Clean Wood Collection and Reuse

Assessment of Source-Separated Wood Loads Delivered to Public and Private Facilities in King County

King County
Department of Natural Resources and Parks
Solid Waste Division

Waste Prevention | Resource Recovery | Waste Disposal

King County Waste Monitoring Program

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Acknowledgments

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- DTG Maltby
- DTG Recovery 1 (Tacoma)
- DTG Redmond
- DTG Renton
- King County's Bow Lake Recycling & Transfer Station
- Rainier Wood Recyclers
- Skanska
- Waste Management
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Executive Summary

Since 1990, King County Solid Waste Division has conducted its Waste Monitoring Program to help plan for future community needs, improve services, and track progress towards recycling goals. As part of this ongoing Program, the County contracted with Cascadia Consulting Group to conduct a wood material characterization study in 2020–2021 to collect data on wood types and attributes related to suitability for diversion and reuse. This study is intended to assess the types and qualities of wood potentially available for reuse. The fieldwork examined the visual composition of source-separated wood loads and piles at King County's clean wood collection at Bow Lake Recycling & Transfer Station, wood processors, construction sites, and processors of construction and demolition materials (C&D materials recovery facilities). The fieldwork also included hand-sorting clean dimensional lumber included in those wood streams and measuring sizes and characteristics of lumber pieces.

Cascadia conducted this study in two phases: 1) initial research to support methodology development; and 2) fieldwork and data analysis. The first phase, conducted in fall 2020, included **online research and interviews with industry professionals** to inform the detailed study methodology for sample collection and analysis of wood loads in King County. Through the initial research and interviews, Cascadia gathered information to guide the sampling protocol regarding specific wood characteristics that influence feasibility for reuse. The sampling protocol developed for this study focused on physical characteristics that can be evaluated in the field, such as wood measurements, sources and types of wood, and the presence of holes and other impurities, which affect feasibility for reuse. Interviewees agreed that the preferred types of wood for reuse are clean, dimensional lumber in large quantities (rather than pallets or composite materials), from sources such as construction sites that are likely to have larger quantities of segregated, unused lumber.

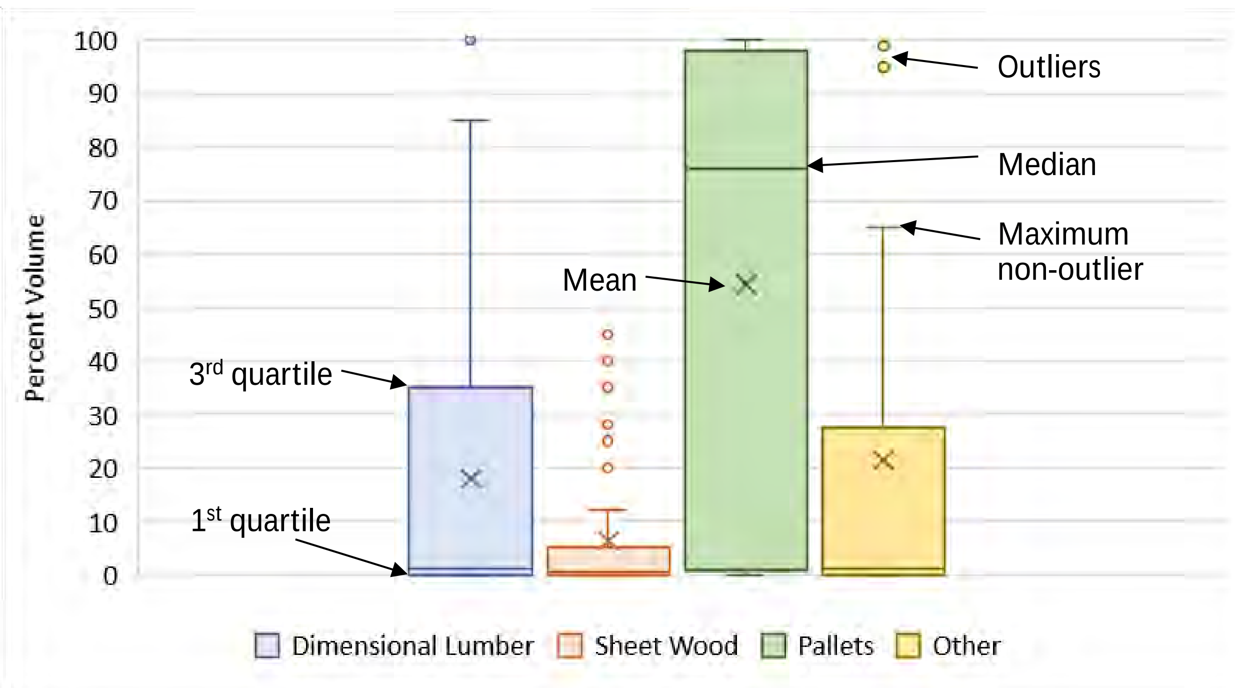
In the second phase, conducted in 2021, Cascadia applied **visual and hand sort characterization** methods to sample inbound clean wood loads at selected wood processing facilities in King, Pierce, and Snohomish counties. For each clean wood load sampled, the field crew visually characterized the entire load to identify the composition of the sample by type:

- **Dimensional Lumber**: Wood lumber cut to pre-defined, standard sizes and processed to be immediately ready for use in many applications. The sizes pertain to the depth and width of the wood in inches (e.g., 2x4, 2x6). Dimensional lumber that was obviously painted, stained, treated (e.g., creosote), or contained clearly visible hardware was included in the "Other" category. (In the subsequent hand sort inspection, some of the dimensional lumber was determined to have paint, stained, splits, holes, or pest damage or contain hardware such as nails, as indicated in Table 1.) Pressure-treated dimensional lumber was generally included in this category.

- **Sheet Wood**: Sheet materials or manufactured products made from wood. Examples include plywood, oriented strand board (OSB), medium-density fiberboard (MDF), and cross-laminated timber (CLT).
- **Pallets**: Constructed, flat wood structures used to store and transport materials.
- **Other**: All other material not previously defined. Includes painted, stained, or treated wood; wood with evident hardware/attachments; wood furniture; branches or stumps; and non-wood materials.

The study included **visual characterization of 58 samples** of wood loads or piles at multiple private C&D material processing facilities, a King County transfer station, a dedicated wood processing facility, and from construction sites. **Pallets** represented the largest volume of wood observed in the visual characterizations, with a mean or average of 52% of sample volumes, as indicated by the " î " symbol in Figure 1. **Dimensional Lumber** had a mean of 18%, and **Other** material averaged 21% of sample volumes. **Sheet Wood** was least prevalent, with a mean of 8%. The shaded box indicates the interquartile range, or the distance between first (25th percentile) and third (75th percentile) quartiles. For definitions and explanations of the statistical measures and boxplot construction, please see page 14.

Figure 1. Composition by Volume of Inbound Wood Load Samples (n=58) at All Facilities



The field work also included **hand sort characterization of 72 samples** of dimensional lumber from the clean wood piles. For the hand sorts, the crew randomly selected samples, each consisting of 20 pieces of **Dimensional Lumber**, for a total of 1,440 lumber pieces. The field crew recorded information about each individual piece by type, dimensions, and quality. Cascadia staff verified the quality and accuracy of collected data and used standardized statistical methods to analyze the composition and characteristics of the wood materials.

Table 1 summarizes the results for various wood characteristics of the **Dimensional Lumber** pieces sampled in the hand sort characterization. The following attributes were most common in the hand sorts: not stamped (73%); free of hardware/attachments (51%); had holes, splits, or pest damage (62%); and/or were not painted, stained, or treated (85%). The large majority—more than 90%—of dimensional lumber sampled was not pressure-treated (96%) or joined (97%); had at least one flat site free of attachments (99%); and/or had at least one clean section of 6 inches or more in length (94%).

Table 1. Wood Characteristics in Dimensional Lumber Pieces in Hand Sorts (n=1,440 pieces)
*(desirable features are indicated with shading; **bold** indicates >50%)*

Characteristics	No	Yes
Stamped	**73.4%**	26.6%
Hardware/Attachments	**51.3%**	48.7%
Holes/Splits/Pest damage	37.9%	**62.1%**
Painted/Stained/Treated	**84.9%**	15.1%
Pressure-treated	**95.6%**	4.4%
Joined	**97.2%**	2.8%
Flat side free of attachments	0.8%	**99.2%**
Section(s) 6 inches or longer	6.3%	**93.8%**

This report presents the research methodology in Chapter 2, findings of the field research in Chapter 3 (visual characterization) and Chapter 4 (hand sorts), and industry interviews in Chapter 5. Chapter 6 summarizes brief conclusions and recommendations. Further research and policy initiatives may be needed to expand opportunities for development of higher-value reused wood products from these materials in King County.

1. Introduction

King County contracted with Cascadia Consulting Group to collect data on the types and quality of clean wood available for potential wood markets such as remanufacturing into other wood products or a salvaged lumber warehouse.

This study was completed in two phases:

- The first phase, in fall 2020, included conducting online research and telephone interviews with wood industry professionals.
- The second phase, in 2021, included visual and hand sort characterizations of inbound source-separated wood loads at selected facilities in King, Pierce, and Snohomish counties, along with analysis and reporting.

This document summarizes study methods, key findings, and conclusions, with additional details in attached appendices. The report includes the following chapters:

- **Chapter 2. Wood Characterization Methods** describes the study methodologies used in visual characterization and hand-sorting of wood samples.
- **Chapter 3. Visual Characterization Results** presents the results of the visual waste characterization of incoming wood loads across all facilities sampled.
- **Chapter 4. Hand Sort Results** describes key findings from the hand sort characterization of dimensional lumber samples.
- **Chapter 5. Industry Interview Research** summarizes key findings from online research and interviews with industry professionals.
- **Chapter 6. Conclusions and Recommendations** briefly reiterates key findings and suggests potential follow-up efforts for research and policy development on opportunities for wood waste reduction, diversion, and reuse.

The **Appendices** include the methodologies for visual and hand sort characterizations of wood materials, along with the interview questions asked of research scientists and experts in salvaged lumber reuse and engineered wood.

2. Wood Characterization Methods

This chapter summarizes procedures for selecting and characterizing samples and presents the findings of field research, including both visual and hand sort characterizations of wood loads.

Definition of Study Universe

The study was designed to include characterization of inbound wood loads at the following facility types and jobsites.

- **King County transfer station** clean wood collections: Wood materials collected at King County's Bow Lake Recycling and Transfer Station.
- **Deconstruction and demolition jobsites**: Outbound wood materials from sites or companies identified by King County or through the County's online permit notification service. King County contacted multiple deconstruction and demolition companies, but none agreed to participate in the study, so these samples were reallocated to the other sectors at the County's direction.
- **Construction jobsites**: Outbound wood materials identified by King County or through the County's online permit notification service. Skanska agreed to participate in the study, and loads from Skanska were sampled on two occasions.
- **Single-stream wood processors**: Wood materials collected at Rainier Wood Recyclers.
- **Construction and demolition (C&D) material processing facilities**: Wood materials collected at C&D processors. DTG Enterprises participated in this study, including four different C&D facilities.

Once King County secured company participation, Cascadia coordinated directly with the companies, including site visits, to develop site-specific sampling and safety protocols for the fieldwork.

Number, Type, and Allocation of Samples

Table 2 summarizes the number of samples and types collected at each participating facility.

Table 2. Visual and Hand Sort Samples Collected by Facility and Type

Facility		Number of Samples	
Facility Name	**Facility Type**	**Visual**	**Hand Sort**
Bow Lake Recycling & Transfer Stn.	King County transfer station	24	23
DTG Maltby	C&D material processing facility	4	4
DTG Recovery 1 (Tacoma)	C&D material processing facility	12	10
DTG Redmond	C&D material processing facility	5	4
DTG Renton	C&D material processing facility	4	17
Rainier Wood Recyclers	Wood processing facility	7	9
Skanska (via Waste Management)	Construction jobsite (off-site)	2	5
	Total Samples	**58**	**72**

Summary of Fieldwork Protocols

Cascadia sampled wood from each of the sites and streams identified above. At each site, the field crew conducted a combination of visual assessments with sub-sampling of wood materials through hand-sorting, inspection, and measurement of **Dimensional Lumber** pieces. The size and number of wood piles or loads sampled varied by facility. A customized sampling protocol was created for each facility or jobsite to address this variability. The field crew that conducted the sampling consisted of one field lead and one field assistant, with the assistance of facility staff. The field team worked with each facility to ensure that sampling was conducted in a safe manner that did not disturb facility operations.

The sampling protocol included two types of wood characterization: visual characterization and hand sort characterization, as described below.

Visual characterizations of wood piles categorized the material into a pre-determined list of material types to estimate the material composition of clean wood collected onsite at each facility (Figure 2). The visual characterization estimated the composition of the wood piles according to four categories: **Dimensional Lumber**, **Pallets**, **Sheet Wood**, and **Other**. The definitions of the categories are as follows:

- **Dimensional Lumber**: Wood lumber cut to pre-defined, standard sizes and processed to be immediately ready for use in many applications. The sizes pertain to the depth and width of the wood in inches (e.g., 2x4, 2x6). Dimensional lumber that was obviously painted, stained, (e.g., creosote), or contained clearly visible hardware was included in the "Other" category. (In the subsequent hand sort inspection, some of the dimensional lumber was determined to have paint, stained, splits, holes, or pest damage or contain hardware such as nails.) Pressure-treated dimensional lumber was generally included in this category (the text box on page 40 in Appendix A provides more information).
- **Sheet Wood**: Sheet materials or manufactured products made from wood. Examples include plywood, oriented strand board (OSB), medium-density fiberboard (MDF), and cross-laminated timber (CLT).
- **Pallets**: Constructed, flat wood structures used to store and transport materials. A typical pallet size is 48 by 40 by 6 inches.
- **Other**: All other material not previously defined. Includes obviously painted, stained, or treated wood; wood with clearly visible hardware/attachments; wood furniture; branches or stumps; and non-wood materials.

See *Appendix A. Fieldwork Methodologies, Sampling Protocols, and Forms* for a more detailed description of the visual characterization methodology.

Figure 2. Visual Characterization in Progress

Hand sort characterizations collected data on **Dimensional Lumber** only. Once the inbound vehicle tipped the wood load on the ground and exited the facility, the Cascadia field crew used the following steps to assess the **Dimensional Lumber** in the load. Figure 3 shows a hand sort in progress.

- The field crew extracted 20 pieces of **Dimensional Lumber** per wood load for detailed examination and measurement.
- The field crew documented the overall length of each lumber piece as well as the number and length of sections measuring 6 inches or longer without hardware/attachments, paint, stain, pest damage, holes, splits, or adhesive.
- The field crew also noted whether the **Dimensional Lumber** pieces had at least one flat side free of attachments, to accommodate high-speed processing on a belt.
- Once the sample was fully assessed and the data recorded and checked to ensure accuracy, the wood sample was discarded back into the main wood pile or handled according to the instructions of the facility operator.

See *Appendix A. Fieldwork Methodologies, Sampling Protocols, and Forms* for a more detailed description of the hand sort methodology.

Figure 3. Hand Sort Characterization in Progress

3. Visual Characterization Results

Cascadia staff verified the quality and accuracy of collected data and used standardized statistical methods to analyze the composition and characteristics of the wood waste. This chapter describes the results obtained from the visual characterization, and Chapter 4 presents the results of the hand sort characterization.

Figure 4 through Figure 7 show examples of wood load samples examined during visual characterization. The visual composition of wood loads varied, from being relatively homogenous to mixed with either other wood types or other, non-wood material.

Typically, samples with higher proportions of **Pallets** were larger in volume, in light of the dimensions of constructed pallets (48 x 40 x 6 inches is a typical size). Wood material in most pallets was intact (unbroken or unfragmented) when the load was tipped on the ground; see example in Figure 5. In other loads that appeared to be from demolition activities, wood was typically broken, fractured, or fragmented; see example in Figure 7.

Figure 4. Example of Wood Load Sampled in Visual Characterization: Load from Construction Jobsite

Figure 5. Example of Wood Load Sampled in Visual Characterization: Load with Mostly Pallets

Figure 6. Example of Wood Load Sampled in Visual Characterization: Load with Mostly Dimensional Lumber

Figure 7. Example of Wood Load Sampled in Visual Characterization: Load with Predominantly Fragmented or Fractured Wood

Samples by Size (Volume)

Figure 8 shows the distribution of the 58 visual samples of inbound wood loads by their corresponding volume ranges. Sample volumes ranged from less than 20 cubic yards to nearly 160 cubic yards. The largest number of visual samples (25) had sample volumes of 20 cubic yards or smaller. Only 5 samples had volumes of 100 cubic yards or greater.

Figure 8. Distribution of Visual Samples (n=58) by Sample Volumes

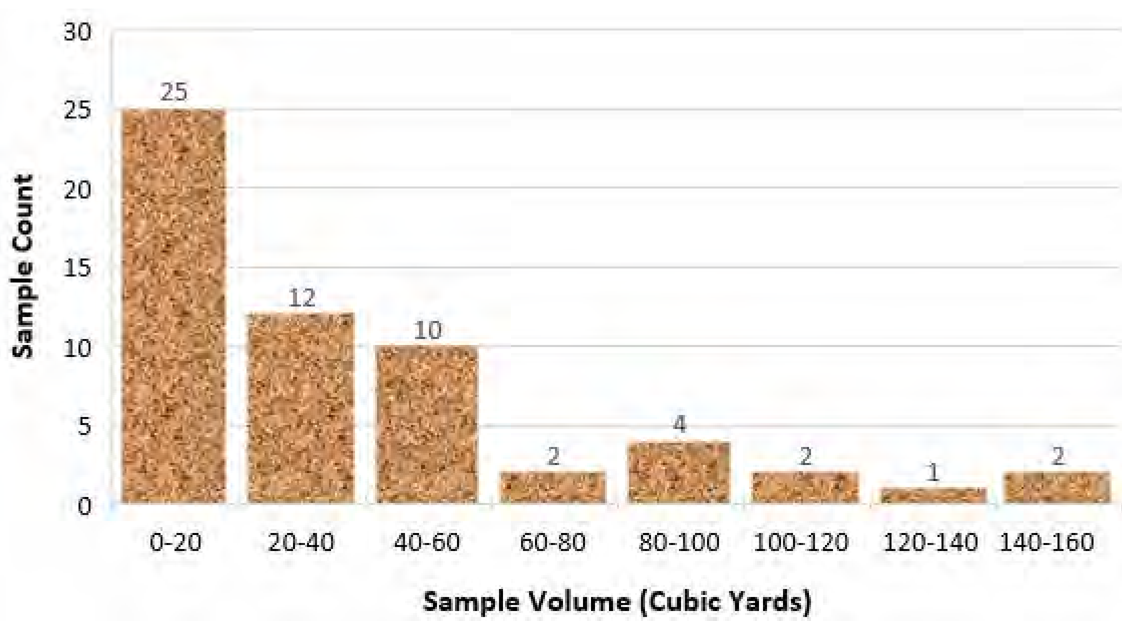
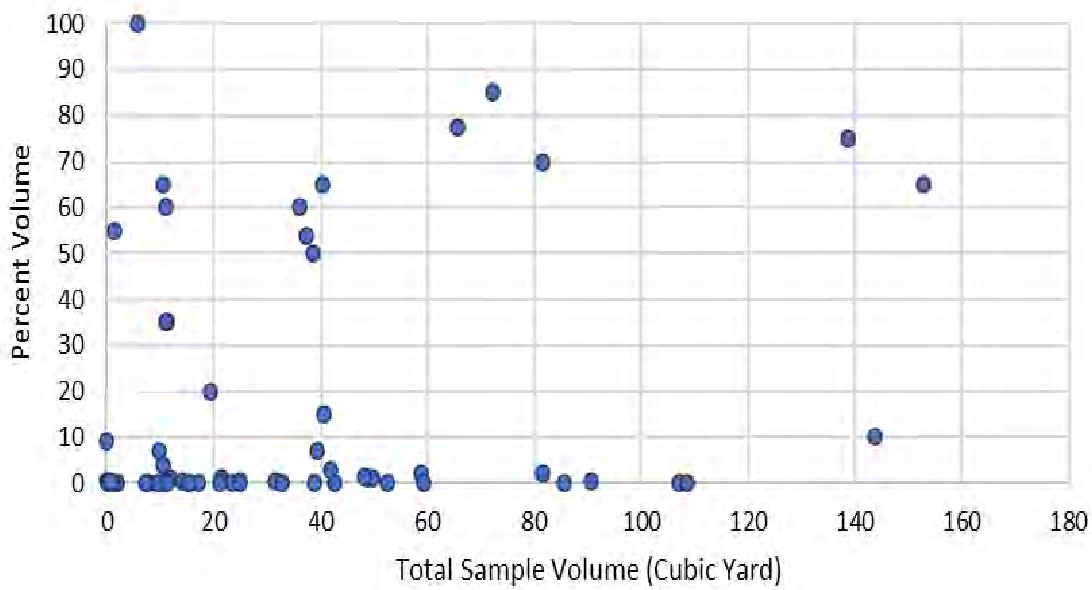


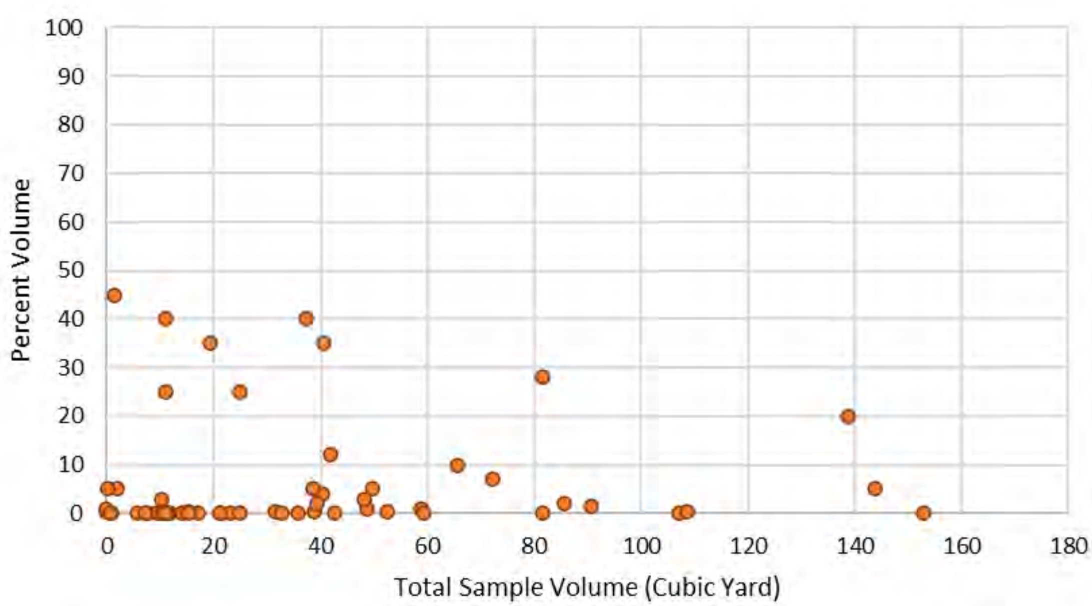
Figure 9 through Figure 12 depict the share (%) of the volume of individual material types relative to total volume for each sample. The shares ranged from 0 to 100% for all material types, except **Sheet Wood**. For **Dimensional Lumber**, the share was typically 20% or less, with zero being common (Figure 9). Only one small sample was 100% **Dimensional Lumber**.

Figure 9. Share (%) of Dimensional Lumber in Total Sample Volume (in cubic yards)



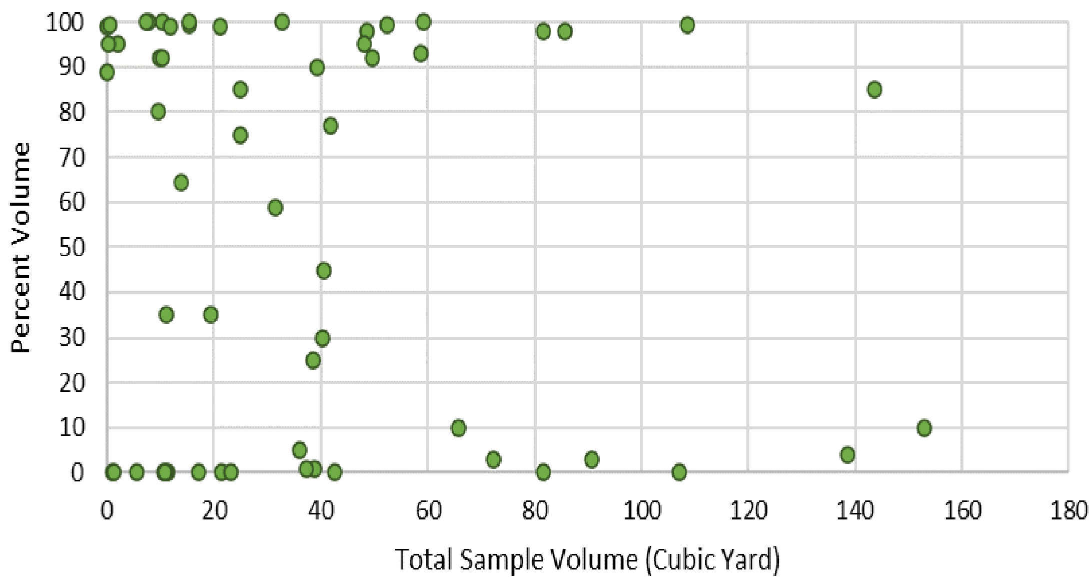
Sheet Wood represented the smallest portion of sample volumes, with 10% or less in the majority of the samples (Figure 10).

Figure 10. Share (%) of Sheet Wood in Total Sample Volume (in cubic yards)



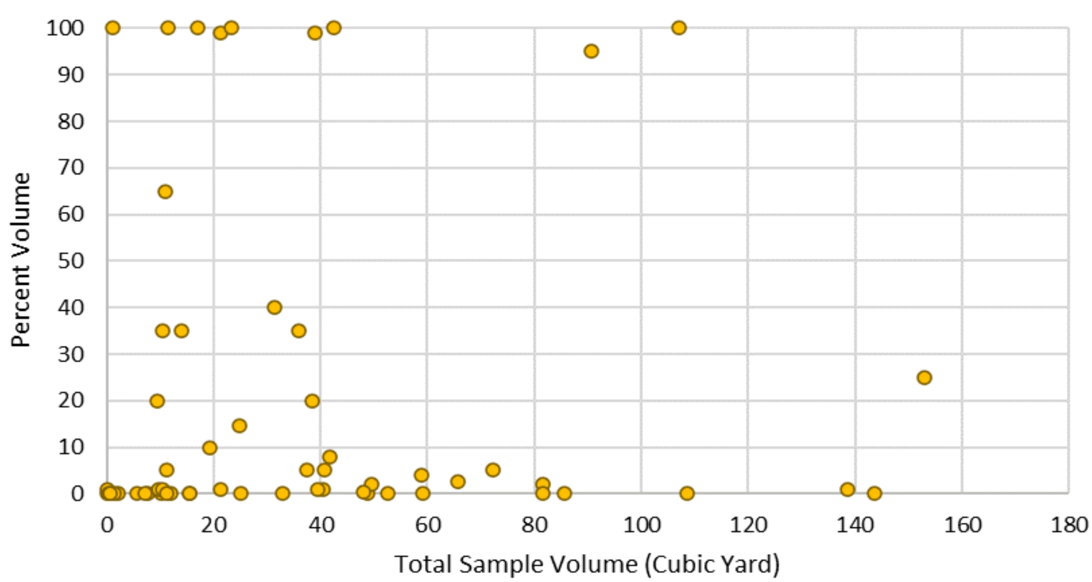
Pallets typically accounted for a large share of the sample volumes, as shown in Figure 11. The majority of samples contained more than 30% **Pallets** by volume, with many samples consisting of 90–100% **Pallets**.

Figure 11. Share (%) of Pallets in Total Sample Volume (in cubic yards)



The portion of **Other** material varied, with the majority of samples at or below 40% **Other** material. Nine samples were categorized as 90–100% **Other** (Figure 12).

Figure 12. Share (%) of Other Material in Total Sample Volume (in cubic yards)



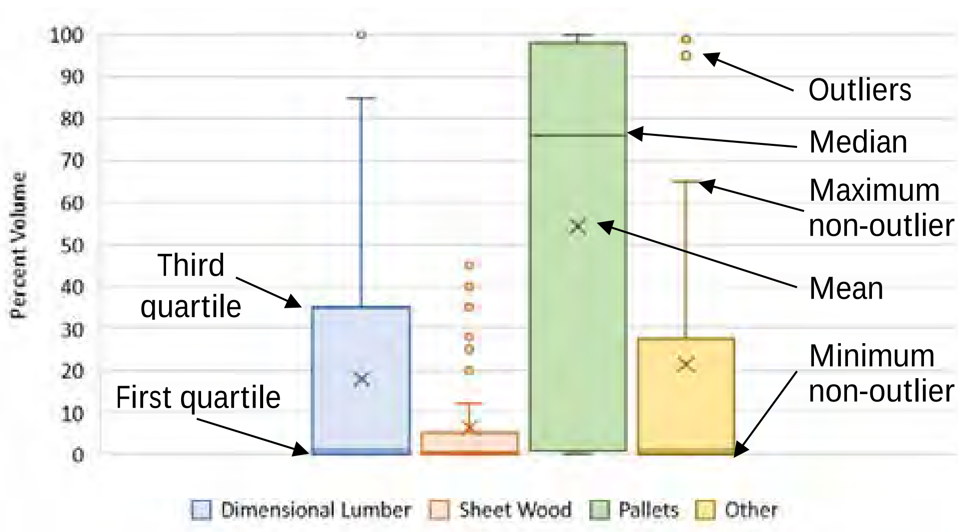
Composition by Volume

Statistical Descriptions

To estimate the composition, Cascadia visually inspected the inbound source-separated wood loads and categorized them into four material types: **Dimensional Lumber**, **Sheet Wood**, **Pallets**, and **Other**. The composition statistics are visually summarized using boxplots. Figure 13 shows an example of how the boxplots are constructed. Each color-coded boxplot represents a particular material type. Each boxplot has the following components:

- **Median**: the middle value of the dataset when the data are arranged in an ascending (or descending) order; shown as the line inside the shaded box.
- **Mean**: the mathematical average value of the dataset (the sum of all sample values divided by the number of samples); shown with " î " symbol.
- **First quartile**: the value at the 25th percentile; the bottom of the shaded box.
- **Third quartile**: the value at the 75th percentile; the top of the shaded box.
- **Interquartile range**: the distance between first and third quartiles; height of shaded box.
- **Maximum non-outlier value**: the highest value in the dataset that is not an outlier, as defined below; shown as lines at the end of a range, or ⊤.
- **Minimum non-outlier value**: the lowest value in the dataset that is not an outlier, or ⊥.
- **Outliers**: values in the dataset above or below 1.5 times the interquartile range; dots.

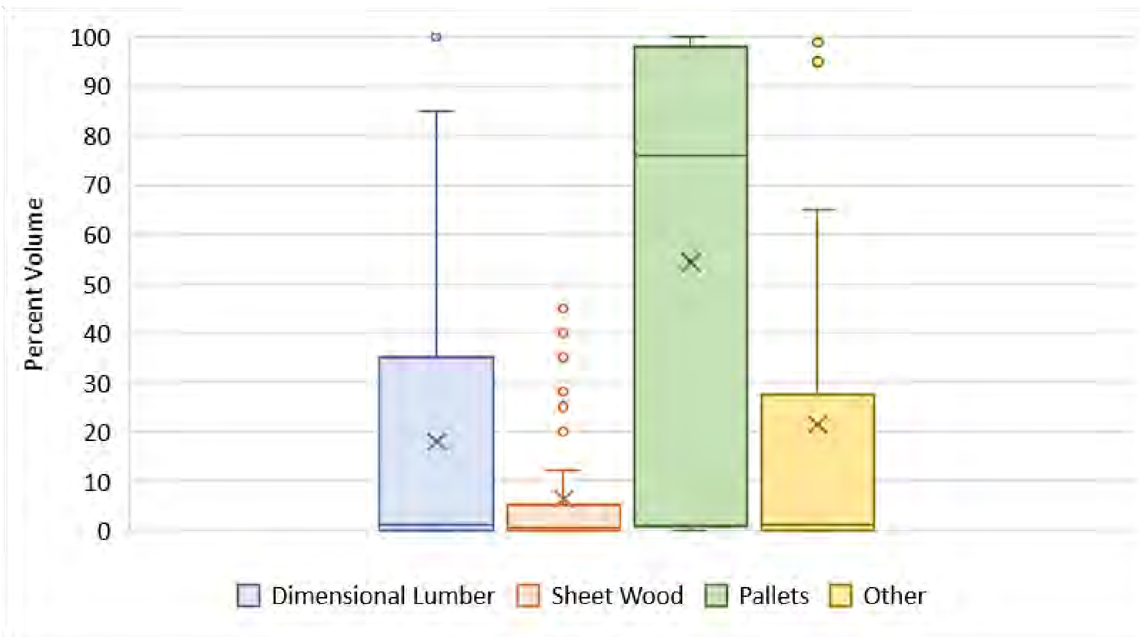
Figure 13. Components of Boxplot Diagrams



Overall Results

Figure 14 shows the estimated composition of inbound wood loads from all 58 samples examined at all participating facilities. **Pallets** were the largest material category by volume (median = 76%, average = 54%). Medians and averages of **Dimensional Lumber** (median = 1%, average = 18%) and **Other** material (median = 1%, average = 21%) were comparable. Proportions of **Pallets** had the greatest variability, as shown in the large interquartile range, followed by **Dimensional Lumber**. The smallest material category by volume was **Sheet Wood** (median = 6.3%, average = 0.5%) and had the most outliers.

Figure 14. Composition by Volume of Inbound Wood Load Samples (n=58) at All Facilities

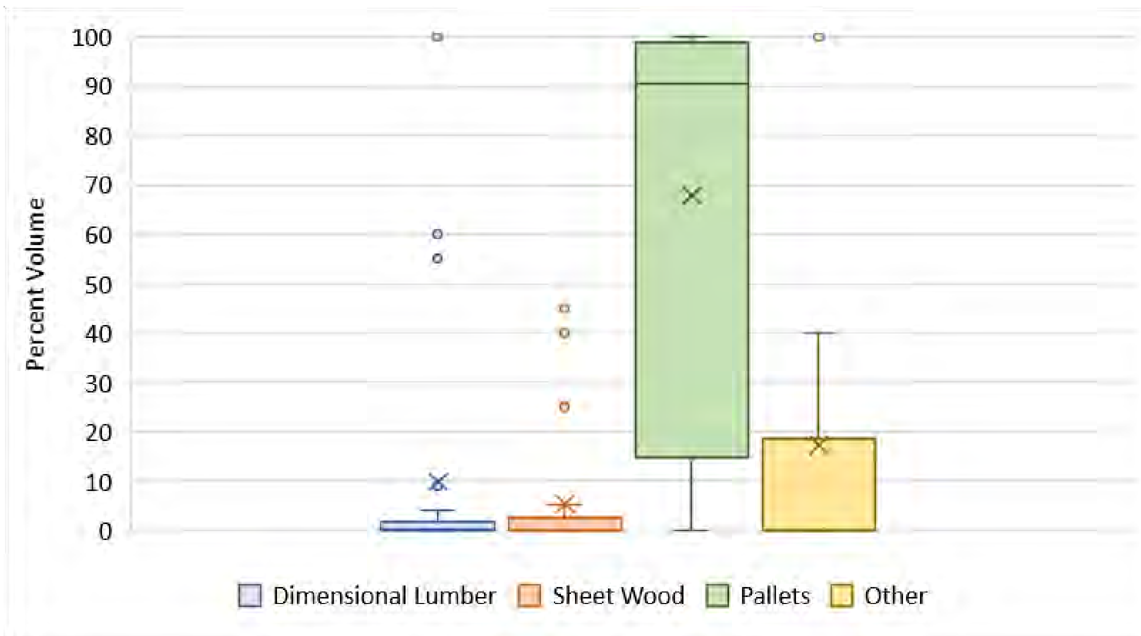


Bow Lake Recycling & Transfer Station

Figure 15 shows the composition of inbound wood loads from 24 samples examined at King County's Bow Lake Recycling & Transfer Station. The field crew captured and examined these samples in an area of the transfer station that is designated exclusively for collection of clean wood, known as "the wood bunker."

Composition estimates show that **Pallets** were the largest material category sampled by volume (median = 91%, average = 68%), followed by **Other** material (median = 0.1%, average = 17%). **Dimensional Lumber** and **Sheet Wood** were the smallest wood categories by volume, with the exception of a few outlier samples (one sample of 100% of **Dimensional Lumber** and one sample of 100% **Other**). **Pallets** had the largest interquartile range, indicating wide variation in the material proportions across samples, followed by **Other**.

Figure 15. Composition by Volume of Inbound Wood Load Samples (n=24) at Bow Lake Recycling & Transfer Station



Composition estimates clearly indicate that inbound wood loads at Bow Lake Recycling & Transfer Station are predominantly composed of **Pallets**. During the fieldwork at several facilities, including Bow Lake, the field crew observed that the process of creating a wood pile using heavy machinery resulted in fracture, fragmentation, or breakage of wood pieces that were structurally integrated or unbroken when they were unloaded from the inbound vehicles (Figure 16). The field crew also observed that different forms of wood—including **Pallets**, **Dimensional Lumber**, and contaminated wood—were often mixed together during the process of creating a wood pile, thereby potentially cross-contaminating wood that would be otherwise relatively pure (uniform in characteristics) upon arrival.

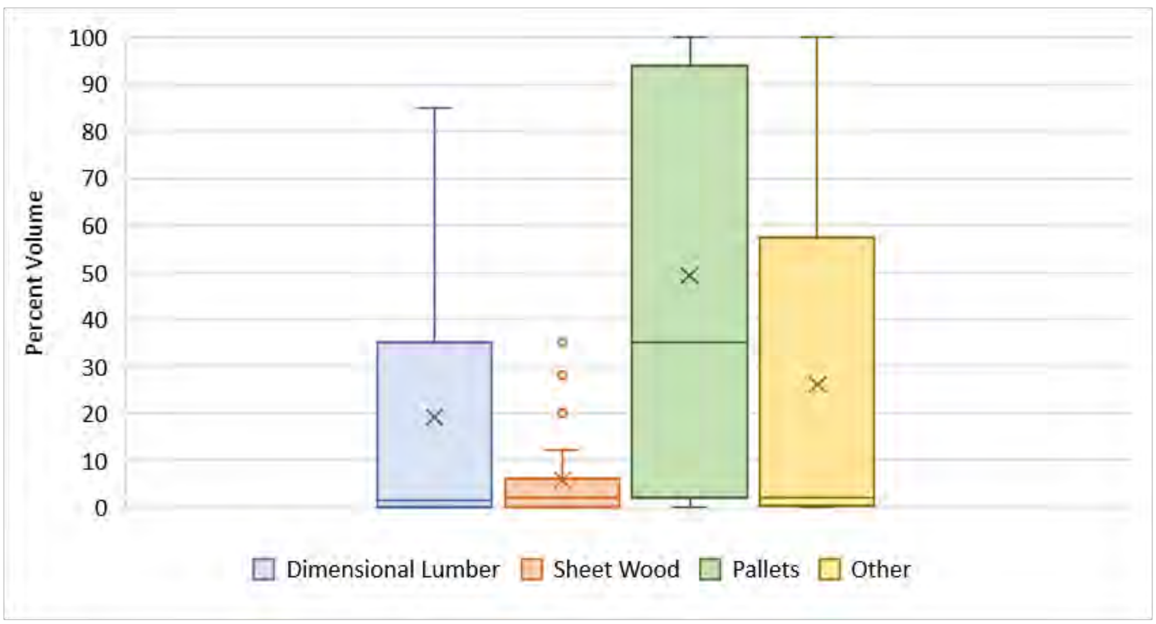
Figure 16. Usage of Machinery to Create Wood Pile, Resulting in Mixing and Breakage

C&D Processing Facilities

Figure 17 shows the composition estimates of inbound wood loads from 25 samples examined at construction and demolition (C&D) material processing facilities. Overall, the composition was relatively heterogeneous. **Pallets** were the largest material category by volume (median = 35%, average = 49%), followed by **Sheet Wood** (median = 26%, average = 2%) and **Dimensional Lumber** (median = 19%, average = 1.5%).

Wood samples examined at the C&D processing facilities during the visual characterization and the hand sort characterization were collected from inbound, pure wood loads. Hand sort samples at DTG Renton were collected from post-processing wood piles—that is, wood that was part of mixed inbound C&D loads containing both wood as well as non-wood materials (such as metal or drywall) that was then separated from the non-wood materials during processing of the C&D loads.

Figure 17. Composition by Volume of Inbound Wood Load Samples (n=25) at C&D Processing Facilities

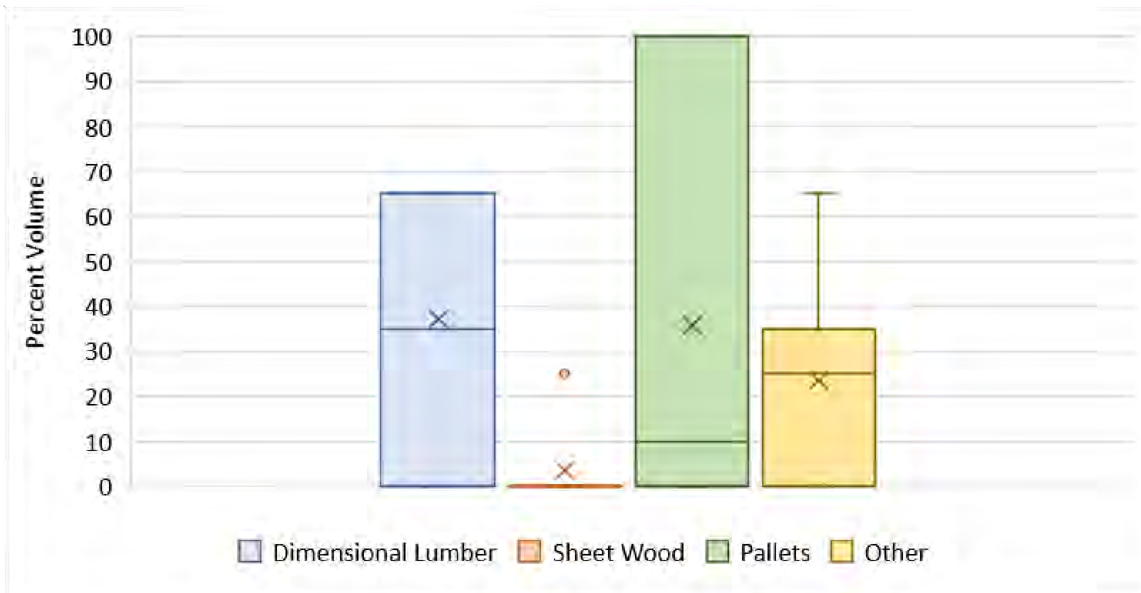


Single-Stream Wood Recycling Facility

Figure 18 shows the estimated composition of inbound wood loads from all 7 samples examined at the single-stream wood processing facility, Rainier Wood Recyclers.

Overall composition estimates show that **Dimensional Lumber** was the largest material category by volume (median = 35%, average = 37%), followed by **Pallets** (median = 10%, average = 36%). **Pallets** had the largest interquartile range, showing wide variation in material proportions across the samples. Quantities of **Sheet Wood** were negligible (less than 1% of samples), with only a single load recorded as having 25% **Sheet Wood**.

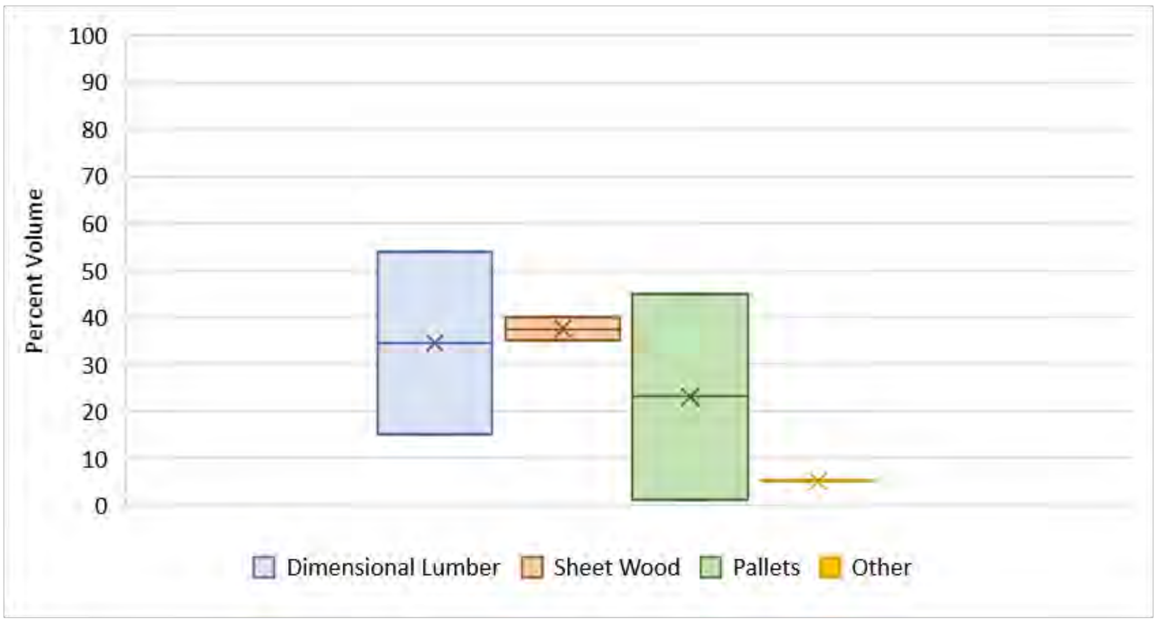
Figure 18. Composition by Volume of Inbound Wood Load Samples (n=7) at Single-Stream Wood Processing Facility



Construction Jobsites

Figure 19 shows the composition of the 2 samples of inbound wood loads from construction jobsites. Of the total wood volume, 34.5% (median and average) was estimated to be **Dimensional Lumber**, followed by 23% of **Pallets** (median and average).

Figure 19. Composition by Volume of Inbound Wood Load Samples (n=2) from Construction Jobsites



Both construction jobsite loads consisted of wood material that had construction-related non-wood material, and/or nails attached to several wood pieces (see Figure 20).

Figure 20. Example of Non-Wood Attachments to Construction Jobsite Wood Material

4. Hand Sort Results

The field work included **hand sort characterization of 72 samples** of dimensional lumber from the clean wood piles and loads at the covered facilities. The field crew randomly selected samples, each consisting of 20 pieces of **Dimensional Lumber**, for a total of 1,440 lumber pieces. Figure 21 shows an example of a hand sort sample. The field crew recorded information about each individual wood piece by type, dimensions, and quality. The crew documented the overall length, as well as the number and length of sections of **Dimensional Lumber** measuring 6 inches or longer without hardware/attachments, paint, stain, pest damage, holes, splits, or adhesive. The field crew also noted whether the lumber pieces had at least one flat side free of attachments. Cascadia staff then verified the quality and accuracy of collected data and used standardized statistical methods to analyze the composition and characteristics of the wood materials.

Figure 21. Example of a Hand Sort Sample Consisting of 20 Pieces of Dimensional Lumber

Overall Results

Table 3 shows the percentage of sampled pieces of **Dimensional Lumber** with various identified characteristics (see Figure 22 for photo examples) based on the hand sort characterization:

- Just over one-quarter of pieces (27%) were **stamped** to indicate grade and lumber standards.
- More than half of the pieces (51%) had some sort of **hardware** attached, such as nails or hooks.
- Nearly two-thirds (62%) of the pieces had **holes**, **splits**, or indications of **pest damage** or infestation.
- The large majority (85%) of the dimensional lumber pieces sorted were not **painted**, **stained**, or **treated** (such as creosote). Pressure-treated wood was tracked as a separate subset and represented 4% of the dimensional lumber sampled.
- Most of the sampled pieces of dimensional lumber were not **joined** (97%).
- Nearly all pieces (99%) had at least one **flat** side free of attachments.
- The large majority of the wood pieces (94%) had at least one clean section that was **6 inches** in length or longer.

Table 3. Wood Characteristics in Dimensional Lumber Pieces in Hand Sorts
*(desirable features are indicated with shading; **bold** indicates >50%)*

Characteristics	No	Yes
Stamped	**73.4%**	26.6%
Hardware/Attachments	**51.3%**	48.7%
Holes/Splits/Pest damage	37.9%	**62.1%**
Painted/Stained/Treated	**84.9%**	15.1%
Pressure-treated	**95.6%**	4.4%
Joined	**97.2%**	2.8%
Flat side free of attachments	0.8%	**99.2%**
Section(s) 6 inches or longer	6.3%	**93.8%**

Examples of Wood Characteristics

The photos in Figure 22 shows examples of different wood conditions observed in hand-sorted samples: stamped, hardware/attachments, holes/splits, pest damage, painted, stained, pressure-treated, and joined wood.

Figure 22. Examples of Wood Conditions Observed in Hand Sort Sampling


Stamped


Hardware/Attachments


Holes/Splits


Pest Damage


Painted


Stained


Pressure-Treated


Joined

Lumber Dimensions: Modern Versus True

Table 4 shows that most (95%) of the sampled pieces of **Dimensional Lumber** had "modern" (or nominal) dimensions, meaning that the thickness of the piece (either one and/or both sides) is slightly smaller than its stated dimensions or lumber with "true" (or actual) measurements. For example, a typical size of modern **Dimensional Lumber** currently sold in stores is called a "two-by-four" (2x4), but it actually measures 1.5 by 3.5 inches. Older lumber, such as from the early 20th century, was typically larger, following the true named measurements. Figure 23 shows examples of modern versus true 2x4 lumber.

Table 4. Dimensional Lumber Characteristics in Samples: Modern Versus True Dimensions

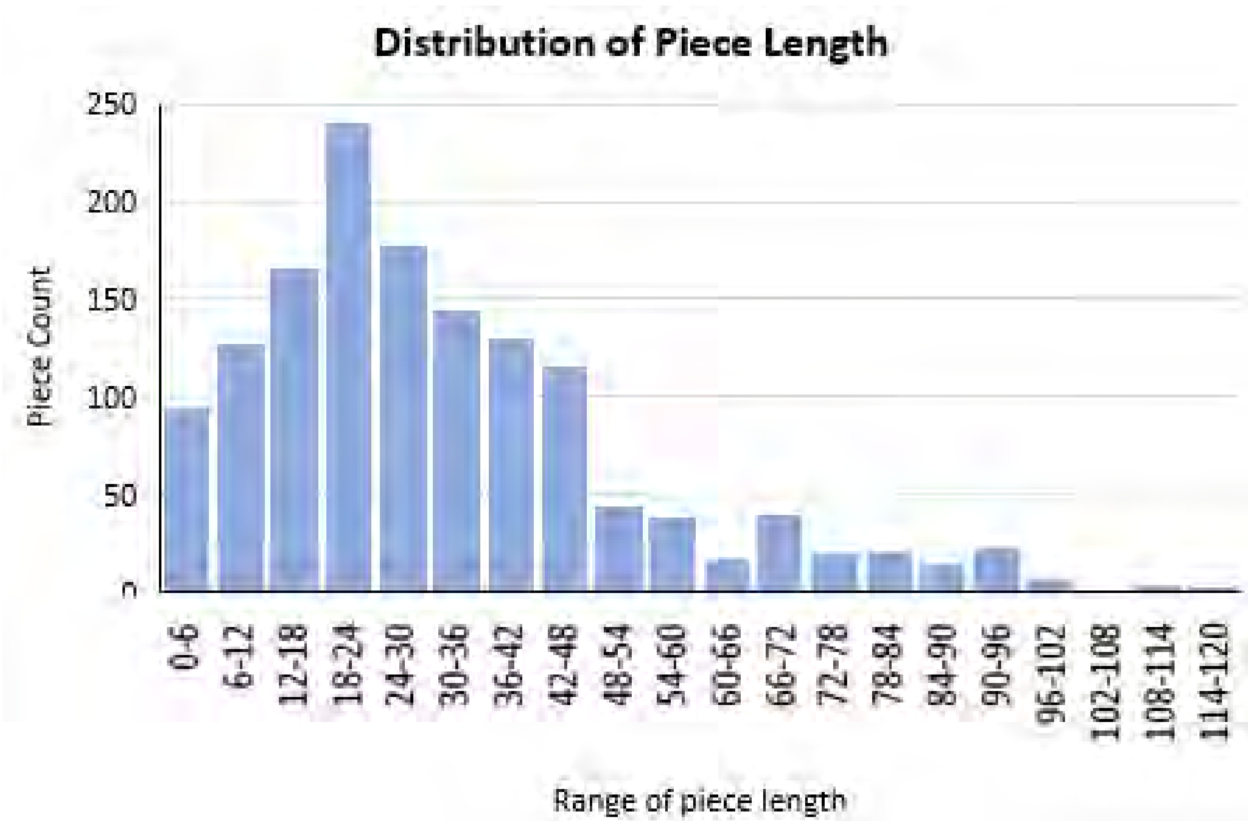
Type of Dimensions	%
Modern (nominal)	95%
True (actual)	5%
Grand Total	**100%**

Figure 23. Examples Showing Variance in Dimensions of 2x4s *(true on left, modern on right)*

Dimensional Lumber by Piece Length

Figure 24 shows the distribution of section or piece lengths of **Dimensional Lumber** measuring 6 inches or longer without hardware/attachments, paint, stain, pest damage, holes, splits, or adhesive. The figure shows a wide range of section lengths, from a minimum 6 inches to a maximum of 120 inches (10 feet). Section lengths commonly range from 6 to 48 inches, with most sections measuring between 18 inches and 24 inches.

Figure 24. Count of Dimensional Lumber Pieces by Length



The total cumulative length of all the **Dimensional Lumber** boards sampled was 75,742 inches, or nearly 6,312 feet. The total cumulative length of all the clean sections that are equal to or longer than 6 inches was 46,051 inches, or nearly 3,838 feet. In other words, 60.8% of the total length of the sampled **Dimensional Lumber** boards were made up of clean sections measuring 6 inches or longer.

Figure 25 shows the distribution of number of sampled **Dimensional Lumber** boards by the fraction of their board length made up of sections measuring 6 inches or longer. For example, of the 1,440 **Dimensional Lumber** boards sampled during the study, 99 **Dimensional Lumber** boards (6.9%) were such that 10% of less of their length consisted of clean sections measuring 6 inches or longer. At the other end of the spectrum, 631 boards (43.8%), the largest portion, were such that 90% or more of their length was made up of sections measuring 6 inches or longer.

Figure 25. Dimensional Lumber by Percentage (of Overall Length) of Sections 6 Inches or Longer

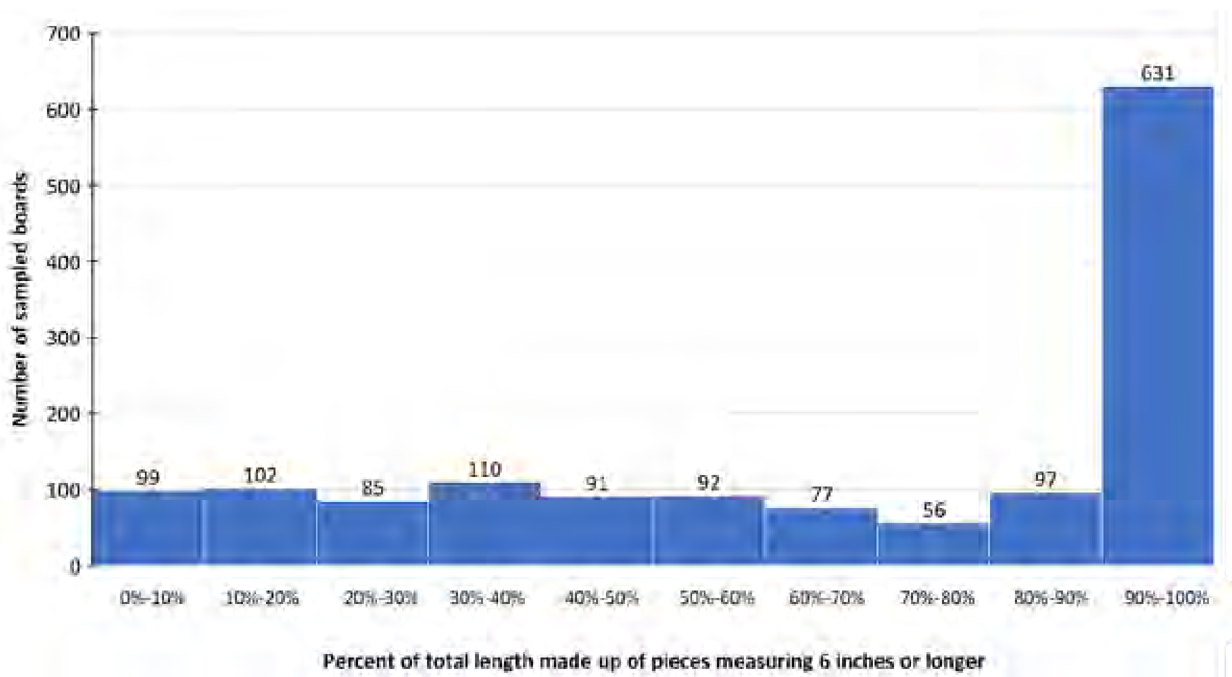
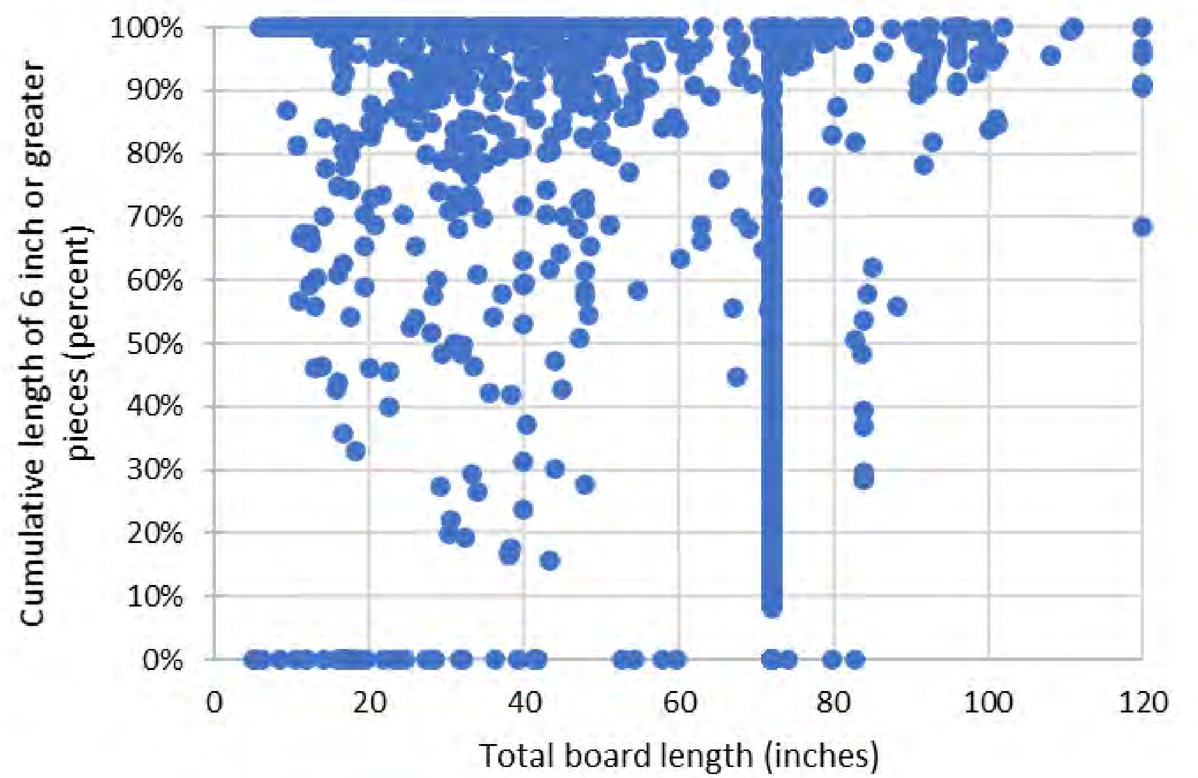


Figure 26 shows the distribution of **Dimensional Lumber** boards by the cumulative length of clean sections measuring 6 inches or longer. There does not appear to be a correlation between the overall length of the sampled board and the cumulative length of sections 6 inches or longer, except at the longer end of the range. In the hand sorts, all boards of 83 inches or longer (84 boards) were found to have at least one clean section 6 inches or longer.

Figure 26. Cumulative Length of Clean Sections 6 Inches or Longer by Board Length

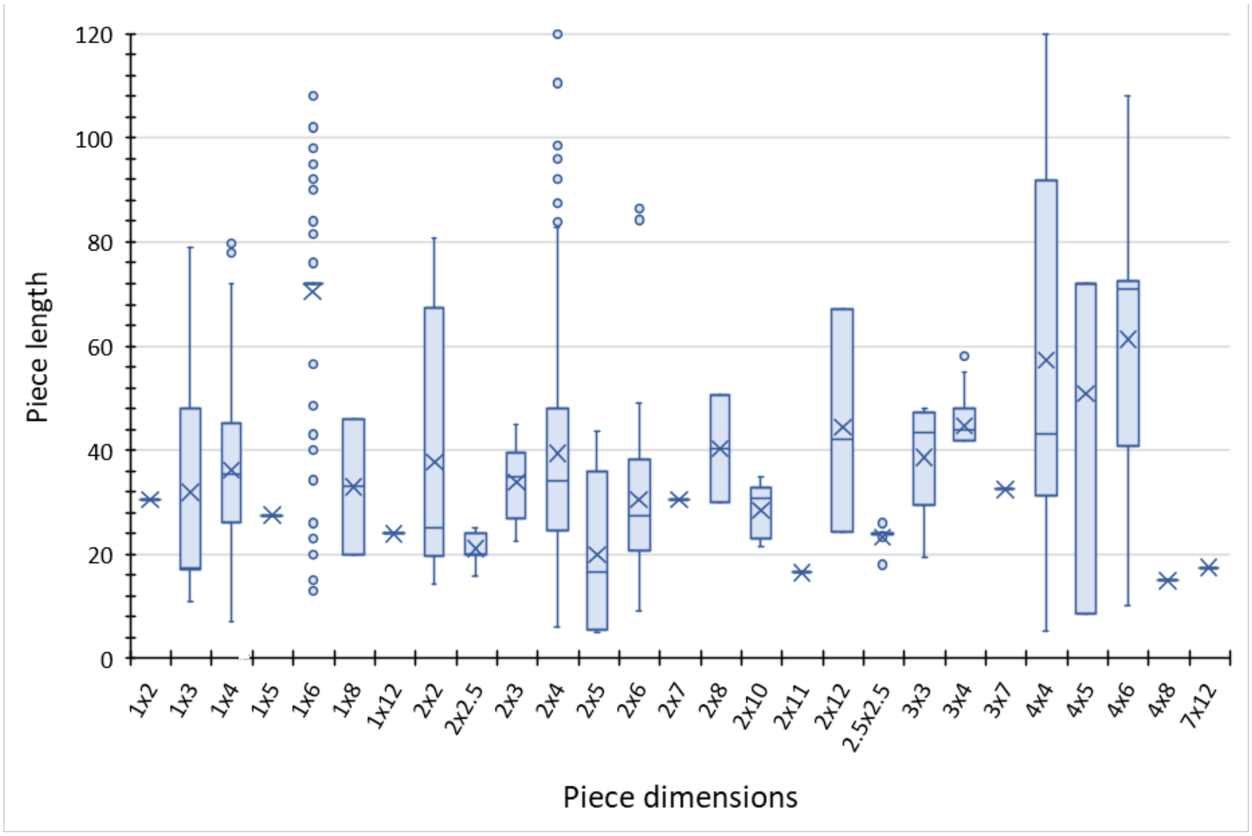


Some wood pieces were found to have long lengths overall, however, but almost no usable or clean sections (free of attachments, holes, etc.) of 6 inches or longer (Figure 27). The total length of the board also constrains the maximum section length or lengths, as the sections clearly cannot be longer than board itself.

Figure 27. Example of Long Dimensional Lumber with Few Usable Sections of 6 Inches or Longer, Due to Nails

Figure 28 shows the distribution of total length of the pieces of **Dimensional Lumber** sampled across different dimensions. A wide variety of dimensions were recorded during the sampling events, ranging from 1 by 2 inches (1x2) to 7 by 12 inches (7x12). The length of the pieces of **Dimensional Lumber** varied across dimension types, from 5 inches to 120 inches. The range of piece lengths varied across different dimension types; the range was quite small in certain cases (such as 2x10 lumber), while the length varied widely in other cases (such as 2x2 and 4x4 lumber).

Figure 28. Size of Dimensional Lumber by Measurements (Inches)



5. Industry Interview Research

Wood Characteristics that Influence Suitability for Reuse

To inform the data collection protocol for this study, Cascadia investigated various wood characteristics that influence suitability for reuse, using a list derived from phone interviews, online research, and discussions with King County. The table below summarizes the findings from research and interviews regarding wood characteristics that influence feasibility for reuse.

Table 5. Wood Characteristics and Notes on Reuse Potential from Industry Interview Research

Characteristics	Notes on Reuse Potential (per Interviews)
Grade	§ Required for commercial structural application (currently). § Salvaged lumber used for residential structural application is assumed to be (depending on dimensions) SPF stud grade (WA State Residential Code R602.1.1.1) or Hem-Fir #2 grade. § Much lumber is already graded, but if cut may need to be re-graded for structural applications.
Consistency	§ Requirements vary based on end markets. § End markets need consistent supplies. § Manufacturers need to know what the product is.
Cleanliness	§ Generally important for most applications.
Impurities/Contaminants	§ Specifications vary based on end market. § Nails and hardware risk damage to equipment. § Zero tolerance if wood is to be processed in machinery. § Initial mechanized processing can address the contamination concerns.
Species	§ Specifications vary based on end markets. § Species type is important for end use but challenging to identify. § Processors usually specialize in local species. § Could test for solid lumber categories instead of species (hardwood, framing lumber, and crating materials) in the field.
Size Requirements	§ Size dimensions must be uniform for some markets. § Standards vary based on end market.
Moisture	§ Stringent requirements for wood product manufacturers; kiln-drying may be required to meet specifications. § Structural applications may allow up to 15% to <20% moisture content, and interior application typically requires lower moisture levels. § Vaagen Timbers, for example, requires a range of 9-15% moisture content for its cross-laminated and glue-laminated (glu-lam) timbers.

Characteristics	Notes on Reuse Potential (per Interviews)
Density	§ Specific standards for some applications but generally less important than other characteristics.
Adhesives	§ Generally not acceptable for reuse.
Treatments	§ Generally not acceptable for reuse.

Testing for Wood Characteristics

In addition to addressing characteristics to measure during data collection, the interviewees also discussed protocols for testing each characteristic and the tools/resources needed to complete data collection. The table below summarizes the findings regarding tools and resources (including field versus lab testing) necessary to test for each wood characteristic.

Table 6. Wood Characteristics and Notes on How to Test/Measure

Characteristics	How to Test	Helpful Tools and Resources
Grade	Visual test/professional guidance	§ Certified grader (also determines species) § Grading book for field reference
Consistency	Visual test	§ None
Cleanliness	Visual test	§ None
Impurities/Contaminants	Visual test	§ Metal detector is helpful for invisible impurities
Species	Visual or lab test	§ Wood specialist (in field) § $100 to $200 per specimen (lab testing)
Size Requirements	Visual test	§ Tape measure
Moisture	Visual test	§ Moisture reader (pin test) reads down ¾ inch
Density	Mechanical test	§ Density tool (e.g., Pilodyn, Hitman)
Adhesives	Visual test	§ None
Treatments	Visual or mechanical test	§ Hand tool for detecting contaminants § Special staff training
Termites/Pest Damage	Visual test	§ None

Based on these findings, Cascadia and King County concluded that supplemental laboratory testing was *not necessary* for the purpose of this study. Key characteristics could be tested in the field with either additional staff training or mechanical hand tools used by the field crew.

Preferred Types of Wood Materials for Reuse

This section summarizes the types of reclaimed wood preferred for reuse according to the interviews with wood professionals.

Clean dimensional (framing) lumber with a valid grade stamp is ideal. Interviewees disagreed about whether a grade stamp remains valid if the wood is recovered from disposed materials. A grade stamp is valid if the wood has not been changed, but it is nearly impossible to confirm that the recovered wood in the waste stream has not been cut or changed since the stamp was applied. The most reliable source for graded lumber is direct from a construction site that is disposing of unused building materials.

Large segments (8 feet or more) of solid wood in large quantity are preferred. Large segments are more likely to meet quantity and consistency requirements than small pieces.

Solid wood such as lumber is more viable for reuse than composite materials. Composite materials often use adhesives which pose concern for contamination. The exception may be large quantities of **Sheet Wood** such as OSB and plywood that offer a high level of quantity and consistency.

Pallets received mixed reviews among interviewees. Some interviewees stated that pallets had high potential for reuse if made of hard wood and collected in large quantities, while others reported they posed too many challenges. Interviewees shared the following arguments against using **Pallets** as reclaimed wood:

- There is already stiff competition for high-quality **Pallets**, leaving an available stock of **Pallets** that are in poor condition. Interviewees reported that high-quality **Pallets** are already collected for existing markets before ending up in a transfer station or landfill.
- **Pallets** are a source of biomass and may be better used as feedstock for compost.
- **Pallets** usually have a significant amount of hardware such as nails that would require too much pre-processing for many reuse applications.

Sourcing Wood for Reuse

This section summarizes recommendations from interviewees regarding sources of wood that offer potential for reuse, including strategies for sourcing reclaimed wood and potential types of wood sources.

- **Collect reclaimed wood as close to its original source as possible.** Doing so can limit the amount of processing required for certain applications. If seeking graded lumber, find the lumber as close to its original source to limit the possibility of alterations after the grade stamp was applied.
- **Collect the wood while it is clean, organized, segregated, and consistent.** Seeking cleaner wood sources can reduce collection and processing costs. Construction jobsites or wood processing facilities are potential sources of clean wood.
- **Source wood found in high volume.** Wood with high quantity and consistency offers more options for end use markets.
- **Commercial construction sites** may be a valuable source for reclaimed wood, specifically dimensional lumber. Wood is often sorted and sometimes completely unused. For example, contractors or designers may over-order and have an excess of consistent supply materials onsite.
- **Residential construction sites** can be less reliable than commercial construction sites as the wood is often mixed and of various specifications, but they could still be a viable source for unused lumber.
- **Deconstruction sites** may be a viable source, but wood previously used in construction will likely need additional processing.
- **Wood recyclers** may accumulate large supplies of wood at their facilities before the material is ground for existing markets, such as hog fuel. This wood may have more options for potential reuse before it is ground.
- **Urban trees** cut down by the Park Department may be a source of reclaimed wood. Cut trees and stumps provide a clean wood source free of contaminants or hardware that could be processed to meet the standards of preferred end markets.

Interviewees generally did not recommend transfer stations and mills for sourcing reclaimed wood. Wood from transfer stations will likely require more effort to sort, clean, and identify due to varying sources and contamination. Mills reportedly have minimal wood waste available as they have existing uses for all wood they keep onsite. However, the findings of this study suggest a substantial portion of **Dimensional Lumber** in source-separated wood loads may be suitable for further collection and processing into higher and better uses.

6. Conclusions and Recommendations

Conclusions

This study demonstrates there is promising opportunity to capture and reuse more clean wood, though further study, with additional sampling and quantitative analysis, is suggested.

94% of the hand sort sampling of **Dimensional Lumber** had at least one section of six inches or more in length without attachments/hardware, paint, stain, pests, holes, splits, or adhesives. Such clean sections could be used as feedstock for finger-jointed studs, cross-laminated timber, glulam, or other mass timber or structural applications.

Pallets represented the largest material category by volume (median = 76%, average = 54%) observed in the visual characterizations of incoming wood loads across the covered sites, followed by **Dimensional Lumber** (median = 1%, average = 18%) and **Other** material (median = 1%, average = 21%).

Visual Characterization Conclusions

The 58 visual characterization samples estimated composition of inbound wood loads across the participating facilities. **Pallets** represented the largest material category by volume (median = 76%, average = 54%), followed by **Dimensional Lumber**. The smallest material category by volume was **Sheet Wood** (median = 6.3%, average = 0.5%). Medians and averages of **Dimensional Lumber** (median = 1%, average = 18%) and **Other** (median = 1%, average = 21%) were comparable. Proportion of **Pallets** varied widely, as indicated by its large interquartile range, followed by **Dimensional Lumber**.

Hand Sort Characterization Conclusions

In the hand sort sampling of **Dimensional Lumber**, the following attributes were most common:

- Had at least one section of 6 inches or more in length (94%).
- Had at least one flat side free of attachments, to accommodate high-speed processing on a belt (99%).
- Had holes, splits, or indications of pest damage (62%).
- Not painted, stained, or treated (85%), including not pressure-treated (96%).
- Not joined (97%).
- Free of hardware/attachments (51%).

§ Not stamped (73%).

About 61% of the total cumulative length of the sampled **Dimensional Lumber** boards was made up of sections measuring 6 inches or longer without hardware/attachments, paint, stain, pests, holes, splits, or adhesive. About 43% of the **Dimensional Lumber** boards were such that 90% or more of their length consisted of non-contiguous sections (such as divided by nails or holes) measuring 6 inches or longer. Boards with high percentages of cumulative length of sections 6 inches or longer were found in all board lengths sampled from 6 inches to 10 feet. There does not appear to be a correlation between the overall length of the sampled board and the cumulative length of sections 6 inches or longer, except at the longer end of the range. In the hand sorts, all boards of 83 inches or longer (84 boards) were found to have at least one clean section 6 inches or longer.

Recommendations for Future Studies

- Future MSW and C&D waste characterization studies should include statistically significant assessments of the types, dimensions, and condition of inbound wood.
- Conduct visual and physical characterization of post-processing wood at C&D processing facilities.
- Work with wood processing facilities to share data on wood types and quantities to support regional markets for wood reuse.
- Assess the feasibility of separating pallets from inbound wood loads, especially at the Bow Lake Recycling & Transfer Station.

Previous characterization studies of construction and demolition (C&D) wastes and materials have mainly sampled at transfer stations and have covered multiple materials, rather than focusing primarily on wood. In this study, the wood samples examined at the C&D processing facilities during the visual characterization as well as hand sort characterization were extracted from inbound, pure wood loads only. For future studies, **Cascadia recommends including an assessment of mixed C&D inbound loads to characterize and quantify the inbound wood that is mixed with other, non-wood C&D materials.**

For the future, **Cascadia recommends working with the wood processing facilities to quantify and characterize the overall volume and tonnages of the inflows and the outflows of wood material**. Collecting qualitative data for the inbound wood is also recommended. Qualitative data on physical and chemical properties of inbound wood—such as bending, compression, hardness, shear, and moisture content—could help to assess the feasibility of reuse of reclaimed lumber in structural applications.[1]

Additionally, **Cascadia recommends working with the wood processing facilities to share facility-specific wood data to support a regional marketplace for wood**. The County could work with the facilities to develop a GIS-based King County infrastructure map published on the internet showing facility-specific wood data, such as quantities, frequencies, throughput, type, and pricing. Such information-sharing will help efforts to not only develop market solutions but also support circular economy solutions at the regional level.

The field crew observed that different forms of wood often are mixed together during the process of creating a wood pile, thereby potentially cross-contaminating wood that would be otherwise relatively pure (uniform in characteristics) upon arrival. In addition, usage of machinery results in fracturing and breakage of constructed wood items such as pallets that could be otherwise salvaged in their intact conditions and potentially reused. On the days observed, visual characterization estimated that the inbound wood loads received at King County's Bow Lake Recycling & Transfer Station often contained up to 90% pallets. **Cascadia recommends assessing the feasibility of separating pallets from the inbound wood loads, especially at the Bow Lake facility.**

[1] ASTM Standards for Wood and Wood Products, https://www.astm.org/Standards/wood-standards.html

Appendices

Appendix A. Fieldwork Methodologies, Sampling Protocols, and Forms

Table 7 summarizes the number of visual samples that were collected at each participating facility.

Table 7. Visual Samples Collected by Facility by Day

Dates	Bow Lake TS	DTG Maltby	DTG Recovery 1	DTG Redmond	DTG Renton	RWR	Grand Total
1/20/2021	9						9
1/21/2021					1		1
1/27/2021	7						7
1/28/2021				3			3
1/29/2021				3			3
3/22/2021						7	7
3/23/2021					3		3
3/24/2021		5					5
3/25/2021			12				12
3/26/2021	8						8
Grand Total	**24**	**5**	**12**	**6**	**4**	**7**	**58**

Table 8 summarizes the number of hand sort samples that were collected at each participating facility.

Table 8. Hand Sort Samples Collected by Facility by Day

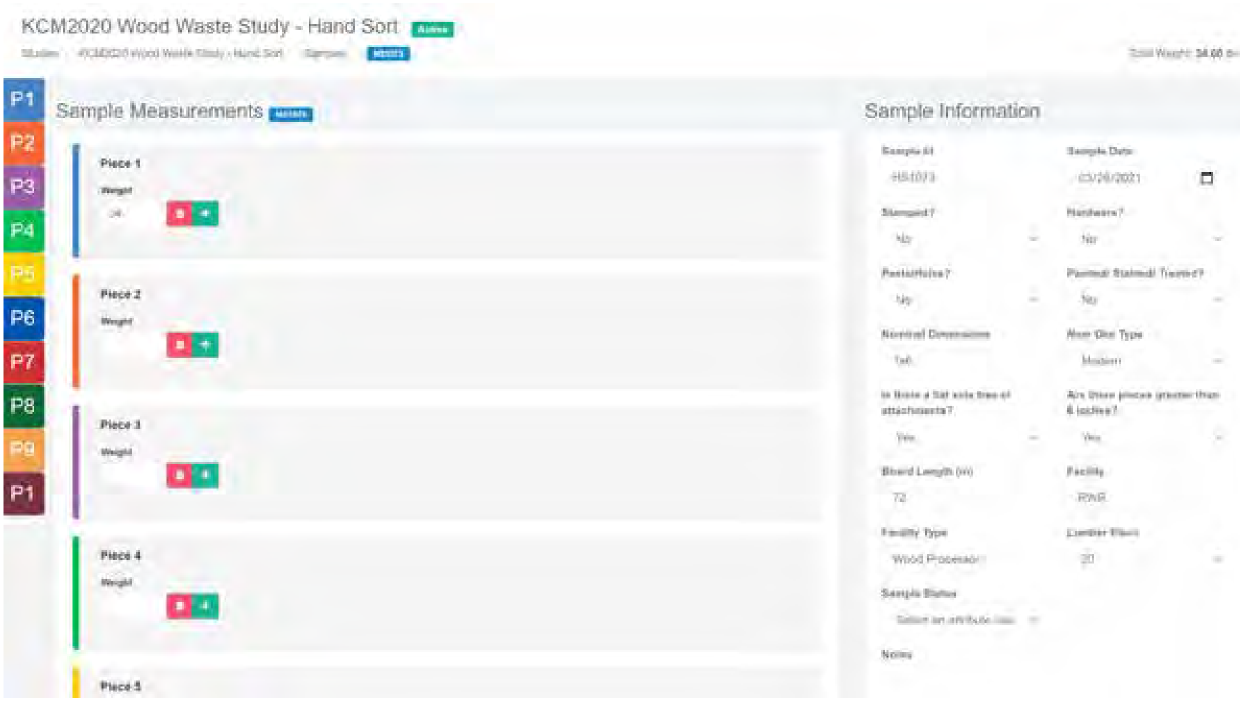
Dates	Bow Lake	DTG Maltby	DTG Recovery 1	DTG Redmond	DTG Renton	RWR	Grand Total
1/20/2021	7						7
1/21/2021					11		11
1/27/2021	8			7			15
3/22/2021						9	9
3/23/2021					6		6
3/24/2021		6					6
3/25/2021			10				10
3/26/2021	8						8
Grand Total	**23**	**6**	**10**	**7**	**17**	**9**	**72**

Visual Characterization Methodology

The field crew visually characterized piles and/or loads of clean wood once they were tipped on the floor from the inbound vehicle carrying the load. The visual characterization method used to characterize piles and/or loads of clean wood is described below:

- **Step 1: Collect information about the load.** At the sampling area, our field crew member recorded key identifying information about the load such as facility name and date.
- **Step 2: Photograph the load.** The crew member photographed of the load. A sample placard that identifying each sample was positioned so it is visible in each photograph.
- **Step 3: Measure load volume.** The crew member estimated the length, width, and height of the load using a laser distance measuring tool and recorded the dimensions in OSCAR, Cascadia's cloud-based database (OSCAR), customized and installed on a handheld iPad (Figure 29).
- **Step 4: Note which material types are present.** The crew member walked entirely around the load if possible and indicated on the *Visual Characterization Form* which material types are present in the load.
- **Step 5: Estimate composition by volume for each material type.** Beginning with the largest material type present by volume, the crew member estimated the volumetric percentage of the material type and recorded it on the form. This process is repeated for the other material types.
- **Step 6: Check and reconcile percentage data.** The crew member ensured that the percentage estimates for all material types added up to 100 percent.

Figure 29. Digital Data Entry Form in OSCAR



Note: The Weight field was used to record the piece lengths.

Hand Sort Methodology

The objective of the hand sorts is to evaluate **Dimensional Lumber** pieces in each sample. A single sample consists of 20 individual pieces of **Dimensional Lumber**. The field crew hand-sorted up to 20 samples per day of fieldwork using the following steps.

- **Step 1. Review methodology and sorting categories with the crew.** To provide consistent sorting, Cascadia used a highly trained field crew throughout the project. Before the sorting begins, all crew members reviewed the procedures, forms, and material definitions in detail.
- **Step 2: Capture the sample.** Once the inbound vehicle tipped the wood load on the ground and exited the facility, the Cascadia field crew proceeded with examining the wood load to detect presence of **Dimensional Lumber** in the load. If it was determined that at least 20 pieces of **Dimensional Lumber** could be safely extracted from the wood pile, the field crew proceeded with extracting the pieces of **Dimensional Lumber** by hand. At times, the crew requested that the facility operator use their machinery to spread out the wood pile to make it easier and safer to extract pieces of **Dimensional Lumber**. If the wood pile had many more than 20 pieces of **Dimensional Lumber**, the field crew collected multiple samples from the same wood pile from different sections of the pile.

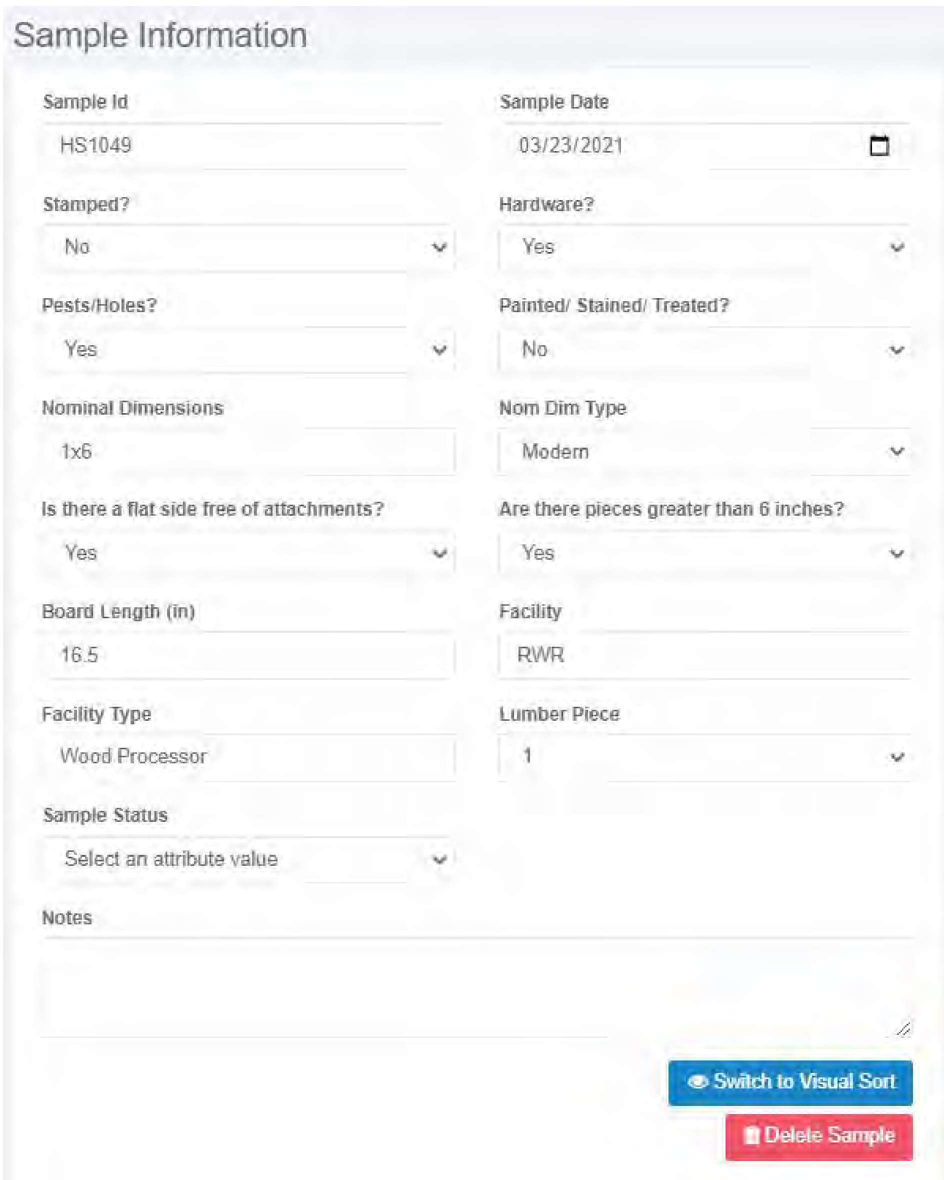
Pressure-treated dimensional lumber was included in hand sort samples of Dimensional Lumber. The field crew noted the pressure-treatment of the wood sample. Where clearly visible at the point of sample extraction, wood with all other treatment types (painted, stained, creosote-treated, etc.) was not included in the hand sort samples of dimensional lumber. Examples are shown below.

Pressure-treated wood	Examples of other treatment types
	Stained wood  Painted wood  

- **Step 3: Collect information about the load.** At the sampling area, our field crew member recorded key identifying information about the load such as facility name and date.
- **Step 4: Photograph the load.** The crew member photographed of the load. A sample placard that identifying each sample was positioned so it is visible in each photograph.

- **Step 5. Measure the sample.** The field crew documented the overall length as well as the number and length of sections of **Dimensional Lumber** measuring 6 inches or longer without hardware/attachments, paint, stain, pests, holes, splits, or adhesive. The field crew also noted whether the **Dimensional Lumber** pieces had at least one flat side free of attachments.
- **Step 6. Review the data.** The field crew used a rugged handheld tablet to record each material weight in Cascadia's cloud-based database, known as OSCAR (Figure 30). At the end of each sorting day, the field crew manager conducted a quality-control review of the data recorded.

Figure 30. Material Weight Data Entry Form



Appendix B. Interview Questions

Introduction

To strengthen wood reuse markets, and divert wood away from current practices of burning and burying, the objective of this study is to characterize wood materials in the waste stream in King County. This study is intended to demonstrate the types and quantities of wood available for alternative wood markets such as engineered wood products manufacturers. This may include visual and/or hand sorts performed by field staff, and potentially follow-up tests of certain samples if necessary. These interviews are meant to inform the study protocol.

General Characteristics of Wood for Reuse

To complete this study, we will need to measure how much of the disposed wood waste stream is viable as feedstock for engineered wood or other uses.

In general, what types of disposed wood should we be looking for that would likely be eligible for reuse? (e.g., clean dimensional lumber, clean engineered wood products)

In general, what sources would the best candidates for reclaimed/reused wood? (e.g., construction sites, wood processors, transfer stations)

What are the highest/best uses for reclaimed wood (such as CLT, construction materials)?

What wood characteristics are most important for a manufacturer of CLT or other engineered wood products?

- Consistency?
- Cleanliness?
- Impurities/contaminants (e.g., nails, screws, hardware)
- Size requirements (length, width, weight)?
- Tree species? Effect on wood properties?
- Moisture content? (consider relationship of moisture levels and potential for wood decay)
- Adhesive content?
- Treated wood?
- Termites/parasites/mites?

Field Testing

We also need to understand what tests we can conduct in the field to determine wood eligibility for reuse versus tests that will need to be conducted in a lab.

What tests could a field crew do in the field without having specialized expertise and what tests would need to be done in a lab? For example, visual/mechanical testing (e.g., size, impurities) versus chemical testing (e.g., moisture, adhesive content)? Grading of the wood may also be a necessary step.

For tests that can be done in the field, how can the field crew make the distinctions?

- **Tree species** – Can the species be determined from photographs?
- **Termites/pest damage** – Can termites or other pest damage be identified if the field crew can see only what is on the outside of the wood samples?
- **Treated wood** – What are the signs? (e.g., "staple" marks, colors)

Is there special equipment or tools to conduct any field tests (e.g., moisture, density)?

Lab Testing

Certain materials characteristics may require lab testing and/or grading.

What types of analysis can labs provide that would be useful for determining if wood is eligible for reuse (or CLT specifically)? Would grading the material be more beneficial than lab testing?

What would be the sample characteristics for lab testing (e.g., what size/shape of samples would be needed)?

If lab tests are necessary, is your organization able to test wood samples for this project?

- Cost?
- Timeline?