

EVALUATING THE DISPLACEMENT MODES AND
ASSOCIATED RISKS OF STACKED LOG STRUCTURES

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“Nothing is lovelier and fits more perfectly into the background from which it came than a Western log-cabin, and nothing is more comfortable. In the summer it is cool, in the winter it is warm. Its walls inside are restful to the eye, taking on a mellow ruddy patina as they get older. Moreover, they form the best of settings for anything you choose to put upon them. There is something of magic about the inevitable correctness of simplicity and usefulness.”

– Struthers Burt, *The Diary of a Dude Wrangler*, 89

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Table of Contents

Acknowledgements	ii
List of Figures	v
List of Illustrations	vi
List of Maps	vii
Chapter 1: Introduction	1
Chapter 2: Stacked Log Structures in the United States	4
Early European and Native American Predecessors	4
Western Frontier and Expansion	6
Cowboy Construction	7
Parkitecture and the Civilian Conservation Corps	9
WWII to Today	10
The Standards and Manuals	12
The Bar BC Dude Ranch	13
Chapter 3: Early 20 th Century Stacked Log Buildings as Structural Systems	15
Construction Sequence	15
Loads Applied to Structures	17
Structural Load Paths of Stacked Log Buildings	20
Stacked Log Buildings at the Bar BC Ranch	22
Chapter 4: Structural Pathologies of Early 20 th Century Stacked Log Buildings	26
Structural Vulnerabilities	26
Types of Displacement	31
Structural Vulnerabilities of the Stacked Log Buildings at the Bar BC Ranch	33
Chapter 5: Assessment Methodologies and Stacked Log Structures	37
Condition Assessment	37
Risk Assessment	41
Rapid Assessment	42
Assessment of Stacked Log Structures	43
Post-mortem Assessment as a Monitoring Tool	43
Appropriate Assessment Conclusions	44
Chapter 6: Development of a Rapid Assessment for Early 20 th Century Stacked Log Structures	46
Survey Preparation	46
Creating the Final Survey	48

Chapter 7: Assessment Protocol	51
Purpose of the Procedure	51
Scope of the Procedure	51
Items Needed to Complete the Survey	51
Pre-survey Documentation	52
Field Survey	53
Assigning a Score	57
Meaning of the Score	65
Repeatability of the Displacement Survey	67
Chapter 8: Recommendations and Conclusions	68
Use Recommendations	68
Possible Modification Recommendations	68
Field Verification Recommendations	69
Other Conclusions	70
Bibliography	73
Appendix A: Figures	77
Appendix B: Illustrations	93
Appendix C: Maps	104
Appendix D: Wood Sample Identification	107
Appendix E: Blank Site Visit Documents	109
Appendix F: Completed Site Visit Documents	117
Appendix G: Displacement Field Survey Documents	132
Appendix H: Displacement Survey Example	136
Appendix J: Glossary	148
Index	151

List of Figures

Figure 1: Swedish Granary in Greenwich, NJ, circa 1664-1684 (Author)	78
Figure 2: Scribe-fit log construction (R. Chambers, www.logbuilding.org)	78
Figure 3: Chinked-style log construction, Bar BC Ranch, circa 1912 (Author)	79
Figure 4: Lean-to Navajo hogon, circa 11th century (Nabokov & Easton, 329)	79
Figure 6: Stacked log barn on Mormon Row, Grand Teton National Park, circa 1913 (R. Beckman)	80
Figure 5: Navajo female, horizontal stacked log hogon, circa 1880 (Nabokov & Easton, 330)	80
Figure 7: Pinned lock joint corner, circa 1889 (Wicks, 14)	81
Figure 8: Entrance of Old Faithful Inn, circa 1903 (NPS Photo by JP Clum Lantern)	81
Figure 9: Excerpt from Oliver Kemp's <i>Wilderness Homes</i> , 1908 (Kemp, 49)	82
Figure 10: Privy and comfort station in Yosemite National Park, circa 1930 (Good, 141)	83
Figure 11: Northeast entrance to Yellowstone National Park, circa 1935 (Good, 29)	83
Figure 12: Detail of modern through-pins (Montana Log Homes)	84
Figure 13: Detail of modern tongue-in-groove members with gasketing (Coventry Log Homes)	85
Figure 14: 1939 Sears, Roebuck and Co. ad for stacked log cabin kit (Sears Archives)	86
Figure 15: Section of a modernized stacked log structure from the Alaska Log Building Construction Guide (ILBA, 41)	87
Figure 16: Photograph of Timbered Island looking north (Author)	88
Figure 17: Eccentric snow load (Author)	88
Figure 18: Weathering process of wood (Wood Handbook, 16-11)	89
Figure 19: Exposed purlin end that has decayed (Author)	89
Figure 20: Evidence of removed fireplace (Author)	90
Figure 21: Failure of a porch located on the eave end of the stack (Author)	90
Figure 22: Deciduous tree within close proximity of a stacked log structure (Author)	91
Figure 23: Coniferous tree within close proximity of a stacked log structure (Author)	91
Figure 24: Tree with overhanging branches (Author)	92
Figure 25: Stagecoach building outside of Hot Sulphur Springs, CO (Author)	92

List of Illustrations

Illustration 1: Members of a stacked log structure (Author)	94
Illustration 2: Typical load path of a stacked log structure (Author)	95
Illustration 3: Gable end racking (Author)	96
Illustration 4: Eave end racking (Author)	96
Illustration 5: Out-of-plane member rotation (Author)	97
Illustration 6: Compromised Corner (Author)	97
Illustration 7: Elevation labels for structure with front door on a gable end (Author)	98
Illustration 8: Elevation labels for structure with front door on an eave end (Author)	98
Illustration 9: Drainage directions (Author)	99
Illustration 10: Length measurement in displacement survey (Author)	99
Illustration 11: Width measurement in displacement survey (Author)	100
Illustration 12: Corner height measurement in displacement survey (Author)	100
Illustration 13: Gable height measurement in displacement survey (Author)	101
Illustration 14: Racking measurements in displacement survey (Author)	101
Illustration 15: Distance between an opening and the nearest corner (Author)	102
Illustration 16: Log count in displacement survey (Author)	102
Illustration 17: Midspan member displacement (Author)	103

List of Maps

Map 1: Bar BC Ranch site map (Historic American Building Survey) *Not to scale	105
Map 2: Relationship of Timbered Island to the Bar BC Ranch, Scale - 1:24,000 (USGS)	106

Chapter 1: Introduction

Scattered across the United States are remnants of homes and structures of the people that came before. As the settlers moved westward from the Atlantic Coast, new buildings had to be quickly assembled to provide one of the necessities of life: shelter. Since settlers were either unsure of how long they would be in the area or limited by the amount of time left to build before the onset of winter, they constructed relatively expedient buildings that were made of locally accessible materials. The abundance of tall timber and ease of the construction process that used whole tree trunks prompted the popularity of stacked log structures among pioneers. This type of building became engrained in the typical notion of pioneering American life and, later on, cowboy culture.¹ Eventually, landowners built stacked log structures purely because of the romantic and aesthetic association with western settlement, pioneering, and the cowboy lifestyle. This was the case with the dude ranches of the Rocky Mountains of the early 20th century, which catered to Eastern aristocrats, who would pay to come west in summer to experience life as a western cowboy.

As stacked log structures age and are abandoned, they begin to deteriorate and displace in ways that differ from more conventional post and beam, balloon-framed, or stud-framed wood structures. As of late, not many engineers have published research on stacked log structures. But they are a part of the American built heritage that deserve some attention and care because of the propensity of stacked log structures to destabilize and structurally fail. This thesis examines the unique character of stacked log buildings as structural systems and proposes a survey protocol to assess the condition of and risks associated with stacked log cabins.

The survey protocol in this thesis is intended to be rapidly applied and contains a quantification of the risks for further comparison. The associated risk severity ratings can be used not only to compare different structures with each other, but also to compare the condition of a singular building over time to determine the effectiveness of a treatment or lack thereof. With such a tool, site stewards will be able to prioritize the stacked log cabins within any one

¹ Bruce D. Bomberger, "Preservation Brief 26: The Preservation and Repair of Historic Log Buildings" (Washington DC: National Park Service, U.S. Department of the Interior, 1991).

area for the purposes of creating a conservation plan for that particular area without having to call in a professional engineer.

The survey protocol in this thesis is based on a case study of the Bar BC Ranch located in Grand Teton National Park of northwestern Wyoming. The Bar BC was created in 1911 by Struthers Burt and Dr. Horace Carncross as a dude ranch. In his autobiography *The Diary of a Dude-Wrangler*, Burt explains why they chose the site and how they decided to lay out the buildings in the area (Appendix C – Map 1).² It was run as a dude ranch until the 1940s and housed summer visitors up into the late 1970s, until it was deeded to the National Park Service (NPS) in the 1980s.³ Since NPS acquisition, the Bar BC has been vacant; not many people visit the ranch on a yearly basis presumably due to its remote location. Some efforts have been made to stabilize the remaining structures on the site, especially after the completion of a Historic Structures Report of the ranch in 1993, yet most of the buildings lack adequate maintenance to provide for their survival.

An interesting environmental factor associated with the Bar BC Ranch is the snow load that comes with being located in a mountainous region. According to the Teton County Building Code, the 50-year design snow load in the area is 175 pounds per square foot, which is significant compared to most other locations such as Philadelphia at 25 pounds per square foot.⁴ For this reason, this analysis pays special attention to the snow load applied to the stacked log structures and how that load has possibly changed over the lifetime of the buildings because of climate change. The snow load and structural performance appear to be significant factors that lead to failure and loss of these structures so it is important that buildings in cold regions be examined in winter conditions, not just when they are easy to get to.

² Maxwell Struthers Burt, *The Diary of a Dude Wrangler* (New York: C. Scribner's Sons, 1924), 94-95.

³ Roy Eugene Graham, *Bar BC Dude Ranch Grand Teton National Park, Wyoming*, Historic Structures Report (Washington DC: National Park Service, U.S. Department of the Interior, 1993), 28-29.

⁴ Teton County, Wyoming, "Code Amendments," last modified 2012, accessed November 2, 2012, <http://www.tetonwyo.org/pdbldg/topics/building-electrical-and-fire-code-amendments-and-resolutions/201935/>; City of Philadelphia Department of Licenses and Inspections, "Structural Design Criteria: Philadelphia Building Code," last modified August 2012, accessed November 2, 2012, https://business.phila.gov/Documents/Permits/structural_design_criteria.pdf.

Recently the cultural resource staff of Grand Teton National Park have shown great interest in saving portions of the Bar BC dude ranch, especially since it is one of the oldest remaining ranches in the area. With the help of these stewards and this new condition and risk assessment protocol, the essence of the ranch can be preserved.

This thesis defines a stacked log structure as a building constructed of logs stacked vertically with perpendicular walls at either end of each member, creating four engaged corners, and capped with a purlin roof assembly. After a brief introduction to the history of stacked log structures in the United States, this analysis will explore the structural system of a typical stacked log structure including the typical loads applied at different points in the building and their resultant load paths. Next, this thesis will examine the causes and indicators of structural pathologies associated with stacked log structures. A review of the types of assessment methodologies currently available precedes the development methodology of the assessment protocol created for this thesis. Then, the proposed condition and risk assessment survey protocol is introduced. The survey protocol includes an explanation of the components that can be used in the field. Finally, possible areas of further exploration are presented as well as other conclusions.

Hopefully this protocol will provide stewards of stacked log structures across the country with a useful, informative, and cost effective tool to monitor the buildings with this rapid and repeatable assessment protocol to create appropriate conservation solutions for these buildings.

Chapter 2: Stacked Log Structures in the United States

A fundamental impetus behind choosing to build a stacked log structure versus other types of construction is the necessity for rapid erection of temporary shelter since the envelope and the structural system are one in the same. The differences in completed stacked log structures result from end use, geographical location, cost, aesthetics, and more recently, manufacturing technology. Some stacked log structures are refined and clean cut which require the involvement of an experienced craftsman during construction, therefore demanding more time, effort, and money. Yet others are made of undressed logs and connected by roughly cut corner notches with variable chinking heights, a structure that can be quickly and cheaply put together by any landowner. Over the last several centuries in the United States, log structures evolved from first-build structures to sophisticated buildings with accompanying codes.

Early European and Native American Predecessors

The possible precedents for stacked log structures found in the western United States include horizontally stacked log buildings of European settlers as well as those of the Native Americans. Horizontally stacked log structures first appeared in the New World in the mid 17th century in an area known as New Sweden, now in Pennsylvania.¹ It was the Swedish, not the English, French, or Dutch, that brought the first version of stacked log construction to their settlement on the Delaware Bay (Appendix A – Figure 1).² The Swedish population was small at the time and by the late 17th century, the influx of German settlers surpassed that of the Swedes. As a result, stacked log construction was actually propagated by the German and Swiss settlers, later to be known as the Pennsylvania Dutch.³ This large group brought with them their expertise in wood construction from the Europe, which could be adapted nicely to the forested New World.⁴ Settlers built one room, one-story log homes as well as a variety of other types of

¹ Mary Wilson et al., "Log Cabin Studies: The Rocky Mountain Cabin, Log Cabin Technology and Typology, Log Cabin Technology and typology, Log Cabin Bibliography," *Forestry*, paper 4 (1984), http://digitalcommons.usu.edu/govdocs_forest/4/.

² Ibid., 5.

³ Ibid., 6.

⁴ Ibid.

structures including stables and other outbuildings, schoolhouses, churches, courthouses, and jails.⁵

Generally there were two typical joining techniques used from this point to the middle of the 19th century: scribe-fit or chinked-style.⁶ In scribe-fit log structures, the logs fit snugly together because a long, cut groove runs the length of each piece at the intersecting face (Appendix A – Figure 2).⁷ Log scribing had been used in America as early as the Swedish settlement on the Delaware Bay in the 1630s.⁸ When the logs are not scribe-fit, there will be gaps between the stacked logs since the log surfaces are uneven. To keep the weather and water out of the interior of the building, the gaps were filled with chinking made of saplings or twigs cut into quarters, clay, moss, or lime early on and eventually shifted towards cement or synthetic materials such as caulk in later years (Appendix A – Figure 3).⁹

Although Native Americans did not adopt horizontal stacked log construction techniques into their repertoire until after the European settlers came to the New World, most Native American peoples used locally available wood species to build shelter and sacred spaces for centuries.¹⁰ Native American architecture has typically been based on locally available materials, climate, means of subsistence, and belief systems of the tribe.¹¹ These migratory people would construct temporary buildings using a variety of materials, but many tribes employed wood or logs configured in tribe-specific formations that had spiritual meaning. For example, the Navajo of the southwestern United States used forked logs to construct conical, lean-to hogons which varied in size depending on the use (Appendix A – Figure 4). Spiritual sweatlodges were typically large enough to house one human sitting down while family dwellings had a larger circular

⁵ C.A. Weslager, *The Log Cabin in America: From Pioneer Days to the Present* (New Brunswick, NJ: Rutgers University Press, 1969), 316.

⁶ Edward Allen and Rob Thallon, *Fundamentals of Residential Construction* (Hoboken, NJ: Wiley, 2006), 517.

⁷ Robert W. Chambers, *Log Construction Manual* (River Falls, WI: Deep Stream Press, 2003), 8.

⁸ Wilson, 5.

⁹ Chambers, 9; Harrison Goodall and Renee Friedman, *Log Structures: Preservation and Problem Solving* (Nashville: American Association for State and Local History, 1980), 103.

¹⁰ Peter Nabokov and Robert Easton, *Native American Architecture* (New York: Oxford University Press, 1989), 333, 86.

¹¹ Carol Herselle Krinsky, *Contemporary Native American Architecture* (New York: Oxford University Press, 1996), 10.

footprint of 25 to 30 feet.¹² With the help of the whole community, the Native Americans could erect these log structures rapidly.¹³ Settlers may have seen the advantages of these Native American structures, such as rapid construction times, ease of assembly, and temporary nature, which made stacked log buildings even more appealing.

The first Native American group to incorporate horizontal stacked logs into their construction techniques was the Delaware Indians from the Delaware Bay. Influenced by the Swedish immigrants of the area who were the first to bring horizontal stacked log construction from Europe, the Delaware built the Big House measuring 25 feet wide, 40 feet long, and 18 feet high at the ridgepole.¹⁴ Not many other Native American peoples adopted stacked log techniques until pioneers started travelling west in the late 19th century. Then, traditional Native American structure forms began to morph to incorporate this construction technique like the Navajo female version of a hogon (Appendix A – Figure 5).¹⁵

Western Frontier and Expansion

As pioneers traveled westward through the late 19th century, variations of stacked log buildings were employed to provide temporary shelter depending on the locally available materials. According to Frederick Jackson Turner, there were three types of western pioneers. Typically the earliest pioneers would construct a temporary one-room stacked log cabin and sometimes a stable or another type of outbuilding on soil that they did not own before moving on a year or two later. The next wave of pioneers would improve these stacked log structures by adding glass windows and expanding the floor plans after purchasing the land. These second-wave pioneers would add newer and larger outbuildings, sometimes made of stacked logs, like the large agricultural barns found at Mormon Row just north of Jackson, Wyoming (Appendix A – Figure 6). The last wave of emigrants would abandon stacked log structures for larger, more sophisticated, and durable buildings. By the time the third group arrived at a location, the early

¹² Nabokov, 38; Michael Joseph Shoriak, “Nondestructive monitoring of wooden Native American pyramidal structures,” M.S. thesis, University of Pennsylvania, 2012, 16.

¹³ Nabokov, 327-329.

¹⁴ Nabokov, 88.

¹⁵ Nabokov, 330, 333.

pioneers had moved farther west and started the process all over again.¹⁶

By the mid 19th century, balloon-framed construction surpassed log construction in settled portions of the country because of two technological developments: machine-sawn dimensional lumber and machine-made nails¹⁷. In the 1870s, the Great Camp Movement started in the Adirondacks of northern New York and was characterized by aesthetically rustic but comfortable and even luxurious interior designs built of native timbers. To achieve the desired aesthetics of these new designs, new construction techniques like pinning tiers of logs to allow for horizontal continuity across corners were introduced in the mid 19th century (Appendix A – Figure 7).¹⁸ This rustic revival style moved westward through the 1920s and revitalized the use of stacked log construction, culminating in the construction of Old Faithful Inn in Yellowstone National Park in 1903.¹⁹ 700 feet in length and seven stories tall, the hotel was a real tour-de-force in exploring and exposing the capabilities of stacked log construction (Appendix A – Figure 8).²⁰

Cowboy Construction

With the westward expansion of the Great Camp Movement came the advent of dude ranching. Starting in the early 1890s, Easterners would travel west by train to camps located throughout the Rocky Mountains to spend two to four months during the summer as a dude, dudene, or dudelet.²¹ During the day the visitors would fish, hike, hunt, or ride horses. During the evenings they would eat and socialize in the large main cabin then retire to individual sleeping cabins, typically 200 feet square. Since the ranches were only inhabited during the summer months when the weather was pleasant, it was not imperative to make the buildings

¹⁶ Frederick Jackson Turner, *The Frontier in American History* (New York: Henry Holt and Company, 1921), 20-21.

¹⁷ Mark Gelernter, *A History of American Architecture: Buildings in their Cultural and Technological Context* (Hanover: University Press of New England, 1999), 157.

¹⁸ William S. Wicks, *Log Cabins: How to Build and Furnish Them* (New York: Forest and Stream, 1889), 14.

¹⁹ Harvey H. Kaiser, *Great Camps of the Adirondacks* (Boston: D.R. Godine, 1982), xii-xiii.

²⁰ "Old Faithful Area Historic Highlights," Yellowstone, National Park Service, accessed February 27, 2013, <http://www.nps.gov/yell/planyourvisit/holdfaith.htm>.

²¹ Maxwell Struthers Burt, *The Diary of a Dude Wrangler* (New York: C. Scribner's Sons, 1924), 60.

weather tight.

To achieve the romantic, rustic appeal associated with the Great Camp Movement, the ranch buildings were constructed using so-called “cowboy construction.”²² Cowboy construction was a rough method of assembly or building erection that was employed when time or money was limited, or if the owners wanted a rustic aesthetic.²³ Locally gathered materials, roughly dressed and unscribed logs, and ease of erection characterized the technique.

Almost all of the materials used to create stacked log structures using cowboy construction techniques were gathered within the vicinity of the chosen building site. Generally, the builders felled trees for logs either on the site or nearby, minimizing the necessary transportation. Twigs from the felled trees could be used as chinking. By the 1910s, the few materials that could not be found at the site, like nails and necessary tools, could be ordered from catalogs produced by department stores and mail-order warehouses, and conveniently delivered to the site for construction.²⁴

For structures erected in the cowboy construction style, most of the bark was left on the trees once they were felled. Roughly hewn logs eliminated the time and cost involved with stripping the bark off each of the logs. Another technique used by the owners was the use of chinking rather than scribing the logs. Even with the use of chinking, cowboy construction structures did not provide airtight shelter.

It did not take an expert to build a stacked log structure in a cowboy construction manner. Since part of the aesthetic appeal was the roughness, it was easy to pick up a manual, like *Log Cabins and Cottages: How to Build and Furnish them* by William Wicks in written in 1889 or *Wilderness Homes* written by Oliver Kemp in 1908, and build a stable cabin (Appendix A – Figure 9).²⁵ In 1903, *Forest and Stream* magazine was selling Wicks’ book for merely \$1.50.²⁶ This accessible and non-expert aspect of cowboy construction was beneficial in remote areas.

²² Roy Eugene Graham, *Bar BC Dude Ranch Grand Teton National Park, Wyoming*, Historic Structures Report (Washington DC: National Park Service, U.S. Department of the Interior, 1993),9.

²³ Ibid., 10.

²⁴ Burt, 89.

²⁵ Oliver Kemp, *Wilderness Homes: A Book of the Log Cabin* (New York: Outing, 1908), ix; Wicks.

²⁶ “Log Cabins and Cottages; How to Build and Furnish Them – an ad,” *Forest and Stream* 16 (1903), v.

Parkitecture and the Civilian Conservation Corps

Once most of the western United States had been settled by the last quarter of the 19th century, some Americans began to see a need to protect extraordinary landscapes from development and exploitation for future generations. In 1872 Yellowstone was instated as the first National Park in America. Over the following 40 years seven new parks were created which drew visitors from all over the country by train. To monitor and tend to all of the visitors, several different government agencies administered different tasks, which made for a disjointed operation.²⁷ To have a unified manager, the National Park Service was created in 1916.

The organizations and governmental institutions invested in creating a national park service were interested in making sure that any necessary buildings fit in with the landscapes of each location. To achieve this initiative, the first Statement of Policy required that any building or other man-made structure constructed in a national park must harmonize with its surroundings.²⁸ For most national parks in the western United States, logs were readily available and the popular rustic style, born from the Great Camp Movement of the 1870s, was a good aesthetic fit. For these reasons stacked log structures were created in a range of sizes from privies (Appendix A – Figure 10) and staff cabins to entrance stations (Appendix A – Figure 11) and visitor centers.²⁹

The NPS's architectural repertoire was well developed by the early 1930s when the Great Depression set in. As part of the New Deal and the Emergency Conservation Work act, the NPS was charged with supervising young men in the Civilian Conservation Corps and put them to work building new structures in the parks consistent with the Statement of Policy, most of which were stacked log structures built in what was now known as the "rustic style" or

²⁷ James F. Kieley, "Early Growth and Administration" in *A Brief History of the National Park Service* (Washington DC: United States Department of the Interior, 1940) http://www.cr.nps.gov/history/online_books/kieley/; James F. Kieley, "National Park Service Created" in *A Brief History of the National Park Service* (Washington DC: United States Department of the Interior, 1940) http://www.cr.nps.gov/history/online_books/kieley/.

²⁸ Laura Harrison, "Introductory Essay" in *Architecture in the Parks: A National Historic Landmark theme Study*. (Washington DC: United States Department of the Interior, 1987) http://www.nps.gov/history/history/online_books/harrison/harrison0.htm.

²⁹ Albert H. Good, *Parks and Recreation Structures* (Washington DC: National Government Printing Office, 1938), 2-3.

“parkitecture.” During World War II, most construction in the parks ceased and after the war, preferred aesthetics for these public buildings shifted away from the rustic style and stacked log structures.³⁰

WWII to Today

Residential stacked log construction continued to gain popularity past World War II and into the 1970s with the spread of the log structure market across the United States.³¹ This widespread popularity was fueled by the need of new housing for soldiers returning from World War II and their new families.³² Because more money was readily available to construct new houses, more reliable and less costly transportation methods were available, and assembly line manufacturing processes were being perfected, new construction methods of stacked log structures with more refined aesthetics than those associated with cowboy construction were possible. Whether a pre-manufactured kit or custom log building, new technological developments, like the addition of long through-pins and lag screws (Appendix A – Figure 12), allowed for larger buildings than were previously possible.³³

One major change in stacked log construction was the introduction of the manufactured kit of hewn and notched logs that were site assembled. Manufacturers, such as Sears, Roebuck and Company, acquired large scale shipments of logs, shaped them, packaged the basic parts of the kit, and sold them to willing property owners to erect on their land similar to the popular toy, Lincoln Logs.³⁴ A significant difference between the manufactured kits and site built construction used in the past was the pre-shaped logs. Each member was planed to the exact same profile so that the logs would fit snugly together with tongue-in-groove connections with gaskets in the

³⁰ Harrison.

³¹ John “Buddy” Showalter and Rob Pickett, “ICC Standard on Log Construction: ICC/ANSI 400-2005,” *Structure Magazine* (March 2006), 14.

³² Gelernter, 262.

³³ Randy J. Scott, “Lateral Force Resisting Pathways in Log Structures,” M.S. thesis, Oregon State University, 2003, 2.

³⁴ Charles George Ramsey, Harold Reeve Sleeper, and John Ray Hoke, *Architectural Graphic Standards* (New York: John Wiley & Sons, 2000), 348; “What is a Sears Modern Home?” Sears Archives, accessed March 1, 2013, <http://www.searsarchives.com/homes/index.htm>.

joints to allow for expansion and contraction (Appendix A – Figure 13).³⁵ The “Nipigon” model log kit home prepared by Sears, Roebuck and Company was one story and about 750 square feet in area (Appendix A – Figure 14).³⁶ Not only did the kits increase the ease of construction but it also allowed landowners to erect stacked log structures in areas that may not have enough local materials to build one from scratch.

If a homeowner wanted a more elaborate building than could be achieved by using a kit home, they could hire an architect to help them create a custom stacked log home. This option allowed the homeowner to choose the dimensions and layout of the final structure, however it was much more expensive than buying a pre-fabricated log home kit. Not only would the landowner have to hire a designer, but also custom milling and shaping of the logs required a professional carpenter with experience in the field.

If the homeowner wished to avoid the cost of a designer, they could choose to design and possibly build the structure themselves. Different organizations began producing commercially available construction guides that outlined not only how to build a stacked log building, but also the necessary materials and tools, all in accordance with typical building codes and standards. One such example is called the Alaska Log Building Construction Guide created by the International Log Builders Association. This manual walks through the entire process of construction as well as other activities such as retrofitting existing stacked log structures to introduce modern amenities such as modern heating stoves, wall insulation, vapor barriers, and gaskets between the logs (Appendix A – Figure 15).³⁷ Creating a custom log home either with or without the help of a professional architect provided a homeowner the latitude to have a house of any size and arrange the structure according to his or her needs.

³⁵ Scott, 2.

³⁶ “Nipigon,” Sears Archives, accessed March 1, 2013, http://www.searsarchives.com/homes/images/1933-1940/1940_fairfield-nipigon.jpg.

³⁷ International Log Builders’ Association, *Alaska Log Building Construction Guide*, accessed November 1, 2012, <http://www.buildwise.org/library/construction/log-construction/log-construction-guide.htm>.

The Standards and Manuals

By the 1970s, Architects and engineers found it difficult to conform these buildings to existing codes that were created for conventional wood framed structures, so select professionals began creating standards for stacked log structures, which were not officially instated until the 1990s and 2000s.³⁸ The professionals recognized the need for a specialized document that would account for the unique properties of stacked log construction such as structural loading, keeping the building weather-tight, and typical details to avoid decay. Today there are a few organizations that lead the way in maintaining and updating these standards as time goes on.

The first major attempt at standardizing the design of stacked log structures in North America came in 1976 when members of the American Log Builders' Association (later to merge with the Canadian Log Builders' Association to become what is now known as the International Log Builders' Association) created a task force focused on creating the first set of standards.³⁹ These prescriptive standards are user friendly and updated every few years, but they are not considered a consensus document since they are not applicable to any type of construction other than residential buildings.

The next attempt to create a more universal standard regarding stacked log buildings came in 1980 with the installation of ASTM 3957 – Standard Methods for Establishing Stress Grades for Structural Members Used in Log Building. The Log Home Council, which was originally created to work towards creating standards for stacked log structures, funded the efforts to create the ASTM standard with the support of the International Log Builders' Association and other similar professional organizations.⁴⁰ ASTM 3957 covers the necessary procedures to grade an individual log or determine its structural capacity. Even after the acceptance of this standard, there were still no universally accepted design standards for stacked log structures, just scattered

³⁸ Showalter, 14.

³⁹ "40 Years of Log Building History," International Log Builders Association, accessed January 22, 2013, <http://www.logassociation.org/docs/ilba-40-years.pdf>, 1; ASTM International, *Standard Practices for Establishing Stress Grades for Structural Members Used in Log Buildings*, ASTM D3957-09, West Conshohocken, PA: ASTM, 2009, 1.

⁴⁰ Showalter, 14.

journal articles.

Finally in 2002, members of the International Code Council applied to the American National Standards Institute in order to create a set of universally accepted standards for the design and construction of stacked log structures. With several years of development and review, in 2005 ICC/ANSI 400 – Standard on the Design and Construction of Log Structures was published. Based on the American Forest and Paper Association’s publication *Wood Frame Construction Manual for One and Two Story Dwellings*, this standard lays out code compliance for stacked log structures based on three paths (prescriptive, engineered, and test paths) and describes administrative provisions, definitions, general requirements, and structural provisions.⁴¹ Now architects, engineers, and contractors have specific standardized guidelines that help their stacked log designs fit within accepted codes.

The Bar BC Dude Ranch

To achieve the rustic notions associated with dude ranching within the short amount of time allowed to construct the buildings at the Bar BC Ranch, the owners, Maxwell Struthers Burt and Horace Carncross, used several techniques to construct the buildings on the ranch that exemplify cowboy construction. These techniques included gathering the materials near the site, not dressing or altering the logs along their length, and constructing the buildings without much previous experience.

In the case of the Bar BC Ranch, it is believed that the wood for the stacked log structures came from a knob of trees located about half a mile above the site called Timbered Island.⁴² This source of timber makes sense because the lumberjacks would have been able to fell the trees and easily transport the felled logs down the two bents or plateaus to the site by using crude wagons or by floating them down the Snake River (Appendix C – Map 2 & Appendix A – Figure 16). This hypothesis is supported by the fact that most of the logs used on the site and

⁴¹ Showalter, 14.

⁴² Roy Eugene Graham, “Bar B-C Dude Ranch Cultural Landscape Study,” in *Bar BC Dude Ranch Grand Teton National Park, Wyoming*, Historic Structures Report (Washington DC: National Park Service, U.S. Department of the Interior, 1993), 12.

many of the trees on Timbered Island are Lodgepole pine.⁴³ Other materials used in the buildings at the Bar BC that most likely came from the site include the quarter saplings and clay used for chinking and the river rocks used to construct some of the fireplaces and foundations at the ranch.

The stacked log buildings at the Bar BC are constructed of undressed logs that are not scribed, leaving some air gaps between the logs. Since the ranch was primarily meant as a summer retreat and not as a winter residence, Burt and Carncross obviously accepted the fact that exterior air would infiltrate but not lower the comfort level of the guests beyond a reasonable temperature with average temperatures in the summer between 40 ° F at night and 77 ° F during the day.⁴⁴

The ease of erection associated with the cowboy construction technique provided a great option of building for remote locations such as Jackson, Wyoming. Although Burt mentioned that several knowledgeable craftsmen came up from town to help construct the first buildings on the site in May and June of 1912, Burt, Carncross, and their ranch hands, none of whom were expertly trained in carpentry or construction, built the rest of the buildings before the first guests arrived in July.⁴⁵

Cowboy construction proved to be a great option for the stacked log structures at the Bar BC Ranch. Not only could the owners quickly erect the necessary structures, but also they achieved a rustic and romantic aesthetic which was part of the appeal to wealthy easterners of spending a summer at a dude ranch in the west.

⁴³ Alex C. Wiedenhoeft, letter to the author, February 21, 2013. (Copy of letter found in Appendix D)

⁴⁴ "Moose, Wyoming," Western Regional Climate Center, accessed November 1, 2012, <http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy6428>.

⁴⁵ Burt, 88.

Chapter 3: Early 20th Century Stacked Log Buildings as Structural Systems

This chapter presents how early 20th century stacked log buildings were constructed and how they dissipate structural loads. By understanding the construction sequence or a description of a typical stacked log structure from the ground up and the types of loads applied to them, it is easier to understand how these buildings transfer loads along their members and connections to the earth. The loads that the stacked log buildings must transfer include dead loads, live loads, moisture loads, and environmental loads. Although most of these loads vary only minimally, environmental loads are being affected by climate change, a fact that must be considered when choosing a plan of action regarding the future of particular stacked log buildings like those at the Bar BC Ranch in Grand Teton National Park.

Construction Sequence

Oliver Kemp's *Wilderness Homes* represents only one of many construction sequence variations that were used across the country in the early 20th century.¹ Illustration 1 in Appendix B displays the member locations and names mentioned in the proceeding narrative that is based on Kemp's book.

After determining the appropriate site, the owner would gather the necessary materials to construct the building such as the logs and nails, as well as the tools needed to shape the materials or secure them in place. To accommodate the structure, the builders dug a shallow hole with dimensions slightly larger than the footprint of the desired structure. Some stacked log structures have continuous perimeter footings while others simply have piers that extend into the earth or foundation pads placed under the corners. While the piers are typically wood in early 20th century stacked log structures, now they can be constructed of poured concrete. The footings and foundation pads could have been made of site-mixed concrete, masonry, or stacked local stones. All of these foundation elements were used to elevate the sill and spandrel logs off of the ground to promote ventilation and drying beneath the building.

¹ Oliver Kemp, *Wilderness Homes: A Book of the Log Cabin* (New York: Outing, 1908), 43-72.

The lowest logs laid on the stack are known as the sill logs. Sill logs of opposite walls were laid parallel to each other, separated by a distance of the width of the building. Corner notches were axed into either end of both sill logs to receive the two spandrel logs, perpendicular to the sill logs and half a unit up due to the corner notching. The sill and spandrel logs were not prescribed to be placed specifically on either the gable or eave wall so both conditions exist. Logs were stacked in this manner until the desired height of the eave walls was reached. The top logs on the eave ends of the structure were known as the plate logs and functioned as the lowest flanking purlin, so they usually extended beyond the stack on the gable ends to support the roof eaves on the gable end. Openings for windows and doors were only cut once the stack was completed in order to maintain lateral stability of the stack during construction.

The engagement of the corners of the stacked log structure was critical and a secure connection at these points could be achieved using several different techniques including tenant or square notches, dovetail notches, reverse saddle notches, and interlocking corners. Tenant or square notches were created by shaving off portions of the ends of each log so that a cube was formed. During construction the cubes were stacked on top of each other in alternate directions. Dovetail notches were similar to tenant notches but rather than square cubes, a fan-shaped wedge was cut into the ends of the members, which when laid locked together and provided even more stability². Reverse saddle notches involved chopping a notch into the bottom of the end of each log so that it fits snug against the log directly below. Interlocking corners were similar but notches were cut on both the bottom and the top of each end of each member.³ All of the aforementioned corner connections are structurally stable because the connections between logs are built into the members themselves and do not rely on other elements such as nails. Box and post and box with no post corner conditions are not considered stacked log assemblies for this analysis because both cases involve toenailing or inserting a nail from an angle through a corner box created by two perpendicular vertical planks, into the ends of the logs. Neither corner type is laterally engaged by the log members.

² "The Building Process: How Log Homes are Built," *Log Home Living* 14, no. 9 (1997), 89. 82-97

³ Ibid.

Progressively shorter logs were stacked creating the pitch of the roof to build up the gable ends. As these logs were stacked, the intermediate mid-slope purlins were incorporated into the gable end at the appropriate points. Erection of the gable ends terminated with placement of the ridgepole at the peak of the gable ends. Sheathing boards parallel to the slope were nailed into the purlins enclosing the interior of the building. The sheathing was clad in either roofing tarpaper or sod.

If the building had a raised floor, joists were laid across the structure from sill to sill or spandrel to spandrel. The flooring could then be nailed into this structural grid. If the building did not have a raised floor, the boards were laid directly on the soil.

Loads Applied to Structures

All structures are subject to dead, live, and environmental loads. Unfortunately, it is difficult to find engineering research regarding structural design practices for stacked log structures.

Dead Load

Dead loads consist of the weight of all of the materials included in the final structure. In the case of stacked log structures this load would include the logs used to form the walls, roof purlins, roof sheathing, finished roof material such as sod roofs, flooring, and any stones, concrete, or masonry for chimneys, fireplaces, or foundations. Dead load remains relatively constant throughout the service life of a stacked log structure until materials are removed, but the actual load path can shift with member displacement. When the load path shifts, there is the possibility that loads will bear on a member that is not adequate to carry that load, overstressing those particular members which could lead to further displacement or even complete failure.

Live Load

Live loads consist of the weight of any moveable objects or occupants within the building. Usually live loads are on the floor but they can occur on the roof during reroofing and other maintenance tasks.

Environmental Loads

Environmental loads come from the surrounding environment specific to a building and within every geographical location there is typically a controlling environmental load that will take precedent over the others, although the other environmental loads cannot be ignored. Snow, wind, or earthquakes apply typical environmental loads. Fortunately there is some, if limited, literature about research completed on the response of stacked log structures with respect to wind and seismic forces. Unfortunately, there is little to none written about the effect of snow loads on log buildings, which is important for this analysis⁴.

Wind loads cannot be ignored when looking at early 20th century stacked log structures. As wind blows across the structure, it creates an air pressure gradient. The elevation of the building directly perpendicular to the direction of the wind is the windward side whereas the opposite elevation is the leeward side. The wind creates a positive pressure on the windward elevation and a negative pressure on the leeward elevation which means that the lateral forces that result from the pressures are additive in the direction of the wind. Not only to winds expose the stack of a structure to this lateral force, but the wind also creates the potential for uplift force. Since early 20th century stacked log structures are not airtight, the wind creates a negative pressure within the building, which can cause the roof assembly to lift. To resist the lateral and uplift forces caused by wind, the stack of the stacked log building must be laterally constrained and the roof of the building must be properly secured.

Little has been published on the effect of snow on heritage buildings.⁵ Most of the research efforts have focused on the scientific ways to determine the possible snow loads on any type of structure in a given location based on *ASCE7-10: Minimum Design Loads of Buildings and Other Structures* and the local governing codes. A majority of these studies have been published in journals produced by the American Society of Civil Engineers, specifically the *Journal of Performance of Constructed Facilities* and the *Journal of Cold Engineering Regions*. Because of the nature of these journals, the articles and studies are calculation heavy and are meant

⁴ J. Stanley Rabun, *Structural Analysis of Historic Buildings: Restoration, Preservation, and Adaptive Reuse Applications for Architects and Engineer*. (New York: Wiley, 2000), 40-45.

⁵ Ibid.

to inform other engineers in the field of how and why snow accumulates the way that it does around existing structures and how to predict that load. Perhaps the lack of knowledge specific to heritage buildings, particularly those that are not inhabited, can be attributed to the small amount of structures that fit this category of non-inhabited buildings subjected to large snow loads.

Design snow loads are determined by using a periodically updated publication of the American Society of Civil Engineers, *Minimum Design Loads for Buildings and Other Structures*. Chapter 7 specifically covers snow loads and the methods used to determine the applicable load in a certain geographical location. These provisions have been developed using an extreme-value statistical analysis to determine the highest snow load that could possibly occur unobstructed on the ground every 50 years.⁶ In other words, every year, there is a 2% chance that the actual ground snow load will exceed the design ground snow load.⁷ The codes also take into account the effects of wind and roof configuration on snow loads, including asymmetrical distribution of snow on the roof due to wind. There are also provisions included to translate the ground snow load to flat roof, sloped roof, unbalanced, drifted, and projection snow loads as well as sliding snow and rain on snow surcharges, but these concepts are beyond the scope of this research.

Climate Change and Environmental Loads

Although these factors should not be minimized, there is another phenomenon taking place that is changing what experts know about and how to mitigate the effects of these environmental loads: climate change. All buildings exist in an exterior environment and are affected by the climate of the location. Whether in the deserts of Arizona, the mountains of Wyoming, or the New Jersey coast, there are environmental factors and loads imposed on structures in those areas. These factors (such as wind, rain, or snow) produce risks that could affect the stability and health of historic buildings. The understanding of these environmental factors is ever progressing, yet climate changes are occurring and breaking the predictive models

⁶ *Minimum Design Loads on Buildings and Other Structures* (Reston, VA: American Society of Civil Engineers, 2002), 323.

⁷ *Ibid.*, 77

that have been experimentally and analytically created over the last century or so.

Some areas of the globe are experiencing warming trends, while others cooling trends, yet either way the cyclical loads applied to them are changing every year. Although research efforts have been launched over the last decade or two concerning climate change in general, preservationists are interested in determining the effects on cultural heritage. Most of the research that has been done on this topic is focused in Europe and, more specifically, the United Kingdom. These efforts were encouraged and advanced by an initiative by English Heritage in 2002 to determine the effects of climate change on cultural heritage and how to mitigate or reduce the risks associated with the changes.⁸ Since then, these initiatives have been taken on by other countries to mitigate these risks to cultural heritage. For example, in 2008, the United States government created the National Climate Change and Wildlife Science Center to explore the effects of climate change to help manage national resources.⁹

Moisture Loads

Although moisture loads are not considered a load in the structural sense, the affects that wetting and drying of the members have on the longevity of the wood are important to consider. Since early 20th century stacked log structures are not airtight and the builders did not install vapor barriers, moisture can easily enter and exit the building which is good because it allows for drying. But if features exist which inhibit the drying process such as build up of debris in splits of the log members or improper details meant to expel liquid water from the roofs, excess moisture can accrue and encourage fungal decay or insect infestations. If these conditions are allowed to thrive, the structural integrity of the members could be compromised.

Structural Load Paths of Stacked Log Buildings

For the structural system of any building to be effective, all of the loads must be transferred from the building to the ground by gravity through members that are able to handle

⁸ May Cassar, *Climate Change and the Historic Environment* (London: University College London, 2005), iii.

⁹ "Climate Change," U.S. Department of the Interior, accessed January 25, 2013, <http://www.doi.gov/whatwedo/climate/index.cfm>.

the forces. Determining the flow or path of these loads can help us understand not only how the structures are functioning now, but also how they were originally supposed to function. Knowing the load paths also can help by pointing out critical junctures and members of the structure so one knows where to look for potential damage.

For the purpose of explaining a typical load path, consider a stacked log structure that is in perfect condition with no displacement, vulnerabilities, or failure. It is easiest to think of load paths from a top down vertical approach because gravity is usually the reigning agent at work, except for some instances when uplift, overturning, and lateral loads come into play. Begin by looking at any environmental loads that may be spread on the roof of the structure. The force of these objects such as debris, snow, or ponding water, is then transferred to the roof deck of the building. In most cases these objects are resting directly on top of the finished roofing material, such as shingles. In some cases, there are installed sod or green roofs. The loads from the roofing materials are then transferred directly on to wood or plywood roof sheathing.

Next, the loads of the sheathing and everything above it are transferred to a series of purlins. These whole log members run from gable end to gable end with about a foot of overhang past the walls. Typically, the center purlin is known as the ridgepole because it creates a ridge at the highest point in the structure, while the purlins resting on the exterior walls of the structure are known as plate logs. The roof sheathing then transfers all of the loads above at the points where it touches the purlins. The purlins then transfer the cumulative load to the logs in the gable-ended walls that they are resting on at the points of contact. By nature, gable roofs thrust loads down and outwards from the ridgepole. The log supporting and spanning between the two plate logs provides restraint for this thrust load.

An important aspect of stacked log structures is that the logs are stacked one on top of the other. In modern structures the logs are planed for intimate contact and load transfer, however, in older, rustic structures, the logs may not have been worked so contact points may be random. In some cases, the only points of contact are at the corners of the structures where the logs are notched to fit together. Therefore, most of the load is transferred to these corner notches where they collect and are carried down to the bottom most logs, also known as the

sill or spandrel logs. But the rest of the load is transferred through the small points of contact that may occur along the lengths of the logs and the chinking closing the gaps. The stack of the building must also resist lateral loads from wind or earthquakes which can cause the building to overturn. The friction between the intimate corner notches and the rigidity provided by the four interconnected walls of the stack help the building resist lateral loads.

The flooring also transfers its loads to the sill logs. The decking which would provide a relatively uninterrupted surface to walk on would either be laid directly on the soil or on a series of joists that would rest either on the soil or the sill logs. Then, the loads are transferred to the foundations of the buildings which transfer them into the ground, where they are ultimately absorbed by and dissipated into the earth (Appendix B – Illustration 2).

Stacked Log Buildings at the Bar BC Ranch

Construction Sequence

Based on the evidence presented by the Bar BC buildings, a similar construction sequence to that found in Oliver Kemp's *Wilderness Homes* was most likely used to construct a majority of the buildings at the ranch with only several variations.¹⁰ Sod, or dirt and natural grasses, were originally installed on a handful of the structures at the Bar BC Ranch while others had roofs of sheathing and tarpaper.¹¹ To reinstate a modern version of the sod roofs, modern green roofs were installed on two of the cabins at the ranch during the fall of 2012.¹² The foundations of most of the stacked log structures at the Bar BC consist of pad foundations made of stacked river rocks or site-mixed concrete located under each corner of the building rather than continuous footings.

¹⁰ Kemp, 43-72.

¹¹ Roy Eugene Graham, *Bar BC Dude Ranch Grand Teton National Park, Wyoming*, Historic Structures Report, Washington DC: National Park Service, U.S. Department of the Interior, 1993, 41.

¹² For more information on the history of sod roofs as a precedent for modern day green roofs, as well as the designs and provisions for the green roofs installed at the Bar BC Ranch, see Jason Cantu's thesis: Richard Jason Cantu, "Green Roofs for Historic Buildings: Case Study of the Bar BC Dude Ranch at Grand Teton National Park," M.S. thesis, University of Pennsylvania, 2012.

Live Loads

For the stacked log structures at the Bar BC Ranch, the live loads were relatively small since only two to four people were meant to stay in each cabin. Therefore at any one time the live load would have been composed of the weight of two to four people, the furniture and furnishings to accommodate them, as well as their belongings. These live loads are even further reduced currently since all of the buildings are padlocked shut. There are stints of small applied live loads when maintenance crews, volunteers, or cultural resource staff are working with the buildings, particularly in the summer months.

Environmental Loads

The most influential environmental load at the Bar BC is due to snow. This area of the United States gets an average of fourteen feet of snow every year, the weight of which translates to a structural design load of 175 pounds per square foot.¹³ For comparison, the design snow load in Philadelphia, Pennsylvania is merely 25 pounds per square foot.¹⁴

During a site visit to the Bar BC Ranch in January of 2013, it was noticed that certain patterns of snow collection around the buildings corresponded with several factors including the predominant wind direction and orientation of the stacked log structures. Most of the drifts were associated with the dominant wind direction through the valley. The winds that come through the site usually flow from south to north making the south elevations of the buildings the windward sides and the north elevations the leeward sides. The size and shape of the drifts also depended on the orientation of the building in question. If the gable ends are perpendicular to the wind, there seems to be less of a snowdrift issue. When the gable ends of a building are parallel to the wind, many more potential issues arise. In these cases, the wind will blow the snow over the windward elevation of the building onto the leeward side where it will collect, creating an unbalanced snow load across the structure (Appendix A – Figure 17. This can be

¹³ Teton County, Wyoming, “Code Amendments,” last modified 2012, accessed November 2, 2012. <http://www.tetonwyo.org/pdbldg/topics/building-electrical-and-fire-code-amendments-and-resolutions/201935/>, 7.

¹⁴ *Minimum Design Loads*, 82-83; City of Philadelphia Department of Licenses and Inspections, “Structural Design Criteria: Philadelphia Building Code,” last modified August 2012, accessed November 2, 2012, https://business.phila.gov/Documents/Permits/structural_design_criteria.pdf.

harmful because structural members could be overloaded causing settlement, displacement, or even failure. Another ill effect of this phenomenon is the potential of trapping moisture from melting snow against the logs of the structure. This can be harmful because it encourages rot in the wood which could eventually turn into a structural issue.

Climate Change and the Environment

In the case of the Bar BC Ranch, the snow loads have changed dramatically over the life span of the site. There are accounts of winter guests having to dig a series of tunnels between the buildings that were occupied during the winter months just to get from one to the other.¹⁵ In comparison, there was approximately one and a half feet of snow on the ground in January of 2013. Until this winter site visit in 2013, no one with the express purpose of observing the site in winter conditions had visited the Bar BC, but some trends have been recognized in research done in other locations. One study in Europe found that there has actually been an increase in snow loads in their locations of interest that may correspond with rising temperatures.¹⁶ But this study also recognizes that no extensive research has gone into determining the exact effects of climate change on snow load or if there even are some. Either way, the amount of snow that falls and collects is dependent on many factors that have been proven to be shifting with climate change like temperatures, precipitation, or jet stream patterns.

Yet based on the personal account of relatively heavy snow loads at the site during its early years compared to the much smaller ones of today, as well as the lower frequency of building collapse as more seasons pass, the snow loads at the Bar BC have decreased since the site was established. These structures are no longer subjected to the larger snow loads that they were during the early years of their lifespan. Although there were 100 buildings on the site at one point and now only 36 remain, the remaining structures have weathered larger structural loads in the past and should be able to handle the ones in the near future if climate change continues on its path. For this reason, the snow load is not a major threat to these remaining

¹⁵ Graham, 239.

¹⁶ Raphael D.J.M. Steenbergen, Chris P.W. Geurts, and Carine A. van Bentum, "Climate change and its impact on structural safety," *HERON* 54, no. 1 (2009), 22.

structures. They have been resilient thus far and will continue to be if nothing changes. This does not mean that maintenance on these buildings can cease. There are other methods of deterioration that are occurring that require monitoring procedures of their structural health and the climate changes occurring so that no critical heritage is lost to destruction.

Chapter 4: Structural Pathologies of Early 20th Century Stacked Log Buildings

Before exploring how and why stacked log structures displace, one must understand the structural vulnerabilities of the building materials and the critical components of a typical stacked log structure. Structural vulnerabilities include foundation issues, material vulnerabilities, critical corner connections, the dimensional ratios of the stack, orientation of the stack to the prevailing wind direction, any discontinuities in the log members, the inclusion of a porch, the potential for ice damming, and contextual issues. These structural vulnerabilities can lead to displacement modes ranging from racking and the unintended transfer of loads to out-of-plane member rotation. Knowing which pathologies are associated with which type of structural movement can help diagnose the underlying problems of a stacked log structure affected by displacement.

Structural Vulnerabilities

Stacked log structures inherently have unique durability weaknesses arising from their predominant material as well as the assembly and configuration that contribute to typical displacement patterns.

Foundations Issues

Having a sound foundation can help keep a building structurally stable despite the soil conditions. If the foundations are inadequate, the stacked log building could be affected by differential settlement which occurs when soil under a structure compacts to different grades across the footprint. This would cause portions of the stack to sink vertically compared to others, causing the building to rack or, in extreme cases, overturn.

Material Vulnerabilities

Wood as a material is prone to certain deterioration mechanisms which in turn affect the structural integrity of stacked log structures. These material vulnerabilities include decay, wood

destroying insects, and checking, all of which are influenced by the species of wood used in the structures.

The principal deterioration mechanism found in wood is decay caused by colonizing fungi. As the fungi attack the wood, the wood loses its original material structure and properties, creating weaknesses in the member. To thrive, these fungi prefer a moist and warm environment between 35 ° F and 95 ° F and at a moisture content above the fiber saturation point, which is on average 30%.¹

There are several sources of water available for the fungi to propagate including ground water, drifted snow, and splashing water. If any of the log members are in contact with the ground, the water in the soil can be wicked into the wood by capillary action. Snow tends to drift up against the lower portions of the stack. Throughout the winter, the snow in contact with the buildings will melt and freeze with the daily cycle of the sun, and be held against the wood by the drifted snow. This process provides a prolonged source of moisture directly against the log members which encourages decay. If there is not a gutter system or the eaves of the structures do not project far from the stack of the building, water dripping off of the eaves can create puddles and splashing action. The water in the puddle will splash on to the log members, providing yet another source of water for the decay producing fungi.

Several types of insects are drawn to wood either as a source of food or shelter including beetles, termites, carpenter ants, and carpenter bees.² These creatures destroy the wood by burrowing into the wood, creating a series of voids that can weaken the members.

In log structures, the large section members are horizontal and unprotected by cladding. Unprotected members with large sections are especially prone to split or check. Although the checks themselves do not pose a structural problem, if the splits are oriented upwards so that they collect water, localized areas of increased moisture content may spur fungal decay activity or an insect infestation. Also, if the checks are large enough, organic debris will collect or small

¹ *Wood Handbook: Wood as an Engineering Material* (Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 2010), 14-1 – 14-3.

² *Ibid.*, 14-9 – 14-13

animals may nest, both of which could encourage decay by harboring moisture.

Although unprotected from ultraviolet radiation, ultraviolet degradation is merely aesthetic, giving a greyish patina to the logs exposed to sunlight. This condition only affects the wood to a certain depth and does not affect the structural properties of the member or moisture retention of the material (Appendix A – Figure 18).³

Critical Assembly Connections

The corner connections of a stacked log structure are critical to its structural performance because the engaged corners provide lateral stability to the wall stacks. All loads on the structure are eventually transferred to the lowest corner points and thence to the foundation piers. Corner engagement and structural performance can be compromised by poor construction fit of the notches, by loss of material in the joint faces due to decay, or by loss of section in the outer end piece of the log (Appendix A – Figure 19). If the corner connections are compromised, it is likely that downward vertical displacement will take place and shift the load path of the building to other members that are not meant to handle such a load.

Dimensional Ratios of the Stack

There are several dimensional ratios of stacked log structures that affect the stability of the building including the width versus length of the stack and the height versus the diameter of the logs used to create the stack. These ratios have been written into the structural design codes for log structures. The ratio of horizontal width versus the horizontal length of the stack, called the aspect ratio, must be greater than 1/4 and less than 4 before a structural engineer should be consulted for the project. This means that if either the length or width is 4 times longer than the other dimension, the stack is not considered stable.⁴ The codes also state that the distance between any two corners cannot exceed 32 feet in length if the average log diameter is greater

³ Ibid., 16-11; Ronald W. Anthony, “Wood in Historic Structures” (presentation given at the annual Colorado Preservation Inc. Saving Places Conference, Denver, Colorado, February 28, 2013).

⁴ *Standard on the Design and Construction of Log Structures: ICC 400-2007, American National Standard* (Washington DC: International Code Council, 2007), 45.

than 12 inches or 24 feet if the average log diameter is less than 12 inches.⁵

The width of the walls of stack, or the average diameter of the logs, versus the height of the stack is important to consider because it affects the ability of the stack to resist lateral movement or racking. The codes state that the average log diameter must be at least 8 inches to be stable.⁶ If the stack racks and the horizontal movement of the top of the stack exceeds the width of the walls of the stack, the lateral stability of the stack is compromised and at risk of further displacement and potential collapse.

Orientation to Prevailing Winds

Not only are the dimensions important, but also, the orientation of the structure to the prevailing winds needs to be considered. Different snow loads and drifts seem to accumulate on particular orientations of the stacked log structure. If the gable ends, which in terms of dimensions are usually the width of the building and tend to be shorter than the length, are perpendicular to the wind, the wind blows the snow across the roof since no features of the building block this path. But if the gable ends are parallel to the direction of the wind, the snow will blow up the windward slope of the roof and deposit on the leeward slope of the roof or below the leeward eave. Unbalanced snow loads can be exacerbated if the wind blows from the south to the north. In this case, the north would be the leeward side while the south would be the windward side. The north side will not only have an unbalanced snow load due to the direction of the wind, but it will also be subjected to much less sun than the southern side because these conditions only exist in the winter when the sun's path is low in the sky.

Stack Discontinuities

Points of weakness in stacked log structures occur where the logs are discontinuous along an entire elevation of the stack. These discontinuities occur with window and door openings, or result from the removal of an original wall element such as a fireplace (Appendix A – Figure 20). Unless laterally braced by rigid framing or by interior partitions, the logs

⁵ "Section A: for Residential, Handcrafted, Interlocking, Scribe-fit Construction," in *2000 Log Building Standards* (Lumby, BC Canada: International Log Builders' Association, 2000), 59.

⁶ Ibid., 56.

interrupted by the openings are susceptible to lateral movement and destabilization of the stack. Since interrupted logs have one end that is free or not laterally constrained by the corner notching of another perpendicular elevation of a the building, there is a potential that structural displacement will occur. Without lateral fixity at the free end, a log member can rotate out of the plane of the stack, leaving a void in the stack and causing deflection or shifting of the members above, which could potentially cause eccentric loading patterns on the structure or essentially negate the purpose of that individual member.

Presence of a porch

The addition of a porch on a stacked log structure promotes eccentric or uneven loading patterns with regards to snow loads or other environmental factors, which create another set of vulnerabilities in these structures. When there is a porch attached to a stacked log cabin, either the gable or eave end of the building extends up to several feet beyond the stability of the engaged stack. The roof extension to form the porch is only supported by three or four thin vertical columns rather than the continuous horizontally stacked members of the laterally restrained stack. The thin columns are more susceptible to buckling or dislodging forces than the stack making the porch one of the first portions of the building that will fail (Appendix A – Figure 21).

Ice Damming

Buildings located in areas where snow can accumulate on the roof are prone to ice damming. This is of special concern in buildings that are heated during the winter months because the heat will escape from the roof and melt the snow. The melted snow will then freeze when the temperature lowers enough and accumulate over time, resulting in ice damming. These large masses of ice on the roof can remain for the entire winter and can have substantial weight.

Contextual Issues

Natural contextual features can affect the structural stability of the stacked log structures on the site. For example, there are different types and sizes of trees scattered between the

buildings. Some are extremely close to the buildings (Appendix A – Figures 22 & 23). A large tree will have an extensive root system below the surface of the ground which extends out from the tree trunk at least as far as the canopy of the tree if not farther.⁷ The mechanical movement of the root network can exert pressures in excess of 116 psi, enough to upset the sill logs or pad foundations which could lead to differential settlement.⁸ This phenomenon is called root jacking. Another problem with having a tree so close to a structure is the influence of the canopy on the roof and stack of the structure. If the canopy hangs directly over the building, the tree has the potential to create a localized climate in that area by blocking sunlight or wind, which promote drying. Overhanging branches collect and deposit excess water from storms and influence how snow collects on and around the building. The resulting uneven snow drifts cause eccentric loads on the structure and introduce an excessive amount of moisture to the structure as the snow melts.

Other potential contextual factors that could lead to displacement mechanisms of stacked log structures are the presence of localized landforms, proximity to other buildings, and drainage direction. Similar to the effects of close trees, landforms and other buildings can influence the localized conditions on a stacked log structure. They can shift the direction of the wind around a nearby building which could influence the eccentricity of a snow load or the location or size of a snowdrift. Landforms or buildings in close proximity can block sunlight from reaching portions of other buildings which could inhibit the drying processes needed to keep the moisture content low for prevention of wood vulnerabilities such as decay and insect attack. The slope of the soil grade near the structures can also influence the availability of water. Ideally, the grade should slope away from the building so that excess water drains with gravity away from the structure. Problems will arise if the soil slopes towards the building or even if it is neutral.

Types of Displacement

The vulnerabilities of wood as a material and the stacked log structures can lead to

⁷ Martin E. Weaver, *Conserving Buildings* (New York: Wiley-Blackwell, 1997), 242.

⁸ Jason C. Grabosky, E. Thomas Smiley, and Gregory A. Dahle, "Research Note: Observed Symmetry and Force of *Plantanus x acerifolia* (Ait.) Willd. Roots Occurring Between Foam Layers Under Pavement," *Arboriculture & Urban Forestry* 37, no. 1 (2011): 35.

several types of displacement or member movements in the buildings including racking, out-of-plane member rotation, and unintended transfer of loads. These displacements can become a concern if they reach a critical point at which the structure is at risk of complete failure or collapse.

Racking

Racking is characterized by the whole stack of a structure leaning to one side or in a certain direction (Appendix B – Illustrations 3 & 4). Since the log members are round, if they come into contact with one another they will have a tendency to rotate because the point of contact is so small. To resolve the loads and attempt to become more stable, the members will rotate until they find stable equilibrium, shifting the load paths to try to adapt. If this begins to occur at the bottom of the structure, it will transfer upwards to each successive member, creating an angled, out-of-plane elevation instead of a vertical or in-plane elevation. Since the log members have a fixed length and are integrated at each corner, the opposite elevation will rack at the same angle and the two perpendicular elevations will shift within their plane to accommodate the displacement. Racking can be caused by several possible factors including differential settlement, deterioration of the sill log or other members, or the presence of eccentric loading either from a porch or an unbalanced snow load.

Out-of-plane Member Rotation

Out-of-plane member rotation occurs with a noncontiguous log member or one that has become disengaged at a point of fixity such as a corner. If disengagement occurs, then the member can rotate out of the plane of its elevation, pivoting at the remaining fixed end (Appendix B – Illustration 5). Openings for windows and doors are especially susceptible to out-of-plane member rotation because disengaged members flank the opening on both sides. This would be problematic because the all of loads imposed on the members above the rotated log would have to be transferred along the length of the upper logs to the corners rather than relying on the rotated member. The rotation of the log could in turn compromise the engagement of remaining fixed corner, leading to collapse of the corner and the differential

horizontal position of the stack above that point.

Unintended Transfer of Loads

Unintended transfer of loads are also of concern when dealing with stacked log structures. This is especially the case with the corner engagement points. Since these vertical joints are the principal paths for the loads to be transferred to the ground, if they change in any way, the stack of the building could easily be affected or even shift. If members begin to deteriorate or rotate at the corners, the loads will begin to be transferred in ways that were not intended, to members that may not be structurally able to effectively transfer the loads to the ground (Appendix B – Illustration6). The members now burdened with the unintended loads have a greater probability of completely failing by mechanical mechanisms. If these secondary members fail, then the loads will either be transferred to another under-designed member or cause collapse of the structure.

Structural Vulnerabilities of the Stacked Log Buildings at the Bar BC Ranch

Foundation Issues

The foundations for the structures at the Bar BC Ranch are typically either small concrete pads or stacked river stone footings located at each of the corners and spanned by two sill logs and two spandrel logs.⁹ The stone and concrete pad footings seem to extend only a few inches into the soil. This relatively shallow depth could be problematic for a couple of reasons. Shallow foundations are not able to mitigate the effects of differential settlement because the soils are poorly compacted or disturbed near the surface. This is especially an issue at the Bar BC Ranch because the first 15 inches of soil at the site are composed of 42% sand and 38% silt and below that point, the soils are predominantly sand.¹⁰ Differential settlement in silty sands and sandy soils such as these is usually governed by variations in the homogeneity of the soil under the

⁹ Mary Catherine Collins, Maria Diadato, Christine Leggio, and Nels Youngborg, *Bar BC Dude Ranch: Condition Assessment and Report, 2011*, Architectural Conservation Laboratory, University of Pennsylvania, 2011.

¹⁰ "Web Soil Survey," Natural Resources Conservation Service, United States Department of Agriculture, accessed October 14, 2012, <http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx>.

structure and a reasonable amount of differential settlement between footings is 7/8 inches or less assuming that the foundations are adequate and extend to the proper depth.¹¹ Due to the severe differential settlement across the site, it is evident that the soil is not homogenous.

Since the foundations at the Bar BC are so close to the surface, they are affected by the frost heaving action of the soils at the surface that occur with freeze-thaw cycles. In Teton County, Wyoming, the code required frost depth (the distance from the soil surface to the bottom of the foundation or footing) must be 34 inches unless otherwise specified by a specific soils report.¹² This means that foundations that are at least 34 inches deep will only be minimally affected by soil freezing action. Since this is not the case, the buildings at the Bar BC most likely move substantially with the heaving of the soil. This could partially explain the differential settlement occurring across the site.¹³

Material Vulnerabilities

Across the Bar BC Ranch, the structures are primarily constructed of Lodgepole pine.¹⁴ Although this species of wood was used because of its availability and proximity to the site, it is easy to work with which made the construction process easier. Generally Lodgepole pine has moderately large shrinkage, rates moderately low in strength, is moderately stiff, is moderately soft, and can hold nails and screws moderately well. This species, however, is not durable under conditions that favor decay.¹⁵

The cabins at the Bar BC are exposed to average air temperature ranges that fall below 35 ° F 9 months out of the year but the average relative humidity ranges from 35-45% during

¹¹ R.F. Craig, *Craig's Soil Mechanics, Seventh Edition* (New York: Spon Press, 2004), 294.

¹² Teton County, Wyoming, "Code Amendments," last modified 2012, accessed November 2, 2012, <http://www.tetonwyo.org/pdbldg/topics/building-electrical-and-fire-code-amendments-and-resolutions/201935/>, 7.

¹³ C.B. Crawford, "CBD-148. Foundation Movements," National Research Council Canada, last modified August 4, 2005, accessed February 18, 2013, <http://archive.nrc-cnrc.gc.ca/eng/ibp/irc/cbd/building-digest-148.html>.

¹⁴ Alex C. Wiedenhoef, letter to the author, February 21, 2013. (Copy of letter found in Appendix D)

¹⁵ David P. Lowery, "Lodgepole Pine (*Pinus contorta* Dougl. Ex Loud.)," Forest Service, United States Department of Agriculture, last modified October 1984, accessed February 26, 2013, <http://www.fpl.fs.fed.us/documnts/usda/amwood/253lodge.pdf>, 6; *Wood Handbook*, 1-16.

the summer and 65-75% during the winter.¹⁶ Although the cabins at the Bar BC are subjected to relatively low relative humidity and temperatures beyond the favorable temperature conditions for fungi growth for most of the year (35 ° F and 95 ° F), there is still evidence of decay, especially in the members nearest to the ground.

There is some evidence of insect infestation in some log members of the stacked log structures at the Bar BC Ranch, but most of the action seems to be dormant. Many of the members composing the stacked log structures across the ranch exhibit pinholes ranging in diameter from 1/16 to 1/8 inch in diameter which were probably created by powder-post beetles. These beetles lay their eggs in the wood cells, the larvae burrow around, and finally the winged adults emerge leaving the holes. But since the holes are not filled with wood flour and there is no frass evident around the exit holes it seems that the infestation is not active.¹⁷ Other insect infestations that could occur in Grand Teton National Park include carpenter ants, carpenter bees, and termites.¹⁸

Dimensional Ratios of the Stack

Most of the single room cabins at the Bar BC are not even close to the limits set forth by the structural design codes regarding dimensional ratios. Yet some of the longer dual occupancy cabins are affected because they exceed the corner-to-corner dimension limitations.

Ice Damming

With the ground snow load of 175 pounds per square foot at the Bar BC ranch, the ice dam load would be approximately 25 pounds per linear foot of the eave, which is enough force to overstress and potentially compromise the strength of the supporting members of the stack

¹⁶ "Moose, Wyoming," Western Regional Climate Center, accessed November 1, 2012, <http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wy6428>; David N. Mott, "Grand Teton National Park, Wyoming: Water Resources Scoping Report," National Park Service, United State Department of the Interior, last modified August 1998, accessed March 30, 2013, http://www.nature.nps.gov/water/planning/management_plans/grte_final_press.pdf, 7.

¹⁷ *Wood Handbook*, 14-10.

¹⁸ *Ibid.*, 14-9 – 14-13.

or porch columns.¹⁹ Fortunately, ice damming is not an issue with the stacked log structures at the Bar BC Ranch because the buildings are not inhabited or heated.

¹⁹ Michael J. O'Rourke, Moumita Ganguly, and Lucas Thompson, "Eave Ice Dams," *ASCE Journal of Architectural Engineering* 16, no. 1 (2010): 16.

Chapter 5: Assessment Methodologies and Stacked Log Structures

Assessment of materials, assemblies, and systems is considered to be a fundamental first step in conserving or preserving a historic building.¹ Understanding the condition and surrounding context of the building elements is crucial when choosing intervention techniques or creating prioritized preservation plans. There are several types of assessments that can be used to determine the state of a heritage building including condition assessments, risk assessments, and rapid assessments. Condition assessments are usually comprehensive and are used to record the material or systematic condition of a structure. Risk assessments utilize quantitative analysis techniques to determine the severity of identified risks a building is exposed to. Rapid assessments are used to collect only the basic necessary information needed in a timely manner. While there is a plethora of existing assessments for heritage buildings, not many have been created that apply specifically to stacked log structures.

Condition Assessment

Condition assessments focus on the typical deterioration and displacement patterns of a structure. These assessments narrow in on the specific weaknesses of the building materials and guide the surveyor to look in certain areas for particular issues to determine the overall condition of the structure. Generally, most survey protocols that were created to determine the condition of wood or timber buildings cover issues relating to insect damage, rot or decay, mechanical failure, and presence and paths of water infiltration since they are the most likely culprits in the deterioration, displacement, and failure of wood structures.² Depending on the

¹ Paul Philippot, "Historic Preservation: Philosophy, Criteria, Guidelines, I" in *Historical and Philosophical Issues in the Conservation of Cultural Heritage*, ed. Nicholas Price, M. Kirby Talley Jr., and Alessandra Melucco Vaccaro (Los Angeles: Getty Conservation Institute, 1996), 271.

² Martin E. Weaver, *Conserving Buildings* (New York: Wiley-Blackwell, 1997) 36-39; Harrison Goodall and Renee Friedman, *Log Structures: Preservation and Problem Solving* (Nashville: American Association for State and Local History, 1980), 23-26; Helena Cruz et al., "Guidelines for the on-site assessment of historic timber structures," *International Journal of Architectural Heritage*, accepted manuscript, March 12, 2013; Thomas D. Visser, "A Primer on Conservation Assessments and Emergency Stabilization for Historic Farm Buildings," *APT Bulletin* 25, no. 3/4 (1993); *Guideline for Structural Condition Assessment of Existing Buildings* (Reston, VA: American Society of Civil Engineers, 2000); Ronald W. Anthony, "Nondestructive Evaluation: Wood," *APT Bulletin* 41, no. 4 (2010): 1.

audience and the necessary data, condition assessments can be prepared in several formats including visual image comparison, field checklists, and physical probing. Once a condition survey has been created for a specific building, it can be difficult to adapt the unique protocol without making some changes.

Visual Image Comparison Condition Assessments

Some condition assessments, like that found in Malcolm Holland's book *Practical Guide to Diagnosing Structural Movement in Buildings*, present images of the types of failure or displacement that are likely to occur in a building and associate the possible locations and causes of that issue with the pattern of deterioration.³ Although this type of assessment could be useful for someone that does not readily understand the mechanisms of failure associated with the deterioration of a typical building, it does not account for the occasions when the patterns are created by a combination of causes that are unique to the situation. This type of methodology is great for visual learners, but there needs to be specific and succinct instructions associated with the images so that the correct diagnosis can be reached and the proper intervention applied.

Checklist Condition Assessments

Condition assessments can also come in the form of a field checklist that includes a series of measurements to be taken and/or questions to be answered.⁴ An organized checklist of possible defects and their locations can point untrained surveyors to the critical areas of the buildings to find the root cause of the issues. Using a likert scale introduces the concept of severity into a condition survey which can be useful when it is necessary to prioritize one building over another in the research set. In his book *Conserving Buildings*, Martin E. Weaver lays out a narrative list containing twenty-three items that should be examined.⁵ This list covers all of the necessary elements to check for but it is not very user friendly because of the lack of field survey formatting. Weaver addresses this by mentioning that the list is not definitive and

³ Malcolm Holland, *Practical Guide to Diagnosing Structural Movement in Buildings* (New York: Wiley-Blackwell, 2012) viii-x.

⁴ Goodall, 23-26; Weaver, 36-39; *Structural Assessment*.

⁵ Weaver, 36-39.

that specific methodologies should be created based on the needs of the surveyor or the desired data.⁶ This checklist does serve as a great starting point for creating a more specific protocol because it allows the user to appoint a risk or severity component to each item while covering all of the critical elements and material interfaces.

Some industries have incorporated detailed checklists into standards and guidelines for conducting condition assessments on existing buildings. One influential reference document created by the American Society of Civil Engineers called *Guideline for Structural Condition Assessment of Existing Buildings* outlines the purpose and procedures of a practical condition assessment dependent on the type of material in question. A disclaimer in the foreword mentions that the information is presented as a reference document and should not be specifically used for prescriptive treatments.⁷ Most effective condition assessments should start with guidance from a reputable source, such as the ASCE guidelines, so that the applicable data is collected in an appropriate manner.

Physical Probing Condition Assessments

Often it is difficult to access certain wood members of a building or determine their condition with the naked eye. In this type of situation, nondestructive evaluation techniques can be used to survey the building.⁸ Technologies such as remote visual inspection, resistance drilling, infrared thermography, and digital radioscopy help give insight into the condition of wood buildings in specific locations that can lead to determining the pathologies of destruction at work. Unfortunately most of the necessary tools are expensive and rare, making this type of in-depth survey quite costly and time-consuming. Therefore it is not always practical to apply such a detailed protocol to a group of buildings in a timely manner.⁹

⁶ Weaver, 37.

⁷ *Structural Assessment*, vii.

⁸ Anthony *APT*, 1.

⁹ Ron Anthony, "Nondestructive Evaluation of Wood" (lecture given at the University of Pennsylvania Historic Preservation Conservation Praxis Course, Helena, Montana, June 9, 2012).

Condition Assessments of Specific Buildings

For unique and monumental buildings, it is sometimes necessary to create a specific condition assessment format to ensure that the pathologies specific to that building are correctly identified.¹⁰ These surveys may include producing measured drawings or rectified photographs upon which critical conditions can be recorded or calling in a professional engineer to assess the structural stability of the building. Typically, survey teams have more resources to spend on these buildings so the extracted data is extensive and detailed, allowing professionals to make appropriate strategies for diagnosis and eventually treatments.

One example of a more complex building that warranted further scrutiny was the Sodankyla Old Church at Sodankyla in Lapland, Finland. This church originally built in 1689, was abandoned in 1859 but has since been maintained as an architectural monument. Constructed of stacked logs and clad with wooden boards, the block pillar church is unique because of the length of its main room. The carpenters found a way to extend the dimensions beyond the limitation of one log by creating a connection point in the middle of each elevation.¹¹ The complexity of this connection, as well as the size and significance of the structure, justified a more in depth survey of the conditions. A survey team was brought in to document the building with measured drawings on which visual condition surveys were completed to determine the overall condition of the building. From these illustrations, the professionals were able to draw conclusions about what deterioration was occurring and what interventive measures were necessary to solve the issues.

Assessments created to record the conditions of a particular building can be difficult to adapt to other structures because certain assumptions are automatically made the more detailed a survey gets. These assumptions revolve around not only what is known about the

¹⁰ Maija Kairamo, "The Restoration of Sodankyla Old Church 1992-1995," in *Wood Structures: A Global Forum on the Treatment, Conservation, and Repair of Cultural Heritage*, ed. Stephen J. Kelley et al. (West Conshohocken, PA: ASTM, 2000); Mehrdad Hejazi, "Structural Analysis of the Wooden Structure of the Historical Building of Ali Qapu," *ASCE Journal of Structural Engineering* 132, no. 11 (2006); Quagliana, Charles. *Condition Assessment for the Mason Farm Historic Log Cabin at Dorothy Carnes County Park, October 30, 2012*. Jefferson County Parks Department, Jefferson, WI, 2012.

¹¹ Kairamo, 132.

building in question, but also the governing preservation philosophy. For example, a condition survey created for a historic structure located in Alaska to determine the affect of snow on the building would not produce much pertinent information if applied to a historic structure in Florida. Similarly, if the preservation philosophy of one building articulates that it is important to restore the building to its original aesthetic state while the preservation philosophy of a different building specifies that the patina acquired over time should be preserved, the condition assessments used for either building would differ. The assessment for the restored building may include mapping the areas that have aged whereas the survey for the preserved building would not. In most cases, condition surveys created for certain buildings are much more complex and time consuming because the building itself is complicated whether it is intricate, considered monumental, or simply large.

Risk Assessment

Often risk assessments are carried out by building stewards to determine the risks that threaten a cultural resource and prioritize the identified risks to create a preventative conservation management plan for the future. Condition assessments can give us a clue as to the present or past conditions of a structure, but when integrated with a risk assessment, we can make educated guesses about the future of the resource.¹² Recently, much research has gone into adapting the broad range of literature that applies to general risk assessments to the needs of the preservation field.¹³ To aid in heritage managerial decisions, it seems beneficial to have a quantitative rating system built into the survey form to determine the severity of the risks associated with any one building. The “Inspection and Rating of Miter Lock Gates” document prepared by members of the Engineering and Materials Division of the US Army Construction Engineering Research Laboratory provides a great example of how such an assessment can be

¹² Joel Taylor, “An Integrated Approach to Risk Assessments and Condition Surveys,” *Journal of the American Institute for Conservation* 44, no. 2 (Summer 2005): 128.

¹³ Jonathan Ashley-Smith, *Risk Assessment for Object Conservation* (Oxford: Butterworth-Heinemann, 1999); “Sources of Information for Cultural Heritage Risk Management,” bibliography and literature review from “Preventative Conservation: Reducing Risks to Collections,” an international course, Beijing, China, 7-25 September 2009. http://www.icrom.org/eng/prog_en/01coll_en/archive-preven_en/2009_09risksCHN_biblio_en.pdf.

broken down component by component, attach an appropriate numerical rating relating to the risks at hand, and create a hierarchy of assemblies at risk as detailed by a condition index scale.¹⁴ Unfortunately, such protocols are time intensive to fully develop because of the iterative testing and data collection processes that are needed to provide a statistical database sufficient for a quantifiable approach.

Other protocols incorporate risk assessment into the survey of structural displacement and condition. These assessments take into account the environmental and contextual risks posed on the building in question. Proper preventive measures can be made to mitigate such risks as long as they are identified and assigned a severity. In a study completed by the Architectural Conservation Lab of the Historic Preservation department at the University of Pennsylvania, a set of survey protocols were developed to determine the contextual risks associated with Native American wood structures in Grand Canyon National Park.¹⁵ The survey form is comprehensive yet concise, which helps ensure that the process is repeatable and that the results from the surveys can be compared over time to determine the effectiveness of interventions.

Rapid Assessment

Rapid assessment techniques can be incorporated into both condition assessments and risk assessments and are useful tools when the allowable survey time is limited due to lack of resources. Typically these surveys are succinct and user friendly so that they can be repeated on many different structures without much variation, even if there are multiple surveyors. Each one is tailored to the specific needs of the steward so that pertinent data is collected and can be used to monitor and determine the condition of the structures in question. This information can then inform decisions regarding conservation strategies and risk management approaches.

A factor to keep in mind when creating or choosing to use an existing assessment

¹⁴ Lowell Greimann, James Stecker, and Kevin Rens, *Inspection and Rating of Miter Lock Gates* (Washington DC: US Army Corps of Engineers, 1990): 4-8.

¹⁵ Michael Shoriak et al., *Native American Wooden Structures Draft Report, 2012*. Architectural Conservation Laboratory, University of Pennsylvania, 2011, 8-9.

method is the importance of the monetary budget. This is usually an issue of concern with historic buildings. For this reason, protocols that are sensitive to money and time have the potential to be extremely useful in the field. One such survey method was created by Thomas D. Visser and is explained in his article “A Primer on Conservation Assessments and Emergency Stabilization of Historic Farm Buildings.” He felt there was a need for a protocol addressing wooden farm buildings of the Northeastern United States that would provide a quick and simple approach to stabilize the structures for the short term to keep them around as a part of the cultural landscape. Instead of looking at the entire building, the emphasis is on diagnosing and treating elements that are the most stressed at the time, enough to keep the building safely standing.¹⁶ This type of survey helps a building steward who is not necessarily an engineer determine if the building is safe to mothball and what steps should be taken to stabilize the building before mothballing it.

Assessment of Stacked Log Structures

Despite their abundance in the world and the United States, there is not much published information on appropriate methods of assessing historic stacked log structures. The only example assessment discovered by the author was a form created by Harrison Goodall and Renee Friedman for their book *Log Structures: Preservation and Problem-Solving*, covering the critical components of a stacked log structure and incorporating the severity of typical issues by using a five-point likert scale.¹⁷ Although surveys like this can be useful when there is only one surveyor, too much variation can be introduced into the data because of the subjectivity of the definitions of the likert scale points.

Post-mortem Assessment as a Monitoring Tool

To evaluate the effectiveness of a condition or risk assessment, a post-mortem assessment can be applied. These surveys involve comparing a structure’s condition and associated risks before and after an assessment technique or intervention was implemented

¹⁶ Visser, 64.

¹⁷ Goodall, 23-26.

on the building. One possible post-mortem assessment methodology involves using published material to gather data about a subset of buildings with certain commonalities. This type of methodology was recently employed by a group of engineering researchers from the University of Colorado at Boulder to look at snow-induced building failures that occurred over the last few decades in the United States and internationally. First the researchers completed a search of all available newspaper articles through the LexisNexis database using keywords such as “snow,” “roof,” and “collapse.” With the results of this inquiry, they were able to gather pertinent data to describe the amount, location, and age of the buildings that failed under snow load.¹⁸

This type of survey is all encompassing regarding types of buildings, but does not account for any minor building failures that were not reported in newspapers. Without the inclusion of these buildings, there is a possibility that the data collected is skewed and therefore should not be used as a risk analysis tool for other structures subjected to snow loads. Despite this weakness, this newspaper based survey method is an effective way to at least collect data on subjects that have not been studied in depth before to give researchers the chance to look for possible patterns of causes of failure and evaluate the effectiveness of any previous interventions or assessments.

Appropriate Assessment Conclusions

After evaluating the existing literature on surveys for historic buildings, the need for a rapid assessment protocol informed by condition and risk for stacked log structures was recognized. Through this research, essential elements that are included in the protocol to survey the conditions and risk factors associated with stacked log structures were identified. This survey method combines condition, risk, and rapid assessments together with numerical factors to prioritize certain conditions and the effect they have on the stability of the structure. In turn, the numbers can be associated with a timeframe to intervene or repeat the monitoring procedure.

Although preservationists normally shy away from cookie cutter solutions, there are

¹⁸ Jamie Geis, Kristen Strobel, and Abbie Liel, “Snow-Induced Building Failures,” *ASCE Journal of Performance of Constructed Facilities* 26, no. 4 (2012): 378.

advantages to a survey that can be applied quickly to a series of similar buildings like the stacked log structures at the Bar BC Ranch in Grand Teton National Park. Not only will a succinct survey methodology provide a timely manner of collecting data from the structures, it will also offer the advantage of repeatability for future monitoring possibilities to determine when to intervene or the effectiveness of an intervention.

Chapter 6: Development of a Rapid Assessment for Early 20th Century

Stacked Log Structures

There are several steps and activities required to create an effective field survey. These processes include preparing for the survey with any necessary background research or site visits, choosing the type of survey desired, tailoring the survey questions towards the potential users, and, if preferred, quantifying the severity of a condition. In this analysis, it was decided that not only should the survey be quantitative, but that the quantification should incorporate the structural condition of the buildings as well as the exposure to certain risks.

Survey Preparation

Quite a bit of planning and time went in to gathering the necessary data to create the final displacement field survey and determine an appropriate way to assign a score to each stacked log structure in question. The process started with completing some background research and preparing for several data gathering site visits that led to the creation of a method to assign severity of certain attributes based on risk, condition, and the structural integrity of each element.

Background Research

The process began by gathering information on several pertinent topics. First, research was completed on the chosen case study site, the Bar BC Ranch in Grand Teton National Park. Most of the research regarding the history of the site came from the historic structures report written in 1993 about the Bar BC Ranch as well as Maxwell Struthers Burt's (one of the original owners of the ranch) autobiography *The Diary of a Dude Wrangler*.¹ Secondly, a series of discussions with the thesis advisor, Michael C. Henry, took place covering the important characteristics of stacked log structures and large timbers used for the construction that influence the structural stability and therefore the modes of displacement. These conversations

¹ Roy Eugene Graham, *Bar BC Dude Ranch Grand Teton National Park, Wyoming*, Historic Structures Report (Washington DC: National Park Service, U.S. Department of the Interior, 1993); Maxwell Struthers Burt, *The Diary of a Dude Wrangler* (New York: C. Scribner's Sons, 1924).

were supplemented with research on the types of surveys that have been created for similar structures, the structural design codes in place for stacked log structures, as well as the engineering research that had been completed in the past. All of these sources of information helped the preparation process for the data-gathering site visits.

Site Visit Preparation

To prepare for the first site visit to the Bar BC Ranch in late October 2012, a set of field documents was created to make sure that all of the pertinent information was collected. This first site visit methodology focused on gathering as many physical measurements as was thought necessary during the actual site visit and recording them on the field documents. See Appendix E for a blank version of this initial set of documents. With a preliminary set ready to go by the middle of October, the field documents were tested out on a stacked log structure known as the Swedish Granary located in Greenwich, a small town in southern New Jersey. Considering it took roughly two hours to gather only about three quarters of the measurements and realizing that there was a high probability of forgetting a field measurement, it was decided to incorporate rectified photography into the site visit documentation methodology. A rectified photograph is created by merging a set of photographs together containing known dimensions between overlapping points to create a high resolution and dimensionally accurate image. The advantage of such an image is that one can gather any forgotten field measurements from the photograph itself. So it was decided to complete a set of rectified photographs of each elevation of as many structures as possible during the October site visit to the Bar BC Ranch.

Site Visits

During the weeklong site visit to the ranch in October, the author was able to take complete sets of rectified photographs of four separate stacked log structures scattered around the ranch. The photographs were supplemented by marking up a blank site plan and a copy of the rectified photographs with measurements and information such as the location of certain conditions, like possible insect infestation, that could not be gathered from the rectified photographs. See Appendix F for an example set of these completed documents.

A major question that concerned the author regarding the structural movement of these stacked log structures at the Bar BC was what is the influence of snow load on the buildings. For that reason, it was thought to be important to visit the site again during the winter to observe how snow was collecting on the site so a second site visit was planned for early January. Although a preliminary survey checklist of dimensions and measurements was created, it was difficult to gather the necessary information because of the remoteness of the site and the weather.² With only two hours at the site for two days, it was decided that instead of physically measuring everything that had been outlined, it was more important to take photographs of the site to document how the snow loads affected the buildings.

Creating the Final Survey

With all of the quantitative and qualitative data collected during the site visits, the author began to think about the best way to distill all of the information down to the critical elements relating to the displacement of stacked log structures. Early on, it was decided that the final result of the survey was to be a score out of 100 total possible points that would characterize the degree of structural displacement and associated risks of each stacked log structure. With this final format in mind, the author first made a list of the overarching categories or components of a stacked log structure under which all of the measurements and questions could be sorted: foundations, material vulnerabilities, stack, interventions, roof, and context. Then the measurements gathered during the site visits and the structural provisions found both in the *ILBA Log Building Standards* and the *ICC Standard on Design and Construction*

² The Bar BC Ranch is located two miles from the nearest vehicle access during the winter and can only be accessed on foot or cross country skis. Although this added two hours to the total travel time to the site, the major problem was the low temperatures during the several days of the site visit in northern Wyoming. Because the author was considered a National Park Service volunteer, she had to follow the government mandated cold-weather working conditions which required the temperature to be above 10° F. It was so cold during the day that it took until at least 12 PM every day to warm above the specified temperature. With this starting time, the author reached the ranch by 1 PM but needed to leave by 3 PM to get back to the vehicle before the sun set behind the Grand Tetons at approximately 4 PM.

of *Log Structures* were sorted into each of these categories.³ Next, any measurements that were redundant or not pertinent to the structural stability of the structure were discarded.

The next task undertaken was determining the best way to ask each survey question and how to lay out the final document. After speaking with Michael C. Henry and Ron Anthony, a wood scientist, both professionals emphasized that repeatability is key to a useful survey. Stewards need to be able to easily and quickly answer the questions on the survey which should be fully explained so that minimal confusion results. This includes using yes-no questions, multiple choice answers, and straightforward measurements.

Understanding Risk

With all of the critical questions laid out, appropriate point deductions for each question were assigned. To accomplish this, the author did some basic research on risk management in the field of object conservation by looking to sources such as *Risk Assessment for Object Conservation* by Jonathan Ashley-Smith and “An Integrated Approach to Risk Assessments and Condition Surveys” by Joel Taylor. Through this research it was discovered that risk assessments are usually executed independently of condition surveys because while risk assessments infer effects from causes, condition surveys infer causes from effects. This makes it difficult to combine the two.⁴ But the author argues that sometimes the presence or extent of a condition can serve as an indicator of risk. For example, if a portion of a sill log is affected by rot, it indicates that there is (or was at one time) a source of water that is encouraging the decay. Since the sill log has already been compromised, it is at a higher risk of causing structural displacement in the structure than a sill log that is fully intact and not exposed to water. The author also argues that this risk will increase as the sill log rots away even more because as the decay spreads, the structural capacity of the member is more and more compromised.

³ “Section A: for Residential, Handcrafted, Interlocking, Scribe-fit Construction,” in *2000 Log Building Standards* (Lumby, BC Canada: International Log Builders’ Association, 2000); *Standard on the Design and Construction of Log Structures: ICC 400-2007, American National Standard* (Washington DC: International Code Council, 2007).

⁴ Joel Taylor, “An Integrated Approach to Risk Assessments and Condition Surveys,” *Journal of the American Institute for Conservation* 44, no. 2 (Summer 2005): 129.

Determining the Point Deductions

When determining how many points to deduct for each question, the author wanted to make sure that risk, an understanding of the present conditions, and importance of that specific factor to the stability of the stacked log structure were all included and weighed accordingly. With all three of these factors in mind, each question was ranked on a scale from 1 to 4, with 1 having the least influence and 4 having the most influence on the final scoring. This number represented the total number of points that could be deducted for that particular question. Next the maximum amount of deductible points for each question were added up and reached a summation of 50 points. To translate this total deduction to a 100-point scale, which is easier to understand and visualize, the total summation was multiplied by 2 and subtracted from 100. This means that if a stacked log structure that earned the maximum amount of deductions across the entire survey, the deductions would add up to 50 points or a final score of 0.

Determining the Meaning of the Final Scores

To give a meaning to the final score that results from completing the survey, the author created a basic list of recommendations for certain point ranges based on the actual conditions and risks associated with the stacked log structures that were studied at the Bar BC Ranch. Each recommendation includes the general condition and risk levels of a building that scores within that range as well as when the survey should be applied to the building again for data collection and monitoring purposes. The author is adamant that this survey will raise to its full potential if it incorporated into the preservation plan of the site in question. If combined with evaluations of integrity and value, a prioritized and sustainable plan can be created that maximizes available funds and also incorporates preventative conservation.

Chapter 7: Assessment Protocol

Purpose of the Procedure

The following description of the procedure provides a guide to the displacement field survey created as a product of this thesis. This document can be used in the field to make sure that the necessary measurements are taken and observations made during the site visit so that the structural health and exposure to risk of each early 20th century stacked log structure in question is accurately determined.

Scope of the Procedure

Please keep in mind that this is a survey designed for true stacked log structures that have overlapping notched connections at each intersecting corner. This fact is fundamental to the definitions of structural stability used to create this survey protocol. This survey was designed specifically for early 20th century stacked log structures of the cowboy construction type in mountainous areas and is based on data and observation from one case study site, the Bar BC Ranch in Grand Teton National Park. The survey should be applicable to similar stacked log structures located in mountainous areas and climates but the provisions and scoring method may need to be adjusted for the environmental risks associated with a specific site that is much different. See Appendix H for an example of all of the documents associated with a completed survey.

Items Needed to Complete the Survey

Before heading out in the field, gather the proper materials and equipment to complete the survey. Each surveyor will need:

- Digital camera, 10 megapixels or more resolution
- 25 foot tape measure
- 12 inch thin, rigid ruler

- Plumb bob and line
- Printed survey (found in Appendix G)
- Printed photo log (found in Appendix G)
- 9" x 12" Clipboard
- Pencil with an eraser
- Sample bags
- Appropriate clothing
- Food and water
- Personal safety equipment

The major information to needed before the site visit include:

- The predominant wind direction across the site
- Climate information
- Soil survey information

Remember that some of these sites can be remote and subjected to risks such as quickly changing weather patterns and animals. Make sure to contact a local expert before heading into the field to make sure that all of the proper clothing is worn, outdoor equipment is acquired, and safety measures are taken to ensure that the site visit is successful and safe.

Pre-survey Documentation

Exterior Photographs

Although no survey should be completed by studying photographs alone, for the sake of posterity and possible use in future reports, the following series of photographs should be taken of each structure before the displacement survey is undertaken. The images should be labeled on a copy of the photo log. Please see Appendix H for a sample set of photographs and the associated photo log.

- Assign an alphanumeric name to each elevation of the stack of the structure. Start by assigning the letter “A” to the primary façade of the building containing the front door and name each elevation moving counterclockwise around the building the following letter of the alphabet (Appendix B – Illustrations 7 & 8).
- Photograph the primary façade or elevation “A” of the stacked log structure.
- Take a photograph looking across elevation “B” from the corner between “A” and “B.”
- Rotate 90° counterclockwise and take a photograph looking across elevation “A” from the corner between “A” and “B.”
- Photograph the corner between “A” and “B” from oblique angle.
- Repeat the previous four photographs for each elevation progressing counterclockwise around the building.
- Take detail shots of any extraordinary elements or conditions.
- Mark each the location of where each photograph was taken on the photo log.

Field Survey

Once the pre-survey documentation of the structure has been completed, the surveyor should prepare to complete the displacement field survey. A series of qualitative observations and quantitative measurements as laid out in the field survey document and described below, need to be collected so that after data analysis, a final score can be assigned to each log structure.

Context

Begin the survey process by examining the surroundings of the stacked log structure in question. Specifically, take note of the following attributes:

- Direction of drainage at the base of each elevation. Note whether the soil slopes towards the structure, away from the structure, or has a neutral slope (Appendix

B – Illustration 9).

- Proximity of trees. Note whether there are any branches hanging directly over the structure in question, any trees that have trunks within the distance of the height of the tree, and the number of trees within that proximity (Appendix A – Figure 24).
- Evidence of root jacking. Movement of the structure due to the growth of the root system of a nearby tree.

Stack

Next, complete the portion of the survey about the stack by measuring the following necessary dimensions to the nearest quarter of an inch:

- Horizontal length of the stacked log structure measured from centerline to centerline of each intersecting wall or corner along the sill log of one of the eave ends of the structure (Appendix B – Illustration 10).
- Horizontal width of the stacked log structure measured from centerline to centerline of each intersecting wall or corner along the sill log of one of the gable ends of the structure (Appendix B – Illustration 11).
- Vertical height from the bottom of the sill log to the top of the plate log of each corner of the stacked log structure (Appendix B – Illustration 12).
- Vertical height from the bottom of the sill log to the top of the ridgepole at the midpoint of both gable ends of the stacked log structure (Appendix B – Illustration 13).
- Vertical height of each corner that has been compromised by decay, removal, loss, or disengagement.
- Racking angle of the structure. To measure this angle on the structure, measure the horizontal midpoint of the sill log on one of the skewed elevations of the stack and mark it with a pushpin. Next measure the mid point of a log about half way up

the corner height of the elevation. From the mid-height midpoint, drop a plumb bob. Measure the vertical and horizontal distances between the two midpoints using a tape measure and the plumb bob (Appendix B – Illustration 14).

- Distance from the edge of each opening to the nearest corner or centerline of the intersecting wall (Appendix B – Illustration 15).

After that, gather the following attribute counts:

- Number of logs stacked vertically, including the sill log and plate log, on one eave elevation of the structure (Appendix B – Illustration 16).
- Number of logs that are laterally displaced at the mid-span of the elevation. Bulges or bows in an elevation of the stack characterize this phenomenon (Appendix B – Illustration 17).
- Number of discontinuous logs in the entire structure. A discontinuous log is one that is interrupted by an opening such as a window, door or removed element, or a vertical spliced joint.

Note the answers to the following questions:

- Are there two openings in one elevation less than 36" apart, edge to edge?
- Do the crowns extend beyond the eave of the roof?

Foundations

Note the answers to the following questions about the foundations of the structure in question:

- For the sill log of each elevation, is the sill log in contact with the ground along the span of the member?
- What is the severity of decay in the sill log? For survey simplicity there are four degrees of sill log rot to consider: no rot, minor rot, major rot, and completely rotted. Mark "No rot" if there is no evidence of decay in the sill log. Mark "Minor rot" if about 1 to 30% of the log is affected by decay. Mark "Major rot" if about 31

to 95% of the sill log is decayed. Mark “Completely rotted” if the sill log has been consumed by decay.

- What type of footings is used under the sill logs? Concrete, river rock, or no footings?

Interventions

Look for any evidence of previous stability-providing interventions, interior or exterior.

Mark the conditions as one of the following:

- No interventions – No evidence of previous bracing.
- Engaged interventions – additional bracing elements have been used to stabilize the building and they are serving the intended function since they are fully engaged between the intended members.
- Disengaged interventions – additional bracing elements have been used to stabilize the building but they have fallen down or are not fully engaged with the intended members.

Roof

Answer the following questions that regard the condition of the roof:

- Are there any openings in the roof structure with a width greater than two inches?

Also, make sure to take note of the following items:

- Orientation of the gable ends to the predominant wind direction. Perpendicular, parallel, or 45° .
- Presence and location of a porch, eave or gable end.
- Type of roof construction and roofing material. Sheathing and tarpaper, sod roof, or green roof.

Material Vulnerabilities

There are several items that need to be examined during the site visit that relate to the material vulnerabilities of wood.

- Is there evidence of an insect infestation including pinholes, shelter tubes, or nesting galleries?
- How many significant checks are found throughout the structure? A significant check is considered one greater than 2 inches in length with a depth into the log member that is $\frac{1}{4}$ the diameter of the log. The depth of the checks can easily be measured by using a thin and rigid ruler measuring 12 inches in length, which can be inserted directly into the void.

Assigning a Score

The purpose of completing this survey is to assign a numerical score to a stacked log structure that is related to the potential risks and structural condition of the building. A building in perfect condition with no associated risks will have a score of 100 while one in extremely poor condition and exposed to many risks will have a score of 0. After completing the field survey, insert the data in the Excel calculation spreadsheet called "SLS Score Calculation" or add up the point deductions outlined below, multiply the summation by 2, and subtract that number from 100 to calculate the score of the stacked log structure. The data and score of each stacked log structure should be cataloged for future reference and monitoring.

Context – Drainage

The slope of the soil near the base of the stack and foundations can provide a good indication of the direction of water drainage in the area. The three conditions that can exist at each elevation of the stack of the structure are as follows: slope towards the structure, neutral slope, and slope away from the structure. If the soil slopes towards the structure, it indicates that water is likely to drain back towards the structure which could encourage harmful mechanisms of deterioration related to the presence of water such as decay. If this is the case,

deduct 1 point. Another condition that may exist at any one elevation is a neutral slope meaning that the soil is flat and does not seem to slope either towards or away from the structure. Since it is still possible for water to pond in this situation, deduct 0.5 points. Lastly, if the soil slopes away from the structure, this condition encourages drainage of water away from the foundation of the structure. Deduct no points if this is the case.

Context – Trees

There are several risks associated with trees located within close proximity of stacked log structures. If a tree is within distance of its height, there is a chance that strong wind or snow loads from a storm could uproot the tree and knock it over onto the building. If there is one tree this close to the building in question, deduct 1.5 points. If there are no trees within this distance, deduct no points. If there is more than one tree that is within distance to the structure of its height, deduct an additional 0.25 points for every tree beyond the first one. Another risk associated with close trees comes with branches that hang over the roof of a structure. Overhanging branches not only can directly fall on the building during a storm but they can also influence how snow and wind loads affect the building by redirecting forces and possibly creating eccentric loading patterns. For these reasons and since a tree this close implies that it is within a distance to the building that is shorter than the height of the tree, deduct 3 points.

Another issue that can arise when a tree is within close proximity to a stacked log structure is a phenomenon known as root jacking. This occurs when the root system of a tree grows underneath a building and as it extends it exerts stress on the foundations that are usually resolved by the structure physically displacing to accommodate the roots. If there is evidence of root jacking, deduct 1 point.

Stack – Required Dimensions

The relationship between the length and width of a stacked log structure plays a role in the overall stability of the building. Generally, the more square the building, the more stable it is. One way of measuring this characteristic is to calculate the aspect ratio, which involves dividing the length or eave side of the building footprint by the width or gable side of the footprint. The

International Code Council standards recommend having an aspect ratio of less than 4:1 or greater than 1:4 unless an engineer is called in to perform structural analysis.¹ If the aspect ratio is equal to 1, do not deduct any points. If the aspect ratio is greater than 4 or less than 0.25, automatically deduct 3 points. For an aspect ratio between 1 and 4, deduct the number of points equal to the calculated aspect ratio divided by 4 multiplied by 3.

Additionally, the International Log Builders Association recommends that the distance between corners should not exceed 24 feet when the average diameter of the logs in use is less than 12 inches or 32 feet when the average diameter is greater than 12 inches.² If either the length or the width of the building exceeds 24 feet with an average log diameter less than 12 inches or 32 feet with an average log diameter greater than 12 inches, deduct 2 points. If both the length and the width exceed the specified maximum, deduct 2 points each or 4 points total.

Also listed in the ILBA Standards is the requirement that the width of the walls must be larger than 8 inches.³ To calculate the average diameter of the logs used in the stack, count the number of logs vertically stacked along the length of the stacked log structure, including the sill and plate logs. Then divide the average corner height by the number of vertically stacked logs. If the average diameter of the logs in the stack is less than 8, deduct 1 point.

Stack – Corner Engagement

An important aspect of stacked log structures is the extent to which the corners are engaged and functioning how they were designed. For this survey, corner engagement is defined as the extent to which a corner condition of a stack is intact and able to transfer the loads. To measure the extent of the engagement of the corners, the total height of each corner (from the bottom of the sill log to the top of the corresponding plate log) and the total vertical height of disengagement or compromised portions of the connection are measured separately. Using these measurements, the percentage of engagement is calculated by dividing the disengagement

¹ *Standard on the Design and Construction of Log Structures: ICC 400-2007, American National Standard* (Washington DC: International Code Council, 2007), 45.

² "Section A: for Residential, Handcrafted, Interlocking, Scribe-fit Construction," in *2000 Log Building Standards* (Lumby, BC Canada: International Log Builders' Association, 2000), 59.

³ *Ibid.*, 56.

height by the total height of the corner. Deduct the decimal amount of each ratio from the total summation. Since a stack with adjacent compromised corners is at a higher risk of displacement, deduct 1 additional point if there are two or more disengaged corners adjacent to each other.

Stack – Racking

The occurrence of racking in stacked log structures is relatively high because of how they are constructed. For the purpose of this analysis, racking is defined as the top of a stack displacing laterally with respect to the bottom of the stack which remains fixed in its original location. The logs will slide along one another to accommodate this movement resulting in two elevations appearing as skewed trapezoids instead of rectangles. This phenomenon tends to occur in stacked log structures because of the relatively small points of contact between the stacked logs. To resolve any eccentric loading patterns, if the logs are engaged correctly the entire structure will adjust to carry the loads to the ground.

The angle of racking becomes critical when the horizontal displacement of the center of the top of the wall exceeds the width of the wall or the average diameter of the logs. To calculate the critical angle of racking, take the inverse tangent of the average log diameter divided by the tallest height of the elevation (height of the corner for an eave end or height of the gable for a gable end). To calculate the actual racking angle, take the inverse tangent of the horizontal distance between the member midpoints divided by the vertical distance between the same points. This set of measurements will be representative of the overall racking of the stack because the entire elevation will have shifted the same angle. If the measured angle of racking is larger than the calculated critical angle of racking, automatically deduct 4 points. If the angle of racking is smaller, deduct the ratio of the angle of racking to the critical angle multiplied by 3.

Stack – Mid-span Log Displacement

Another indicator of changing loads and displacement is the movement of individual or small groups of logs. This phenomenon is usually characterized by one or a few adjacent logs bulging out of the plane of the rest of one elevation of the stack, whether towards the interior or the exterior of the structure. For the first 8 logs that are out of plane, deduct 0.25 points each. If

more than 8 logs are displaced, deduct a maximum of 2 points.

Stack – Discontinuities

Logs that are not fixed on both ends are at risk of rotating out of the plane of the wall and changing the load paths of the wall. Most openings, whether intended or not, automatically introduce discontinuities in the wall. Another point of discontinuity in a log wall is at a vertical joint at the mid-span of an elevation of the stack when the connection is not keyed into a partition wall. In this situation, the logs are simply toenailed into a vertical board. If there are less than 10 logs interrupted by an opening or splice including doors, windows, removed elements, or mid-span vertical splices, deduct 0.05 points for each log. If there are between 10 and 26 discontinuous logs, deduct 0.075 points for each log. If 27 or more logs are interrupted, deduct 2 points total.

The stability of a stacked log structure can also be compromised by the location of the openings with regards to either the corner of the building or another opening. The ILBA standards state that the edge of an opening cannot be within 36 inches of the edge of another opening or 10 inches plus half of the average log diameter of the stack from the centerline of an intersecting wall or corner.⁴ If either of these situations occur on the stacked log structure in question, deduct 1 point. If both occur, deduct 2 points.

Stack – Crown Extension

Another item to consider regarding the type of corner used is how far out the logs extend from the corner intersection. These extensions are known as crowns. If the crowns protrude past the eave of the roof, then the logs are at a higher risk of decaying because of the direct exposure to water.⁵ If the crowns on the log structure in question extend beyond the roof, deduct 1 point.

⁴ 2000 Log Building Standards, 66.

⁵ Harrison Goodall and Renee Friedman, *Log Structures: Preservation and Problem Solving* (Nashville: American Association for State and Local History, 1980), 28.

Foundations – Sill Log

Sill logs are extremely key components of any stacked log structure and their condition can give an indication of the risk posed by continued deterioration. For this reason, each sill log must be looked at individually for the purposes of this survey. Using the same A through D designations for each elevation of the stack assigned at the beginning of the survey process, examine the sill logs by answering the following questions: is the sill log in contact with the ground and what is the severity of the rot already occurring in the sill log? If the sill log is in contact with the ground, it is at a higher risk of decay and insect infestation because water collecting in the soil can easily be transported into the sill log. If the sill log is in contact with the ground, deduct 1/2 of a point, if not, do not deduct any points. The actual decay condition of the sill log can indicate whether or not the necessary and sufficient factors for decay to occur are present or have been at one time or another. For survey simplicity there are four degrees of sill log rot to consider: no rot, minor rot, major rot, and completely rotted. If there is no evidence that rot or decay has occurred in the sill log, mark the condition as “no rot” and deduct no points. If there is minor evidence of decay in the log (about 1 to 30% of the sill log is affected or gone), deduct 0.25 points. If there is major evidence of decay in the log (about 31 to 95% is affected or gone), deduct 0.5 points. If the sill log is completely deteriorated, deduct 0.75 points.

Foundations – Footings

The type of footings beneath the corners of stacked log structures can influence the stability and vulnerability to decay of the sill logs. Most of the time, one of three situations exists: concrete footings, river rocks footings, or no footings. Concrete footings provide the most stable foundation and prevent water from seeping through the soils into the sill log. River Rock footings provide some stabilization, yet not as much as concrete footings, and allow for water drainage away from the sill logs. Without any footings, the sill logs rest directly upon the soil and are subjected to any moisture from the soil. Deduct no points if the stacked log structure has concrete footings, 0.5 points for river rock footings, and 1 point for no footings.

Interventions – Previous Interventions

In some cases, previous measures may have been taken to remediate displacement within stacked log structures such as wood purlin poles. Such measures are taken to relieve any members suffering from fatigue by transferring a portion of the load down the bracing intervention to the ground or a stable log member. Even if purlin poles or other types of bracing interventions are present, it does not necessarily mean that they are serving their intended function. Over several years, the wood purlin poles have a tendency to shrink and disengage, redirecting the structural loads back to the compromised member. If some sort of bracing is present in the stacked log structure but it is not engaged on at least one end, deduct 2 points. If the bracing is intact, deduct no points. If there are no bracing interventions, deduct no points.

Roof – Roof Openings

Openings in the roof of any structure can cause major problems related to moisture such as decay. Since the purpose of a roof is to keep the weather out, it is important that there are no unintended openings in this building element. The interiors of most buildings are not meant to be exposed to rain or snow and if they are, rapid deterioration of the building is possible. Repairing the roof should be a major priority for any steward. Deduct 3 points if there are any openings in the roof larger than 2 inches wide, otherwise do not deduct any points.

Roof – Orientation of Roof

The orientation of the building with regards to the predominant wind direction has a great influence on how snow collects around the structure in question. Since the least eccentric loads occur if the gable end of the structure is oriented perpendicular to the wind direction, no points are deducted. If the gable end of the structure is oriented parallel to the wind direction, then 3 points are deducted because this orientation is likely to incur eccentric snow loads. If the gable end of the structure is oriented closer to 45° to the main direction of the wind in the area, deduct 1.5 points.

Roof – Porch

The inclusion of a porch on a stacked log structure adds the possibility of eccentric snow loading patterns since the surface area of the roof is extended beyond the stability of the stack. There are two possible porch locations on a stacked log structure: the gable end of the structure or along the eave end. Because there is a greater probability that eccentric snow loading will occur on a roof with an extended eave porch over one with an extended gable porch, deduct 1 point for an eave porch and only 0.5 points for a gable ended porch. Deduct no points if there is no porch or there is evidence of a porch that no longer exists since the threat has been removed.

Roof – Construction

The type of roof construction used on the stacked log structure affects the dead load of the building because different roofing materials vary in weight. Since a roof of just sheathing planks covered in tarpaper does not add much load to the structure, deduct no points. If the roof is covered in sod, deduct 0.5 points because not only is there pressure associated with the soil and plant life of a sod roof, but also this type of roof has the potential to harbor moisture against the wood members and enable decay. If the roof has been replaced with a modern green roof, deduct 1 point because of the large weight associated with these roofing systems.

Material Vulnerabilities – Insect Damage

One major vulnerability of wood as a material is its susceptibility to insect infestation. Without professional expertise and practice, it can be difficult to determine whether or not a building has been subjected to insect damage and whether or not the infestation is active. However, there are several clues that can help the average observer determine whether a professional should be called in or not. At the Bar BC Ranch, many of the stacked log structures exhibit small pinhole voids in the log members that raise questions about insects, as such holes are usually associated with an infestation of powder post beetles. Other signs of insect infestation are grub holes, networks of galleries, and tunnels.⁶ If any of these indicators or other

⁶ *Wood Handbook: Wood as an Engineering Material* (Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 2010), 14-8.

suspicious evidence are found on the structure in question, 1 point should be deducted and an entomologist should be called in to determine the severity of the infestation and whether it is an active issue or not.

Material Vulnerabilities – Checks

The presence of significant checks or splits in log members of a stacked log structure can put the building at a higher risk of decay since the checks and splits are likely to harbor an excessive amount of water. The question is, what characteristics define a significant check? For the purposes of this survey, a significant check greater than 2 inches in length and has a depth into the log member that is one quarter the diameter of that log. It assumed that the width of the check is proportional to the depth so that dimension will not be factored into the definition. For example, if there is a check that is 38 inches long and 2 inches deep in a log with a diameter of 6 inches, it is considered to be significant (38" is greater than 2" and $2"/6" = 0.33$ which is greater than 0.25). For the first 8 significant checks in the entire structure, deduct 0.125 points per check. If there are more than 8 significant checks, deduct 1 point total.

Meaning of the Score

A set of general recommendations regarding the structural stability of and when to resurvey the stacked log structure are associated with certain scores. Keep in mind that some conditions should be remediated or looking into further, even if the score from this survey suggests otherwise. These prioritized conditions include fixing any holes or gaps in the roof, calling in an entomologist to determine the extent and activity of any insect damage, hiring an engineer to provide structural analysis if any of the prescriptive provisions laid out by the codes are surpassed, or calling in an engineer or other trained specialists if any questions about life safety are brought up. With this important note in mind, here is what the resultant scores from this displacement survey suggest:

- 85-100: The stacked log structure is in great condition and is exposed to few risks. Because of these circumstances, no immediate remedial measures need to be taken care of other than any existing prioritized conditions. Resurvey the structure

on an annual basis if time and money allows, mostly to monitor the buildings and determine rates of change.

- 70-84: The stacked log structure is in fairly good condition and is exposed to a normal number of risks. Although no immediate remedial interventions need to be completed other than any of the existing prioritized conditions, some action may be needed in the near future. Resurvey the building on a biannual basis if practical, otherwise monitor at the same time as the structures with scores between 85 and 100 for convenience.
- 45-69: The stacked log structure is in satisfactory condition and is exposed to some risks. This structure is a candidate for immediate intervention to avert faster, more substantial deterioration. If possible, the structure should be resurveyed once every season or four evenly spaced times throughout the year to determine if and how the seasonal loads affect the building. If resources do not allow quarterly survey visits, resurvey the building on a biannual basis.
- 25-44: The stacked log structure is in fairly poor condition and numerous risks are evident. While parts of the structure still function, other parts are beyond repair and will be very costly to repair or may even call to be rebuilt. If many economic and temporal resources are abundant, somewhat extensive stabilizing measures can be justified. The structure most likely will have a high rate of deterioration and it would be useful to resurvey the building once every season or during four evenly spaced site visits throughout the calendar year.
- 0-25: The stacked log structure is in extremely poor condition and may even be completely collapsed. There are also many risks associated with the building. This dire combination indicates that the building may be beyond repair and the cost to restore and preserve it will not be an economical choice if there are others that are more salvageable. The structure should be resurveyed twice a year to help determine typical rates of change given the specific site conditions.

Repeatability of the Displacement Survey

The whole purpose of this displacement survey is to provide a tool to assess and monitor the structural condition and associated risks of stacked log structures over time. To serve this purpose, the survey was made to be as simple and straightforward as possible. This way the assessment can be repeated quickly and accurately according to a planned survey schedule. With the collection of this data over time, overall rates of displacement and change can be calculated and help determine when it is appropriate to structurally intervene.

The results of this survey will be most beneficial if the scores and calculated rates are incorporated into the preservation plan of the site in question. Since this displacement survey particularly concerns the structural stability and associated risks, if paired with an evaluation of the integrity and value of each structure, a powerful preservation tool could be created. A preservation plan that includes all of these elements would help stewards prioritize conservation efforts and budgets, laying out a map of the most efficient use of resources.

Chapter 8: Recommendations and Conclusions

This thesis presents a method of surveying the structural displacement modes and associated risks of stacked log structures in mountainous sites for the future use of stewards of these sites. Although this is a useful tool as presented, there are a few possible improvements and forms of expansion that could benefit this survey and its applicability to a greater number of sites.

Use Recommendations

Because the context of every stacked log structure or site is different, it is difficult to create a universally applicable survey. Although efforts were made to include situations that occur at sites other than the Bar BC Ranch, there may be other situations that were not brought to the attention of the author or that are unique to other locations. Before employing this survey, make sure to consider the differences between the context of the Bar BC Ranch and the site in question. For example, this field survey was created for simple stacked log structures that are only one story tall and no larger than about 500 square feet. Larger stacked log structures are prone to additional modes of structural displacement due to their size, like the two-story stagecoach stop found near Hot Sulphur Springs in Grand County, Colorado (Appendix A – Figure 25). This survey as it currently exists would need to be adapted to include these other displacement possibilities. Also, make sure that any critical features of the survey site are addressed in the actual displacement survey. For example, if the site is not subjected to heavy or prolonged snow loads but rather seismic loads are more prevalent, the survey may need to be adjusted to account for the associated risks of earthquakes. For this reason, further development or even adaptation of this survey will be necessary for applicability to any stacked log structure in any location.

Possible Modification Recommendations

Currently, the survey and calculation form have been created in Microsoft Excel. Although this is powerful software with regards to arithmetic and in this case, calculating the

final scores associated with each building, it is not the best software for data management. For easy comparison between data sets in the future, the author recommends creating a Microsoft Access Database file that could not only incorporate the survey form, but would also serve as a digital repository for all of the responses to each question for each structure. With such a tool, the data of a single building or even an entire site could be compared relatively easily and used to track the rate of change of the final scores.

To create this survey, the author used an understanding of the typical load paths and displacement modes of stacked log structures, the types of loads applied to these buildings and how they are changing with external forces such as climate change, and the types of risks that are associated with stacked log buildings and their context. A more scientific method of determining the appropriate amount of points to deduct for each question would require using statistical analysis. Although this could be done, the author argues that this method does not accurately take into account how each of the relevant factors influence and interact with one another. Since the results of this displacement survey are purely meant to inform stewards of the relative structural condition and associated risk level of buildings so that they can make appropriate decisions, it is more important to include an accurate understanding of the interaction of factors versus a precise score with a detailed description of what interventions to make. Stewards should not act with prescriptive interventions based on an arbitrary number. Each situation is different and the scores from this survey should be used to inform preservation decisions, not make them.

Field Verification Recommendations

Now that the survey has been created, it needs to be field verified. The author recommends that it be used to evaluate the stacked log structures at the Bar BC Ranch for several reasons. First, it would be useful to evaluate the buildings used to create the survey in person to see if all of the original field measurements taken during earlier site visits were correct. Secondly, a preservation plan has been created for the ranch based on a condition survey completed by the Architectural Conservation Laboratory of the University of Pennsylvania

as well as a valuation of the integrity of the buildings completed by the cultural resource staff at Grand Teton National Park. It would be interesting to compare the results of the structural displacement survey to the results of the condition and integrity assessments to see how they relate.

This structural displacement survey should also be field tested because it has only been tested out on two buildings. During the original site visits, the author took detailed measurements of four stacked log cabins at the Bar BC, not knowing exactly what would be needed eventually. Later on in the process, the definition of a stacked log structure for the purposes of this survey was determined to include that the corners must be overlapping and engaged. Unfortunately, two of the four structures originally measured were constructed with box and post corners, which do not constitute fully engaged corners. Although the author is confident in the numbers used as deductions, more work may need to be done on the meaning of the score ranges once the survey has been field tested and analyzed.

Once this survey has been carried out on the same set of buildings multiple times as a monitoring tool, a rate of change could be inferred from the data and the final scores. With some field-testing and observation, one could relate these rates to relative intervention time frames. Then, not only would the steward know the relative structural condition of the building, but also understand how quickly the structural stability is deteriorating.

Other Conclusions

This thesis provides a survey meant to capture the condition and associated risks of stacked log structures by assigning a final relative score based on deductions for certain risks and conditions. If a structure is assessed at multiple points over time, one can determine a rate of deterioration of the condition and risk of that stacked log structural system. By using the rates of deterioration as well as the relationships between the scores of multiple buildings across a site, the scores can inform stewards when making a comprehensive preservation plan for a cultural heritage asset.

The deductions were based on a basic understanding of how stacked log structures

are constructed, how they typically displace, observations made by the author, the condition of and risks associated with the structures at the Bar BC Ranch, and structural design codes for log buildings. The major threats to and components of the structural stability of stacked log structures were determined as the following: contextual issues such as the direction of drainage from the building and the proximity of trees, the relationship of the structure's nominal dimensions to one another, the degree of corner engagement, the appearance of any deformations or discontinuities, the condition and types of foundations used, the inclusion of any previous interventions, the condition and orientation of the roof, and the material vulnerabilities of wood, especially those related to decay. Each of these threats and conditions were incorporated into the final displacement survey.

Despite the abundance of snow in Grand Teton National Park during six months of the year, field observations completed by the author revealed that snow is not a major threat to the remaining structures at the Bar BC Ranch. The stacked log structures that remain standing have endured harsher winters during the early years of their existence than today, leading the author to conclude that the extant buildings are not only more robust than the buildings on the site that have collapsed, but that the remaining structures are subjected to smaller snow loads. The milder winters and smaller snow loads are due to climate change. Fortunately, the structural affect of an evenly distributed snow load is not a major risk to the stacked log structures at the Bar BC Ranch. However, when eccentric snow loads are applied to the buildings, structural displacement is likely. Eccentric loads can result from contextual site features such as overhanging tree branches or from the orientation of the building related to the predominant wind direction. Structures oriented with gable ends parallel to the wind have a greater chance of incurring eccentric snow loads than structures oriented with gable ends perpendicular to the wind. This phenomenon is proved by the generally more displaced condition of the structures oriented with gable ends parallel to the wind.

Although the displacement survey was created using data from the Bar BC Ranch in Grand Teton National Park, it can be adapted to other sites at least in the same type of climate, if not in other types of locations as well. Universal characteristics of stacked log structures, how

they are meant to act structurally, and how the loads typically shift as they displace were used during the creation process. Although this protocol should be improved and expanded, this tool will provide a solid starting point for such efforts. With this protocol available to stewards of stacked log structures, effective conservation plans for sites with these buildings can be created that include long term monitoring plans. With timely monitoring and informed preventative measures, this portion of American built heritage can be preserved as cost effectively and efficiently as possible.

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Appendix A: Figures



Figure 1: Swedish Granary in Greenwich, NJ, circa 1664-1684 (Author)



Figure 2: Scribe-fit log construction (R. Chambers, www.logbuilding.org)



Figure 3: Chinked-style log construction, Bar BC Ranch, circa 1912 (Author)

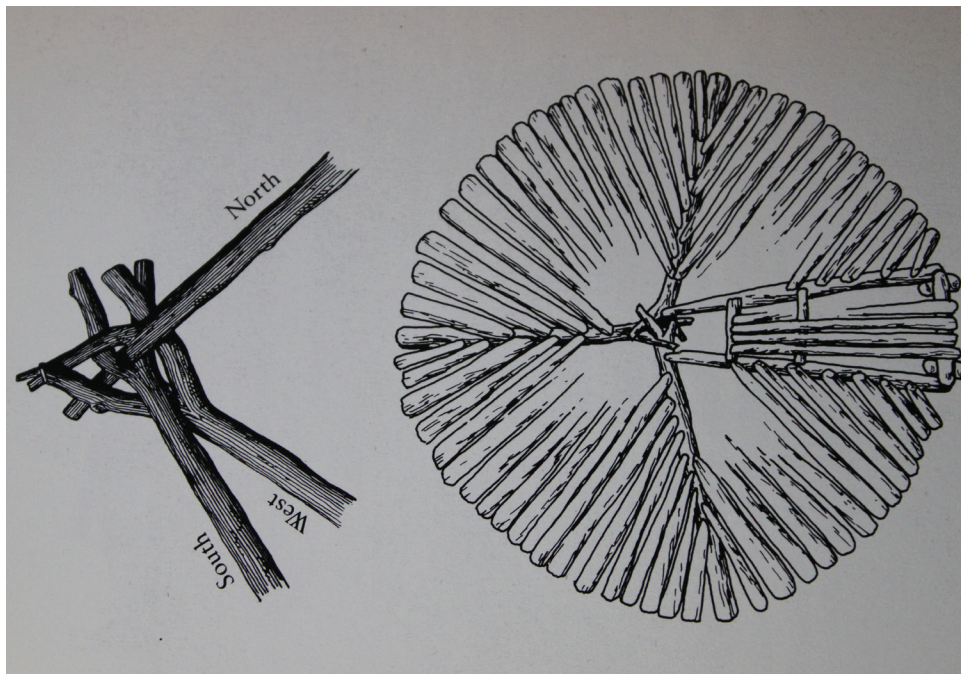


Figure 4: Lean-to Navajo hogon, circa 11th century (Nabokov & Easton, 329)



Figure 5: Navajo female, horizontal stacked log hogon, circa 1880 (Nabokov & Easton, 330)



Figure 6: Stacked log barn on Mormon Row, Grand Teton National Park, circa 1913 (R. Beckman)

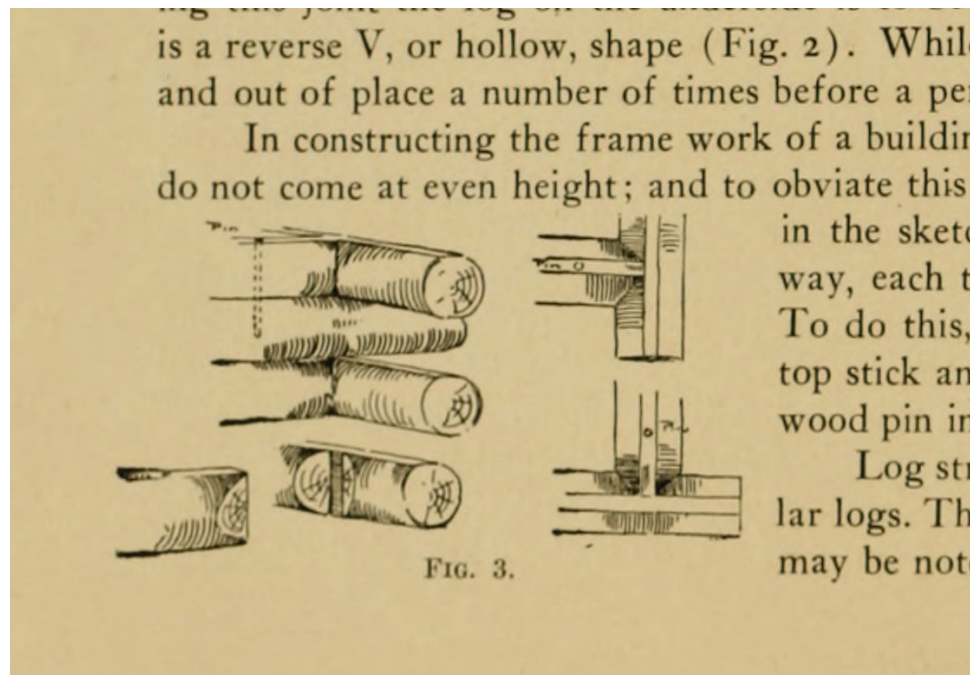


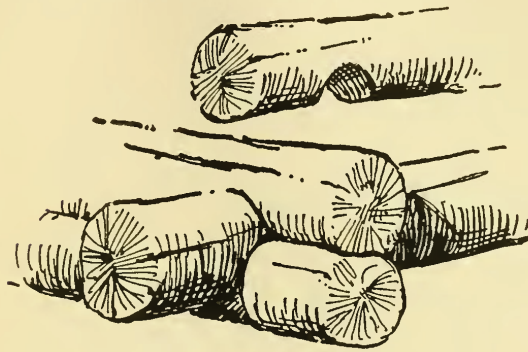
Figure 7: Pinned lock joint corner, circa 1889 (Wicks, 14)



Figure 8: Entrance of Old Faithful Inn, circa 1903 (NPS Photo by JP Clum Lantern)

BUILDING THE CABIN

the log. The notch should be slightly scooped out in the center, so that the outer edges may be brought to a joint. The log is now put in place and, if it fits properly, may be fastened to the under log by a spike driven through the corner.



On a long reach on the sides of a larger building (eighteen feet or more) the logs should be fastened together by an additional iron pin, driven through about the center of the logs.

It will often happen that the poles are not straight; you may force the bend out

Figure 9: Excerpt from Oliver Kemp's *Wilderness Homes*, 1908 (Kemp, 49)



Figure 10: Privy and comfort station in Yosemite National Park, circa 1930 (Good, 141)



Figure 11: Northeast entrance to Yellowstone National Park, circa 1935 (Good, 29)

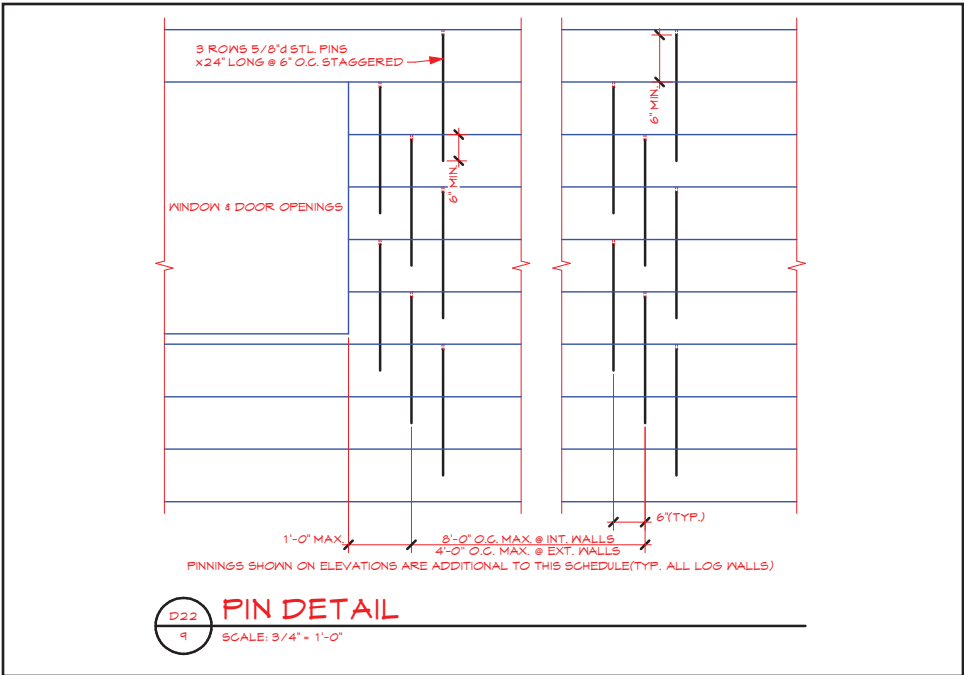


Figure 12: Detail of modern through-pins (Montana Log Homes)

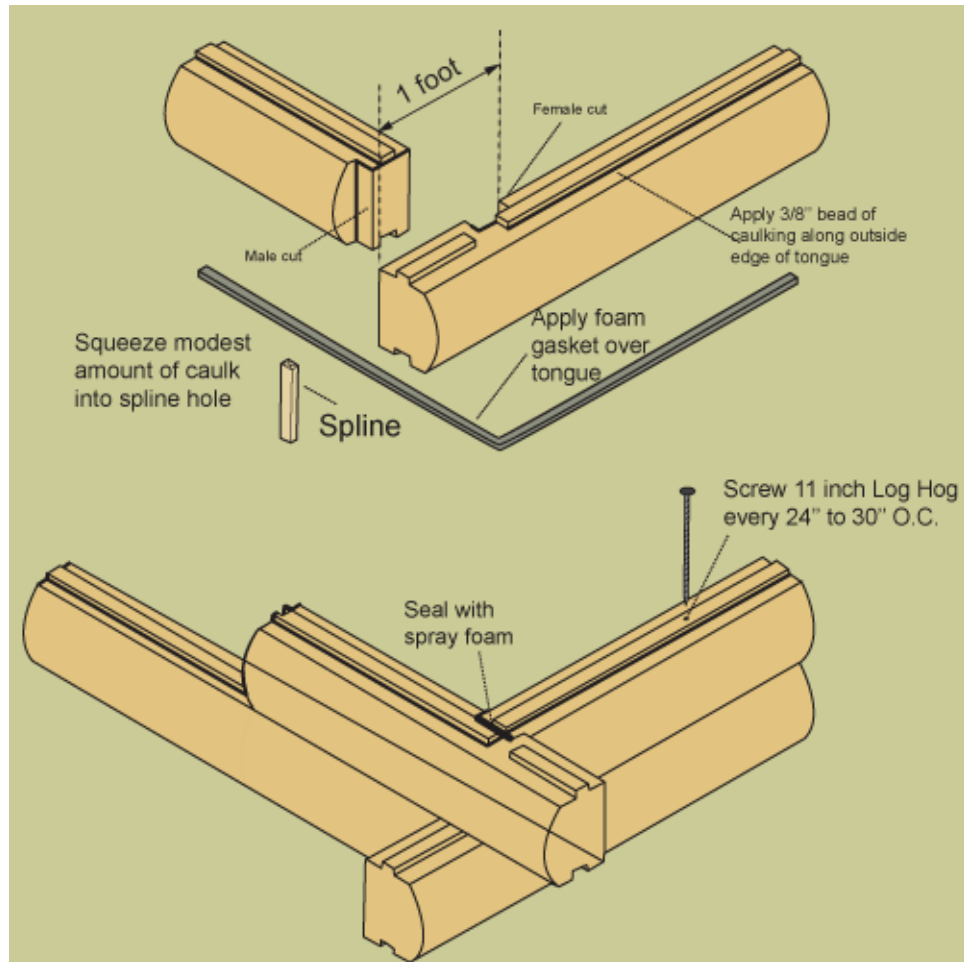
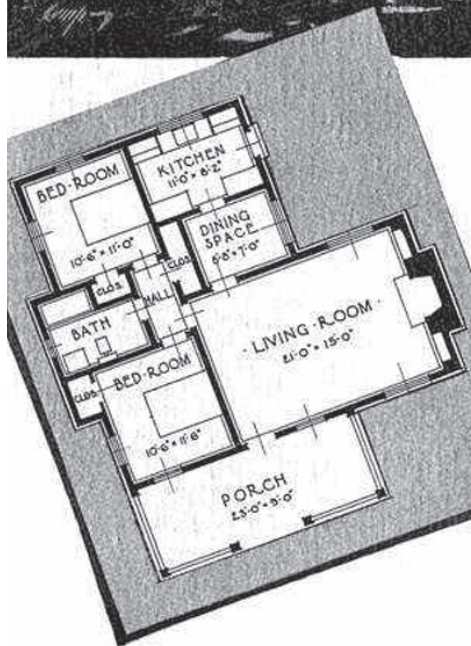


Figure 13: Detail of modern tongue-in-groove members with gasketing
(Coventry Log Homes)



Nipigon

The Nipigon has all the rustic backwoods charm you expect in a log cabin. Still, at the end of the summer, you'll say it's just as comfortable as living at home—and a good deal more fun.

First of all, the bath is conveniently located between two cross-ventilated bedrooms. You'll find lots of use for the open shelves flanking the very large fireplace in the living room. With twin windows on opposite walls, this room is excellently ventilated.

You won't miss your kitchen back home at all, for you'll find this one to be every bit as modern and efficient.

Figure 14: 1939 Sears, Roebuck and Co. ad for stacked log cabin kit (Sears Archives)

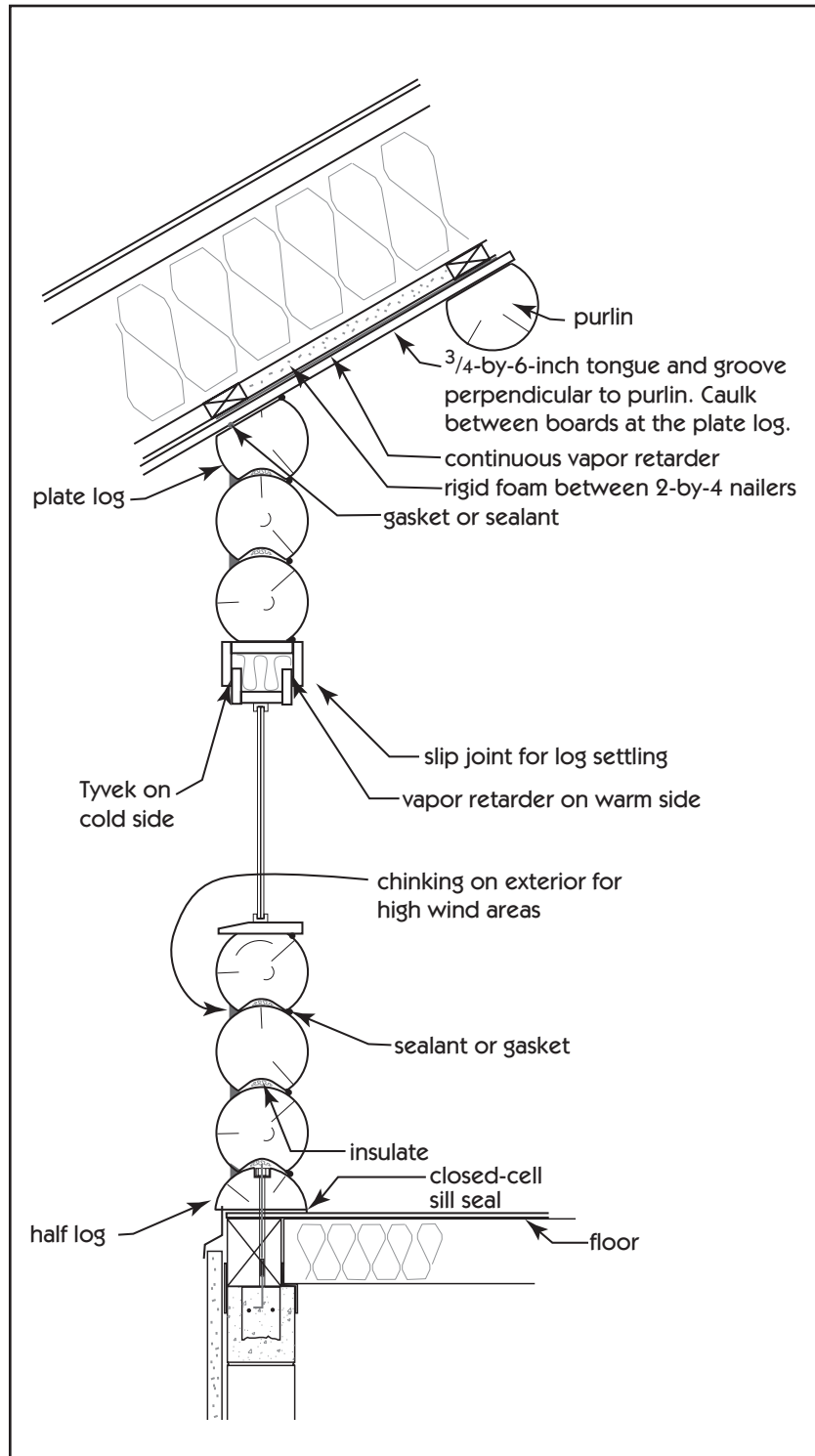


Figure 15: Section of a modernized stacked log structure from the Alaska Log Building Construction Guide (ILBA, 41)



Figure 16: Photograph of Timbered Island looking north (Author)



Figure 17: Eccentric snow load (Author)

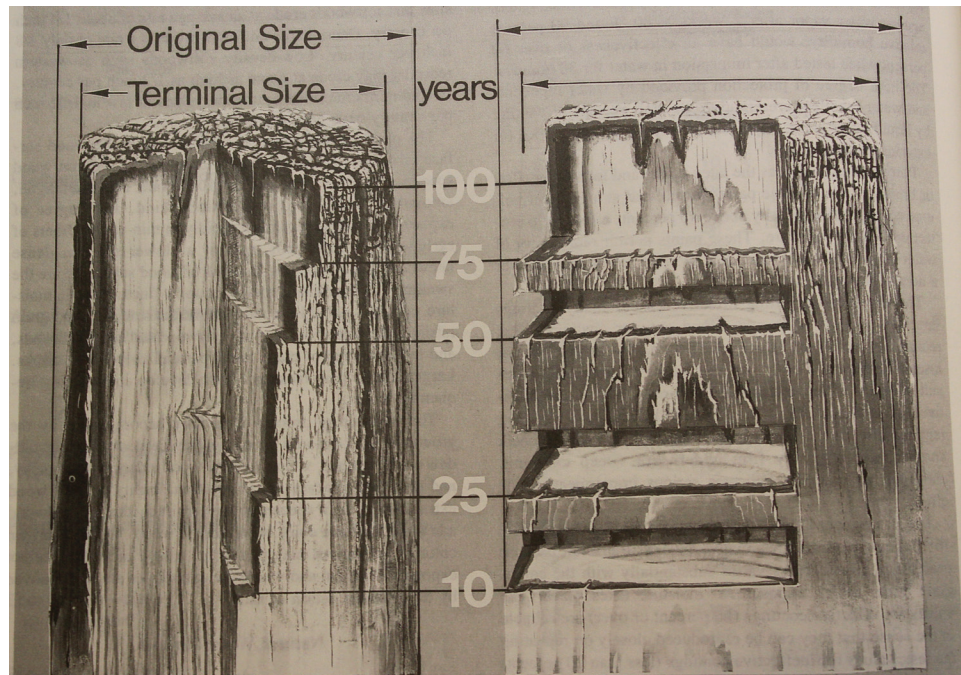


Figure 18: Weathering process of wood (Wood Handbook, 16-11)



Figure 19: Exposed purlin end that has decayed (Author)



Figure 20: Evidence of removed fireplace (Author)



Figure 21: Failure of a porch located on the eave end of the stack (Author)



Figure 22: Deciduous tree within close proximity of a stacked log structure (Author)



Figure 23: Coniferous tree within close proximity of a stacked log structure (Author)



Figure 24: Tree with overhanging branches (Author)



Figure 25: Stagecoach building outside of Hot Sulphur Springs, CO (Author)

Appendix B: Illustrations

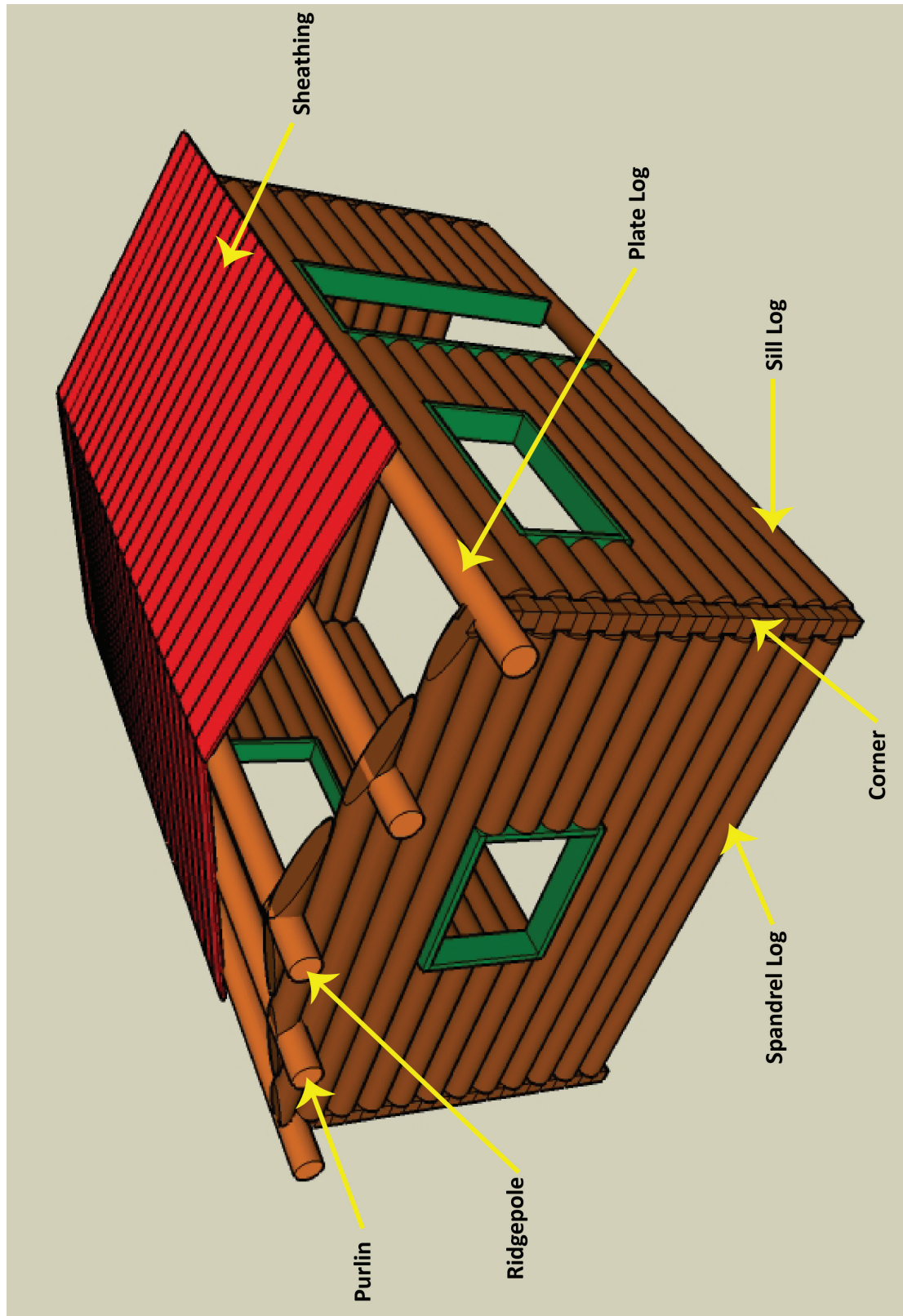


Illustration 1: Members of a stacked log structure (Author)

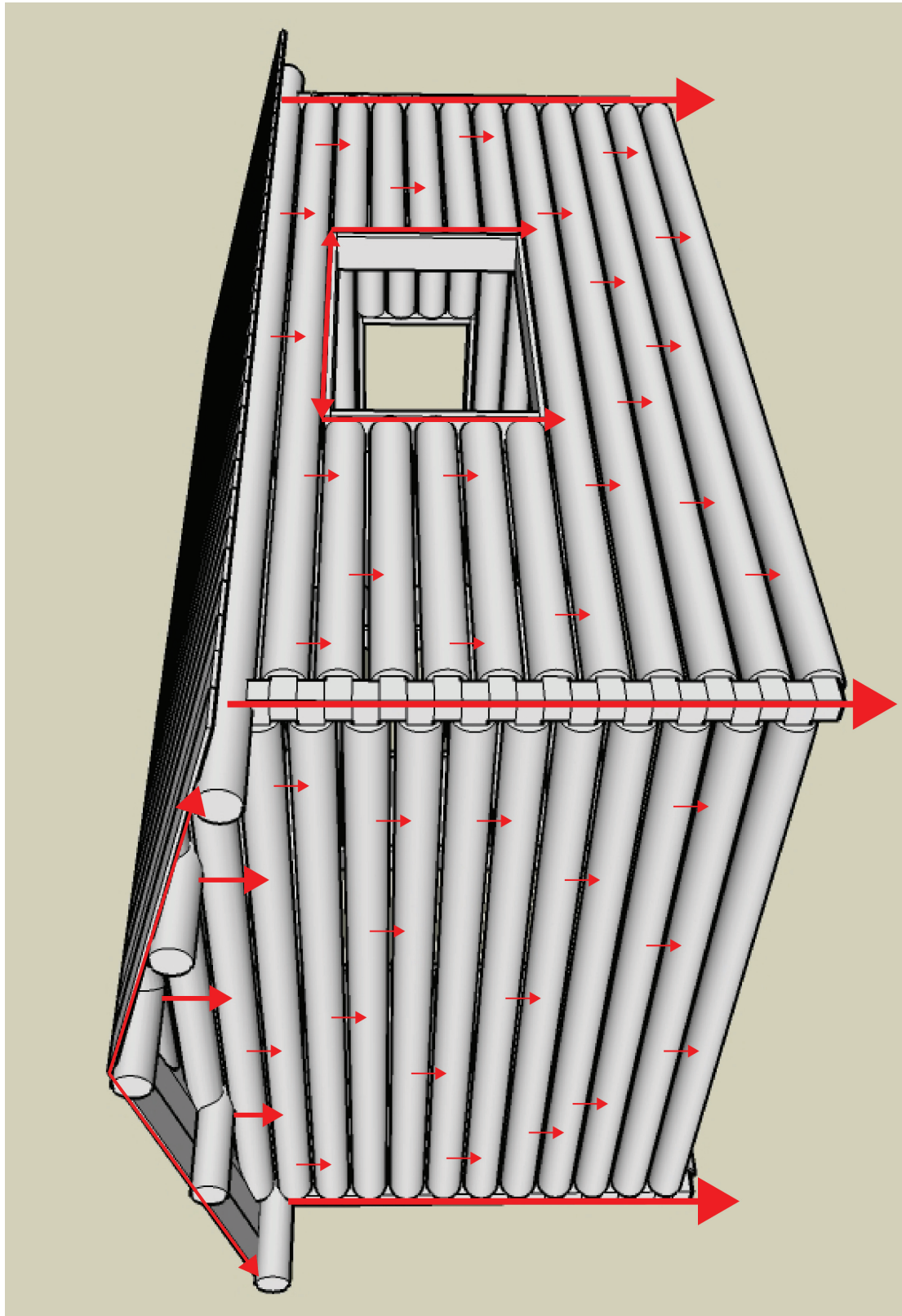


Illustration 2: Typical load path of a stacked log structure (Author)

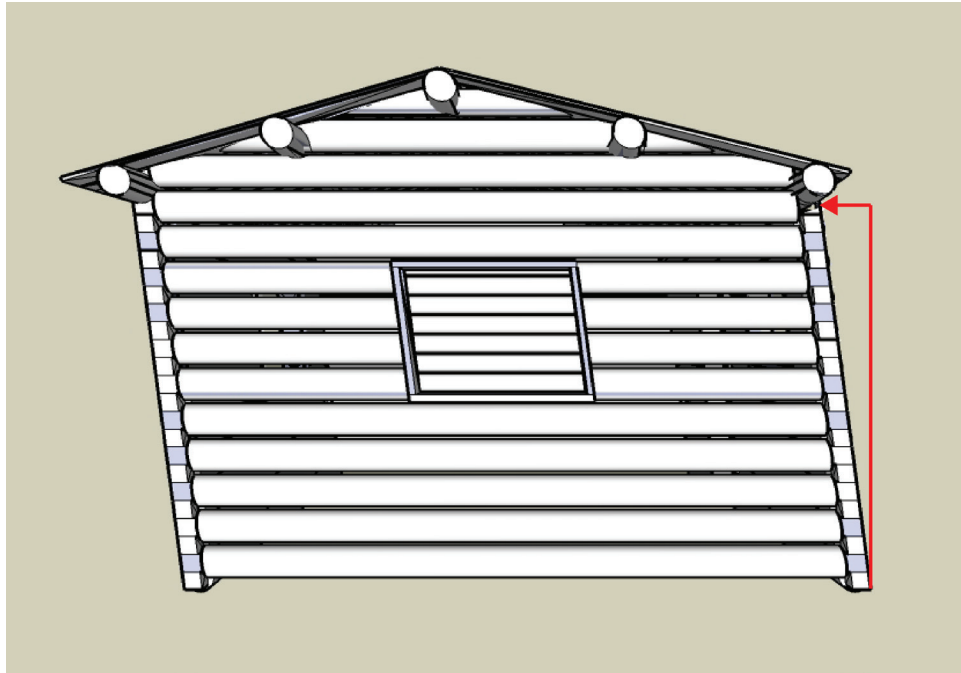


Illustration 3: Gable end racking (Author)

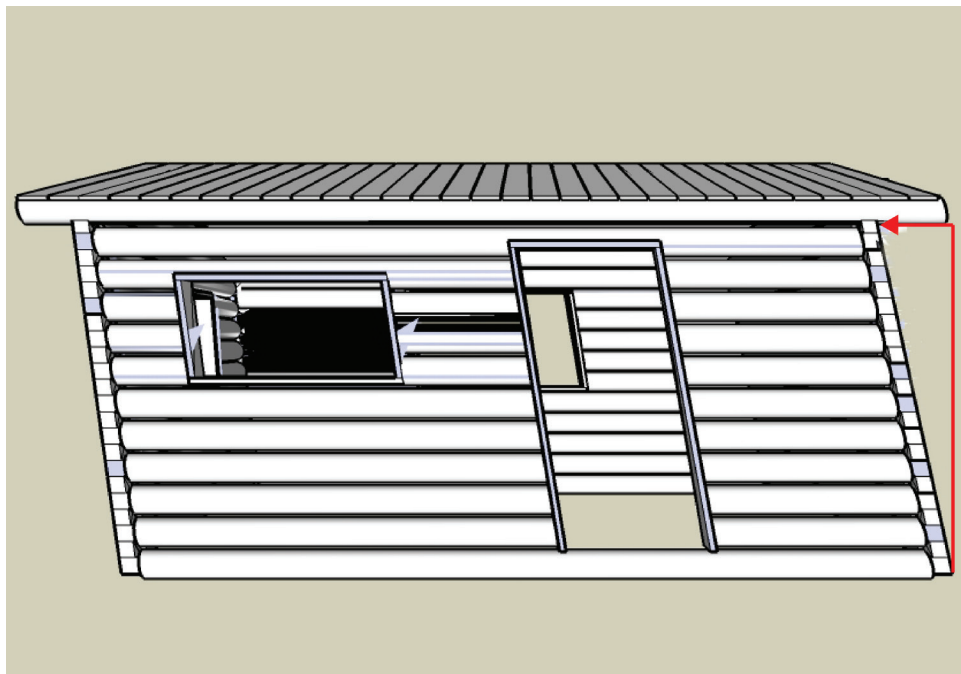


Illustration 4: Eave end racking (Author)

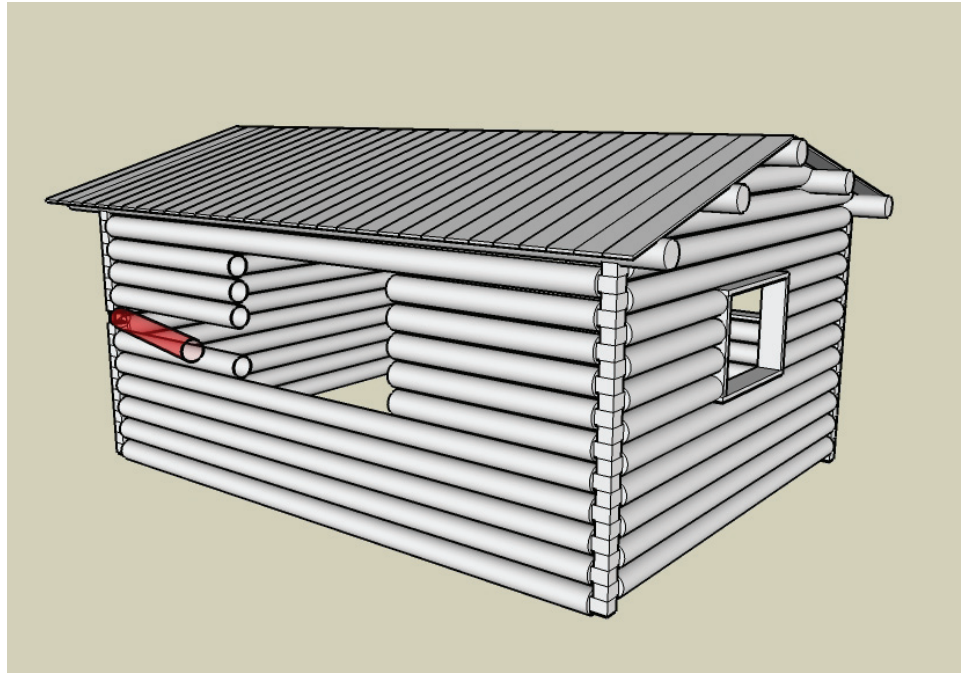


Illustration 5: Out-of-plane member rotation (Author)

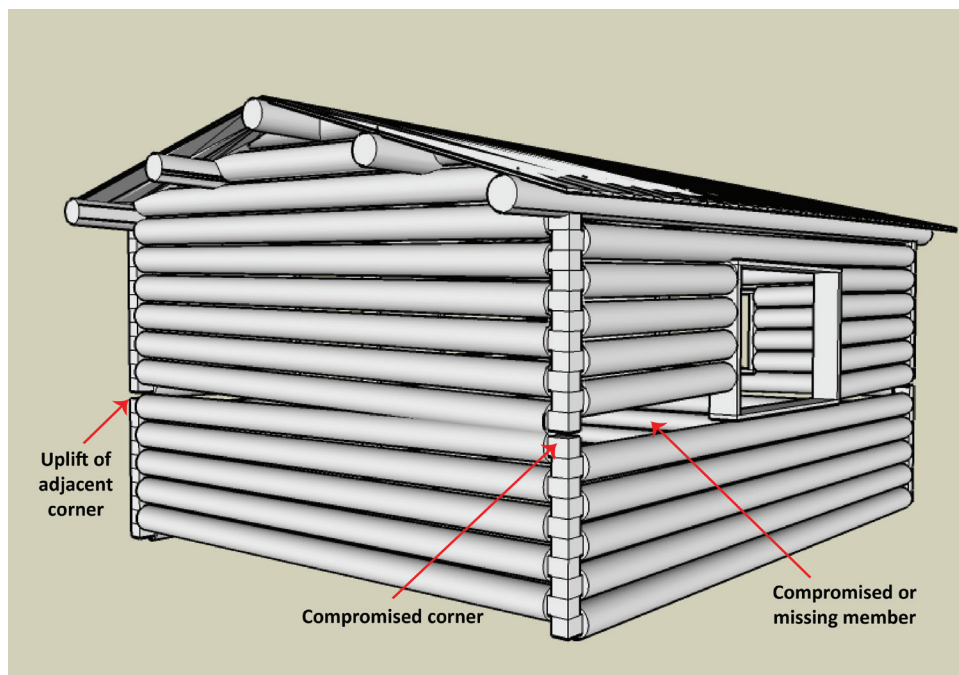


Illustration 6: Compromised Corner (Author)

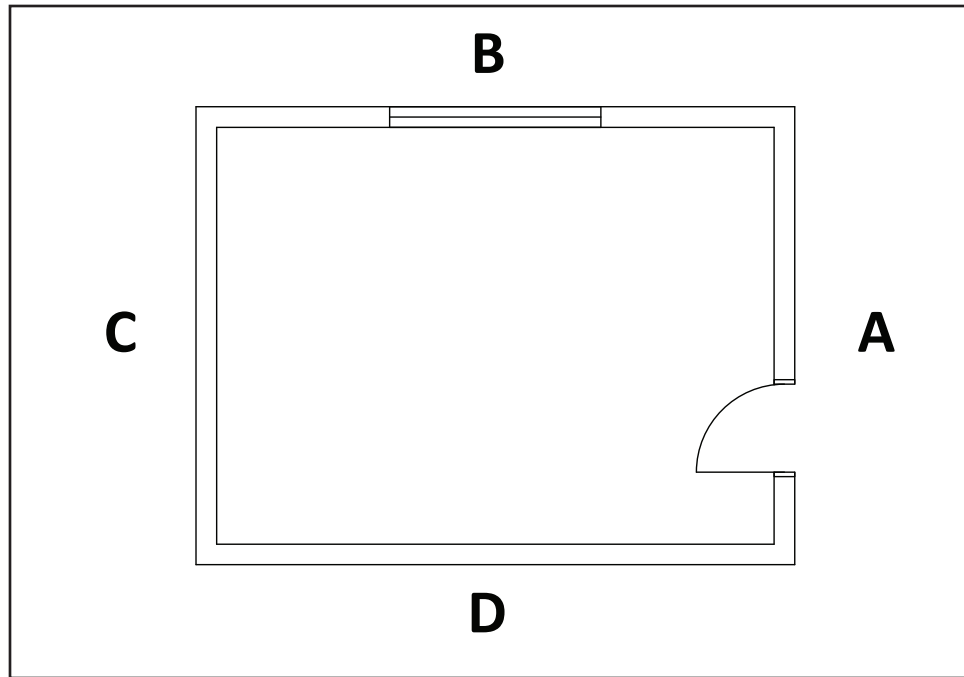


Illustration 7: Elevation labels for structure with front door on a gable end (Author)

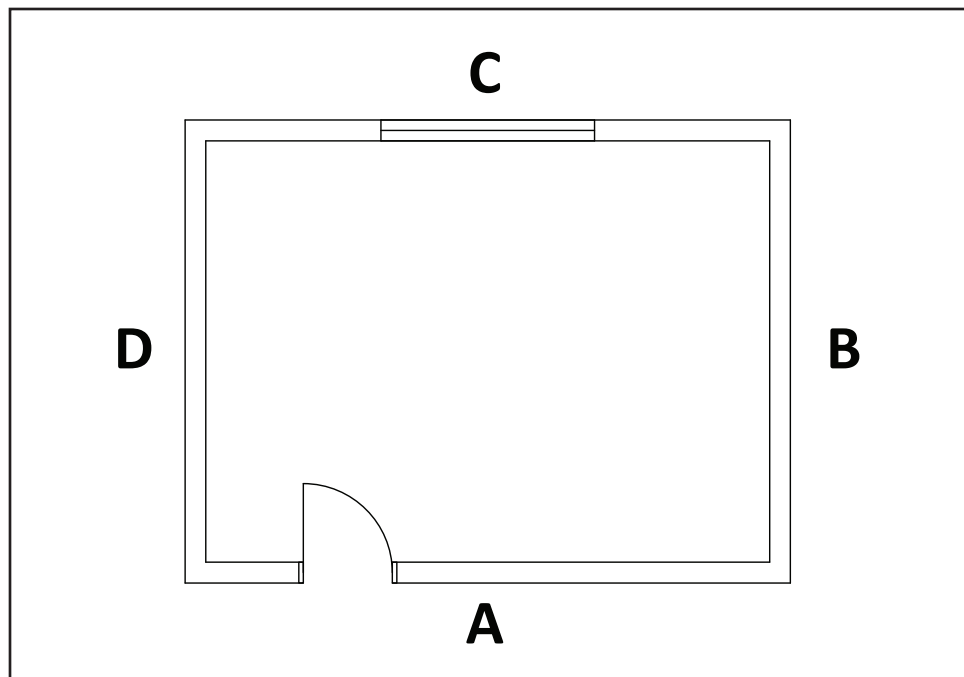


Illustration 8: Elevation labels for structure with front door on an eave end (Author)

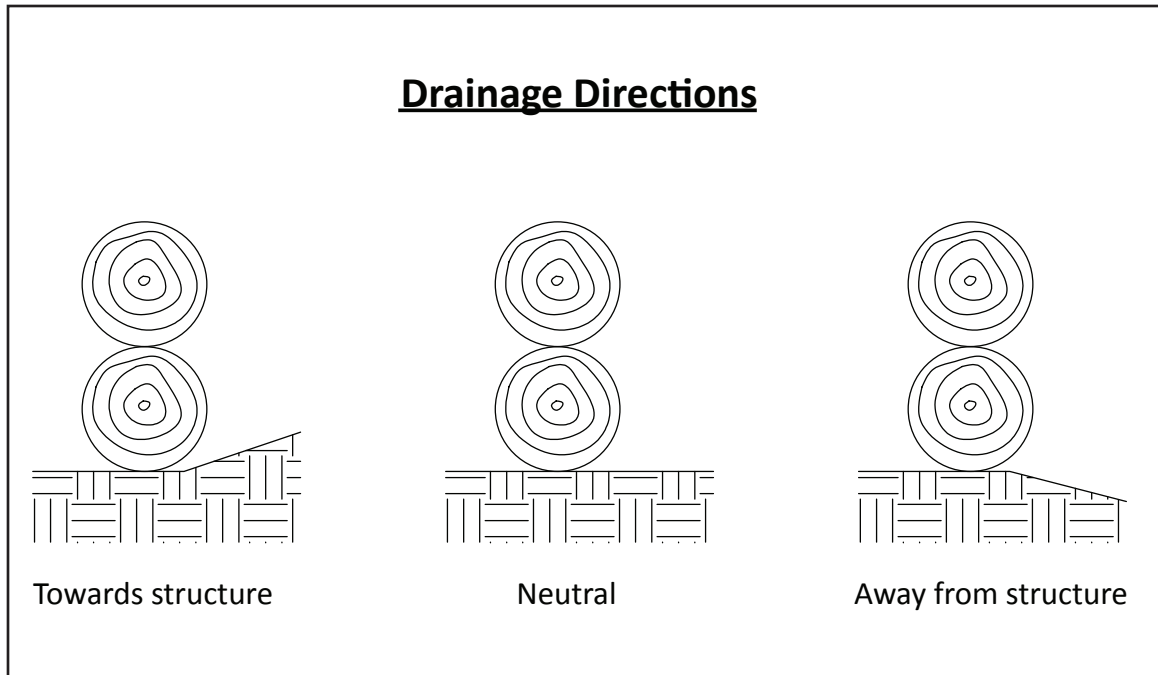


Illustration 9: Drainage directions (Author)

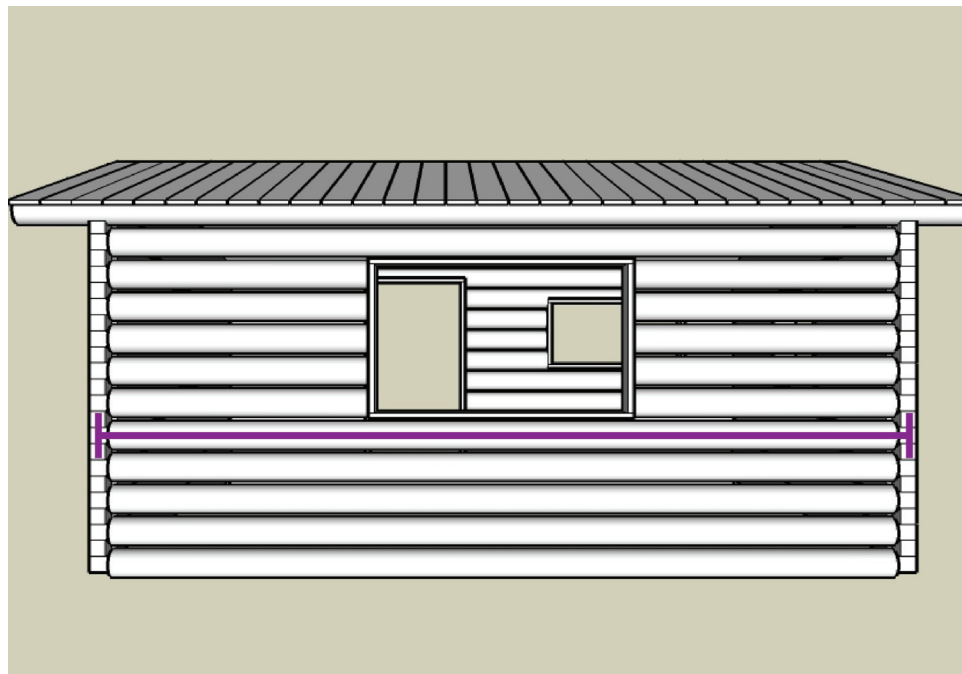


Illustration 10: Length measurement in displacement survey (Author)

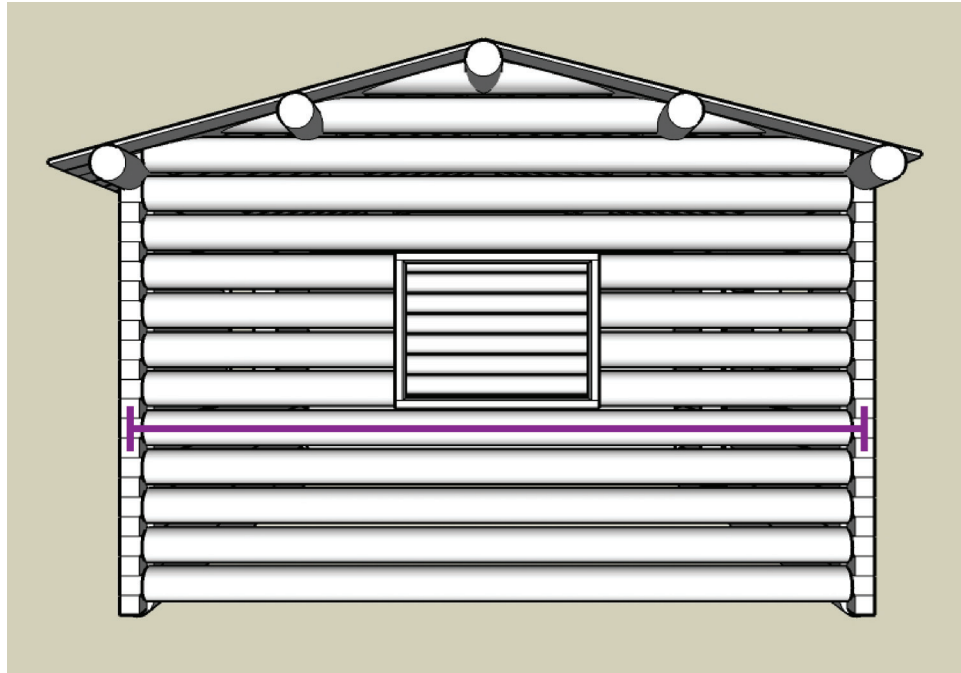


Illustration 11: Width measurement in displacement survey (Author)

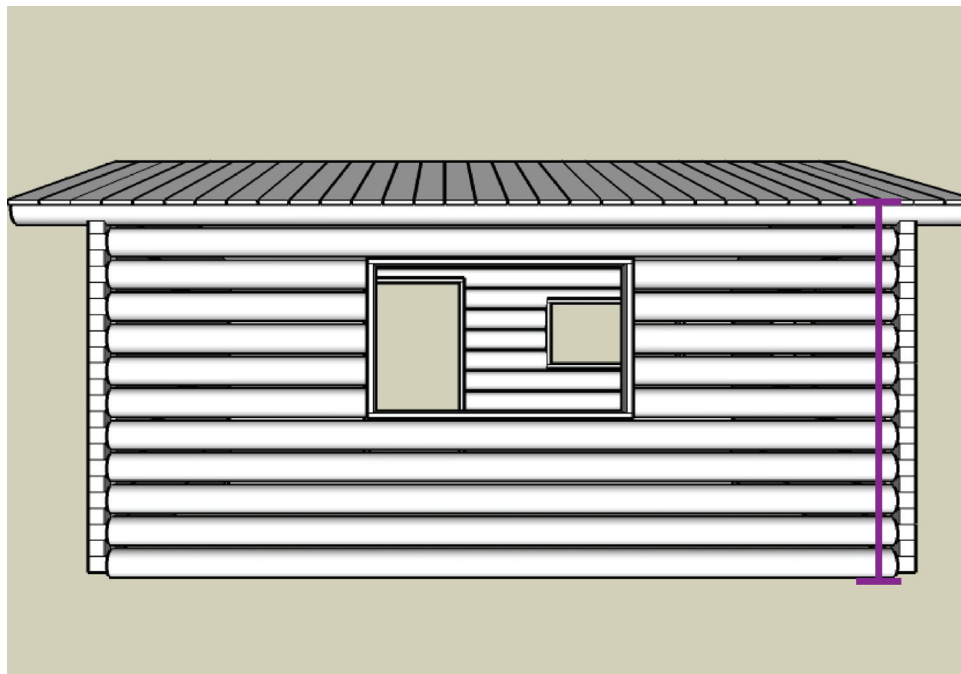


Illustration 12: Corner height measurement in displacement survey (Author)

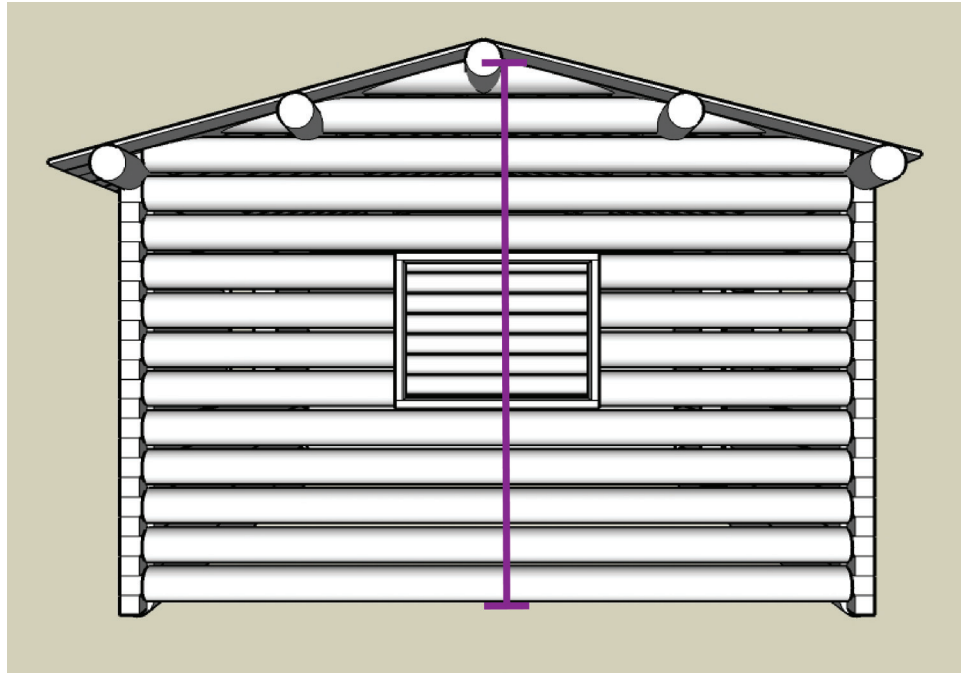


Illustration 13: Gable height measurement in displacement survey (Author)

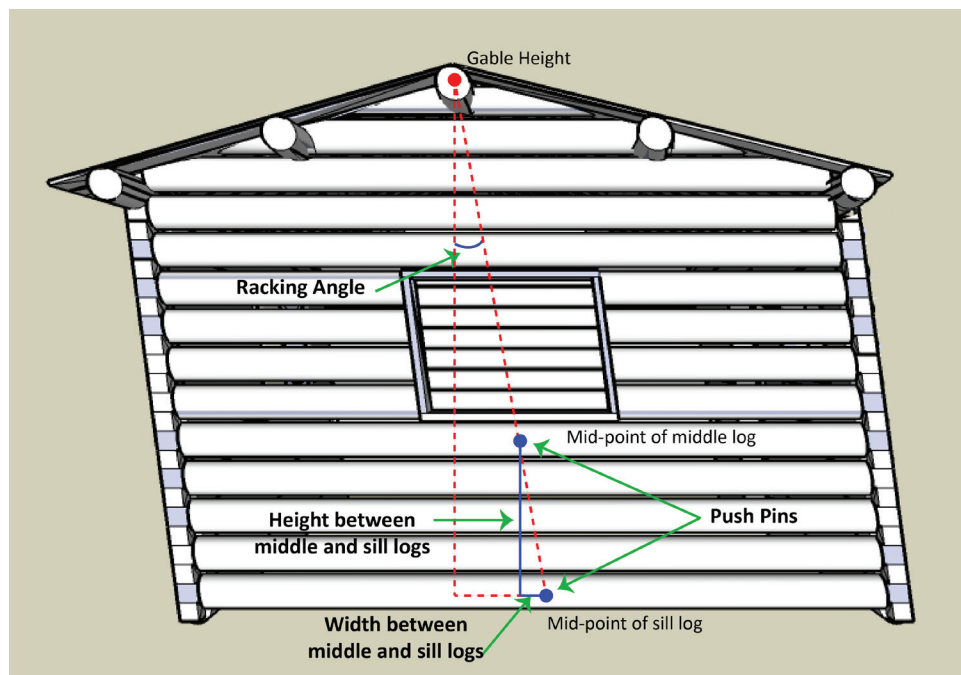


Illustration 14: Racking measurements in displacement survey (Author)

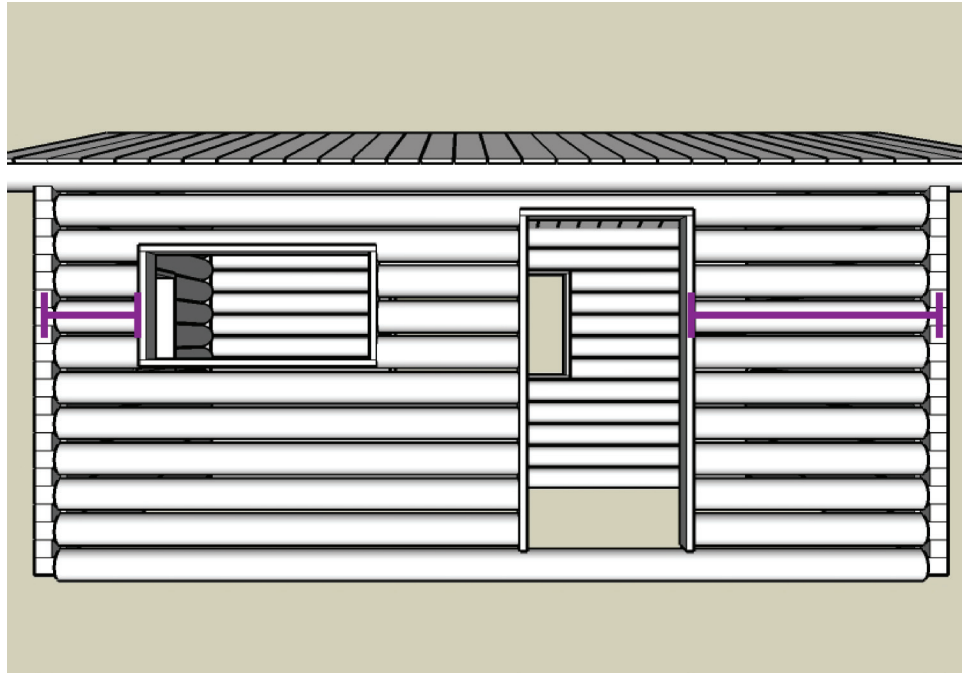


Illustration 15: Distance between an opening and the nearest corner (Author)

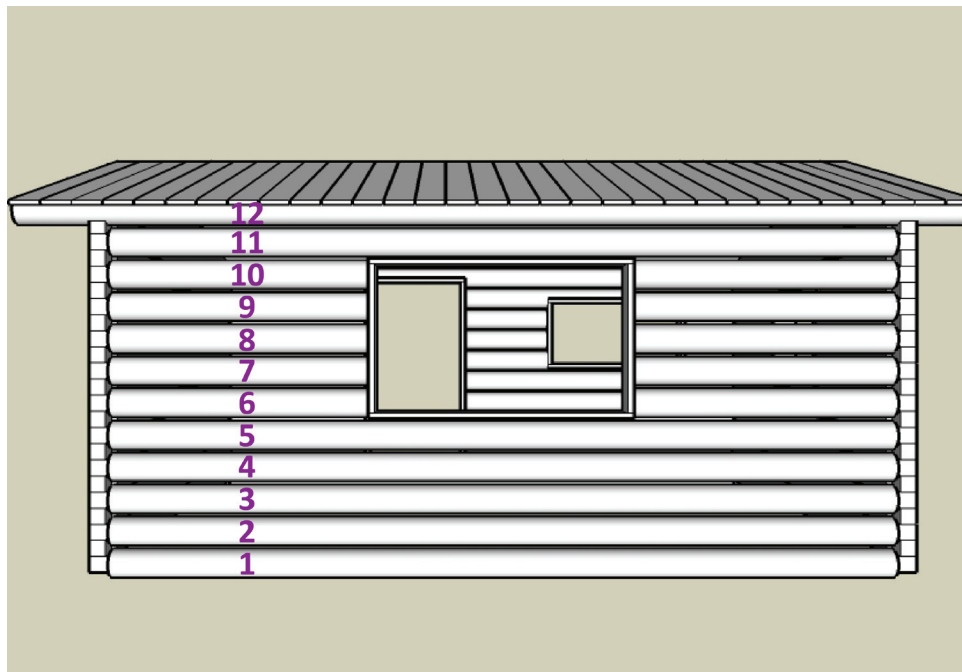


Illustration 16: Log count in displacement survey (Author)

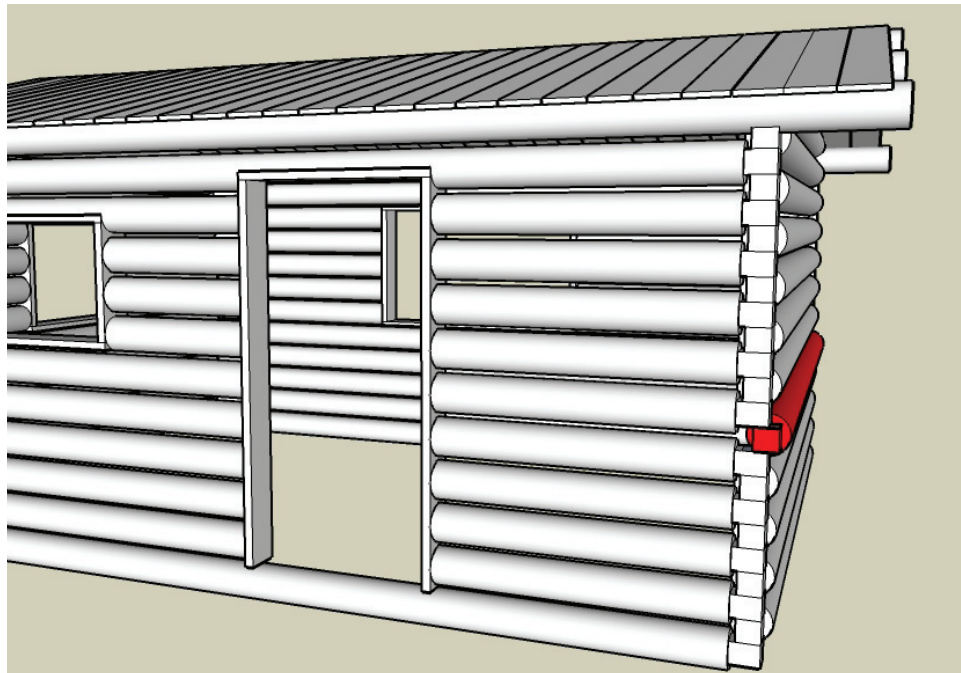


Illustration 17: Midspan member displacement (Author)

Appendix C: Maps

SURVEY NO. WY- 92	HISTORIC AMERICAN BUILDINGS SURVEY SHEET 1 OF 1 SHEETS	LIBRARY OF CONGRESS INDEX NUMBER
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ETON COUNTY, WYOMING

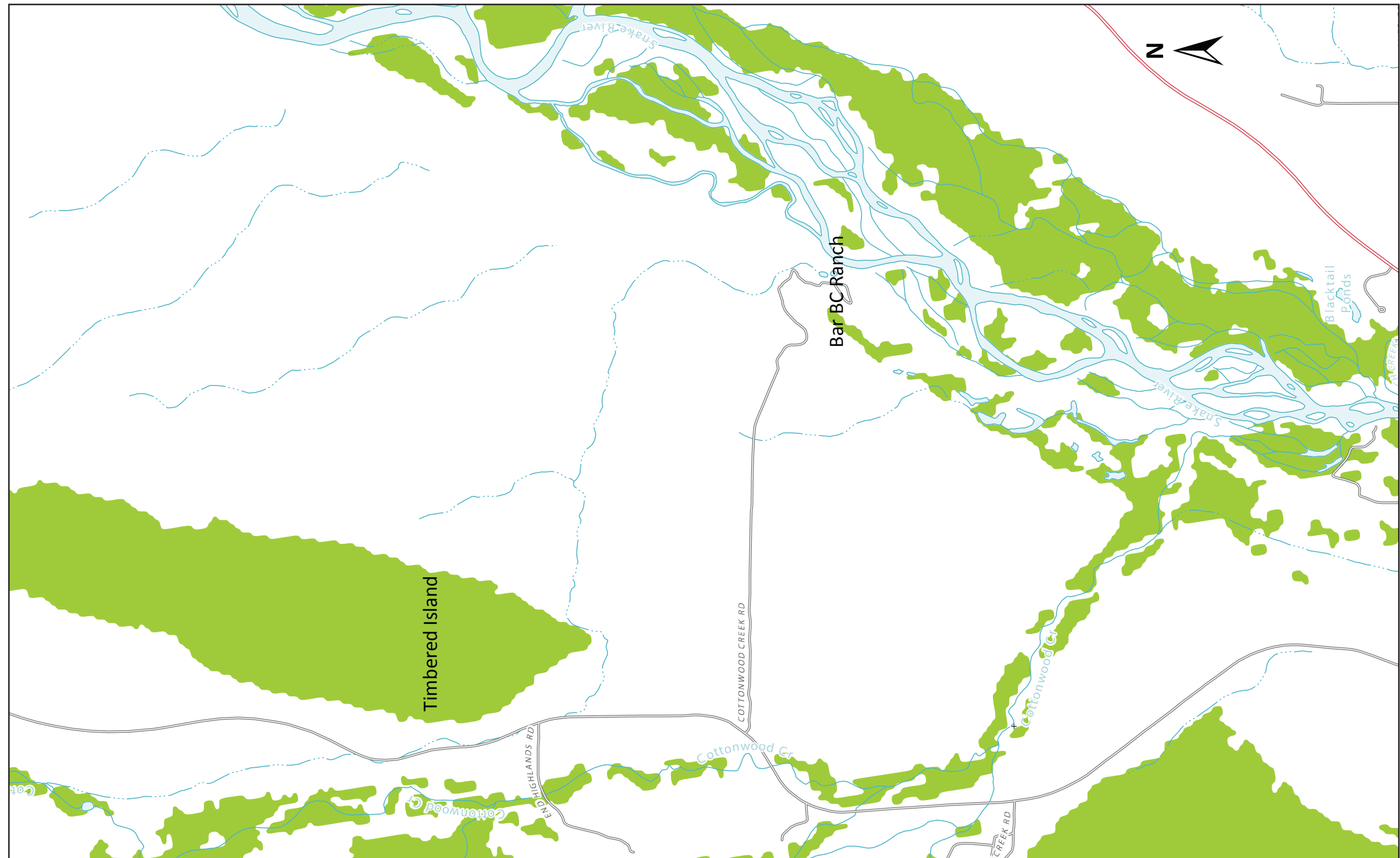
NAME AND LOCATION OF STRUCTURE	DATE	BY
BAR BC RANCH		
MOOSE VICINITY		

80) REVISED BY JEFFREY K. JACOBSON, SUMMER (1980)

ROCKY MOUNTAIN REGIONAL OFFICE
OFFICE OF ARCHEOLOGY AND HISTORIC PRESERVATION
HERITAGE CONSERVATION AND RECREATION SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

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Map 2: Relationship of Timbered Island to the Bar BC Ranch, Scale - 1:24,000 (USGS)

Appendix D: Wood Sample Identification



United States
Department of
Agriculture

Forest
Service

Forest
Products
Laboratory

One Gifford Pinchot Dr.
Madison, WI 53726-2398

Date: February 21, 2013

CHRISTINE BECKMAN
3512 SPRING GARDEN STREET, APT. 1F
PHILADELPHIA, PA 19104

Dear CHRISTINE BECKMAN,

I have identified the specimen(s) you submitted to the Center for Wood Anatomy Research wood identification service. Your specimen(s) was/were received on 12/4/2012 and identification(s) was/were completed on 2/14/2013 the identification(s) is/are as follows:

1. YELLOW PINE GROUP - PINUS CONTORTA
2. YELLOW PINE GROUP - WESTERN YELLOW PINE GROUP
3. YELLOW PINE GROUP - WESTERN YELLOW PINE GROUP
4. YELLOW PINE GROUP - PINUS CONTORTA
5. WHITE PINE GROUP

You can find information on wood, wood properties, and ongoing research at www2.fpl.fs.fed.us or at www.fs.fpl.fed.us.

Respectfully,

Alex C. Wiedenhoef, Ph.D.



Caring for the Land and Serving People

Printed on Recycled Paper



Bar BC wood sample identification results from Alex C. Wiedenhoef, Ph.D. at the Center for Wood Anatomy Research division of the Forest Product Laboratory and Forest Service. Sample 1 was taken from the porch purlin of cabin 1388. Sample 2 was taken from a log member of cabin 1370. Sample 3 was taken from the quarter sapling chinking of cabin 1388. Sample 4 was taken from the quarter sapling chinking of cabin 1398. Sample 5 was taken from the door framing of cabin 1370.

Appendix E: Blank Site Visit Documents

GRAND TETON LOG STRUCTURE THESIS: SITE VISIT PRODUCTS AND PROCEDURES

- **Photographs**
 - Record all photographs on the photo log sheet
 - Clockwise rotation around the structure
 - From the corner, down the right wall
 - From the corner, down the left wall
 - Oblique of the corner itself
 - Elevation of left wall
 - Next corner, repeat
 - Detail shots
 - Deformations such as bows, s-curves, log failure etc.
 - Sill logs
 - Chinking
 - Joint conditions/connections
 - Wall to wall
 - Wall to roof
 - Wall to floor/foundation
 - Rectified photographs
 - Set up targets with push pins, measure between them, take photos, rectify photos
 - Do condition survey on rectified photos
 - Basic condition survey
 - Rot, punkiness, UV bleaching, open joints, insect damage, voids, significant checks, biogrowth
 - Define all of these parameters and their extents in the field e.g. how wide does a check need to be to be significant
 - Built off of the survey done summer 2012 of Bar BC Cabin 1388
 - Recorded punkiness, slope of grain, knots, partial loss, open joints, in and out of plane, moisture content, direction of grade
- **Measurements**
 - Before leaving, draw basic schematic floor plan and roof plan to mark dimensions on
 - After taking rectified photographs, print to record specified measurements on the measurement checklist
 - Always mark measurement benchmarks for survey repeatability
 - Small, clear push pins
 - Measurements gathered during the photo rectification process, all using tape
 - Length and width (both walls)
 - Height at wall and gable/ridge
 - All sides of every corner and midpoint of each side
 - Wall thickness
 - Location of purlins
 - Openings
 - Plumb, wall
 - If other supports, location and type
 - Measurements physically gathered – take when finished with rectified photos of one cabin
 - Deflection of eaves
 - Tape and plumb bob
 - Deflection of ridge
 - Laser level, twine, push pins, tape
 - Plane/ out of square walls (interior)
 - Folding ruler and protractor
 - Floor, mid point, and top of wall (if possible)
 - If other supports, type, dimensions and location
- **Samples**
 - Take samples from each type of species used across the sample set (if visibly different)
 - Walls

- Roofing material
- Purlins
- **Supplies needed**
 - Check out from the green gangbox at school
 - Disto
 - Laser level
 - Infrared glasses
 - 100 ft tape measure
 - 26 ft tape measure
 - Photograph ruler
 - Calipers
 - Folding ruler
 - Tripod
 - Plumb bob
 - To bring on my own
 - Camera
 - Color card
 - Scale
 - Knife
 - Awl
 - Colored Sharpies
 - Transparent protector sheets
 - Clear push pins
 - Chalk
 - Spirit Level
 - Pre-printed survey sheets (see attached)
 - From the lab
 - Coin envelopes
 - Get in Jackson Hole
 - Ladder
- **Schedule**

Saturday (10.20)	Sunday (10.21)	Monday (10.22)	Tuesday (10.23)	Wednesday (10.24)	Thursday (10.25)
Buy a color card/grey card at the camera store	Keep on taking photos for rectification and measurements	Meet with Katherine (11:30 am)	Finish up taking photos for rectification and measurements	Finish printing photos at Staples	Finish condition survey
Start taking photos for rectification and measurements	Take samples	Keep on taking photos for rectification and measurements	Start Condition survey	Work on Condition Survey	Finish up any necessary items
Work on rectifying photos for printing	Work on rectifying photos for printing	Start printing photos at Staples	Work on rectifying photos at Staples		
		Work on rectifying photos for printing			

CABIN _____ BAR BC RANCH GRAND TETON NP	FLOOR PLAN	DATE: _____ SURVEYOR: _____ WEATHER: _____	
	3/8"=1'		

* MARK DIRECTION OF DRAINAGE SLOPE
AT MIDDLE AND CORNERS OF EACH ELEV.

* MARK NORTH ARROW DIRECTION

* MARK LOCATION OF ANY SITE FEATURES
SUCH AS VEGETATION OR LANDFORMS

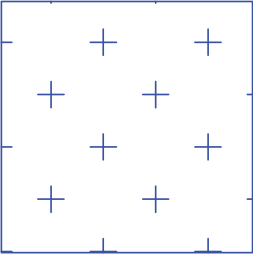
The diagram is a floor plan of a rectangular building. It features a central horizontal line and two vertical lines, one on each side, creating three vertical sections. The outermost sections are wider than the central one. At each of the four corners of the entire structure, there is a quarter-circle arc. Small tick marks are placed at the center of each arc and at the midpoint of each of the four outer walls. A north arrow, represented by a large 'N', is located in the bottom right corner of the drawing area.

CABIN _____ BAR BC RANCH GRAND TETON NP	PHOTO GRID	ELEVATION _____ DATE: _____ SURVEYOR: _____ WEATHER: _____		
	1/2"=1'			

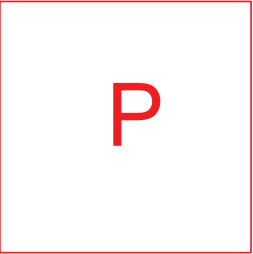
CABIN _____ BAR BC RANCH GRAND TETON NP	SURVEY KEY	DATE: _____ SURVEYOR: _____ WEATHER: _____	



UV Bleaching



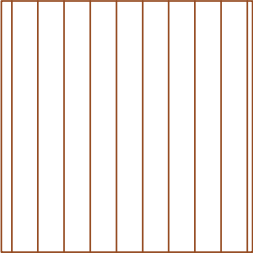
Insect Damage



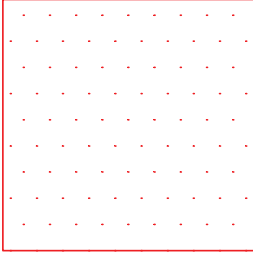
Punkiness



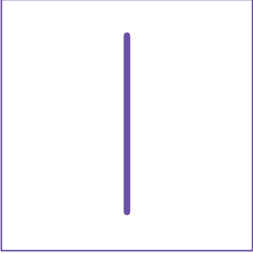
Biogrowth



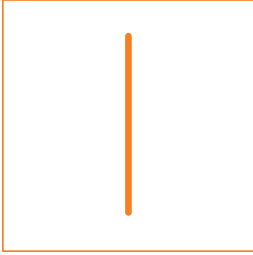
Voids



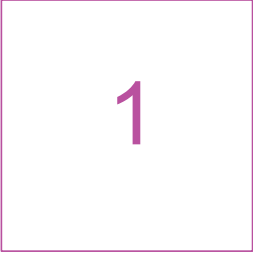
Rot



Significant Checks



Open Joints



Condition Unique

Appendix F: Completed Site Visit Documents

CABIN 1370
BAR BC RANCH
GRAND TETON NP

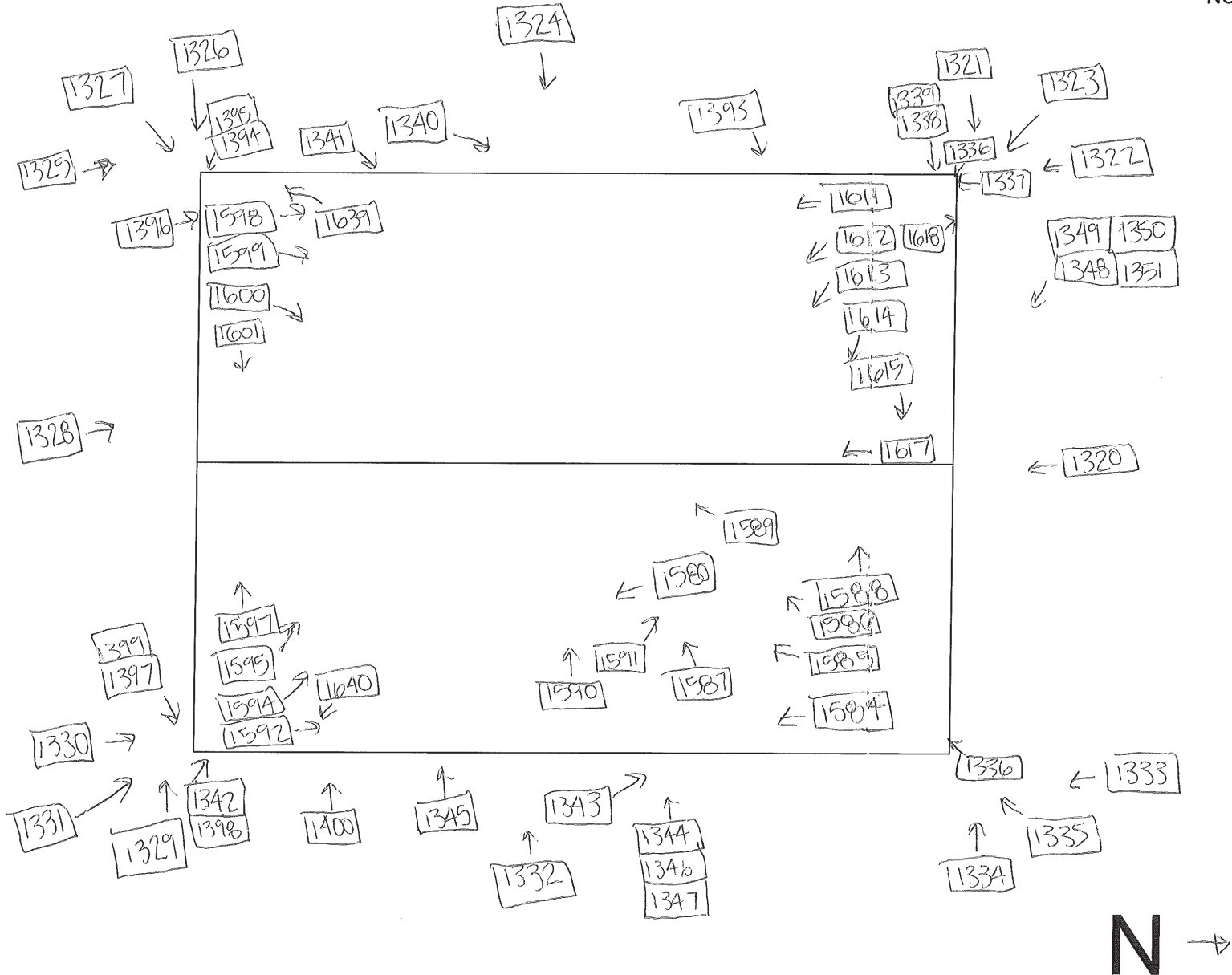
PHOTO LOG

3/8"=1'

DATE: 10/26/2012 SURVEYOR: C. Beckman WEATHER: mostly Sunny ~20°F

* MARK NORTH ARROW DIRECTION

NOTES:



CABIN 1370
BAR BC RANCH
GRAND TETON NP

FLOOR PLAN

3/8"=1'

DATE: 10/26/12

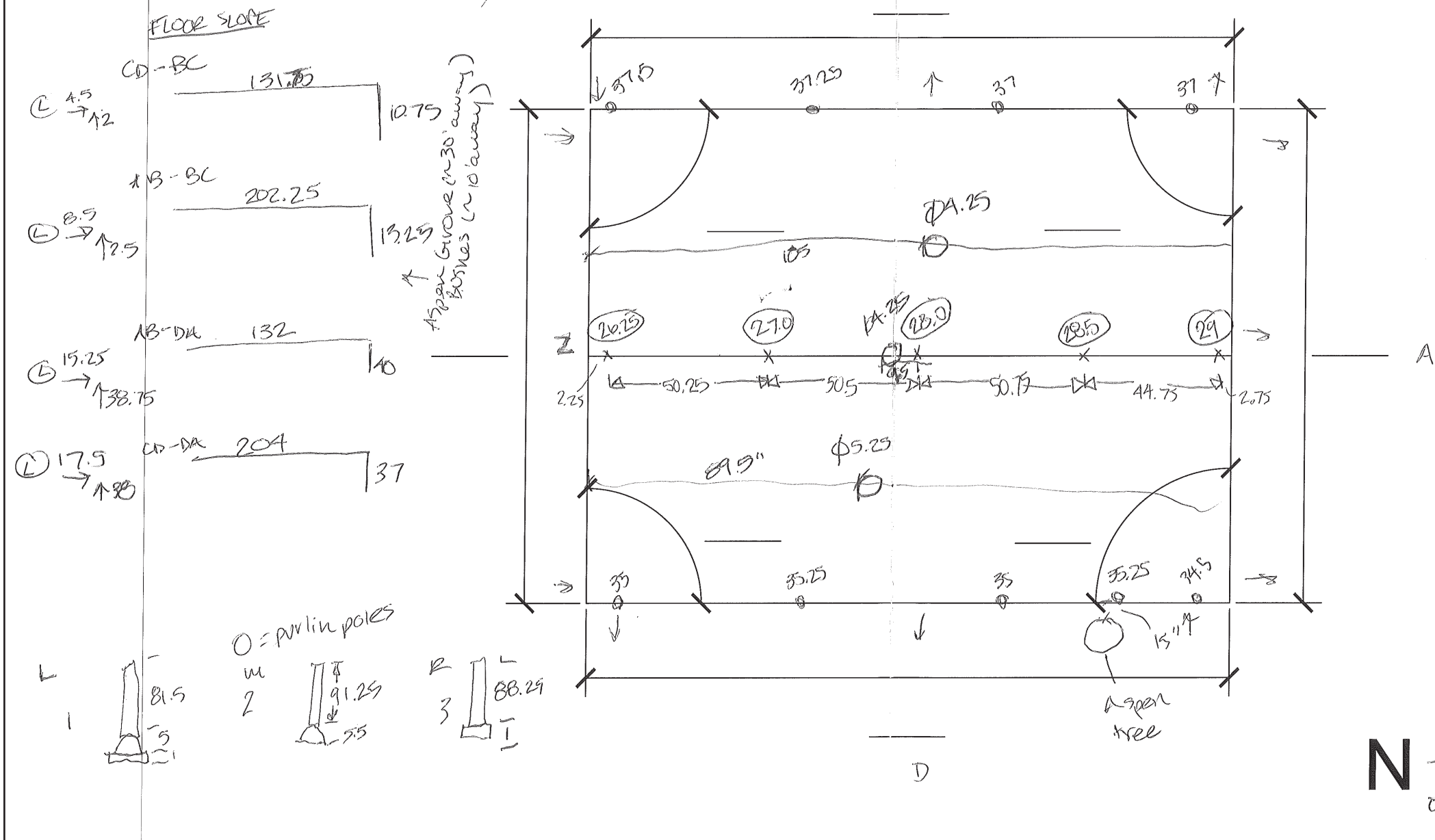
SURVEYOR: C. Beckman

WEATHER: Mostly Sunny ~20°F

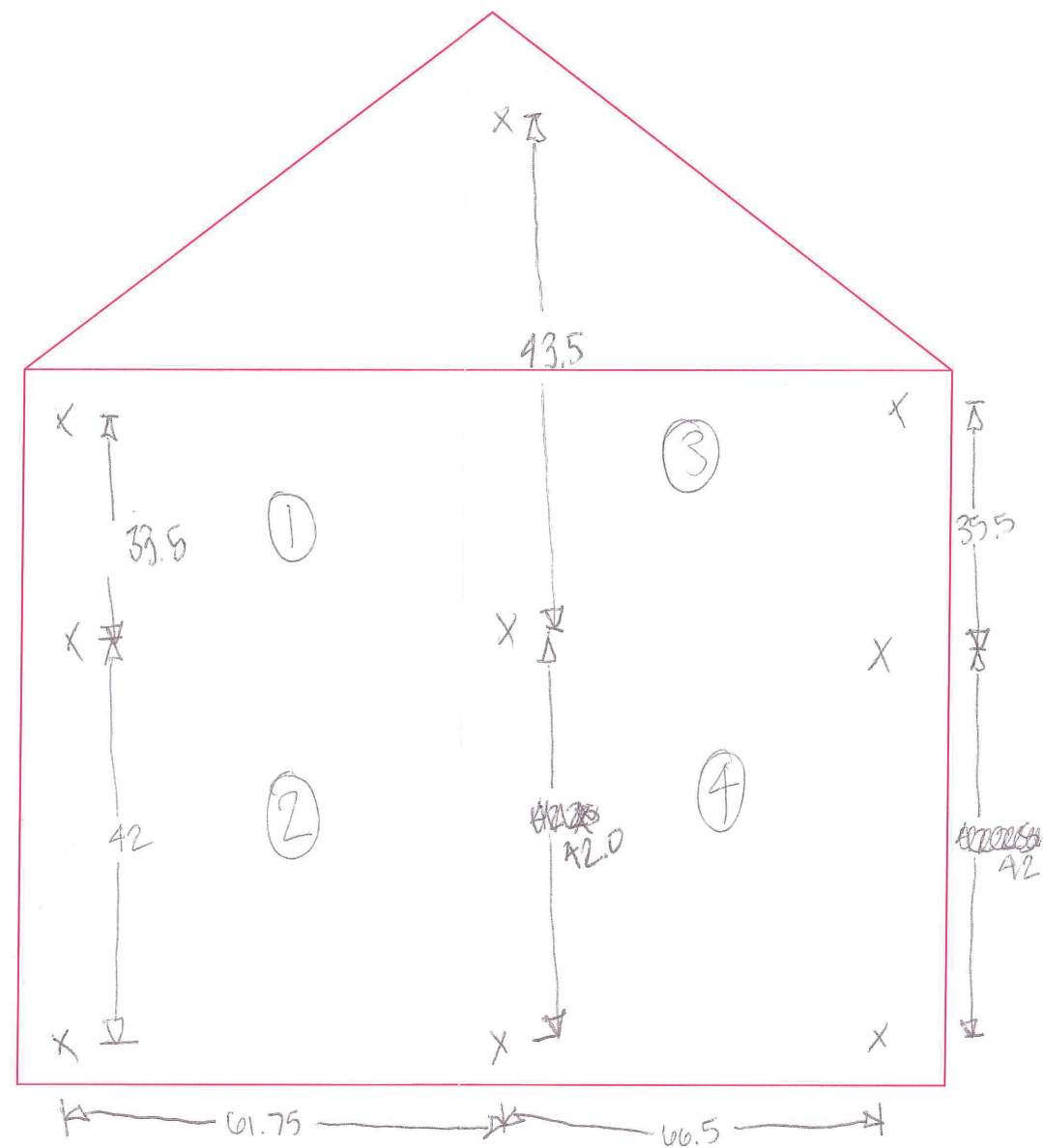
* MARK DIRECTION OF DRAINAGE SLOPE
AT MIDDLE AND CORNERS OF EACH ELEV.

* MARK NORTH ARROW DIRECTION

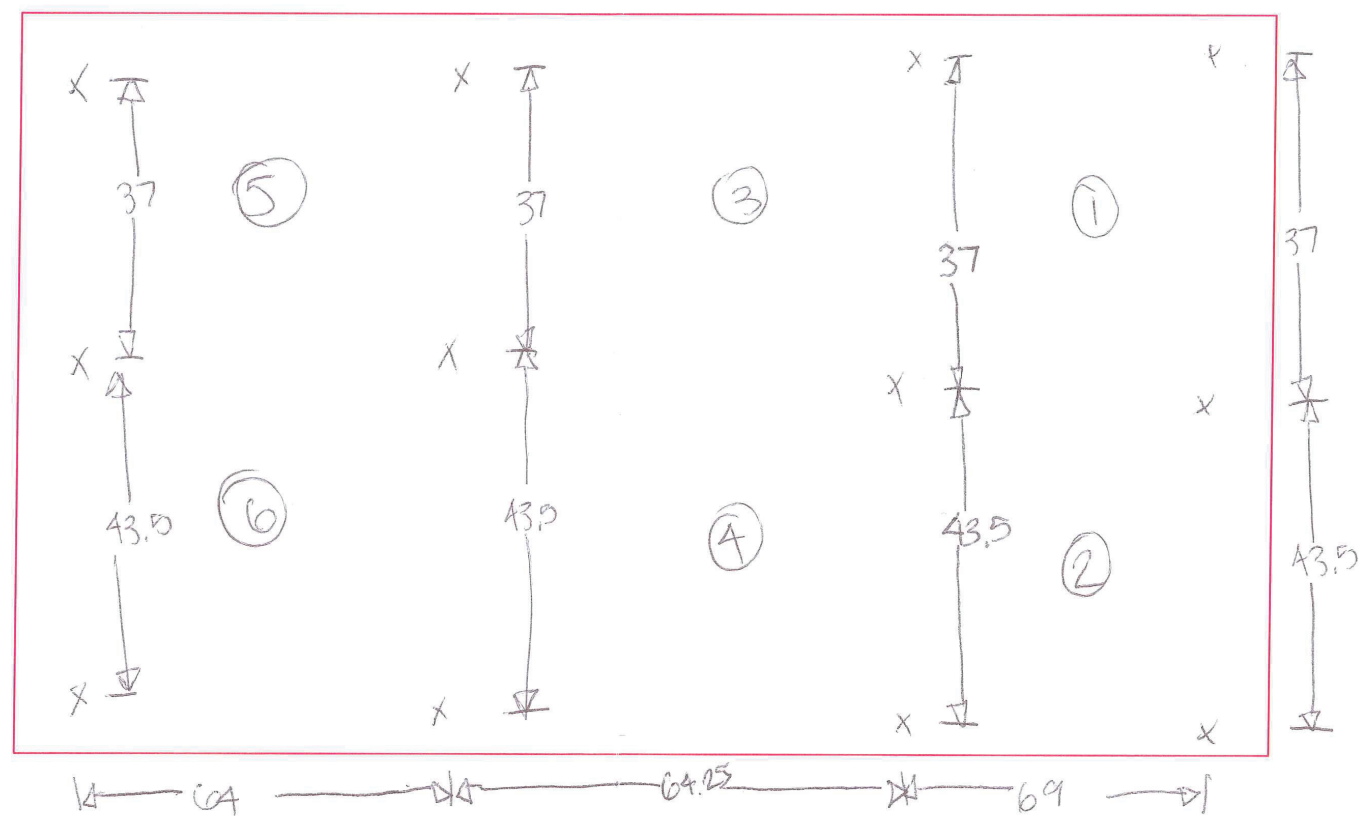
* MARK LOCATION OF ANY SITE FEATURES
SUCH AS VEGETATION OR LANDFORMS

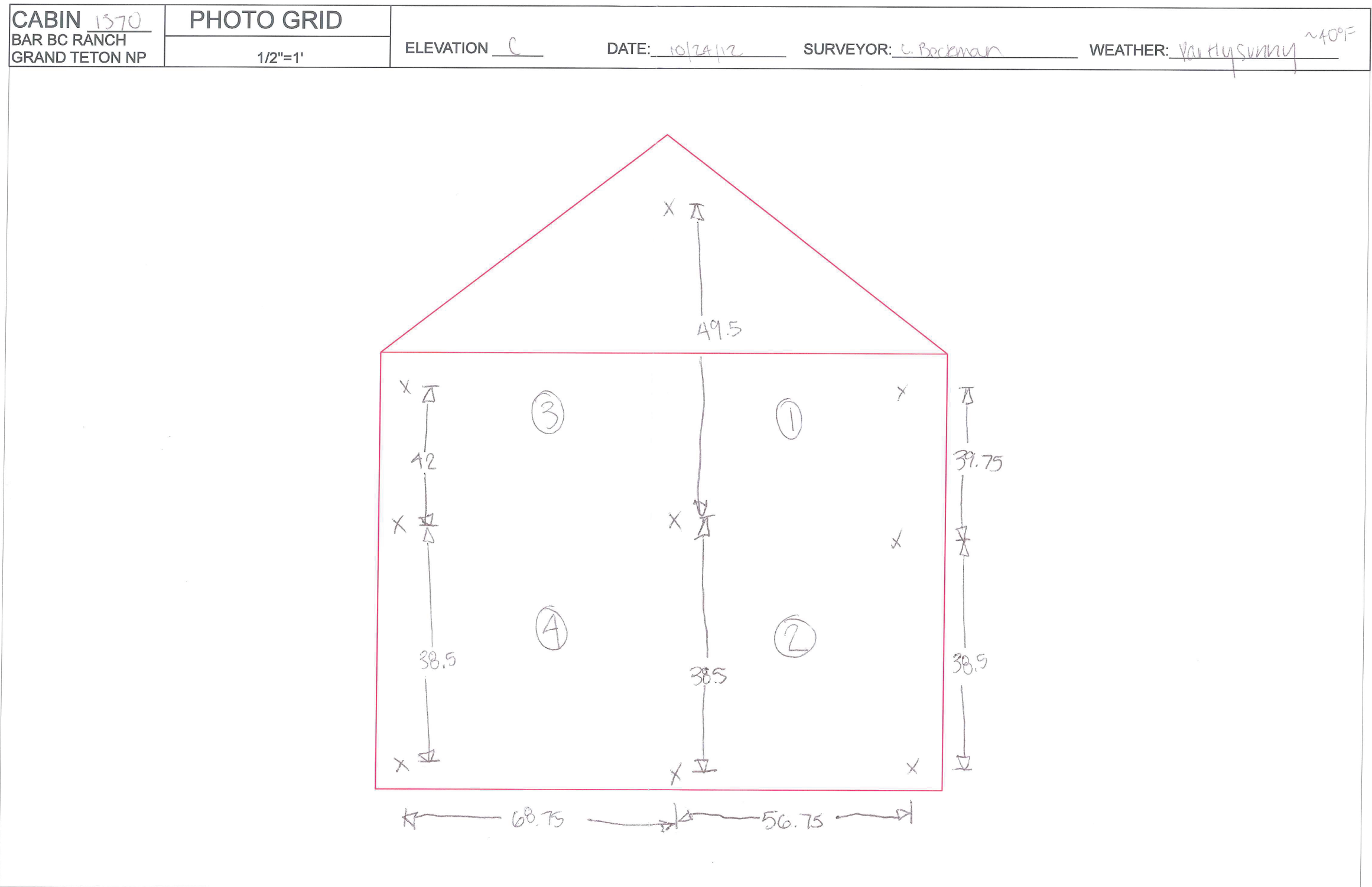


CABIN <u>1370</u> BAR BC RANCH GRAND TETON NP	PHOTO GRID	ELEVATION <u>A</u>	DATE: <u>10/24/12</u>	SURVEYOR: <u>C. Beckman</u>	WEATHER: <u>Sunny ~40°F</u>
	1/2"=1'				



CABIN <u>1370</u> BAR BC RANCH GRAND TETON NP	PHOTO GRID	ELEVATION <u>B</u>			DATE: <u>10/24/12</u>	SURVEYOR: <u>C. Beckman</u>	WEATHER: <u>Sunny ~40°F</u>
	1/2"=1'						





CABIN 1370
BAR BC RANCH
GRAND TETON NP

PHOTO GRID

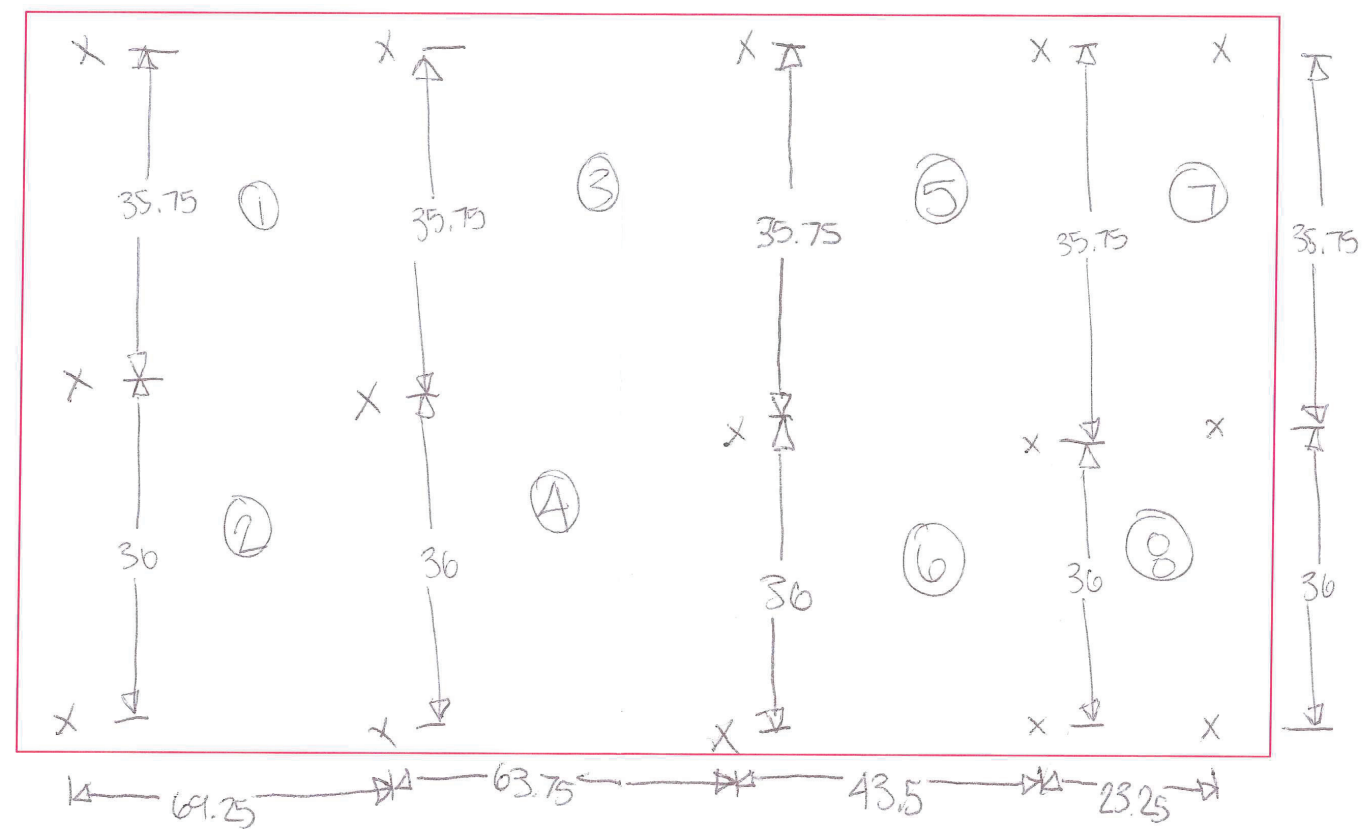
1/2"=1'

ELEVATION D

DATE: 10/24/12

SURVEYOR: C Beckman

WEATHER: Mostly Sunny ~40°F



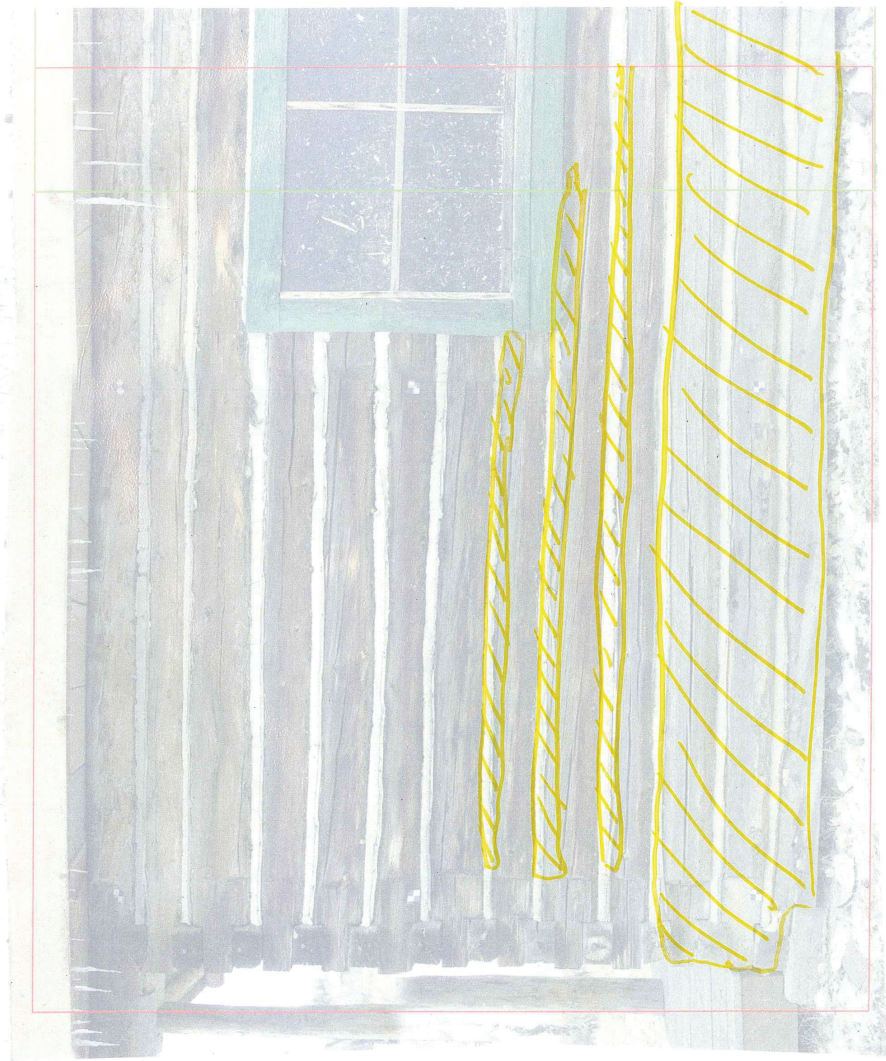
CABIN <u>13710</u> BAR BC RANCH GRAND TETON NP	CONDITION	ELEVATION: <u>A-left</u>	SURVEYOR: <u>C. Beckman</u>
	SURVEY	DATE: <u>10/26/2012</u>	WEATHER: <u>Mostly Sunny ~70°F</u>



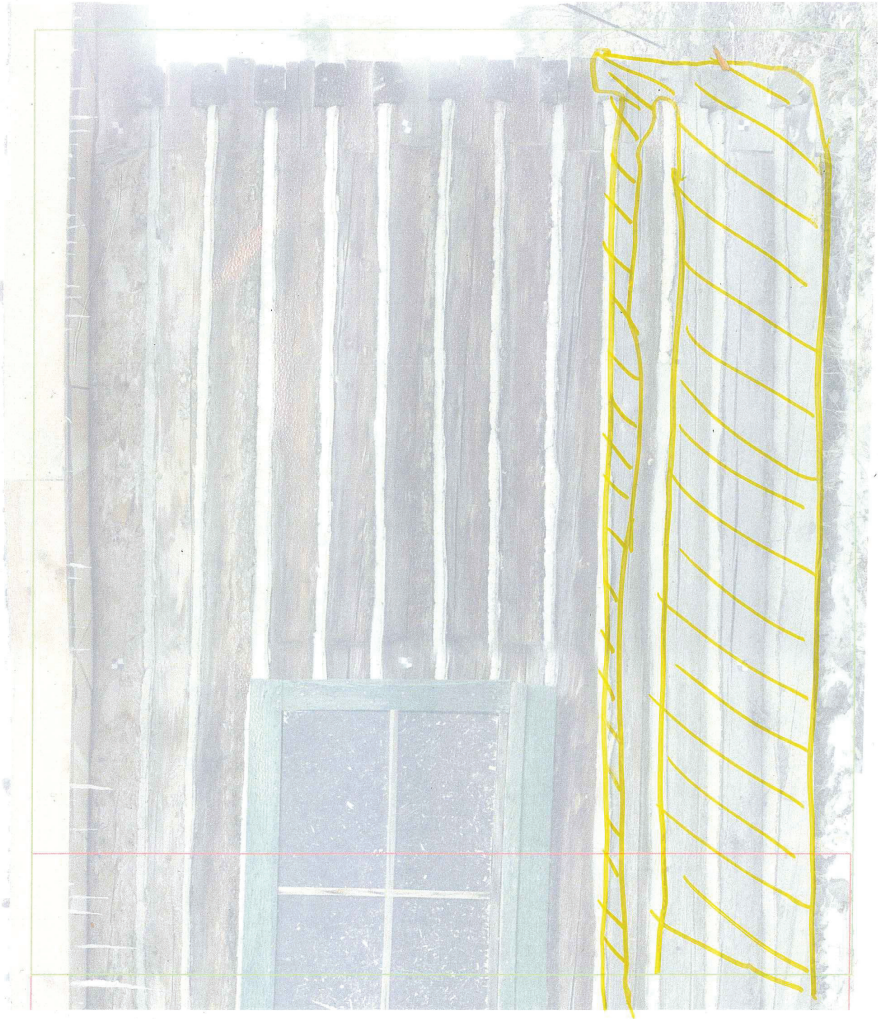
CABIN <u>1370</u> BAR BC RANCH GRAND TETON NP	CONDITION	ELEVATION: <u>A-^{right}1000</u>	SURVEYOR: <u>C. Beckman</u>
	SURVEY	DATE: <u>10/26/2012</u>	WEATHER: <u>mostly sunny ~70°F</u>



CABIN <u>1370</u> BAR BC RANCH GRAND TETON NP	CONDITION SURVEY	ELEVATION: <u>8-16ft</u>	SURVEYOR: <u>C. Beckman</u>
		DATE: <u>10/26/2013</u>	WEATHER: <u>Mostly Sunny ~ 20°F</u>



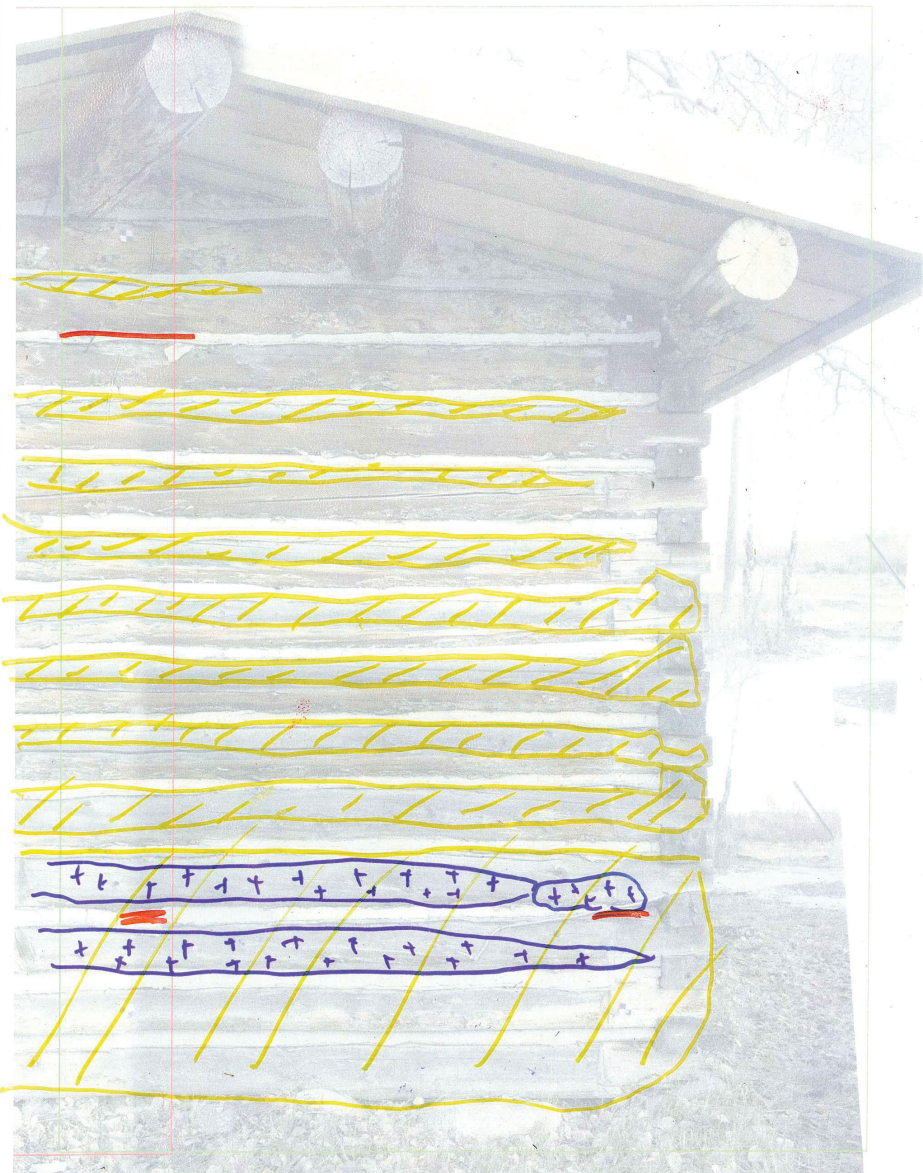
CABIN <u>B70</u> BAR BC RANCH GRAND TETON NP	CONDITION	ELEVATION: <u>Bright</u>	SURVEYOR: <u>C. Beckman</u>
	SURVEY	DATE: <u>10/26/2012</u>	WEATHER: <u>Mostly Sunny ~20°F</u>



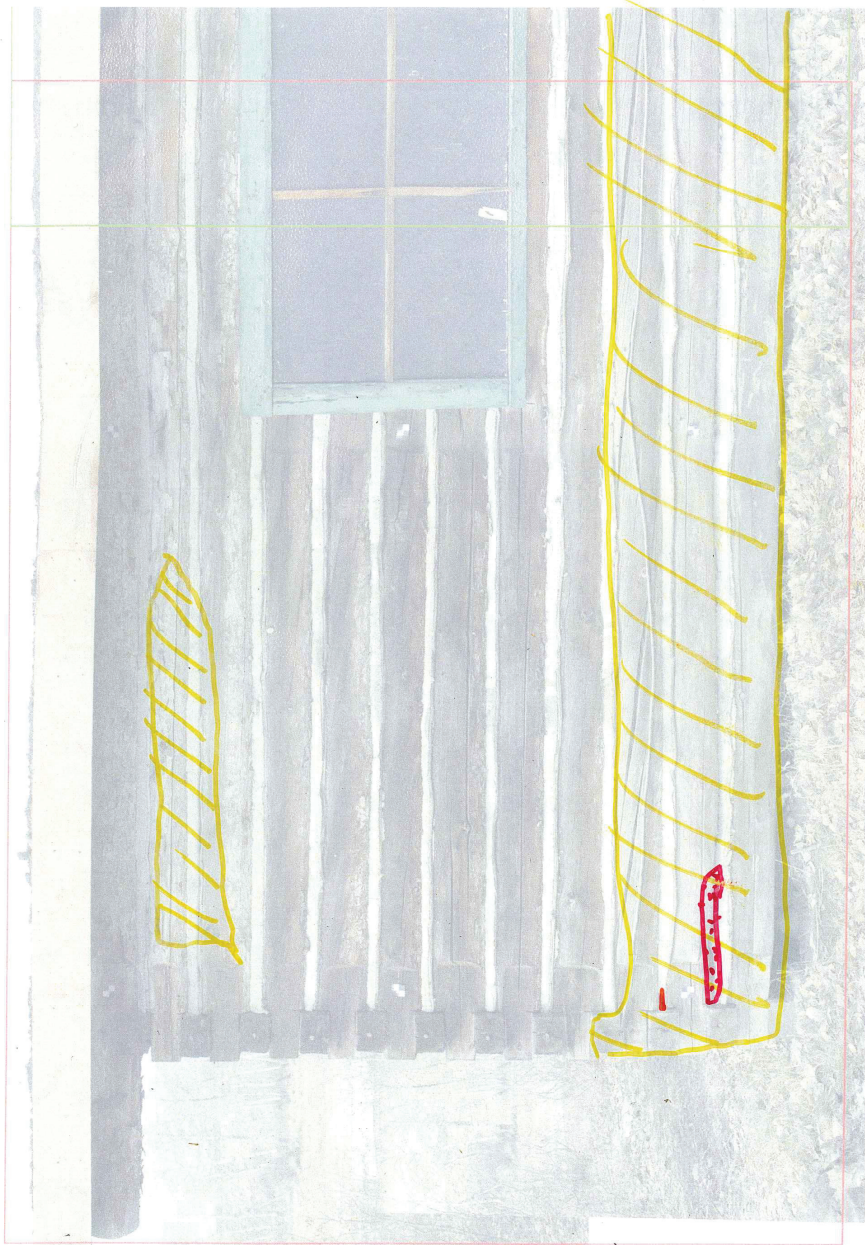
CABIN 1370 BAR BC RANCH GRAND TETON NP	CONDITION	ELEVATION: C-10ft	SURVEYOR: C. BAILEMAN
	SURVEY	DATE: 10/26/2012	WEATHER: Mostly Sunny ~20°F

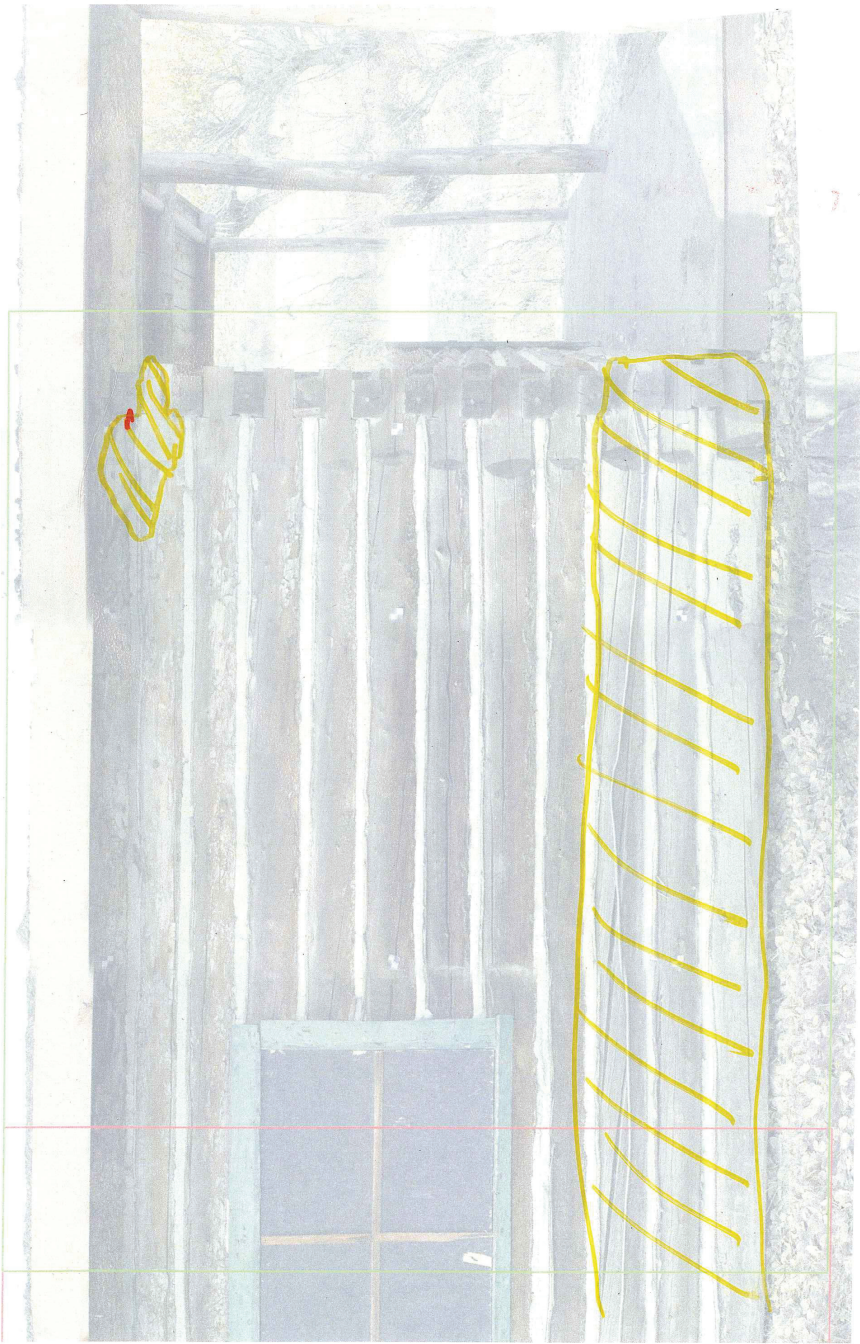


CABIN <u>1370</u> BAR BC RANCH GRAND TETON NP	CONDITION SURVEY	ELEVATION: <u>Circa 11,000 ft</u> DATE: <u>10/26/2012</u>	SURVEYOR: <u>C. Beckmann</u> WEATHER: <u>Mostly sunny ~20°F</u>
--	-----------------------------------	--	--



CABIN 1370 BAR BC RANCH GRAND TETON NP	CONDITION	ELEVATION: D-10 ft	SURVEYOR: C. Beckman
	SURVEY	DATE: 10/26/2012	WEATHER: Mostly Sunny ~20°F



CABIN <u>13-10</u> BAR BC RANCH GRAND TETON NP	CONDITION SURVEY	ELEVATION: <u>Dry</u> SURVEYOR: <u>C. Bademan</u> DATE: <u>10/26/2013</u> WEATHER: <u>Windy Sunny ~20°F</u>
		

Appendix G: Displacement Field Survey Documents

DISPLACEMENT FIELD SURVEY	
STACKED LOG STRUCTURE ID:	
SURVEYOR:	
DATE:	

Context					
A1	A	Drainage Direction	☐ Away from structure ☐ Neutral ☐ Towards structure		
		B	Drainage Direction	☐ Away from structure ☐ Neutral ☐ Towards structure	
			C	Drainage Direction	☐ Away from structure ☐ Neutral ☐ Towards structure
				D	Drainage Direction
	A2	Trees	Are there trees near the structure?	☐ No ☐ Yes, within distance of the tree height ☐ Yes, overhanging branches	
			How many trees are near the structure?	trees	
			Evidence of root jacking?	☐ No ☐ Yes	

Stack				
B1	Required Dimensions	Length	inches	
		Width	inches	
		Gable Height	Gable Height 1	inches
			Gable Height 2	inches
		Corner Height	Corner Height A/B	inches
			Corner Height B/C	inches
			Corner Height C/D	inches
			Corner Height D/A	inches
B2	Corner Engagement	Log Dimensions	logs	
		Corner A/B	inches	
		Corner B/C	inches	
		Corner C/D	inches	
		Corner D/A	inches	
		Adjacent corners disengaged?	☐ No ☐ Yes	
		Racked Elevation	☐ No racking ☐ Gable ☐ Eave	

B3	Deformations	Angle of Racking	Height between middle and sill logs	inches
			Width between middle and sill logs	inches
			Number of logs displaced at midspan	logs
			Number of discontinuous logs	logs
		Openings	Are there two openings on one elevation less than 36" apart?	☐ No ☐ Yes
			Distance from Corner 1	inches
			Distance from Corner 2	inches
			Distance from Corner 3	inches
B4	Discontinuities	Distance from Corner 4	inches	
		Distance from Corner 5	inches	
B5	Crown Extension	Crowns extend beyond roof eave?	☐ No ☐ Yes	

Foundations			
C1	A	Sill log in contact with the ground?	☐ No ☐ Yes
		Severity of sill log rot?	☐ No rot ☐ Minor rot ☐ Major rot ☐ Completely rotted
		Sill log in contact with the ground?	☐ No ☐ Yes
		Severity of sill log rot?	☐ No rot ☐ Minor rot ☐ Major rot ☐ Completely rotted
	B	Sill log in contact with the ground?	☐ No ☐ Yes
		Severity of sill log rot?	☐ No rot ☐ Minor rot ☐ Major rot ☐ Completely rotted
	C	Sill log in contact with the ground?	☐ No ☐ Yes
		Severity of sill log rot?	☐ No rot ☐ Minor rot ☐ Major rot ☐ Completely rotted
D	Sill log in contact with the ground?	☐ No ☐ Yes	
	Severity of sill log rot?	☐ No rot ☐ Minor rot ☐ Major rot ☐ Completely rotted	
C2	Footings	Type of footing	☐ Concrete ☐ River Rock ☐ No footings

Interventions			
D1	Previous Interventions	Condition of interventions	☐ No interventions ☐ Engaged interventions ☐ Disengaged interventions

Roof			
E1	Openings	Are there any openings in the roof with a width greater than 2 inches?	☐ No ☐ Yes
E2	Orientation	Orientation of gable end to the wind	☐ Perpendicular ☐ 45° ☐ Paralell
E3	Porch	Location of the porch	☐ No porch ☐ Gable ☐ Eave
E4	Construction	Type of roof construction and material	☐ Sheathing and tarpaper ☐ Sod roof ☐ Green roof

Material Vulnerabilities			
F1	Insect damage	Is there evidence of an insect infestation?	☐ No ☐ Yes
F2	Checks/Splits	How many significant checks are there?	checks

STRUCTURE	PHOTO LOG	DATE:_____ SURVEYOR:_____ WEATHER:_____
	LOCATION _____	

* MARK NORTH ARROW DIRECTION

N

Appendix H: Displacement Survey Example

DISPLACEMENT FIELD SURVEY	
STACKED LOG STRUCTURE ID: Cabin BTD - Bar BC Ranch, Grand Teton NP	
SURVEYOR: C. Beckman	
DATE: 10/26/2012	

Context		
A1	A	Drainage Direction ☒ Away from structure ☐ Neutral ☐ Towards structure
	B	Drainage Direction ☒ Away from structure ☐ Neutral ☐ Towards structure
	C	Drainage Direction ☐ Away from structure ☐ Neutral ☒ Towards structure
	D	Drainage Direction ☒ Away from structure ☐ Neutral ☐ Towards structure
	Are there trees near the structure? ☐ No ☐ Yes, within distance of the tree height ☒ Yes, overhanging branches	
A2	Trees How many trees are near the structure? <u>A</u> trees Evidence of root jacking? ☒ No ☐ Yes	

Stack		
B1	Length	<u>204.0</u> inches
	Width	<u>144.0</u> inches
	Gable Height	Gable Height 1 <u>106.0</u> inches Gable Height 2 <u>107.5</u> inches
	Corner Height	Corner Height A/B <u>92.75</u> inches Corner Height B/C <u>93.75</u> inches Corner Height C/D <u>90.0</u> inches Corner Height D/A <u>88.0</u> inches
	Log Dimensions	Number of logs, eave end <u>17</u> logs Corner A/B Disengaged Height <u>0</u> inches Corner B/C Disengaged Height <u>0</u> inches Corner C/D Disengaged Height <u>0</u> inches Corner D/A Disengaged Height <u>0</u> inches
B2	Corner Engagement	Adjacent corners disengaged? ☒ No ☐ Yes
B3	Deformations	Racked Elevation ☒ No racking ☐ Gable ☐ Eave Angle of Racking Height between middle and sill logs <u>-</u> inches Width between middle and sill logs <u>-</u> inches Number of logs displaced at midspan <u>0</u> logs Number of discontinuous logs <u>32</u> logs
B4	Discontinuities	Are there two openings on one elevation less than 36" apart? ☒ No ☐ Yes Openings Distance from Corner 1 <u>27.0</u> inches Distance from Corner 2 <u>77.0</u> inches Distance from Corner 3 <u>14.0</u> inches Distance from Corner 4 <u>77.0</u> inches Distance from Corner 5 <u>-</u> inches
B5	Crown Extension	Crowns extend beyond roof eave? ☒ No ☐ Yes

Foundations			
C1	A	Sill log in contact with the ground?	☒ No ☐ Yes
		Severity of sill log rot?	☒ No rot ☐ Minor rot ☐ Major rot ☐ Completely rotted
		Sill log in contact with the ground?	☒ No ☐ Yes
		Severity of sill log rot?	☒ No rot ☐ Minor rot ☐ Major rot ☐ Completely rotted
	B	Sill log in contact with the ground?	☒ No ☐ Yes
		Severity of sill log rot?	☒ No rot ☐ Minor rot ☐ Major rot ☐ Completely rotted
	C	Sill log in contact with the ground?	☒ No ☐ Yes
		Severity of sill log rot?	☒ No rot ☐ Minor rot ☐ Major rot ☐ Completely rotted
D	Sill log in contact with the ground?	☒ No ☐ Yes	
	Severity of sill log rot?	☒ No rot ☐ Minor rot ☐ Major rot ☐ Completely rotted	
C2	Footings	Type of footing	☒ Concrete ☐ River Rock ☐ No footings

Interventions		
D1	Previous Interventions	Condition of interventions
		☐ No interventions ☒ Engaged interventions ☐ Disengaged interventions

Roof		
E1	Openings	Are there any openings in the roof with a width greater than 2 inches? ☒ No ☐ Yes
E2	Orientation	Orientation of gable end to the wind ☒ Perpendicular ☐ 45° ☐ Paralell
E3	Porch	Location of the porch ☐ No porch ☒ Gable ☐ Eave
E4	Construction	Type of roof construction and material ☐ Sheathing and tarpaper ☐ Sod roof ☒ Green roof

Material Vulnerabilities		
F1	Insect damage	Is there evidence of an insect infestation? ☐ No ☒ Yes
F2	Checks/Splits	How many significant checks are there? ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20 ☐ 21 ☐ 22 ☐ 23 ☐ 24 ☐ 25 ☐ 26 ☐ 27 ☐ 28 ☐ 29 ☐ 30 ☐ 31 ☐ 32 ☐ 33 ☐ 34 ☐ 35 ☐ 36 ☐ 37 ☐ 38 ☐ 39 ☐ 40 ☐ 41 ☐ 42 ☐ 43 ☐ 44 ☐ 45 ☐ 46 ☐ 47 ☐ 48 ☐ 49 ☐ 50 ☐ 51 ☐ 52 ☐ 53 ☐ 54 ☐ 55 ☐ 56 ☐ 57 ☐ 58 ☐ 59 ☐ 60 ☐ 61 ☐ 62 ☐ 63 ☐ 64 ☐ 65 ☐ 66 ☐ 67 ☐ 68 ☐ 69 ☐ 70 ☐ 71 ☐ 72 ☐ 73 ☐ 74 ☐ 75 ☐ 76 ☐ 77 ☐ 78 ☐ 79 ☐ 80 ☐ 81 ☐ 82 ☐ 83 ☐ 84 ☐ 85 ☐ 86 ☐ 87 ☐ 88 ☐ 89 ☐ 90 ☐ 91 ☐ 92 ☐ 93 ☐ 94 ☐ 95 ☐ 96 ☐ 97 ☐ 98 ☐ 99 ☐ 100 ☐ 101 ☐ 102 ☐ 103 ☐ 104 ☐ 105 ☐ 106 ☐ 107 ☐ 108 ☐ 109 ☐ 110 ☐ 111 ☐ 112 ☐ 113 ☐ 114 ☐ 115 ☐ 116 ☐ 117 ☐ 118 ☐ 119 ☐ 120 ☐ 121 ☐ 122 ☐ 123 ☐ 124 ☐ 125 ☐ 126 ☐ 127 ☐ 128 ☐ 129 ☐ 130 ☐ 131 ☐ 132 ☐ 133 ☐ 134 ☐ 135 ☐ 136 ☐ 137 ☐ 138 ☐ 139 ☐ 140 ☐ 141 ☐ 142 ☐ 143 ☐ 144 ☐ 145 ☐ 146 ☐ 147 ☐ 148 ☐ 149 ☐ 150 ☐ 151 ☐ 152 ☐ 153 ☐ 154 ☐ 155 ☐ 156 ☐ 157 ☐ 158 ☐ 159 ☐ 160 ☐ 161 ☐ 162 ☐ 163 ☐ 164 ☐ 165 ☐ 166 ☐ 167 ☐ 168 ☐ 169 ☐ 170 ☐ 171 ☐ 172 ☐ 173 ☐ 174 ☐ 175 ☐ 176 ☐ 177 ☐ 178 ☐ 179 ☐ 180 ☐ 181 ☐ 182 ☐ 183 ☐ 184 ☐ 185 ☐ 186 ☐ 187 ☐ 188 ☐ 189 ☐ 190 ☐ 191 ☐ 192 ☐ 193 ☐ 194 ☐ 195 ☐ 196 ☐ 197 ☐ 198 ☐ 199 ☐ 200 ☐ 201 ☐ 202 ☐ 203 ☐ 204 ☐ 205 ☐ 206 ☐ 207 ☐ 208 ☐ 209 ☐ 210 ☐ 211 ☐ 212 ☐ 213 ☐ 214 ☐ 215 ☐ 216 ☐ 217 ☐ 218 ☐ 219 ☐ 220 ☐ 221 ☐ 222 ☐ 223 ☐ 224 ☐ 225 ☐ 226 ☐ 227 ☐ 228 ☐ 229 ☐ 230 ☐ 231 ☐ 232 ☐ 233 ☐ 234 ☐ 235 ☐ 236 ☐ 237 ☐ 238 ☐ 239 ☐ 240 ☐ 241 ☐ 242 ☐ 243 ☐ 244 ☐ 245 ☐ 246 ☐ 247 ☐ 248 ☐ 249 ☐ 250 ☐ 251 ☐ 252 ☐ 253 ☐ 254 ☐ 255 ☐ 256 ☐ 257 ☐ 258 ☐ 259 ☐ 260 ☐ 261 ☐ 262 ☐ 263 ☐ 264 ☐ 265 ☐ 266 ☐ 267 ☐ 268 ☐ 269 ☐ 270 ☐ 271 ☐ 272 ☐ 273 ☐ 274 ☐ 275 ☐ 276 ☐ 277 ☐ 278 ☐ 279 ☐ 280 ☐ 281 ☐ 282 ☐ 283 ☐ 284 ☐ 285 ☐ 286 ☐ 287 ☐ 288 ☐ 289 ☐ 290 ☐ 291 ☐ 292 ☐ 293 ☐ 294 ☐ 295 ☐ 296 ☐ 297 ☐ 298 ☐ 299 ☐ 300 ☐ 301 ☐ 302 ☐ 303 ☐ 304 ☐ 305 ☐ 306 ☐ 307 ☐ 308 ☐ 309 ☐ 310 ☐ 311 ☐ 312 ☐ 313 ☐ 314 ☐ 315 ☐ 316 ☐ 317 ☐ 318 ☐ 319 ☐ 320 ☐ 321 ☐ 322 ☐ 323 ☐ 324 ☐ 325 ☐ 326 ☐ 327 ☐ 328 ☐ 329 ☐ 330 ☐ 331 ☐ 332 ☐ 333 ☐ 334 ☐ 335 ☐ 336 ☐ 337 ☐ 338 ☐ 339 ☐ 340 ☐ 341 ☐ 342 ☐ 343 ☐ 344 ☐ 345 ☐ 346 ☐ 347 ☐ 348 ☐ 349 ☐ 350 ☐ 351 ☐ 352 ☐ 353 ☐ 354 ☐ 355 ☐ 356 ☐ 357 ☐ 358 ☐ 359 ☐ 360 ☐ 361 ☐ 362 ☐ 363 ☐ 364 ☐ 365 ☐ 366 ☐ 367 ☐ 368 ☐ 369 ☐ 370 ☐ 371 ☐ 372 ☐ 373 ☐ 374 ☐ 375 ☐ 376 ☐ 377 ☐ 378 ☐ 379 ☐ 380 ☐ 381 ☐ 382 ☐ 383 ☐ 384 ☐ 385 ☐ 386 ☐ 387 ☐ 388 ☐ 389 ☐ 390 ☐ 391 ☐ 392 ☐ 393 ☐ 394 ☐ 395 ☐ 396 ☐ 397 ☐ 398 ☐ 399 ☐ 400 ☐ 401 ☐ 402 ☐ 403 ☐ 404 ☐ 405 ☐ 406 ☐ 407 ☐ 408 ☐ 409 ☐ 410 ☐ 411 ☐ 412 ☐ 413 ☐ 414 ☐ 415 ☐ 416 ☐ 417 ☐ 418 ☐ 419 ☐ 420 ☐ 421 ☐ 422 ☐ 423 ☐ 424 ☐ 425 ☐ 426 ☐ 427 ☐ 428 ☐ 429 ☐ 430 ☐ 431 ☐ 432 ☐ 433 ☐ 434 ☐ 435 ☐ 436 ☐ 437 ☐ 438 ☐ 439 ☐ 440 ☐ 441 ☐ 442 ☐ 443 ☐ 444 ☐ 445 ☐ 446 ☐ 447 ☐ 448 ☐ 449 ☐ 450 ☐ 451 ☐ 452 ☐ 453 ☐ 454 ☐ 455 ☐ 456 ☐ 457 ☐ 458 ☐ 459 ☐ 460 ☐ 461 ☐ 462 ☐ 463 ☐ 464 ☐ 465 ☐ 466 ☐ 467 ☐ 468 ☐ 469 ☐ 470 ☐ 471 ☐ 472 ☐ 473 ☐ 474 ☐ 475 ☐ 476 ☐ 477 ☐ 478 ☐ 479 ☐ 480 ☐ 481 ☐ 482 ☐ 483 ☐ 484 ☐ 485 ☐ 486 ☐ 487 ☐ 488 ☐ 489 ☐ 490 ☐ 491 ☐ 492 ☐ 493 ☐ 494 ☐ 495 ☐ 496 ☐ 497 ☐ 498 ☐ 499 ☐ 500 ☐ 501 ☐ 502 ☐ 503 ☐ 504 ☐ 505 ☐ 506 ☐ 507 ☐ 508 ☐ 509 ☐ 510 ☐ 511 ☐ 512 ☐ 513 ☐ 514 ☐ 515 ☐ 516 ☐ 517 ☐ 518 ☐ 519 ☐ 520 ☐ 521 ☐ 522 ☐ 523 ☐ 524 ☐ 525 ☐ 526 ☐ 527 ☐ 528 ☐ 529 ☐ 530 ☐ 531 ☐ 532 ☐ 533 ☐ 534 ☐ 535 ☐ 536 ☐ 537 ☐ 538 ☐ 539 ☐ 540 ☐ 541 ☐ 542 ☐ 543 ☐ 544 ☐ 545 ☐ 546 ☐ 547 ☐ 548 ☐ 549 ☐ 550 ☐ 551 ☐ 552 ☐ 553 ☐ 554 ☐ 555 ☐ 556 ☐ 557 ☐ 558 ☐ 559 ☐ 560 ☐ 561 ☐ 562 ☐ 563 ☐ 564 ☐ 565 ☐ 566 ☐ 567 ☐ 568 ☐ 569 ☐ 570 ☐ 571 ☐ 572 ☐ 573 ☐ 574 ☐ 575 ☐ 576 ☐ 577 ☐ 578 ☐ 579 ☐ 580 ☐ 581 ☐ 582 ☐ 583 ☐ 584 ☐ 585 ☐ 586 ☐ 587 ☐ 588 ☐ 589 ☐ 590 ☐ 591 ☐ 592 ☐ 593 ☐ 594 ☐ 595 ☐ 596 ☐ 597 ☐ 598 ☐ 599 ☐ 600 ☐ 601 ☐ 602 ☐ 603 ☐ 604 ☐ 605 ☐ 606 ☐ 607 ☐ 608 ☐ 609 ☐ 610 ☐ 611 ☐ 612 ☐ 613 ☐ 614 ☐ 615 ☐ 616 ☐ 617 ☐ 618 ☐ 619 ☐ 620 ☐ 621 ☐ 622 ☐ 623 ☐ 624 ☐ 625 ☐ 626 ☐ 627 ☐ 628 ☐ 629 ☐ 630 ☐ 631 ☐ 632 ☐ 633 ☐ 634 ☐ 635 ☐ 636 ☐ 637 ☐ 638 ☐ 639 ☐ 640 ☐ 641 ☐ 642 ☐ 643 ☐ 644 ☐ 645 ☐ 646 ☐ 647 ☐ 648 ☐ 649 ☐ 650 ☐ 651 ☐ 652 ☐ 653 ☐ 654 ☐ 655 ☐ 656 ☐ 657 ☐ 658 ☐ 659 ☐ 660 ☐ 661 ☐ 662 ☐ 663 ☐ 664 ☐ 665 ☐ 666 ☐ 667 ☐ 668 ☐ 669 ☐ 670 ☐ 671 ☐ 672 ☐ 673 ☐ 674 ☐ 675 ☐ 676 ☐ 677 ☐ 678 ☐ 679 ☐ 680 ☐ 681 ☐ 682 ☐ 683 ☐ 684 ☐ 685 ☐ 686 ☐ 687 ☐ 688 ☐ 689 ☐ 690 ☐ 691 ☐ 692 ☐ 693 ☐ 694 ☐ 695 ☐ 696 ☐ 697 ☐ 698 ☐ 699 ☐ 700 ☐ 701 ☐ 702 ☐ 703 ☐ 704 ☐ 705 ☐ 706 ☐ 707 ☐ 708 ☐ 709 ☐ 710 ☐ 711 ☐ 712 ☐ 713 ☐ 714 ☐ 715 ☐ 716 ☐ 717 ☐ 718 ☐ 719 ☐ 720 ☐ 721 ☐ 722 ☐ 723 ☐ 724 ☐ 725 ☐ 726 ☐ 727 ☐ 728 ☐ 729 ☐ 730 ☐ 731 ☐ 732 ☐ 733 ☐ 734 ☐ 735 ☐ 736 ☐ 737 ☐ 738 ☐ 739 ☐ 740 ☐ 741 ☐ 742 ☐ 743 ☐ 744 ☐ 745 ☐ 746 ☐ 747 ☐ 748 ☐ 749 ☐ 750 ☐ 751 ☐ 752 ☐ 753 ☐ 754 ☐ 755 ☐ 756 ☐ 757 ☐ 758 ☐ 759 ☐ 760 ☐ 761 ☐ 762 ☐ 763 ☐ 764 ☐ 765 ☐ 766 ☐ 767 ☐ 768 ☐ 769 ☐ 770 ☐ 771 ☐ 772 ☐ 773 ☐ 774 ☐ 775 ☐ 776 ☐ 777 ☐ 778 ☐ 779 ☐ 780 ☐ 781 ☐ 782 ☐ 783 ☐ 784 ☐ 785 ☐ 786 ☐ 787 ☐ 788 ☐ 789 ☐ 790 ☐ 791 ☐ 792 ☐ 793 ☐ 794 ☐ 795 ☐ 796 ☐ 797 ☐ 798 ☐ 799 ☐ 800 ☐ 801 ☐ 802 ☐ 803 ☐ 804 ☐ 805 ☐ 806 ☐ 807 ☐ 808 ☐ 809 ☐ 810 ☐ 811 ☐ 812 ☐ 813 ☐ 814 ☐ 815 ☐ 816 ☐ 817 ☐ 818 ☐ 819 ☐ 820 ☐ 821 ☐ 822 ☐ 823 ☐ 824 ☐ 825 ☐ 826 ☐ 827 ☐ 828 ☐ 829 ☐ 830 ☐ 831 ☐ 832 ☐ 833 ☐ 834 ☐ 835 ☐ 836 ☐ 837 ☐ 838 ☐ 839 ☐ 840 ☐ 841 ☐ 842 ☐ 843 ☐ 844 ☐ 845 ☐ 846 ☐ 847 ☐ 848 ☐ 849 ☐ 850 ☐ 851 ☐ 852 ☐ 853 ☐ 854 ☐ 855 ☐ 856 ☐ 857 ☐ 858 ☐ 859 ☐ 860 ☐ 861 ☐ 862 ☐ 863 ☐ 864 ☐ 865 ☐ 866 ☐ 867 ☐ 868 ☐ 869 ☐ 870 ☐ 871 ☐ 872 ☐ 873 ☐ 874 ☐ 875 ☐ 876 ☐ 877 ☐ 878 ☐ 879 ☐ 880 ☐ 881 ☐ 882 ☐ 883 ☐ 884 ☐ 885 ☐ 886 ☐ 887 ☐ 888 ☐ 889 ☐ 890 ☐ 891 ☐ 892 ☐ 893 ☐ 894 ☐ 895 ☐ 896 ☐ 897 ☐ 898 ☐ 899 ☐ 900 ☐ 901 ☐ 902 ☐ 903 ☐ 904 ☐ 905 ☐ 906 ☐ 907 ☐ 908 ☐ 909 ☐ 910 ☐ 911 ☐ 912 ☐ 913 ☐ 914 ☐ 915 ☐ 916 ☐ 917 ☐ 918 ☐ 919 ☐ 920 ☐ 921 ☐ 922 ☐ 923 ☐ 924 ☐ 925 ☐ 926 ☐ 927 ☐ 928 ☐ 929 ☐ 930 ☐ 931 ☐ 932 ☐ 933 ☐ 934 ☐ 935 ☐ 936 ☐ 937 ☐ 938 ☐ 939 ☐ 940 ☐ 941 ☐ 942 ☐ 943 ☐ 944 ☐ 945 ☐ 946 ☐ 947 ☐ 948 ☐ 949 ☐ 950 ☐ 951 ☐ 952 ☐ 953 ☐ 954 ☐ 955 ☐ 956 ☐ 957 ☐ 958 ☐ 959 ☐ 960 ☐ 961 ☐ 962 ☐ 963 ☐ 964 ☐ 965 ☐ 966 ☐ 967 ☐ 968 ☐ 969 ☐ 970 ☐ 971 ☐ 972 ☐ 973 ☐ 974 ☐ 975 ☐ 976 ☐ 977 ☐ 978 ☐ 979 ☐ 980 ☐ 981 ☐ 982 ☐ 983 ☐ 984 ☐ 985 ☐ 986 ☐ 987 ☐ 988 ☐ 989 ☐ 990 ☐ 991 ☐ 992 ☐ 993 ☐ 994 ☐ 995 ☐ 996 ☐ 997 ☐ 998 ☐ 999 ☐ 1000 ☐ 1001 ☐ 1002 ☐ 1003 ☐ 1004 ☐ 1005 ☐ 1006 ☐ 1007 ☐ 1008 ☐ 1009 ☐ 1010 ☐ 1011 ☐ 1012 ☐ 1013 ☐ 1014 ☐ 1015 ☐ 1016 ☐ 1017 ☐ 1018 ☐ 1019 ☐ 1020 ☐ 1021 ☐ 1022 ☐ 1023 ☐ 1024 ☐ 1025 ☐ 1026 ☐ 1027 ☐ 1028 ☐ 1029 ☐

STRUCTURE Cabin 1370	PHOTO LOG LOCATION Grand Teton NP Bar BC Ranch	DATE: 10/26/2012 SURVEYOR: C. Beckman WEATHER: Mostly Sunny ~20°F
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* MARK NORTH ARROW DIRECTION

The diagram shows a central rectangular structure divided into two horizontal sections. Surrounding this structure are 26 numbered points, each with an arrow indicating the direction of the photo shot. The points are distributed as follows:

- Top Section:**
 - Point 1: Right, arrow pointing left.
 - Point 2: Top right, arrow pointing down.
 - Point 3: Right, arrow pointing left.
 - Point 4: Top right, arrow pointing down-left.
 - Points 17, 18, 19: Stacked vertically on the right side of the top section, with arrows pointing left.
 - Point 20: Top center, arrow pointing down-left.
 - Point 21: Top center, arrow pointing left.
 - Point 22: Right side, arrow pointing down-left.
- Bottom Section:**
 - Point 14: Right, arrow pointing left.
 - Point 15: Bottom right, arrow pointing up.
 - Point 16: Bottom right, arrow pointing up-left.
 - Point 23: Bottom right, arrow pointing up.
 - Point 24: Bottom center, arrow pointing up.
 - Point 25: Bottom left, arrow pointing down.
 - Point 26: Bottom right, arrow pointing up.
 - Point 10: Bottom center, arrow pointing up.
 - Point 11: Bottom left, arrow pointing right.
 - Point 12: Bottom left, arrow pointing up-right.
 - Point 13: Bottom center, arrow pointing up.
 - Point 9: Left, arrow pointing right.
 - Point 6: Left, arrow pointing right.
 - Point 7: Top left, arrow pointing down.
 - Point 8: Top left, arrow pointing down-right.



Exterior Photograph 1: Cabin 1370 (Elevation A)



Exterior Photograph 4: Cabin 1370 (Corner A-B)



Exterior Photograph 2: Cabin 1370 (Across Elevation A)



Exterior Photograph 3: Cabin 1370 (Across Elevation B)



Exterior Photograph 5: Cabin 1370 (Elevation B)



Exterior Photograph 8: Cabin 1370 (Corner B-C)



Exterior Photograph 6: Cabin 1370 (Across Elevation B)



Exterior Photograph 7: Cabin 1370 (Across Elevation C)



Exterior Photograph 9: Cabin 1370 (Elevation C)



Exterior Photograph 12: Cabin 1370 (Corner C-D)



Exterior Photograph 10: Cabin 1370 (Across Elevation C)



Exterior Photograph 11: Cabin 1370 (Across Elevation D)



Exterior Photograph 13: Cabin 1370 (Elevation D)



Exterior Photograph 16: Cabin 1370 (Corner D-A)



Exterior Photograph 14: Cabin 1370 (Across Elevation D)



Exterior Photograph 15: Cabin 1370 (Across Elevation A)



Exterior Photograph 17: Cabin 1370 (Detail Corner A-B)



Exterior Photograph 19: Cabin 1370 (Detail Corner A-B)



Exterior Photograph 18: Cabin 1370 (Detail Corner A-B)



Exterior Photograph 20: Cabin 1370 (Elevation B)



Exterior Photograph 21: Cabin 1370 (Elevation B)



Exterior Photograph 22: Cabin 1370 (Elevation A)



Exterior Photograph 25: Cabin 1370 (Elevation C)



Exterior Photograph 23: Cabin 1370 (Detail Corner C-D)



Exterior Photograph 24: Cabin 1370 (Elevation D)



Exterior Photograph 26: Cabin 1370 (Corner D-A)

DISPLACEMENT SURVEY SCORE CALCULATION

STACKED LOG STRUCTURE ID: Cabin 1370 - Bar BC Ranch, Grand Teton NP
SURVEYOR: C. Beckman
DATE: 10/26/2012

Radio Button
Fill in
Calculated points

SCORE76.88

Deducted Points

Context			
A1	A	Drainage Direction	☒ Away from structure ☐ Neutral ☐ Towards structure
	B	Drainage Direction	☒ Away from structure ☐ Neutral ☐ Towards structure
	C	Drainage Direction	☐ Away from structure ☐ Neutral ☒ Towards structure
	D	Drainage Direction	☒ Away from structure ☐ Neutral ☐ Towards structure
	Are there trees near the structure?		☐ No ☐ Yes, within distance of the tree height ☒ Yes, overhanging branches
A2	How many trees are near the structure?		4 trees
	Evidence of root jacking?		☒ No ☐ Yes

Stack		
B1	Length	204.00 inches
	Meet code?	Yes
	Width	144.00 inches
	Meet code?	Yes
	Aspect Ratio	1.42
	Meet code?	Yes
	Gable Height 1	106.00 inches
	Gable Height 2	107.50 inches
	Average Gable Height	106.75 inches
	Corner Height A/B	92.75 inches
B2	Corner Height B/C	93.75 inches
	Corner Height C/D	90.00 inches
	Corner Height D/A	88.00 inches
	Average Corner Height	91.13 inches
B3	Log Dimensions	Number of logs, eave end Average Log Diameter Meet code? No
	Corner A/B	Disengaged Height 0.00 inches
	Corner B/C	Disengaged Height 0.00 inches
	Corner C/D	Disengaged Height 0.00 inches
	Corner D/A	Disengaged Height 0.00 inches
	Adjacent corners disengaged?	☒ No ☐ Yes ☒ No racking ☐ Gable ☐ Eave
	Angle of Racking	Racked Elevation
		Height between middle and sill logs 0.00 inches
		Width between middle and sill logs 0.00 inches
		Racking Angle N/A
B4	Deformations	Critical Angle N/A
		Number of logs displaced at midspan 0 logs
		Number of discontinuous logs 32 logs
		Are there two openings on one elevation less than 36" apart? ☒ No ☐ Yes
	Discontinuities	Distance from Corner 1 27.00 inches
		Distance from Corner 2 77.00 inches
		Distance from Corner 3 14.00 inches
		Distance from Corner 4 77.00 inches
		Distance from Corner 5 n/a
	Is one or more of the openings closer than 10 inches plus half the average width of the wall? No	
B5	Crown Extension	Crowns extend beyond roof eave? ☒ No ☐ Yes

Foundations				
C1	A	Sill log in contact with the ground?	☒ No ☐ Yes	0.00
		Severity of sill log rot?	☒ No rot	0.00
			☐ Minor rot	
			☐ Major rot	
	B	Sill log in contact with the ground?	☒ No ☐ Yes	0.00
		Severity of sill log rot?	☒ No rot	0.00
			☐ Minor rot	
			☐ Major rot	
C	Sill log in contact with the ground?	☒ No ☐ Yes	0.00	
	Severity of sill log rot?	☒ No rot	0.00	
		☐ Minor rot		
		☐ Major rot		
D	Sill log in contact with the ground?	☒ No ☐ Yes	0.00	
	Severity of sill log rot?	☒ No rot	0.00	
		☐ Minor rot		
		☐ Major rot		
C2	Footings	Type of footing	☒ Concrete ☐ River Rock ☐ No footings	0.00
Interventions				
D1	Previous Interventions	Condition of interventions	☐ No interventions ☒ Engaged interventions ☐ Disengaged interventions	0.00
Roof				
E1	Openings	Are there any openings in the roof with a width greater than 2 inches?	☒ No ☐ Yes	0.00
E2	Orientation	Orientation of gable end to the wind	☒ Perpendicular ☐ 45° ☐ Paralell	0.00
E3	Porch	Location of the porch	☐ No porch ☒ Gable ☐ Eave	0.50
E4	Construction	Type of roof construction and materials	☐ Sheathing and tarpaper ☐ Sod roof ☒ Green roof	1.00
Material Vulnerabilities				
F1	Insect damage	Is there evidence of an insect infestation?	☐ No ☒ Yes	1.00
F2	Checks/Splits	How many significant checks are there?	0 checks	0.00
Deductions				11.56
SCORE				76.88

Appendix J: Glossary

Stacked Log Construction

Stack: the system of intersecting walls created by stacking logs perpendicular to each other to form a rectangular prism.

Gable end: the two elevations of a stacked log structure that are topped with a triangle created by the eaves and ridge of the structure.

Eave end: the two elevations of a stacked log structure that are rectangular in shape and perpendicular to the gable ends.

Corner engagement: the extent to which a corner condition of a stack is intact and able to transfer the loads.

Sill log: the two full-size members, parallel to one another, located at the bottom of the stack.

Spandrel log: the two members stacked perpendicular to and half a unit up from the two sill logs.

Vertical spliced joint: a vertical wood board used to toenail disengaged log ends at the mid-span of an elevation of the stack. Usually installed when the length of a wall exceeds the length of a typical log member.

Plate log: the exterior, flanking roof purlins resting on the top of the eave end walls.

Ridgepole: the middle and highest purlin in the roof framing system of a stacked log structure.

Context

Frost depth: the locally designated depth below the soil surface which is not subjected to freezing action. Foundations need to exceed this depth so that they are not affected by freeze-thaw cycles and frost heaving of the soil.

Differential settlement: uneven vertical movement of soils across a site due to varying soil types, unstable soils, or non-uniform loads.

Bench: a massive landform that results from the general elevation of a site increasing dramatically to a plateau.

Wood Material

End grain: the resulting surface of a piece of wood cut perpendicular to the longitudinal

cellular structure.

Structural Terms

Load: a force acting over an area that can be applied by many sources.

Dead load: the load imposed by the materials used to create the structure.

Live load: the load imposed by any impermanent or moveable objects including humans and furniture.

Environmental load: any load imposed by external forces including wind, snow, and earthquakes.

Moisture load: the amount of moisture imposed on a material or space.

Load path: the pathway through structural members that loads travel through the building to reach the earth.

Displacement modes: types of movement that occur in a building that can affect the load paths of a building.

Eccentric load/loading: an unbalanced load or loading pattern.

Index

B

Barn — 6

Burt, Struthers — i, 2, 7, 8, 13, 14, 46, 73

C

Carncross, Horace — 2, 13

Checks — 27, 38, 57, 65

Chinking — 4, 5, 8, 14, 22, 108

Climate Change — 2, 15, 19, 20, 24, 69, 71

Condition Assessment — 37, 38, 39, 40, 41, 42

Construction Sequence — 15, 22

Corner Engagement — 16, 28, 32, 33, 59, 71, 149

Cowboy Construction — 8, 9, 10, 13, 14, 51

D

Decay — 12, 20, 26, 27, 28, 31, 34, 35, 37, 47, 49, 54, 55, 56, 57, 62, 63, 64, 65, 71

Delaware Bay — 4, 5, 6

Differential Settlement — 26, 31, 32, 33, 34

Dimensional Ratios — 26, 28, 35

Aspect Ratio — 28, 58, 59

Discontinuous Members — 26, 29, 61, 71

Drainage Direction — 31, 53, 57, 58, 62, 71

F

Foundations — 14, 17, 22, 26, 31, 33, 34, 48, 55, 57, 58, 71

Frost Heave — 34

G

German — 4

Grand Teton National Park — ii, v, 2, 3, 8, 13, 15, 22, 35, 45, 46, 51, 69, 71, 73, 74, 75, 80

Great Camp Movement — 7, 8

Green Roof — 21, 22, 56, 64

H

Hogon — v, 5, 6, 80

I

Ice Damming — 26, 30, 35, 36

Insects — 20, 27, 31, 35, 37, 57, 62, 64, 65

Interventions — 42, 44, 48, 56, 63, 66, 69, 71

K

Kit Homes — v, 10, 11, 86

L

Load Path — vi, 17, 21, 28, 95

Loads

Dead Load — 15, 17, 150

Eccentric Loads — 30, 31, 32, 58, 60, 63, 64, 71

Environmental Load — 15, 17, 18, 19, 21

Snow Load — v, 2, 18, 19, 23, 24, 29, 30, 31, 32, 35, 44, 48, 58, 63, 68, 71, 88

Wind Load — 18

Live Load — 15, 17, 18, 23

Moisture Load — 15, 20

Lodgepole — 13, 34, 75

M

Manual — 5, 8, 11, 13, 73

Material Vulnerabilities — 26, 48, 57, 71

Mid-span Log Displacement — 55, 60, 61, 149

N

National Park Service — ii, 1, 2, 7, 8, 9, 13, 22, 35, 46, 48, 73, 74, 75, 76

Native American — iii, 4, 5, 6, 42, 75, 76

Navajo — v, 5, 6, 79, 80

Notches, corner

Dovetail — 16

Reverse Saddle — 16

Square or Tenant — 16

O

Out-of-plane Member Rotation — 26, 31, 32, 61

P

Parkitecture — iii, 9, 10

Pioneers — 1, 6, 7

Plate Log — 16, 21, 54, 55, 59

Porch — v, 26, 30, 32, 35, 56, 64, 90, 108

Post-mortem Assessment — 43, 44

Prevailing Winds — 23, 26, 29, 52, 56, 63, 71

Purlins — v, 3, 16, 17, 21, 63, 89, 108, 149

R

Racking — vi, 26, 29, 31, 32, 60, 96

Rapid Assessment — 42

Ridgepole — 6, 17, 21, 54

Risk Assessment — ii, 3, 37, 41, 42, 43, 49

Root Jacking — 54, 58

S

Scribe-fit — v, 5, 14, 29, 49, 59, 73, 75, 78

Settlers — 1, 4, 5, 6

Sill Log — 15, 16, 17, 22, 31, 32, 33, 49, 54, 55, 56, 59, 62, 149

Snake River — 13

Sod Roof — 17, 22, 56, 64

Spandrel Log — 15, 16, 17, 22, 33

Survey Equipment — 51

Swedish — v, 4, 5, 6, 47, 78

T

Timbered Island — v, vii, 13, 88, 106

Trees — 8, 13, 30, 31, 54, 58, 71

U

Ultraviolet — 28

Unintended Load Transfer — 33

Y

Yellowstone National Park — v, 7, 9, 76, 83