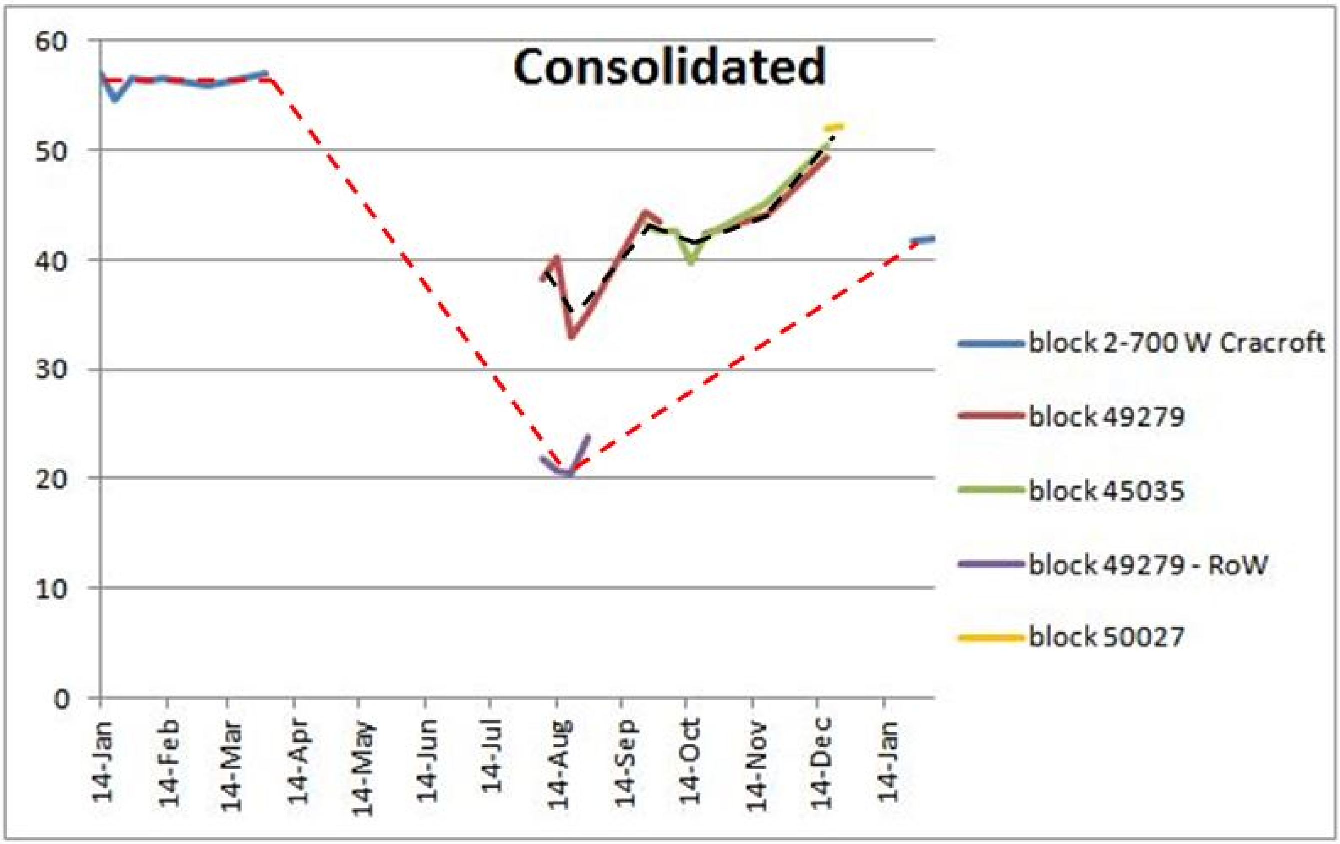

Figure 10. Consolidated graph with trend lines.

The black trend line follows actual data throughout. The red trendline has large gaps in data. It begins with the West Cracroft data, then follows the ROW wood from Block 49279 felled in Janary (and measured in August), and then it picks up again with the West Cracroft data.

Where the trend lines occupy the same timeline, their basic shapes move roughly in parallel. It is interesting that wood felled two seasons earlier (6-8 months) consistently has about 10-15% less moisture content than that felled mid-year. It seems that felling before, or possibly at, springtime produces long lasting differences in moisture content. Can the literature help us make sense of this?

As noted above, Clark and Gibbs (1957) found that there was a dip in sapwood MC for hemlock in May, followed by re-uptake of moisture during the summer and another dip in August-September. The first measurements in Lower Adams are in August and may be at or approaching the second dip. Certainly, the MC declines in August before rising again in Fall.

Both they and Beedlow observe that during the summer, wood MC rises despite decreasing moisture content in the soil. This would be unexpected in a non-living system. Perhaps then, the physiological processes of the tree can continue to increase wood MC inspite of decreasing soil MC (soil drought) in order to supply the tree's increased water demand during the productive summer months.

But if the tree were felled, the processes that allow this re-uptake of moisture even in the face of soil drought, might not function. The severing of the connection to the roots would then be instrumental in allowing the wood to dry out in reflection of the ambient conditions. Then when the ambient conditions become more moist in fall and winter, moisture content increases in accord with the local micro-climate.

This increase in MC in fall and winter occurs for both freshly-felled wood and older wood, but the freshly-filled wood may have experienced a boost in MC in spring and early summer because of the physiological processes of the tree. The previously-felled wood would not have this physiological boost, since it is already severed from the roots. It is possible that the MC of wood in a living tree may largely follow the ambient conditions except for the physiological boost in spring and summer when more moisture is required for the short but intense growing season.

Recommendations for hemlock drying

It appears then, that in order to experience the best drying of hemlock, it would be most effective for timber managers to fell Hw before growth begins in spring, so that the tree does not charge itself with water to facilitate its growth. Further, if there is some drying during the summer months, it is probably best to take advantage of any reduction in moisture content and 'water' the Hw (place it in water for transport) before the wetter ambient conditions of fall raise the MC of the logs, especially if the logs would otherwise be close to the sinking threshold.

It might also be possible to fell the hemlock shortly after it starts to grow in May when its moisture demands produce the dip described by Clark and Gibbs (described above). That might produce the lowest possible green density for marginal floaters. Then a few months of drying could further lower MC without the counter-productive physiological MC re-uptake. However finding the exact timing would require careful monitoring of the MC in standing trees.

Although this may be a good strategy for drying of hemlock, it must be recognized that this suggested timing for felling invites infestation by ambrosia beetles. Therefore it is important to only target blocks for felling before spring and drying through the early growing season, if they are likely to be near the sinking threshold. Blocks that have lower moisture contents may not need drying in the same way.

Of further consideration here are the findings of Blackburn (2016b) concerning the density and moisture profiles of the logs. If at the time of watering, the logs are quite close to the green density critical for flotation, then extra care must be taken in considering the age of logs and what parts of the tree they are from, since some logs will be more likely to sink or have high moisture content than others.

Blackburn found that log butts were heavier than log middles – likely due to tighter rings and denser wood. He also found that log tops had higher moisture content than other parts of the log – likely due to larger lumens to store water, combined with large pits in Hw that facilitate water transfer between lumens.

This jives with anecdotal evidence that younger hemlock are more likely to sink than older hemlock. Younger hemlock has more sapwood and larger lumens. Because the wood is also less dense than older hemlock and has higher MC there is greater potential to reduce its green density, and increase its flotation, through drying. There is also anecdotal evidence that wetter sites are more likely to produce trees with flotation problems. This seems logical but is unconfirmed at this time.

It seems then that younger Hw and the tops of Hw trees are the most likely candidates for sinking. Additionally, freshly felled trees are more likely to take on water, just like Christmas trees or freshly cut flowers, but they seem to lose this ability as time passes – requiring possibly two or three months. This seemed to be one of the messages of FPInnovations' 2014 wicking study (Friesen, 2014).

The logical course of action for timber managers concerned about flotation problems in Hw is to test their moisture content before watering, and if problems are found, to frequently monitor MC until it reaches acceptable levels. Looking at Figure 10 (above), the best time for watering marginal wood would be June to October when MC is at its lowest, providing it has had 2-3 months to cure to prevent uptake of MC when placed in the water (to prevent it behaving like a freshly cut Christmas tree).

When sampling standing trees, or from the butts of felled trees, timber managers should be aware that the tops of logs will likely have 5-7% more MC than butts (Blackburn, 2016b). Drying through the summer can be effective at reducing moisture content, even in logs felled after spring. The data suggest that drying through the summer will likely produce a reduction in MC of at least 5-7%, possibly more.

Putting these together, a log butt sampled in late spring or early summer should have a top log that has the same MC by late summer as the butt had at time of sampling. For example, a felled log's butt sampled in mid-June shows 45% MC. Expect the top log to have a MC of 51% in mid-June. By the beginning of September, the butt should have a moisture content of about 39% and the top log should be about 45% - which is what the butt had in June.

The data also show that whatever the MC is at the end of summer, an increase of 15-20% should be expected during the fall to mid-December. Then, as the 2015 West Cracroft data show, MC should be stable through the winter. Then it can be expected to drop in spring. The spring decline may be the most significant and may be up to 20% or more, especially if extended into the hottest summer months.

Putting together the three years of studies conducted by FPInnovations highlights that there is a gap in the data from April to July. Discovering the specifics of Hw drying during this time could be the subject of further study. Tracking the differences during the last half of this period between wood felled before and after May could be especially illuminating.

There are other questions still to be answered. What is the effect of ecosystem / ecotype on Hw moisture content? What is the required length of waiting (curing) time after felling to prevent Hw from taking up moisture during flotation? How quickly does Hw take up moisture during flotation if it is not properly cured beforehand? What is the length of curing time required for Hw to become non-responsive to ambient moisture content – does this ever happen?

General guidelines for timber managers

So how to make sense of all these numbers? The following rules of thumb may be used with reasonable, but not absolute, confidence.

1. In order to decide if Hw logs can safely be watered, it is essential to know their moisture content (MC) at time of watering. Follow the sampling procedures below to determine the average MC of the population.

2. It is unwise to process the logs or cut off a butt-cookie just before watering. This is like making a fresh cut at the base of a Christmas tree so that it soaks up more water. This removes some of the hardened off wood that can help prevent water uptake when watered. Rather, processing should be done soon after felling, and then curing (drying) trees to reduce MC, if necessary, should be done to processed trees.
3. Curing (drying) processed trees should be for at least 2 months, to prevent water uptake when watered. (Future study may show that this time frame is shorter).
4. Hw may be watered anytime MC is below 51% (at time of watering) and it has been felled for at least two months.
5. Hw tops or young logs have 5-8% higher MC than butts, so if butt logs are measured, add 5-8% for the top logs.
6. If Hw is in the danger zone (above 51% MC) it must sit through May-June.

From the above rules, the following corollaries can be derived.

1. If the last MC determination is not recent, any stand or log sample that has at one time had a MC of ≤ 36% can be watered without fear of sinking, providing it has been felled for at least 2 months. Even if the sample was from the butt at 36% MC, the top will have been about 42% at time of sampling. In the worst case scenario where the sample was taken at end of summer and the logs are watered in December-January, there will be about a 15% increase in MC during the fall, but the tops should still come in at no more than 57% MC, which will just barely float. If the sample MC was not taken in summer, the logs should float if the sample showed MC of ≤ 45%.
2. Any stand or log sample that showed a MC of ≤ 51% may be watered in the summer, (providing it has been felled for at least 2 months). MC does not increase during the summer, unless there is protracted very wet weather. Although flotation is possible at 57% MC, 51% allows for normal variability in the population. If only the butts have been sampled, top logs or young logs should not be watered unless MC is ≤ 45% at the butt.
3. The best time to water logs is at the end of summer when MC is typically at its lowest, (providing the logs have been felled for at least 2 months).
4. The critical felling date is near bud burst, usually in early May – probably in the range of May 1 to May 15 (the Mother's Day Rule). This day might be earlier in a particular year if global warming really takes hold or if spring is very early and bud burst happens before May 1. Logs felled before this date should not have flotation issues if watered after August 31. Logs felled before May 1 may be watered before August 31 if MC is ≤ 51% (providing they have been felled for at least 2 months).
5. Logs felled after early May should be watered after August 31 and before October 1, (providing they have been felled for at least 2 months). It would be wise to test MC of these logs before watering to ensure it is < 51%.
6. Logs felled in winter (after November 1, but before May 1) should only be watered if their MC is ≤ 51%. If only the butts have been sampled, top logs or young logs should not be watered unless MC is ≤ 45% at the butt.
7. Logs felled in winter (after November 1, but before May 1) can be safely watered after they have dried through the summer. Or they may be watered anytime their MC is ≤ 51%.

8. For MC samples taken between Nov 1 to May 1 (winter), any sample showing ≥ 60% MC should be dried through the summer and watered before Oct 1.

Sampling moisture content in western hemlock

Knowing the MC of hemlock logs is one of the most effective tools for managing their flotation. Taking samples of Hw stands or logs does not have to be onerous. After performing this procedure only once, most forest workers will find it welcome and easy work. If a worker is sent out to sample a block in the morning, the sample can be collected, weighed and drying begun that day, so that MC can be known the next day when drying ends. Figure 11 shows the author collecting wedges on West Cracroft Island for MC processing.

1. For ensuring statistical significance, sample set size should be 30, however usually a reasonable average can be arrived at with only 10 samples.
2. Each block should have it's own sample set. If the block is stratified into younger and older stands, or wetter and drier, these should be treated separately, and each unit should have its own sample set.
3. Each sample should weigh about 80-100 grams, about 2/3 the weight of a cell-phone. The recommended sample is a small wedge, 10-20 cm (4-8 inches) across, with a width of 2 cm (1 inch) at the fat end. Sawdust shavings or cookies are also acceptable. It is preferred to have samples without bark.
4. Samples may be from standing trees or felled logs. Samples should not be cut off the very end of logs. Rather cut the sample at least 10 cm (4 inches) from the end of the log so that it is more representative of the log interior than an end cut.
5. Samples should be weighed immediately, or sealed in plastic bags with the air largely removed. If bagged, samples should be weighed at the earliest possible convenience. A small, cheap, electronic, kitchen scale can suffice for weighing.
6. Once the weights of all samples are recorded – these are the 'wet weights' or 'green weights' – samples should be dried in a 200°F oven for 24 hours. Weights of the dried samples should then be recorded – these are the 'dry weights'.
7. The moisture content of each sample can now be calculated with the formula: MCwet = ((wet weight – dry weight) / wet weight) x 100. The average of the MC's is the MC for the block or stratum.

Figure 11. Collecting sample wedges for MC processing.

Note the size of the wedge (this is a large one), the plastic bag it is being sealed in, and the location of the wedge cuts on the logs.

Conclusion

Based on the data from this study and a literature review, this study concludes that there are likely two distinct trajectories for western hemlock wood moisture content, depending on if the wood was felled before or after May.

Hemlock felled before May gain the full benefit of spring drying according to the ambient conditions of their local micro-climate. Wood felled after May suffers from a physiological spike in tree MC that the tree generates to promote its growth and survive the summer soil drought. Hemlock felled after May may be up to 15-20% higher in MC than Hw felled before May when both are measured in August or later. Analysis showed that there was no advantage in reduced MC for falling in July versus September or November.

Study data showed that felled Hw may gain up to 10-15% MC during the fall months and MC will likely remain constant during the winter months. Interpolating from the data shows that spring and summer drying may be 20% or more, provided the trees were felled before May. FPInnovations does not have data on Hw drying during April to July.

The study also showed that there was no difference in MC between shavings or cookies as a sampling method. It showed there is no difference in MC between bark and white wood, shortly after felling. The study confirmed that log tops have higher MC than log butts. The study was inconclusive in determining if ecotype affected wood MC.

The "General guidelines for timber managers" section can serve as a rough prediction tool for knowing if western hemlock will sink or float when watered and what are the best management strategies to control Hw moisture content. In general, Hw felled before May can be watered after August and throughout the following fall and winter. For safety, hemlock felled after May should be watered after August but before October. Any hemlock may be watered if its MC is ≤ 51% at the time of the watering, providing it was felled at least two months earlier. It is always best to check the MC at time of watering to ensure Hw will float. Samples taken from log butts will likely show 5-8% lower MC than their top logs. Frequent MC monitoring provides empowering information for timber managers, and may be especially useful when dealing with younger logs or wetter ecotypes.

A streamlined moisture content sampling method was presented. In brief, separate sample sets should be taken from each distinct stratum, and may be as few as 10 samples per set (more are desirable). Each sample can be a small wedge taken at least 10 cm from the cut log end, and should be weighed or stored in a sealed plastic bag immediately. After wet weights are taken, drying should occur, and then wet and dry weights can be used to determine moisture content. Detail on sample specifications and MC calculation is in the report.

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