Cold Climate Housing Research Center

CCHRC

Wood Storage Best Practices in Fairbanks, Alaska

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A project report prepared by CCHRC for:
Sierra Research

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Executive Summary

It is a common notion that firewood takes multiple years to fully cure in Fairbanks, Alaska, however, there is a lack of documented evidence to refute or confirm this belief. To determine the storage methods and time necessary to fully cure firewood in Fairbanks, CCHRC studied the moisture content of firewood stored using a variety of methods for spring and fall tree harvests. The spring harvest was conducted in April and May 2010; the fall harvest was conducted in September 2010. All firewood was monitored for moisture content from the harvest until May 2011, unless a full cure (20% moisture content) was reached before that time.

This study shows that if firewood from a spring harvest is split, several firewood storage methods allow for rapid curing over the summer months, achieving moisture contents equal to or less than 20% in 6 weeks to 3 months. When firewood was kept as whole logs, it was unable to fully cure over the summer under any storage scenario. Whole logs contained between 21% and 43% moisture content by late summer 2010; however, some storage scenarios with whole spruce logs cured fully by May 2011. The type of wood and storage method were important variables, but less so than whether the firewood was split or unsplit. Aspen tended to dry more slowly than birch or spruce, and uncovered firewood was at risk of gaining moisture from rain.

In contrast, firewood harvested in fall did not cure fully by any means of storage or preparation throughout the study period. However, it is notable that split firewood stored in a simulated wood shed dried significantly throughout the winter.

The method of firewood storage was more significant during the winter than the summer. While all storage methods allowed for rapid drying of the spring-harvested firewood over summer, the tarp-covered and uncovered firewood dried slower than firewood stored in a simulated wood shed over the winter. Some tarp-covered and uncovered firewood accumulated a significant amount moisture over the winter. Firewood in a simulated wood shed from the spring harvest only showed a small increase of moisture content over the winter, while firewood from the fall harvest cured significantly.

The results of this study clearly demonstrate that it is possible to dry firewood cut in the spring in Fairbanks over a single summer to moisture content levels that optimize wood burning efficiency and minimize emissions. This finding deserves some caution in generalizing to all locations in the Fairbanks vicinity, as the wood was stored in an open field with minimal obstruction of solar radiation and air movement.

Introduction

The use of firewood for space heating is a significant contributing factor to winter-season PM2.5 in the Fairbanks airshed. Furthermore, it is suspected that burning inadequately cured firewood is a contributing factor that could be partially mitigated by changes in firewood storage and curing methods. Burning dry wood provides immediate benefit for homeowners by optimizing heat output while reducing the release of particulate air pollutants. However, ensuring an adequate supply of dry firewood requires preparation and planning, including knowledge of appropriate storage methods and duration of storage to achieve a full cure.

This project is designed to study the time necessary to achieve an adequate cure of firewood (i.e. 20% moisture content) for common storage scenarios in Fairbanks, Alaska. The data generated from this study are intended for use in an educational campaign to teach homeowners best practices for firewood storage.

Project Structure

This report documents work conducted by CCHRC from Spring 2010 through early Summer 2011. The primary phases completed for this project are summarized below:

Spring Harvest

This project phase simulates the practice of homeowners planning ahead for the winter by allowing the firewood to dry over the summer months.

a. Work plan preparation;
b. Spring harvest of trees;
c. Cutting trees to length and segregation of piles;
d. Initial moisture content sampling and analysis;
e. Splitting and stacking of firewood in various storage scenarios;
f. Interim reporting (June 30, 2010);
g. Periodic sampling of storage scenarios for moisture content.

Fall Harvest / Continuation of Spring Harvest Monitoring

The fall harvest simulates the practice of homeowners who have not planned ahead for the needs of the upcoming heating season, or are preparing for long-term storage for subsequent heating seasons.

a. Fall harvest of trees;
b. Fall firewood preparation and storage;
c. Cutting of trees to length and segregation of piles;
d. Initial moisture content sampling and analysis;

e. Splitting and stacking of firewood in various storage scenarios;

f. Periodic sampling of storage scenarios for moisture content over the winter and spring;

g. Interim reporting (April 18, 2011);

h. Final project reporting.

CCHRC expected the moisture content of birch and aspen trees to be at a relative maximum in the spring and early summer, and a relative minimum in fall. As discussed in the results below, this anticipated standing tree moisture content variation was not observed. White spruce trees were not expected to show a strong seasonal variation in moisture content, which was observed in the moisture content data.

Study Variables

The following variables in wood storage and preparation were included in this study to determine how homeowners can achieve a moisture content of 20% or less of from an initial green wood condition.

Wood species

- White spruce
- Birch
- Aspen

Storage condition

- Covered on top and stacked on pallets (a simulated wood shed)
- Covered completely and stacked on the ground (covered with a tarp)
- Uncovered and stacked on the ground
- Within a solar kiln and stacked on the ground

Preparation

- Whole logs
- Split at least once

Season

- Spring tree harvest
- Fall tree harvest
- Drying over summer
- Drying over winter

CCHRC chose multiple means of storing firewood to study the effect of different storage methods on drying rates. Because of the large number of variables identified above, only some combinations could be studied directly. A total of 16 storage scenarios were studied from the spring harvest, and 10 storage scenarios were studied from the fall harvest, as detailed below.

Each storage scenario from the spring and fall harvests are comprised of approximately 0.75 to 1.0 cords of firewood, respectively, where a cord is defined as 128 cubic feet of stacked wood. Each of the firewood storage scenarios have subsets for whole and split logs, stored together in roughly equal volumes. Photographs of the storage scenarios are provided in Appendix A.

While referred to as "aspen," the poplar trees included in this study are a mix of white and black poplar trees. In common language, these trees are referred to as "aspen" and "cottonwood", respectively. Both poplar trees are common in Fairbanks vicinity, are similar in their heat content, and are commonly less desired as a fuel wood.

Acquisition and Storage of Firewood

Spring Harvest

CCHRC obtained a firewood cutting permit from the Environmental Division of the Fort Wainwright Directorate of Public Works, U.S. Army Alaska on April 23, 2010. This permit allowed CCHRC to harvest trees from specified areas on base through April 23, 2011. From April 27 through May 7, CCHRC cut approximately 5 to 6 cords of white spruce, birch and aspen trees from Fort Wainwright, which were brought to CCHRC's Research and Testing Facility. The trees cut were in the base's northwest corner within the lowlands and hillsides close to Birch Hill. All trees harvested were live, standing trees.

CCHRC secured an additional firewood gathering permit from the U.S. Army Corps of Engineers, Chena Flood Control Project on May 20, 2010. Firewood freshly cut for maintenance of the Flood Control Project was made available to the public. The permit allowed for only a single truck load of firewood, which CCHRC acquired on May 20. Approximately 0.75 cords of white spruce was hauled to CCHRC's Research and Testing Facility.

From mid- to late-May 2010, CCHRC prepared, sampled, and established the storage scenarios for the spring firewood harvest. The 8 storage scenarios are summarized below in Table 1, and documented by photographs included in Appendix A.

Table 1 – *Spring Firewood Sample Scenarios**

Wood Storage Method	Birch	Spruce	Aspen
Simulated wood shed	X	X	X
Covered with a tarp	X	X	
On ground and uncovered	X	X	
In a solar kiln			X

**Each scenario consists of approximately 0.75 cords of firewood*

First, CCHRC cut the firewood into approximately 12 – 16 inch lengths and divided the accumulated firewood into 8 roughly equal piles. These piles were then sampled to characterize the initial wood moisture content. Approximately half of each pile was then split at least once with an electric log splitter. The split and remaining whole logs were then stacked to be comingled. Each pile was then covered in accordance with the storage scenario plan, comprising a total of 16 different storage scenarios within 8 piles.

Fall Harvest

Under the same permit acquired previously from the U.S. Army Alaska, in mid-September 2011 CCHRC harvested approximately 5 cords of white spruce, birch, and aspen from the hillside area of the former Birch Hill Tank Farm. All trees harvested were live, standing trees. From mid- to late-September, CCHRC prepared, sampled, and established storage scenarios for the fall firewood harvest. The 8 storage scenarios are summarized below in Table 2, and documented by photographs in Appendix A.

Table 2 – *Fall Firewood Sample Scenarios*			
Wood Storage Method	**Birch**	**Spruce**	**Aspen**
Simulated wood shed	X	X	X
Covered with a tarp	X	X	

**Each scenario consists of approximately one cord of firewood*

CCHRC cut the firewood into approximately 12 – 16 inch lengths and divided the accumulated firewood into 5 roughly equal piles. These piles were then sampled to characterize the initial wood moisture content. Approximately half of each pile was then split at least once with an electric log splitter. The split and remaining whole logs were then stacked to be comingled and covered in accordance with the storage scenarios, comprising a total of 10 different storage scenarios within 5 piles.

Deviations from Study Plan

The birch and spruce wood piles from the spring harvest intended to be fully covered were found in early May to be mostly uncovered due to the tarps being carried in the wind. The duration for which these 2 wood piles were uncovered is unknown, but potentially could have extended from mid-April through early-May 2011.

Sampling and Analysis

Sample Collection

Throughout the process of dividing the firewood into separate piles, whole logs were collected to characterize the initial wood moisture content. Each storage scenario was represented with a primary sample that filled a container approximately 4 cubic feet in volume, consisting of 4 to 8 whole logs, depending on log diameter.

Whereas the first sampling event for a harvest characterized the firewood's initial moisture content, all subsequent sampling events differentiated between split and whole logs stored under varying conditions. After the initial sampling event, each primary sample from a wood pile included 2 whole logs or 4 split logs. Final sampling events, such as August 2010 and May 2011 had larger primary samples (3 – 4 whole logs or 6 – 8 split logs). For each sampling event, logs were selected from throughout the pile.

When a monthly sampling event indicated that the moisture content of a specific storage scenario was at or under 20%, then the subsequent sampling event was conducted as a final sampling (i.e. more logs in the primary sample) to ensure accurate documentation of the final firewood condition.

During sampling of the firewood piles in winter, bulk snow and frost was brushed from the logs prior to subsampling and analysis; however, this sample preparation would not remove ice and hardened frost. This methodology was adopted to simulate the most probable user behavior in handling firewood.

Sample Preparation

The logs collected from the firewood piles constitute the primary samples, which require subsampling to allow for moisture content analysis. After collection, primary samples were stored as whole logs at CCHRC's Research and Testing Facility; subsamples were prepared from the primary samples within a few days of sample collection. Because firewood moisture content can vary within different zones of the wood, e.g. sapwood versus heartwood, cross-sectional discs approximately one inch thick were cut from the logs to ensure that each zone was represented proportionally in the analysis. Two cross-sectional discs were cut from each log in the primary sample: one from a log end and one from the log center. For large diameter logs, these discs were halved or quartered to facilitate subsequent drying and weighing. Subsamples were stored in a sealed plastic bag until ready for analysis. The determination of the wood disc mass before drying took place within 10 minutes to an hour after the discs were cut. Photographs of example firewood subsamples are provided in Appendix A.

Sample Analysis

CCHRC analyzed all firewood subsamples for moisture content following Method B of ASTM Standard Test Method D4442-07 (*Direct Moisture Content Measurement of Wood and Wood-Base Materials*). This method provides an absolute measure of firewood moisture content on a dry-weight basis. The drying oven used was a Quincy Lab convection oven model 40 GC. The mass balance used was an Acculab VICON with readability to 0.1 g. No attempt was made to differentiate the mass loss of water versus that of any other volatile constituents within the wood samples. All firewood moisture content data presented are on a dry-weight basis. The moisture content results of individual subsamples, per ASTM D4442-07 Method B, are estimated to have a precision of ±1%.

The duration of oven time for each subsample varied based on practical considerations, such as drying overnight during the weekdays versus over weekends. Therefore drying time was not standardized for the subsamples, but was evaluated based on the stability of multiple mass measurements over time. When each subsample had changed approximately 0.5 grams or less in mass from the prior mass determination, the drying was considered complete. This provides a conservative determination of the drying endpoint following Method B of ASTM D4442-07.

Data Analysis

Because the goal of the primary sampling is to represent the entire firewood pile, and the intent of the subsampling is to represent the primary sample with a fraction amenable to analysis, the chosen method for calculating the average moisture content is:

$$Average\ moisture\ content_x = \frac{(\sum_{i=1}^{n} Initial\ mass_i) - (\sum_{i=1}^{n} Oven\ dry\ mass_i)}{\sum_{i=1}^{n} Oven\ dry\ mass}\ (100\%)$$

where $x = specific\ wood\ and\ storage\ scenario$

$$n = number\ of\ subsamples$$

This method accounts for the contribution of each subsample towards the total sample mass, and also allows for splitting large wood discs without over representing the disc as several subsamples. If it were practical to weigh the entire cord of stacked wood over time, that approach would be ideal (i.e. a census of the entire population available for sampling). Instead, the chosen approach was to collect a fragment of the entire pile mass to represent the whole mass. In other words, the moisture content of the individual subsamples isn’t of interest, but rather the moisture content of the subsamples in aggregate as a representation of the entire wood pile.

Results for Firewood Moisture Content

The results from the moisture content monitoring for the spring firewood harvest are tabulated in Table 3 and illustrated in Figures 1a-d. The results for the fall firewood harvest are tabulated in Table 4 and illustrated in Figures 2a-b. The complete record of the moisture content data is contained in an electronic spreadsheet provided to Sierra Research.

The findings come with the caveat that the wood was stored in an open field with minimal obstruction of solar radiation and air movement. Wood piles stored in shade-covered areas will presumably require more time to cure, and large continuous firewood piles (e.g. multiple cords) may dry faster on the edges than within the pile.

Simulated Wood Shed

As shown in Figure 1a, the moisture content of spring harvest firewood stored in the simulated wood shed dropped rapidly over the summer months of 2010. Split firewood met the 20% moisture content criteria for a full cure within approximately 6 weeks to 3 months. Whole firewood logs dried less rapidly during the summer and did not dry over the winter. When grouped as “split” and “whole” logs, spruce dried most rapidly, followed by birch and aspen. The difference between the drying times for the different wood types was accentuated for whole logs.

The moisture content of the firewood from the fall harvest dropped steadily over the winter, but at a much slower rate than spring-harvested firewood over the summer (Figure 2a). As noted with the spring harvest, split wood dried substantially more than wood left as whole logs. However, none of the wood harvested in fall dried to 20% moisture content by the final sampling event in May 2011. The significance of wood types in the drying over the winter was much less distinct than for the spring harvest.

Fully (Tarp) Covered

The moisture content of the spring-harvest firewood covered by tarps lowered rapidly over the summer months (Figure 1b). Split firewood met the 20% moisture content criteria for a full cure within approximately 6 weeks to 3 months. The rate of drying was similar to the firewood stored in the simulated wood sheds, although it appears the wood covered by a tarp dried at a slightly lower rate. While the whole log moisture content remained approximately constant over the winter, the split spruce firewood gained some moisture by absorption or frost accretion. There is no data for the split birch covered with a tarp over winter, as that firewood reached a full cure by August 2010, therefore sampling was discontinued.

As shown in Figure 2b, the moisture content of fall-harvest firewood stored under tarps over the winter varied depending on wood type and preparation. Birch tended to decline in moisture content slowly, and without much difference in split and whole logs until the beginning of Summer 2011. Spruce firewood as whole logs dried over winter slightly, then regained some moisture content at the beginning of Summer 2011, whereas split spruce showed the opposite trend. None of the wood harvested in fall dried to 20% moisture content by the final sampling event in May 2011.

Uncovered

This storage method was studied only for the spring firewood harvest. The moisture content of the spring harvest firewood left uncovered fell rapidly over the summer months (Figure 1c). Split firewood met the 20% moisture content criteria for a full cure within approximately 6 weeks. The rate of drying was similar to the firewood stored in the simulated wood sheds. However, the uncovered firewood was highly susceptible to absorption of moisture from rain, snow, and frost. For example, the split birch had dried from an initial moisture content of 57% to 19% by early July, then had increased to 35% by late August, presumably due to rain immediately prior to the August sampling event. The moisture regained by the firewood over the late summer and winter had dissipated by the final sampling event in early summer 2011.

Solar Kiln

This storage method was studied only for the spring firewood harvest. The moisture content of the spring harvest firewood enclosed within a solar kiln dropped rapidly over the summer months (Figure 1d). The firewood stored in the solar kiln dried to lower moisture contents than the firewood stored in simulated wood sheds. However, due to heterogeneity of the moisture content amongst the various firewood piles, the initial condition of the aspen stored in the solar kiln was substantially lower than the aspen stored in the simulated wood shed. The rates of moisture loss in the aspen were very similar for the solar kiln and simulated wood shed storage methods.

Table 3 - Spring Wood Harvest, Summary of Moisture Content Data

Simulated Wood Shed						
Wood Type	**Late May**	**Early July**	**Late Aug**	**Jan**	**March**	**May**
Birch – split (PBS –S)	52%	20%	18%	Dry	Dry	Dry
Birch – whole (PBS – W)	52%	30%	25%	29%	28%	24%
Spruce – split (PSS – S)	86%	16%	17%	Dry	Dry	Dry
Spruce – whole (PSS – W)	86%	28%	21%	23%	24%	17%
Aspen – split (PAS – S)	76%	26%	20%	Dry	Dry	Dry
Aspen – whole (PAS – W)	76%	49%	44%	40%	--	26%

Tarp Covered						
Wood Type	**Late May**	**Early July**	**Late Aug**	**Jan**	**March**	**May**
Birch – split (TBS – S)	49%	21%	20%	Dry	Dry	Dry
Birch – whole (TBS – W)	49%	28%	31%	32%	--	25%
Spruce – split (TSS – S)	86%	22%	22%	35%	--	18%
Spruce – whole (TSS – W)	86%	67%	30%	29%	--	23%

Table 3 - Spring Wood Harvest, Summary of Moisture Content Data (continued)

Uncovered						
Wood Type	**Late May**	**Early July**	**Late Aug**	**Jan**	**March**	**May**
Birch – split (UBS – S)	57%	19%	35%	46%	38%	17%
Birch – whole (UBS – W)	57%	29%	32%	52%	39%	25%
Spruce – split (USS – S)	77%	17%	19%	Dry	Dry	Dry
Spruce – whole (USS – W)	77%	29%	27%	47%	29%	17%

Solar Kiln						
Wood Type	**Late May**	**Early July**	**Late Aug**	**Jan**	**March**	**May**
Aspen – split (KAS – S)	59%	24%	16%	Dry	Dry	Dry
Aspen – whole (KAS – W)	59%	38%	32%	34%	31%	27%

Table 4 - Fall Wood Harvest, Summary of Moisture Content Data

Simulated Wood Shed				
Wood Type	**Mid Sept**	**Jan**	**March**	**May**
Birch – split (PBF – S)	80%	49%	42%	30%
Birch – whole (PBF – W)	80%	55%	56%	47%
Spruce – split (PSF – S)	85%	63%	40%	37%
Spruce – whole (PSF – W)	85%	77%	72%	51%
Aspen – split (PAF – S)	83%	63%	51%	34%
Aspen – whole (PAF – W)	83%	65%	--	48%

Tarp Covered				
Wood Type	**Mid Sept**	**Jan**	**March**	**May**
Birch – split (TBF – S)	78%	63%	70%	49%
Birch – whole (TBF – W)	78%	67%	--	57%
Spruce – split (TSF – S)	92%	117%	--	84%
Spruce – whole (TSF – W)	92%	80%	--	89%

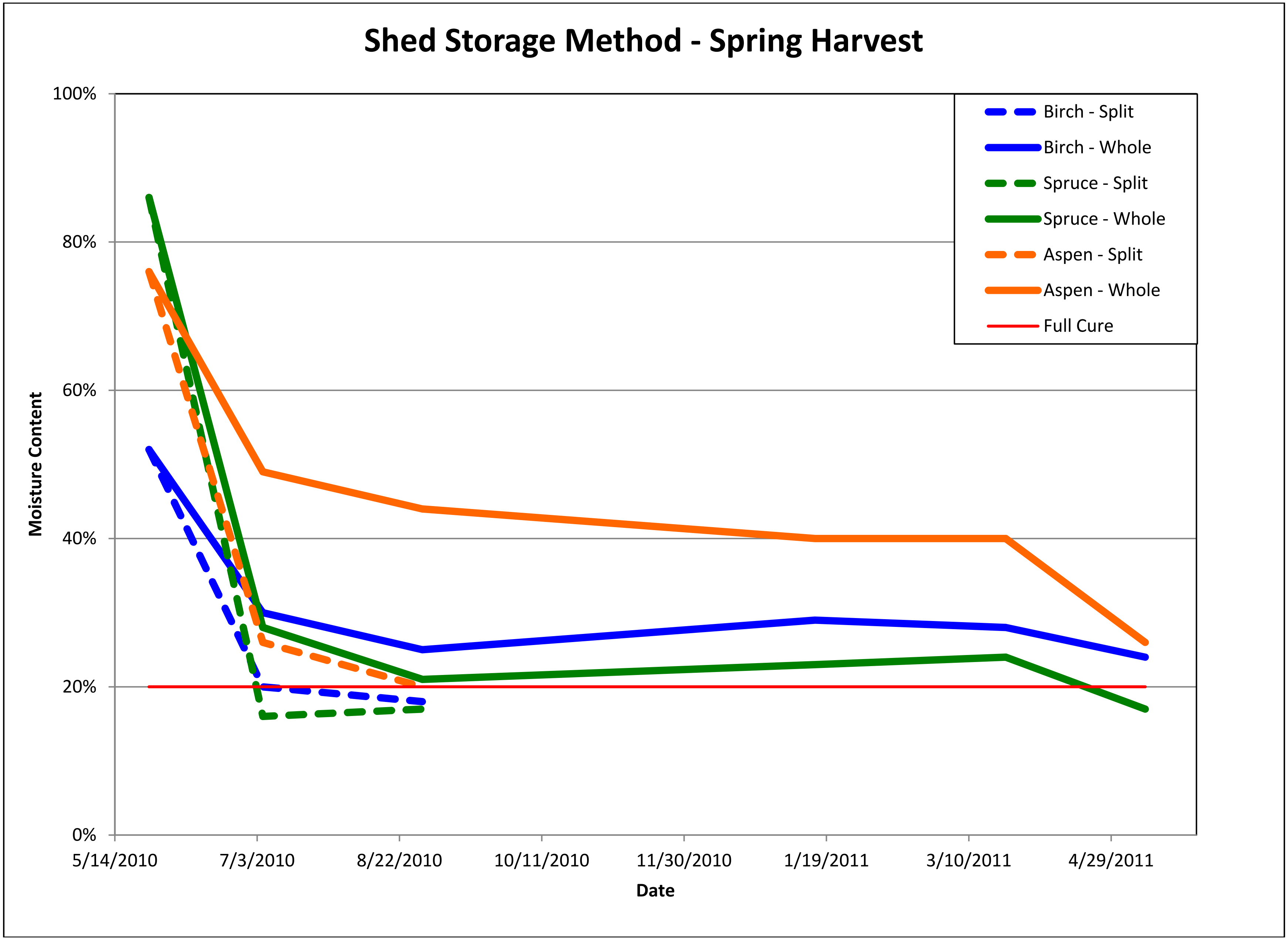

Figure 1a – Moisture content of spring harvest firewood over time for the different wood types and preparation methods.

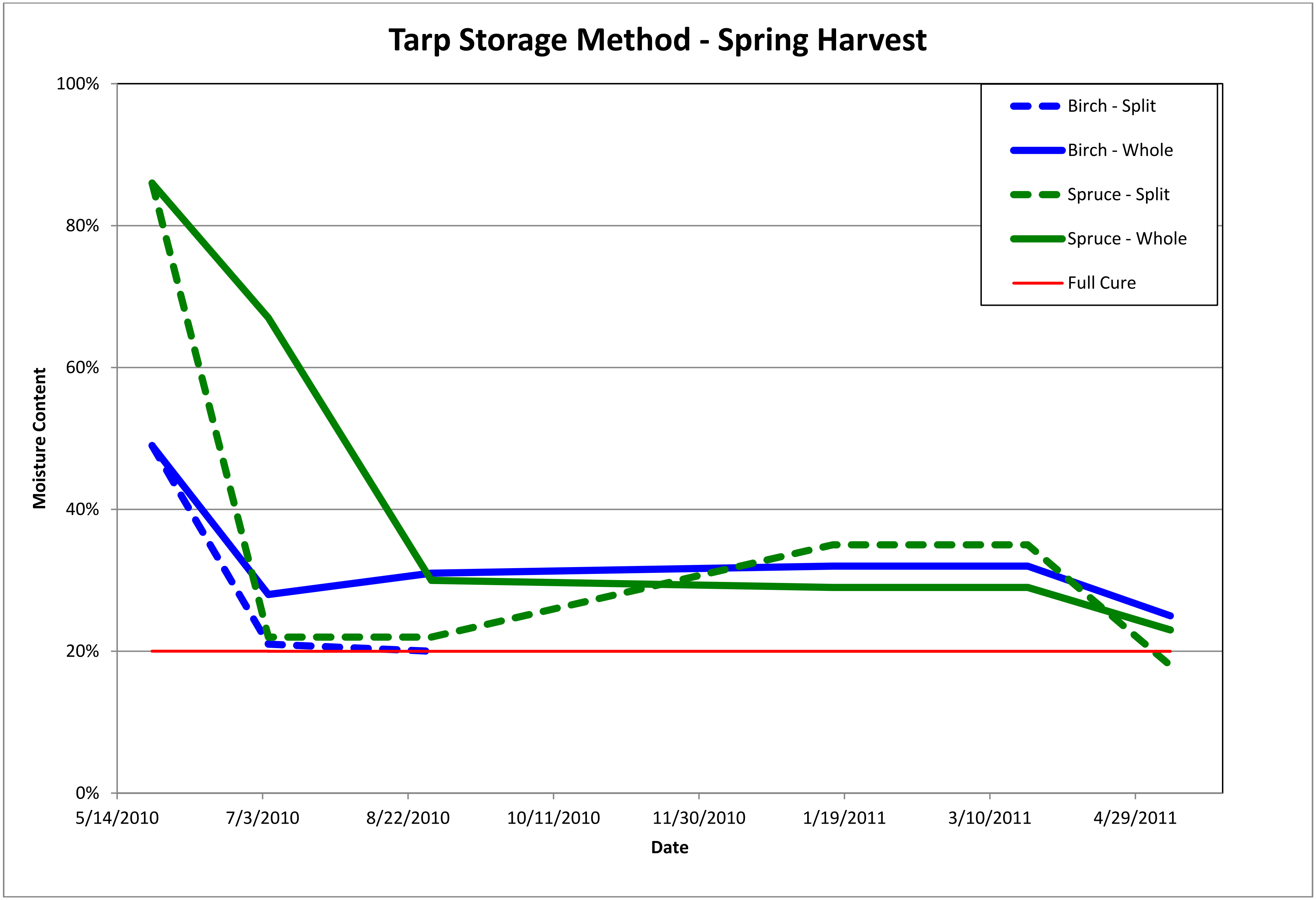

Figure 1b – Moisture content of spring harvest firewood over time for the different wood types and preparation methods.

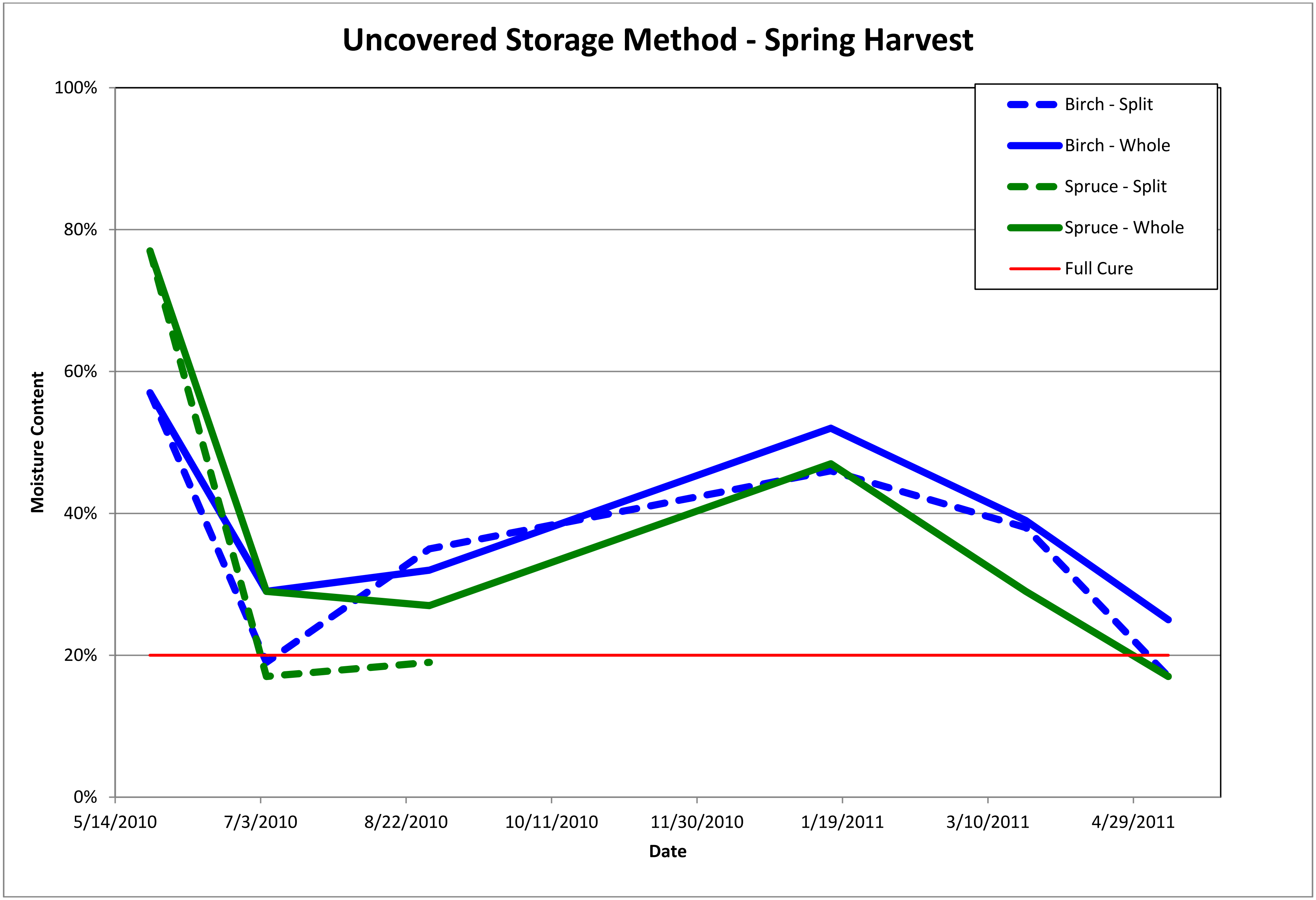

Figure 1c – Moisture content of spring harvest firewood over time for the different wood types and preparation methods.

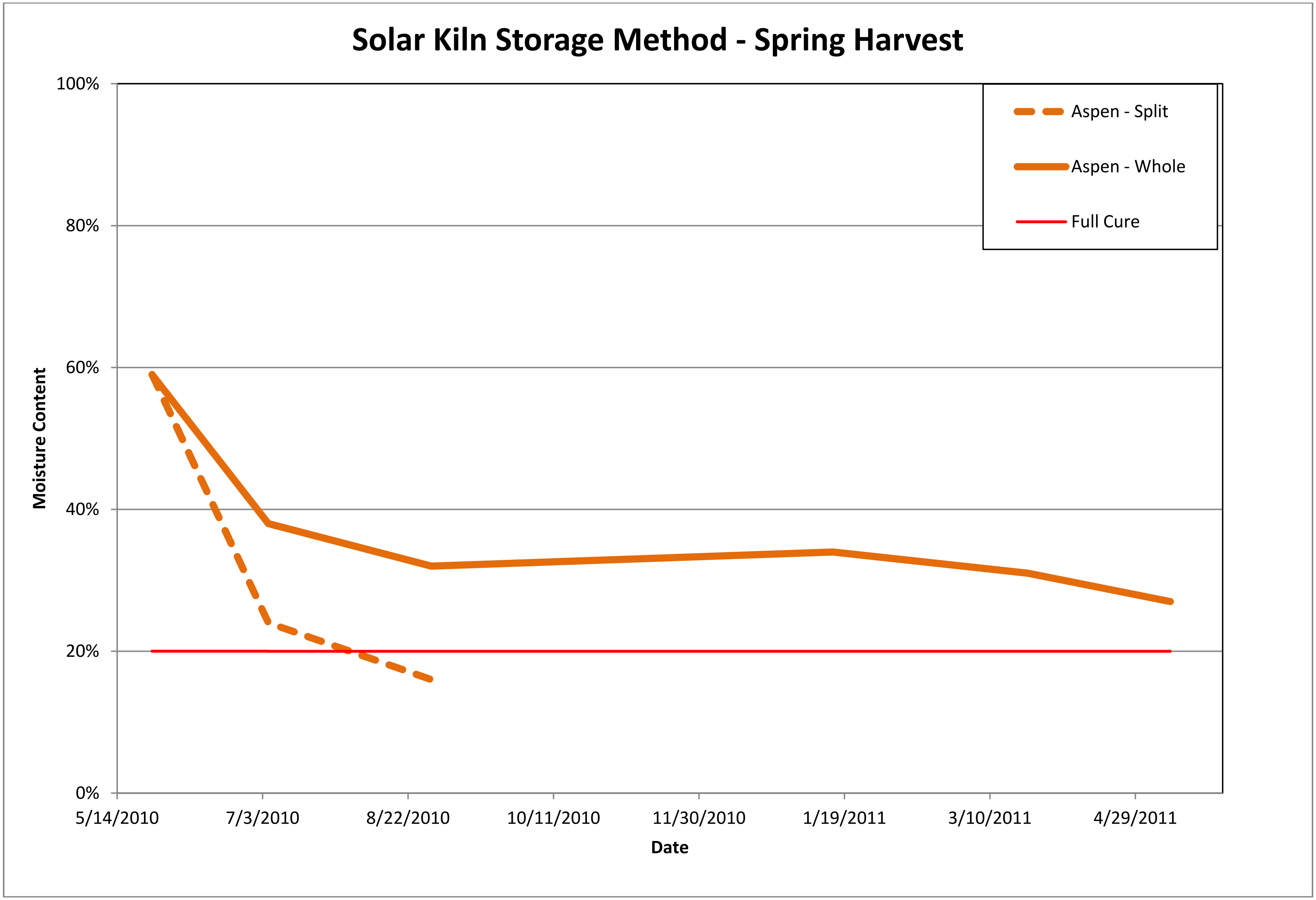

Figure 1d – Moisture content of spring harvest firewood over time for the different wood types and preparation methods.

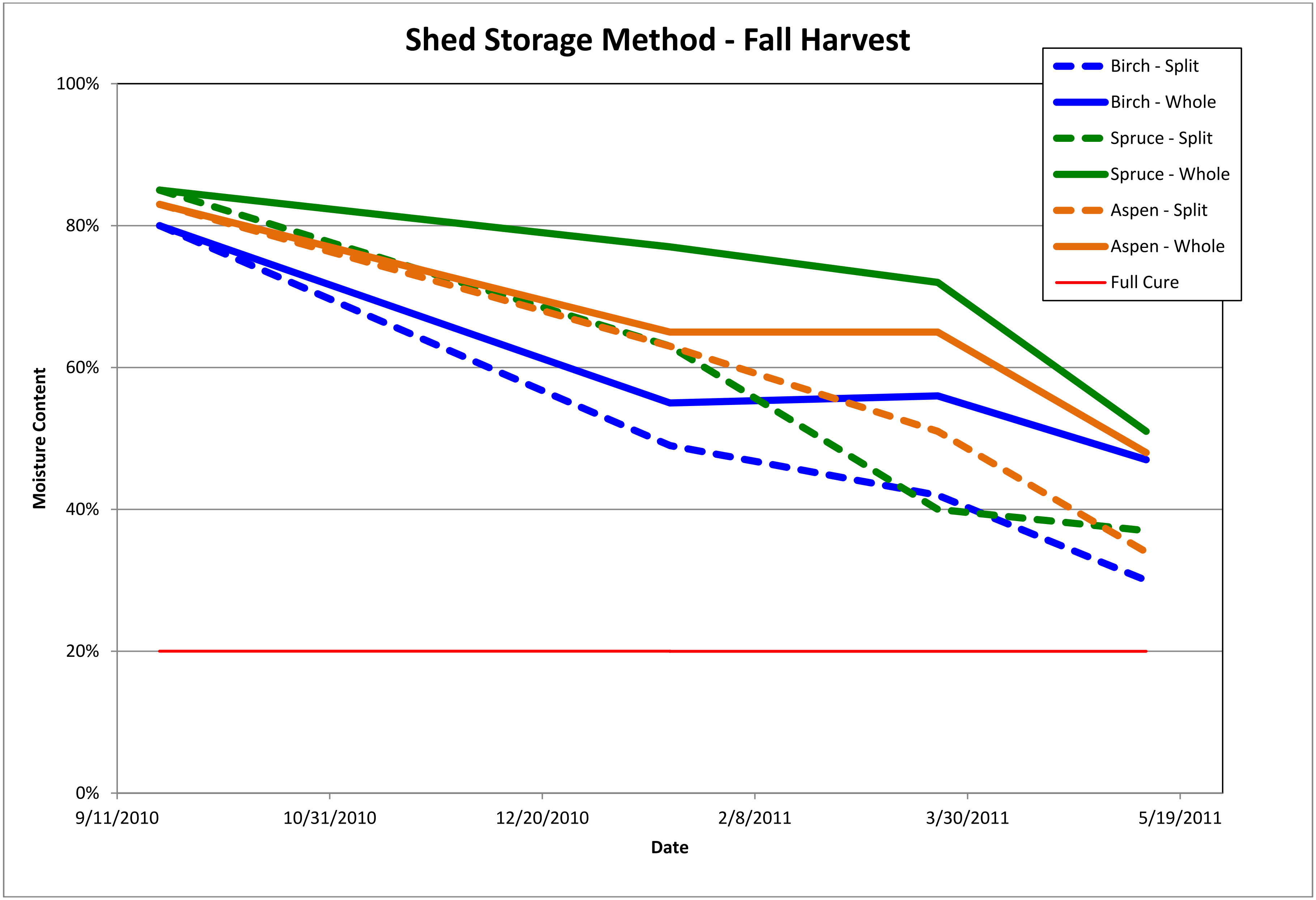

Figure 2a – Moisture content of fall firewood over time for the different wood types and preparation methods.

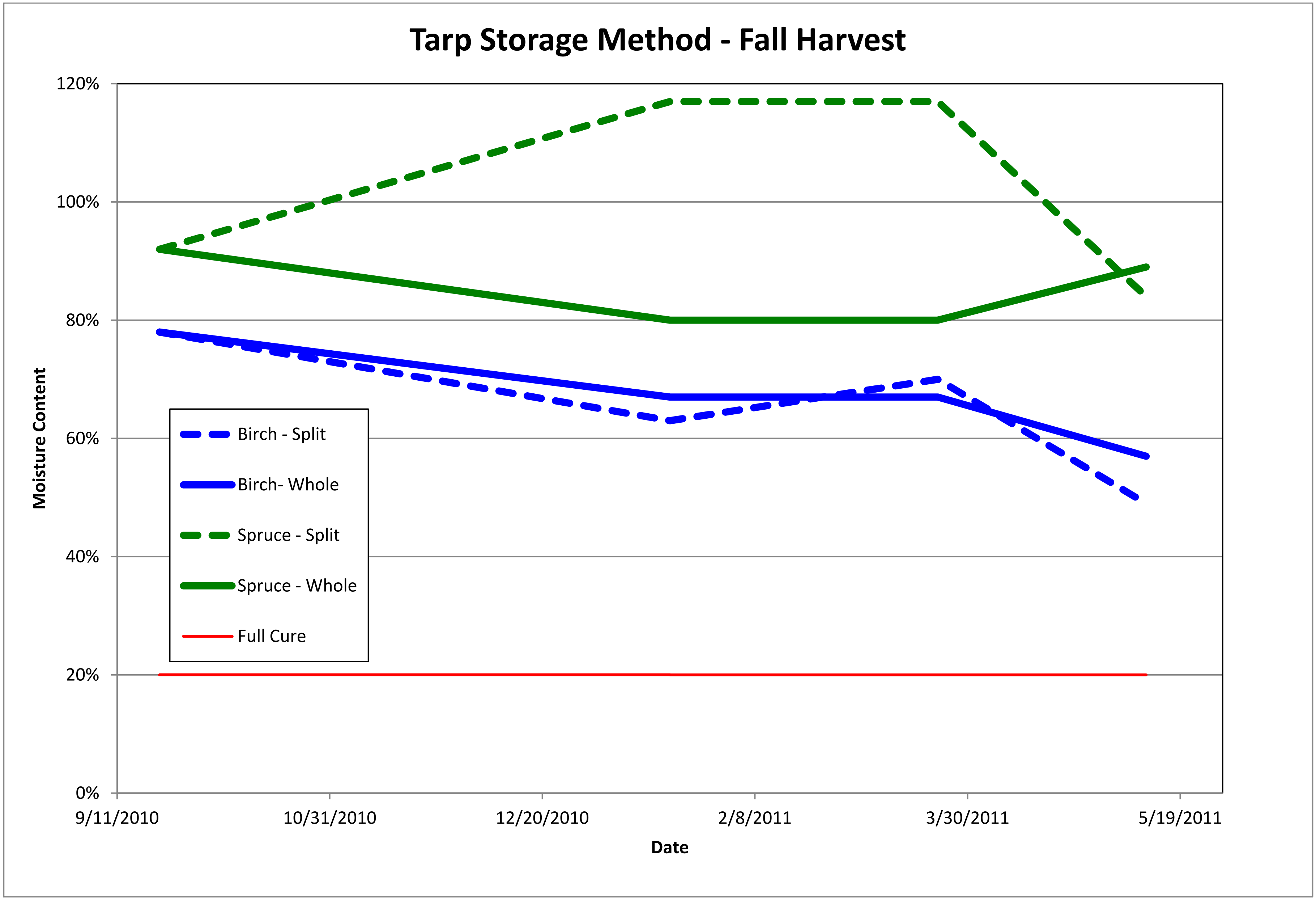

Figure 2b – Moisture content of fall firewood over time for the different wood types and preparation methods.

Appendix A – Photographs

The firewood storage scenarios initiated in May 2010 in the field west of the CCHRC Research and Testing facility.

The firewood storage scenarios initiated in May 2010.

Example of the simulated wood shed (top-covered and off-ground) storage scenario.

Example of the tarp-covered (fully-covered and on-ground) storage scenario.

Example of the uncovered and on-ground storage scenario.

Simple solar kiln storage scenario with wood placed on the ground.

The firewood storage scenarios initiated in May 2010 (left side of picture) and September 2010 (right side of picture).

The firewood storage scenarios initiated in September 2010 (foreground) and May 2010 (background).

Firewood subsamples stored at CCHRC's Research and Testing Facility

Close-up of firewood subsamples.