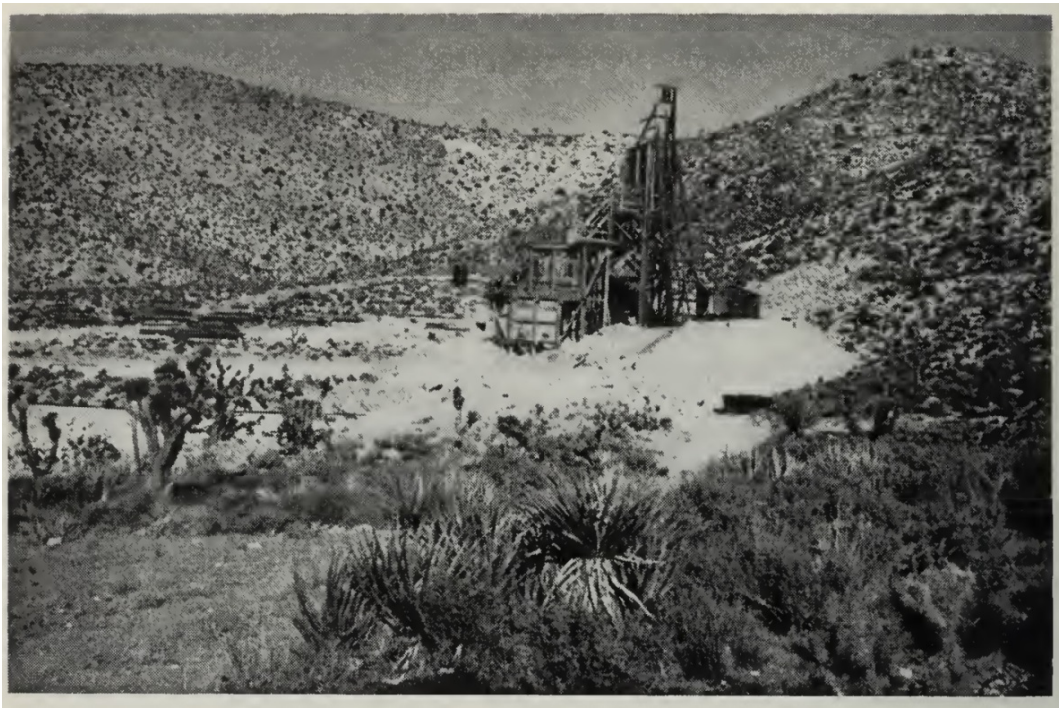
CONDITION ASSESSMENT AND TREATMENT RECOMMENDATIONS: LIVE OAK AND EVENING STAR MINES

MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA



PREPARED FOR THE NATIONAL PARK SERVICE

by

THE SCHOOL OF ENGINEERING

UNIVERSITY OF VERMONT

February 2014

Cooperative Agreement No: H8W07110001
Task Agreement No: P13AC00923

Agreement Executed Through

Pacific Northwest Cooperative Ecosystem Studies Unit
Effective Dates: 08/15/2013 - 06/30/2015

Prepared for
THE NATIONAL PARK SERVICE

by
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UNIVERSITY OF VERMONT

FEBRUARY 2014

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Cover photo: Evening Star Mine, Mojave National Preserve, 1943. Photo from "MOJA Evening Star Mine rough draft physical history, November 18, 2013". p. 11.

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EXECUTIVE SUMMARY

The Live Oak and Evening Star mine sites in Mojave National Preserve (MOJA) retain historic timber structures erected by mining companies in the early- to mid-20th century. The Live Oak site is located in the New York Mining District in the northeastern area of the Preserve, and surviving structures include a trestle consisting of timber and dimensioned lumber bents that support a radial track that was used to convey mine carts to a timber ore bin.

At the Evening Star mine, in the Mescal Mining District in the north central region of the Preserve, surviving structures include a sixty-foot headframe that supplied ore to a sorting structure consisting of three massed towers of varying heights, the lower tower being an ore bin. Differences in size and quality of construction reflect the productivity of the two mines and the wealth of the mining companies that developed them.

The Evening Star Mine structure is in generally good condition, with structural distress limited to a few members. The Live Oak structure is in poorer condition and in danger of collapse, largely due to the out-of-plumb condition of the ore bin and the partial collapse of bent 1, the ore chute, and the supported floor deck. The Preserve hopes to make repairs resulting in the stabilization of both structures.

The National Park Service and the School of Engineering at the University of Vermont are collaborating in the condition assessment, repair design, and pilot treatment of the mine structures. A site visit by the assessment team (11/04/2013 - 11/08/2013) was focused on documentation of the Live Oak structure, the collection of data for condition assessment and analysis of both mine structures, and development of stabilization strategies.

This report presents condition assessment results and stabilization recommendations, and is divided into six parts, including a description of the mine structures and a brief review of their history and significance; a summary of condition assessment results for structures at both sites that include narrative descriptions of deterioration conditions, results of moisture diagnostics, and wood species identification data; a summary statement of the structural condition of the structures at each site; presentation of preservation strategies, including an overview of

recommended repair techniques and specific repair recommendations; and appendices devoted to resistance drill results and architectural drawings of the Live Oak trestle.[1]

[1] While drawings of the mine structures are not included in the scope of work, the level of deterioration at the Live Oak site is extensive enough that a set of drawings is essential to successful completion of the repairs. Drawings have not been prepared for the Evening Star site, where the number of repairs is small and dimensions of repair and replacement pieces can be collected directly from surviving material.

HISTORY AND SIGNIFICANCE

LIVE OAK

The Bronze-Live Oak Mining camp is a small mining site located in the north fork of Keystone Canyon on the eastern slope of the New York Mountains of Mojave National Preserve, within the New York Mining District. The mine site was claimed in 1896, and was probably worked until sometime in the 1920s. The camp contains several structures in various states of preservation, including the rail trestle and ore bin, a miner's cabin, and surveyor's shed. This is the last surviving rail trestle within the Mojave National Preserve, and as such, provides a detailed view of early 20th-century small-scale mining technology in the Mojave region. The camp is also unique in that it expresses the entire process of ore extraction through the surviving structures, and the relative completeness of the fabric record is likely due to its remote location.

The New York Mining District was formed in 1870. The Elgin Mines Company prospected the area in 1872, and in the process uncovered several abandoned mines likely dug by Spaniards in the early 19th century. Those early mines produced the first recorded silver strike in San Bernardino County in 1873, and development of the area was steady until the Panic of 1893 and the resulting fall of silver prices.[2]

In 1896, Edmund Rich and Catherine Bohme claimed the Live Oak Mine site, which was then called the Bronze Mine. Seven claims were made over the course of the life of the camp, but the only record of production was in 1912, claiming one ton that contained 10 percent lead and 24 ounces of silver. Other mining and prospecting ventures returned to the area after the turn of the century as the construction of the San Pedro, Los Angeles, and Salt Lake Railroads reinvigorated development throughout the region. New veins of silver were discovered in the existing mines, spurring further prospecting in other parts of the district. World War I plunged the region into recession, and the Bronze Mine was not reopened until the 1980s. It was at this time that the mine was renamed the Live Oak Mine.[3] The area became part of the East Mojave National Scenic Area in 1981, and later part of the Mojave National Preserve with the signing of the California Desert Protection Act in October of 1994.

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[2] Ibid, p. 4.

[3] Ibid, pp. 4-5. No information is currently available regarding the type or level of activity from that time period.

EVENING STAR

The Evening Star Mine is located at the western base of the Ivanpah Mountains, in what is now the north central section of the Mojave National Preserve. The mine was originally developed with a 740-foot-deep shaft sunk between 1900 and 1910, and was the first significant claim of the Mescal Mining District in northeastern San Bernardino County. Much of this region was being prospected at the turn of the century, encouraged in part by a swiftly developing system of roads and railways, including a South Pacific line from Barstow to Goffs in 1883, and a Los Angeles, San Pedro, and Salt Lake Railroad line just south of the mine, which led to the construction of a water station in Kelso in 1905. Precious metals mining in San Bernardino County at the time was focused on the extraction of gold and silver, as well as copper, lead, zinc, chromium, manganese, tungsten, and vanadium, all of which were mined in large quantities to satisfy rising demands.[4]

The Evening Star Mine is first listed in the county's index to mines in 1926, when a placer mine claim was filed for Evening Star #1, #2, and #3 by D. Blakeslee et al., M. Adams, and M. Turk.[5] The mine changed hands several times over the next decade, but very little mining was done before the late 1930s. The excavation of two additional shafts for the extraction of tungsten, tin, and copper led to the production of several hundred tons of tungsten ore, which were processed at the nearby Valley View gold mine in 1939 and 1940.[6]

Immediately prior to the United States' involvement in World War II, the country made a large investment in extracting tin, which spurred development throughout the Mescal Mining district and resulted in increased production at Evening Star and neighboring mines during the early 1940s in an effort to add to the United States' stockpile. In 1943, Evening Star was leased to the Steel Service and Sales Company in Chicago, which operated under a government loan to develop the mine.[7] The company made several improvements to the mine, including the deepening of two of the mineshafts, the excavation of additional shafts and surface cuts, the installation of ore processing machinery such as crushers, screens, and rollers, and the addition

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[4] "MOJA Evening Star Mine rough draft physical history November 18 2013," pp. 3-4. Report in preparation. Received from National Park Service, Pacific West Regional Office.

[5] Ibid, p. 4.

[6] Ibid, p. 6.

[7] Ibid, p. 7.

of a gasoline-driven hoist and a portable compressor. The sixty-foot headframe was also constructed in 1943 (Figure 1). Eight men worked the mine, and a mill was constructed ten miles north of Evening Star near the Las Vegas highway in order to process ore from neighboring mines. The capacity of the mill was about 30 tons per day.[8] Other surviving structures at the mine site are thought to date from this period, including a wood-framed hoist shed clad in corrugated metal, a concrete and stone explosives locker, and several concrete pads for equipment and buildings.[9]

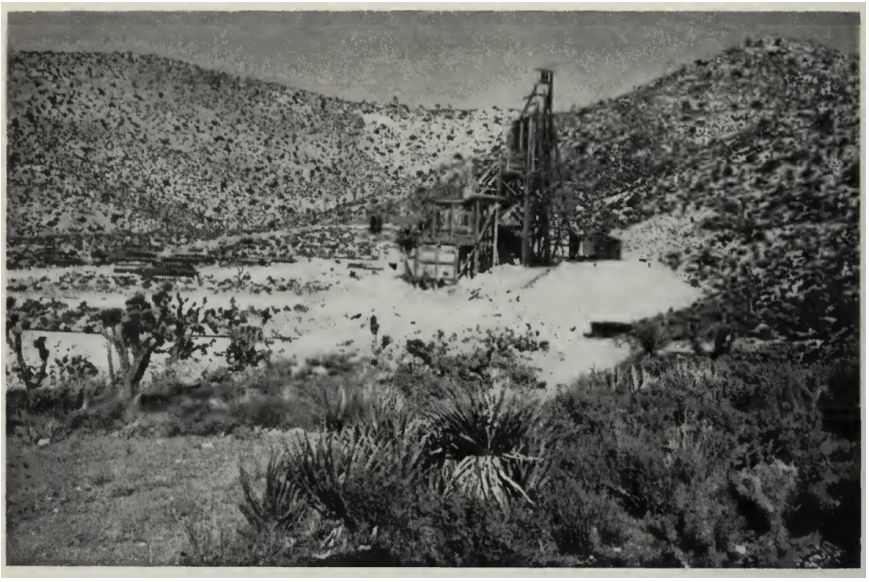


Figure 1: View of Evening Star Mine, 1943. From "MOJA Evening Star Mine rough draft physical history, November 18, 2013", p. 11.

Approximately 400 tons of ore from the Evening Star Mine was processed during the war. Tin concentrates were sold to the government stockpile in Jean, Nevada, which was located on the San Pedro, Los Angeles, and Salt Lake Railroad line located south of the mine. The last of the activity during the war period included a fifty-foot-deep drill hole from the bottom of Shaft #2, which produced no ore. The stockpile in Jean, Nevada was closed in June of 1944, and records suggest that little mining occurred at Evening Star after this date.[10]

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[8] "MOJA Evening Star Mine rough draft physical history November 18 2013", p. 8. Report in preparation. Received from National Park Service, Pacific West Regional Office.

[9] D. Nichols, personal communication to D. Porter, November 7, 2013.

[10] "MOJA Evening Star Mine rough draft physical history November 18 2013", p. 9. Report in preparation. Received from National Park Service, Pacific West Regional Office.

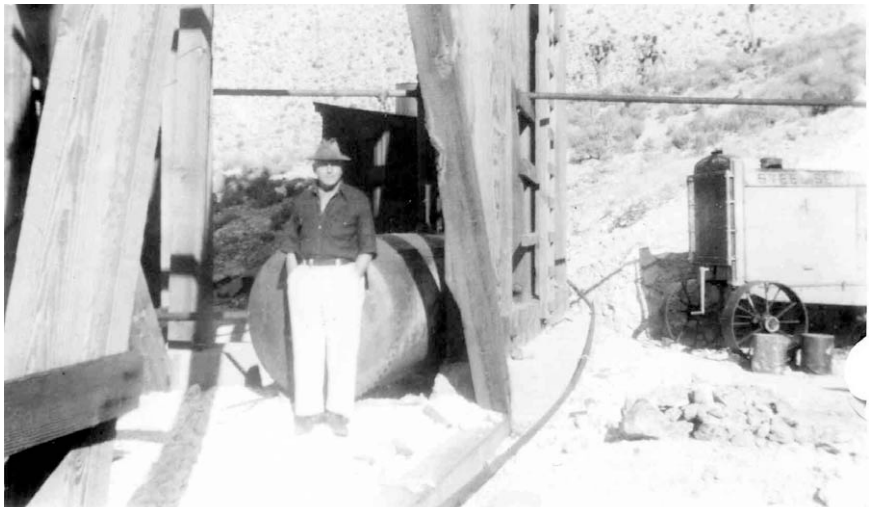


Figure 2: View of the Evening Star Mine headframe, with Frank Ki[?], in 1946. From "MOJA Evening Star Mine rough draft physical history, November 18, 2013", p. 11.

Various companies filed proof of labor notices for Evening Star over the next few decades, accompanied by limited exploration for ore, but there were no significant discoveries. Minor improvements were made to the mine facilities in the 1970s in order to maintain the mining claims, including road work, survey work, and metallurgical testing.[11] As with the Live Oak Mine, the area became part of the East Mojave National Scenic Area in 1981. On October 8, 1994, President Clinton signed the California Desert Protection Act, abolishing the East Mojave National Scenic Area and incorporating its lands into the Mojave National Preserve.[12]

[11] Ibid, p. 9.

[12] Ibid, p. 10.

WOOD INVESTIGATION AND CONDITION ASSESSMENT

ASSESSMENT GOALS

Prior to condition assessment of the mine structures at the Live Oak and Evening Star mines, the species, condition, and structural grade of the timbers used in their construction were unknown. Structures at both sites had areas of visible wood deterioration, but the extent of the deterioration caused by wood decay fungi and/or wood boring insects was not known. The out-of-plumb condition of the ore bin at the Live Oak site, and partial collapse of one of the trestle bents appeared to be at least partially the result of the decay and crushing of supporting members. Assessment focused on evaluation of structure geometry, connection capacity, and material quality. Through detailed assessment of wood condition, lumber grading, and analysis of current and anticipated loads, it was possible to determine whether the wood members in the structures were (a) generally unfit to remain in service, (b) deteriorated and in need of repair or (c) generally in sound condition and suitable for continued use.

The assessment tasks for both mining sites included:

- Inspecting locations that have potential decay activity or other damage, using visual inspection, probing, moisture diagnostics, and selected resistance drilling.
- Resistance drilling to quantify the loss of wood in select structural members due to decay or insect damage to provide an assessment of the location and extent of the damage.
- Measurement of moisture content in select wood members to determine the level of moisture and its potential impact on long-term performance of the members.
- Identification of wood species of structural members as needed by the assessment team to determine current capacity and identify appropriate replacement material.
- Determining the lumber grade of the structural wood members as needed for structural evaluation.
- Assessing the structural condition of structures at both sites and evaluating the capacity of individual members to support current or anticipated loads.
- Developing repair recommendations and replacement options for damaged wood members.

FIELD PROCEDURES

Species Identification

Identifying wood species makes it possible to determine material properties for conducting a structural analysis and to identify compatible material for repairs. Small samples were removed

from various wood components of both sites (Figure 3), and the species or species group of each sampled element was identified under microscopic examination.



Figure 3: Location of a species identification sample, removed from a bent column, Live Oak site.

Wood Grading

Lumber and structural timbers, such as beams, used in new construction are intended to comply with the relevant building code for that jurisdiction. For wood construction, structural engineers rely on design values referenced in the building code to determine an acceptable species, size and grade for a particular load condition. The design values given in the building code for solid wood products are established by the American Forest & Paper Association[13] and are published as the *National Design Specification for Wood Construction*. The published design values are based on test data and procedures published by the American Society for Testing and Materials[14] (ASTM) that demonstrate the engineering performance of the material.

[13] American Forest & Paper Association and American Wood Council, 2005, *National Design Specification for Wood Construction*, Washington, D.C.

[14] American Society for Testing and Materials, 2006, *Annual Book of Standards*, Vol. 04.10: D245, Standard Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber; D2555, Standard Test Methods for Establishing Clear Wood Strength Values. ASTM, West Conshohocken, PA.

Wood products are graded in accordance with procedures promulgated by one of several forest products industry associations, such as the Western Wood Products Association (WWPA).[15]

For existing structures the engineer often relies on available species and current standards to determine adequacy of the wood members to remain in service. Since many older structures were constructed before building codes or design values for wood products were established (and, thus, before grade stamps were used), engineers require a method for determining appropriate design values. Frequently, the species and grade of structural members are assumed, and calculations based on overly conservative assumptions often show the wood members to be structurally deficient. The results can include unnecessary replacement, repair and retrofit decisions, along with associated project costs. For this assessment, representative members from both structures were examined to provide grading data so that appropriate design values and load capacity could be determined (Figure 4).



Figure 4: Measuring knots to determine structural grade at the Evening Star site.

Visual Inspection and Probing

Visual examination of the wood allows for identifying components that are missing, broken, or in an advanced state of deterioration. Missing components are those that have been intentionally

[15] Western Wood Products Association, 2004, *Standard Grading Rules for Western Lumber*, Portland, Oregon.

removed or have fallen away due to deterioration. If missing components were intended to provide structural support, their replacement may be essential to prevent long-term damage to the structure. Visual inspection also allows for the detection of past or current moisture problems, as evidenced by moisture stains on the exposed surface of the wood. Further, visual inspection enables detection of external wood decay fungi or insect activity as determined by the presence of decay fruiting bodies, fungal growth, insect bore holes or wood substance removed by wood-destroying insects. Visual inspection provides a rapid means of identifying areas that may need further investigation.

Internal decay and insect damage are often difficult to detect due to the lack of evidence on the exposed surface of the wood. Probing the wood with an awl enables rapid detection of voids in the wood that may not be visible on the surface. It can also indicate the approximate depth of any deterioration that is visible on the surface (Figure 5).



Figure 5: Example of probing with an awl into a sill that is below the current grade, Live Oak site. The extent of penetration indicates that advanced decay is present.

Probing can often reveal areas of incipient (early-stage) decay or insect damage in timber that has experienced sufficient deterioration to allow for easy penetration of an awl although no internal void is yet present. Wood without deterioration just below the surface tends to offer greater resistance to probing due to the higher density and more intact internal wood structure than wood that has wood decay fungi present in sufficient quantity to impact structural performance.

Moisture Content Determination

Even in a dry environment such as the Mojave Desert National Preserve, exposure to moisture is possible and can produce undesirable conditions and long-term maintenance issues for wood in a structure. Excessive shrinkage or swelling, checking, loose connections, and decay are typical problems. Moisture content measurements were taken using a resistance-type moisture meter to determine the internal moisture content in structural timbers (Figure 6).



Figure 6: Use of a resistance-type moisture meter at the Live Oak site to determine moisture content of a sill that is partially below the current grade.

Moisture content measurements identify wood with favorable moisture levels for the growth of wood-decay fungi. Generally, if the moisture content is less than 20 percent, wood-decay fungi are unable to grow. While fungi may be present at lower moisture contents, they are unable to continue to deteriorate the wood without sufficient moisture. Moisture contents from 20 to 30 percent indicate areas of concern where sufficient moisture is present for fungi to grow but not sufficient to indicate advanced decay. Moisture contents above 30 percent are often an indication of advanced decay with internal voids and / or surface deterioration.

Resistance Drilling

Resistance drilling is a quasi-nondestructive technique for determining the relative density of wood (Figure 7). It is best suited for determining internal problems in larger wood members or timbers that do not show obvious external signs of deterioration. Any internal void or early stage of decay at the location drilled can be detected by determining the relative density of the

wood. The relative density is recorded on a strip of paper as a small diameter needle penetrates the wood. Voids, areas of incipient decay, and areas of insect damage can be identified and quantified through resistance drilling. At both the Live Oak and the Evening Star sites, resistance drilling was conducted primarily on wood elements in ground contact and at the bases of columns to determine internal conditions.



Figure 7: Resistance drilling of a buried sill beam, Live Oak.

WOOD INVESTIGATION FINDINGS: LIVE OAK

Nomenclature

The Live Oak site consists of an intact ore bin and trestle. The ore bin is oriented on an approximate north-south axis, while the trestle carries a radial ore cart track on a wood floor deck that curves from the west to the south to intersect the ore bin (Figures 8 and 9, and Appendix B, sheets 02 and 03). The ore bin has four timber framing bents and associated timber braces, sills, and columns. Each ore bin bent is made up of sills, columns, hopper girders, joists, and braces. The ore bin bents are numbered from west to east, with timber elements referred to by bent number, type of element, and elevation, where necessary. The trestle is composed of four timber and dimension lumber bents with associated braces, caps, stringers, ties, and sills. The bents are numbered from south to north, with bent 1 being the closest to the ore bin and bent 4 being the northernmost bent. Bents 1 and 2 have timber

columns, while the columns for bents 3 and 4 are constructed of paired dimension lumber elements (Figure 10). Timber elements for each bent are referred to by bent number, cardinal orientation, and type of element. For more information on nomenclature, see the Live Oak measured drawings in Appendix B.



Figure 8: Live Oak trestle in foreground, ore chute and ore bin in background.



Figure 9: Live Oak ore bin, viewed from the northeast.



Figure 10: Bent 4, viewed from the west. Paired dimension lumber elements make up the columns for bents 3 and 4.

General Observations

The Live Oak mining structure is thought to have been constructed around 1900, and despite the harsh climate, the wood is generally in fair condition with a few exceptions. The primary mechanisms of deterioration of timbers above grade are weathering, crushing, and decay (Figure 11). Some diagonal braces and thinner elements have failed at bolted connections, due in part to the effects of weathering (Figure 12). The hopper girders exhibit crushing that likely resulted from overload events while the mine was in operation (Figure 13). Timbers in ground contact tend to exhibit deterioration due to wood decay fungi (Figure 14). In particular, the sill beams of the ore bin and the trestles are severely decayed, resulting in some settlement, particularly of the south elevation of the ore bin. Some evidence of deterioration due to wood boring insects (likely termites) was also identified; it is unknown if the insect damage is from an active infestation.



Figure 11: Example of a severely weathered wood element on the Live Oak structure. The weathered wood is an aesthetic characteristic of the structure.



Figure 12: Failure of a diagonal brace on bent 1, due in part to the effects of weathering and overload.



Figure 13: Crushing of a hopper girder under the ore bin.



Figure 14: Visible evidence of wood decay on the east column and the sill of bent 2.

Based on pre-existing notches visible in many of the timbers at the Live Oak site, it appears that it was constructed using a number of recycled elements (Figure 15). One sill beam with incising and a stamp on the end grain was observed (Figures 16 and 17); incising is indicative of use of a wood preservative, and the stamp may indicate the type of preservative that was used.



Figure 15: West timber column, bent 1, with a notch possibly indicating a previous use.



Figure 16: Incised timber sill, oriented east-west and located on the north elevation of the ore bin.



Figure 17: End of incised timber sill with stamp that may indicate preservative treatment.

Species Identification

Samples were removed from structural member types (columns, braces, sills, etc.) and non-structural elements (ore bin planks) of interest to the assessment team and examined under the microscope to identify the species or species group. The primary wood species used in the construction of the Live Oak mine structures is Douglas-fir (*Pseudotsuga menziesii*). One sample pulled from a bent brace was identified as spruce (*Picea* spp.), and one sample removed from a trestle tie was identified as redwood (*Sequoia sempervirens*). Table 1 shows the location of samples removed from the Live Oak site for species identification. For sample locations, see Appendix A.

Table 1. *Wood Species Identified from the Live Oak Site*

Sample #	Member ID	Species
1	south elevation, sill between fifth and sixth columns from the west	Douglas-fir (*Pseudotsuga menziesii*)
2	south elevation, east 9" x 9" diagonal brace	Douglas-fir

Sample #	Member ID	Species
3	south elevation, east beam (2 pieces)	Douglas-fir
4	south elevation, west beam	Douglas-fir
5	south elevation, ore bin bent 2, column	Douglas-fir
6	south elevation, easternmost column, 6" x 6"	Douglas-fir
7	south elevation, third column from west, 12" x 12"	Douglas-fir
8	south elevation, upper 3.5" x 5.5" brace between second and third columns from west	Douglas-fir
9	west elevation ore bin siding, 2.5" x 11"	Douglas-fir
10	east elevation ore bin siding	Douglas-fir
11	ore bin bent 1, hopper girder	Douglas-fir
12	north elevation, ore bin bent 2, column	Douglas-fir
13	north elevation, ore bin bent 3, hopper joist	Douglas-fir
14	north elevation, brace 4	Douglas-fir
15	ore bin north sill, east segment, incised	unidentifiable
16	bent 1, west column	Douglas-fir
17	bent 3, south and east column, 1.625" x 7.5"	Douglas-fir
18	bent 4, south and west column, 2.75" x 11.75"	Douglas-fir

Sample #	Member ID	Species
19	bent 2, west to east diagonal brace, 1.875" x 11.25"	spruce (*Picea* spp.)
20	center stringer between bent 4 and bulkhead, 5.5" x 6"	redwood (*Sequoia sempervirens*)
21	west stringer between bents 3 and 4, 5.5" x 7.75"	Douglas-fir
22	3.5" x 3.75" rail tie from between bents 3 and 4	Douglas-fir
23	bent 4 cap, 5.75" x 6"	Douglas-fir
24	plank on trestle from between bulkhead and bent 4, 1.75" x 12"	Douglas-fir

Lumber Grade

Knots tend to be the grade-limiting defect for lumber in this structure, i.e., the size and position of the knots determines how the lumber can be classified. Some of the structural timbers used in the construction of the Live Oak ore bin do not contain large knots and can be assigned a relatively high structural grade, while others have knots or slope of grain that preclude them from a high structural grade (Figure 18). To be assigned a particular grade, 95 percent of the pieces graded should fall within the grade. Since there are only a few wood members of any type within the Live Oak mining structure, the percentage within a grade can fall below the 95 percent level even if only a few members fail to meet the higher grade. In these cases, the structural engineer may elect to use engineering judgment and apply a higher grade if knowledge of the wood condition and structural loads warrants it, particularly if individual members are graded.

Based on in-situ grading, all of the structural elements of the ore bin can be assigned the grade of Douglas-fir No. 2 within the current *National Design Specification for Wood Construction*

(NDS). Approximately 97 percent of the structural framing meets or exceeds the grade of Douglas-fir No. 2. **It should be noted that approximately 88 percent of the structural framing members meet or exceed the grade requirements for Douglas-fir No. 1, with only four members that failed to meet the requirements.**



Figure 18: Timbers used in the Live Oak ore bin construction with a variety of grade qualities as determined by the presence and size of knots.

The assignment of a structural grade is based on visual characteristics of the lumber (or timbers). Lumber that had deterioration limited to the ends or the top or bottom surface of the member was included in the grading on the assumption that the member could be repaired or reinforced if the full dimension was needed to meet load requirements. Connections were not considered during the grading process but often control the ability of a structure to withstand applied loads. Finally, adjustments to the allowable design values for end use conditions need to be considered by the structural engineer.

Wood Moisture Content

Moisture content measurements of structural members were taken in a number of locations; timbers prone to moisture intrusion (such as those in ground contact or below grade) were the focus of the moisture diagnostics. Moisture contents below 20 percent are insufficient for the growth of active wood decay. Moisture contents above 30 percent are indicative of favorable conditions for severe deterioration due to active decay fungi. At the time that fieldwork was

conducted, moisture contents ranged from 8 percent to 24 percent. High moisture content readings (near or above 20 percent) were taken in locations that were excavated below the existing ground level. Periods of precipitation can raise the moisture content of wood in ground contact to the 30 percent threshold for deterioration by wood decay fungi, and additional deterioration can continue to occur at moisture contents above 20 percent in wood in ground contact when the soil is able to retain moisture.

Wood Condition

Based on visual inspection, probing, resistance drilling, and moisture content readings, the wood used to construct the Live Oak mining structure appears to be, in general, in fair condition, and the majority of wood is suitable to remain in service. The most severe deterioration condition, resulting in settlement and structural distress of the ore bin and the trestle structures, is decay of sills and other timber in ground contact or located below the current grade. The primary mechanisms of deterioration of timbers above grade are weathering, crushing, and decay.

Weathering is the result of exposure to ultraviolet light, the action of cyclic wetting and drying of the wood, and erosion of the wood through wind-blown debris (a process similar to sand blasting). Unlike wood decay or insect attack, weathering is typically not a significant factor in the failure of wood components and the collapse of structures. Weathering will change the appearance of wood exposed to the elements but the process is slow enough that failure of components due to decay generally occurs long before weathering becomes a major factor in the failure. We typically think of weathered wood as aesthetically pleasing because, unlike decay or insect attack, it seldom damages the wood enough to require replacement. Many of the wood members used in the Live Oak mine structure are severely weathered and should not be considered defective based on the weathered appearance alone. However, severe weathering has affected some bolted and nailed connections.

Conditions of the wood elements, based on the findings of the wood investigation, can be classified into one of four descriptive groups: excellent, good, fair, and poor. For wood with no deterioration due to decay or insect damage and showing minimal effects of weathering (primarily discoloration), a rating of excellent can be applied; the ore bin joists and braces are in excellent condition. For wood with moderate weathering but no deterioration due to decay or insect damage, a rating of good can be applied. The ore bin planks and the north elevation columns are generally in good condition. For wood with minor deterioration (early stages of

decay) or severe checking, splitting, or movement (such as warp or twist), a rating of fair can be applied. Most of the wood members at the Live Oak site fall within this category. For wood with advanced decay or insect damage such that the member is in jeopardy of succumbing to the effects of the deterioration, a rating of poor can be applied. The sill beams are an example of wood at the Live Oak site in poor condition.

Ore Bin. Most of the large structural timbers of the ore bin are in good to fair condition, with a few exceptions. The ore bin joists, braces, and some of the columns are in excellent condition (Figure 19). On the south elevation, the sill beam, which has become partially buried by debris build-up over time, was found to have severe deterioration when subjected to resistance drilling (Figure 20). Also on the south elevation, the third column from the west was found to have deterioration that extends a minimum of 14 inches above the sill beam. The hopper girders at ore bin bents 2, 3, and 4 exhibit crushing on both the north and south elevations at the column bearing areas. The hopper girders at ore bin bents 2 and 4 exhibit the most severe crushing on the south elevation; the hopper girder at ore bin bent 4 exhibits the most severe crushing on the north elevation (Figure 21) and is split along its length, probably due to overload during operation. The plate timber that supports the hopper girders on the south elevation is exhibiting significant deflection near mid-span (Figure 22).



Figure 19: Timber columns and braces on the north elevation of the ore bin in good to excellent condition.



Figure 20: Deterioration of the substructure sill below the fifth column from the west, south elevation of the ore bin.



Figure 21: The hopper girder at ore bin bent 4 on the north elevation showing crushing and a shear failure due to overloading.



Figure 22: Deflection of the plate timber on the south elevation (view from the north) where the hopper girder at ore bin bent 4 is offset from the supporting column.

There are six long diagonal brace timbers that provide additional support to the ore bin; two on each of the south, east, and west elevations. The east brace on the south elevation is in poor condition with crushing and deterioration near the existing grade. The west brace on the south elevation was found to have a large internal void at the existing grade. On the east elevation, both braces were found to have deterioration at the existing grade but were free of voids at 24 inches above grade. On the west elevation, both braces were found to be in good condition at the existing grade with no internal voids. None of the brace-ore bin connections (at the top) were accessible for direct assessment but generally the wood near the top of the braces appears to be in relatively good condition, with the exception of the southern brace on the east elevation (Figure 23). The angle of the brace may have allowed moisture to be retained on the exposed top face, leading to some deterioration.

Sills that support the ore bin are predominantly below the current grade or in ground contact; nearly all sills exhibit deterioration where they are in contact with the ground (see Figure 14), including the incised timber sill that has been treated with a wood preservative, although that sill has limited decay compared to the non-treated sills. All sills below the current grade exhibit evidence of severe deterioration in areas where they were excavated and assessed (through visual inspection and probing, resistance drilling, or a combination of techniques).



Figure 23: Top of the south brace, east elevation, showing some deterioration. The type and condition of any metal fasteners is unknown.

Bent 1. Bent 1 exhibits structural damage due to settlement of the ore bin and partial collapse of the ore bin chute (Figure 24). Safety concerns regarding potential collapse require that this bent be a priority for repair, as many of the elements have rotated out of plane and could cause further collapse of the floor deck and ore chute should they become additionally displaced.

The sill beam below bent 1 was not assessed using resistance drilling because of the extent of visible deterioration (Figure 25). The west column was found to be solid at the base, but the east column was found to have insect and wood decay damage at the base. The damage to the east column base extends a minimum of 13 inches above the sill beam. The cap and stringers were not accessible for direct assessment, but appear to be in good condition with some weathering. One of the diagonal braces has split at the top connection (visible on the north elevation). Additionally, a supplementary brace extending diagonally down to the west of the bent has failed and is no longer providing structural support.



Figure 24: Bent 1, viewed from the north, showing rotation and partial collapse of the ore bin chute, cap, stringers, and rail ties.



Figure 25: Deterioration of the sill and the east column of bent 1 below grade.

Bent 2. The two timber columns and the sill beam below bent 2 were subjected to resistance drilling. The west column and the west end of the sill are currently above grade and are in good condition (Figure 26). The east column has minor deterioration of the bearing area and the east end of the sill, which is located below the current grade, is deteriorated (Figure 27). The diagonal braces are weathered but intact. The stringers appear to be weathered but in good to fair condition; direct assessment was not possible due to lack of safe access. The cap has no visible deterioration on the west elevation but does have a small channel of decay visible on the east face (Figure 28).



Figure 26: Base of west column and sill, Bent 2, in good condition.



Figure 27: Base of east column in fair condition and the east end of the sill, which has deteriorated, bent 2.



Figure 28: Decay channel visible on the east face of the cap, bent 2.

Bent 3. Bent 3 is constructed with paired dimension lumber boards serving as columns. Areas around the column bases were excavated; the column bases were found to have visible evidence of deterioration and the sill was easily penetrated when probed with an awl (Figure 29). The columns were not resistance drilled. The stringers associated with bent 3 are weathered and are in fair condition. The west end grain of the cap has a small channel of deterioration. The east end grain of the cap is weathered and has some damage from a bolt hole but does not appear to have extensive deterioration (Figure 30).



Figure 29: Base of the east column of bent 3 (consisting of paired dimension lumber members) showing deterioration of the boards where they were buried below the current grade.



Figure 30: Bent 3, east end of cap showing weathered end grain and a minor split at a bolt hole.

Bent 4. Bent 4 is a simple structure composed of paired dimension lumber columns without diagonal bracing. The column bases were not resistance drilled but areas were excavated around the columns and the boards were found to have visible deterioration; a sill, if present, has completely deteriorated (Figure 31). The stringers associated with bent 4 are weathered but appear to be in fair to good condition. The cap for bent 4 is in poor condition; it exhibits extensive deterioration and is extremely friable at both the east and west end grain (Figure 32).



Figure 31: Base of the south board of the west column, bent 4, showing visible signs of deterioration and being easily penetrated with an awl.



Figure 32: Extensive decay visible in the end grain of the cap on bent 4.

Floor Deck Planks and Ties. The deck planks visible from the northwest end of the trestle are extensively weathered. This degree of weathering is the result of the horizontal positioning of the planks, which exposes a large surface area to direct ultraviolet radiation and precipitation. Because of the degree of weathering, the boards are in fair to poor condition, but do not exhibit evidence of extensive deterioration due to wood decay fungi. The ties, which are larger in dimension, however, do show evidence of wood decay fungi activity, and have visible pockets of decay (Figure 33). In general, the ties are in poor condition.



Figure 33: Weathered trestle planks and ties with visible decay pockets.

WOOD INVESTIGATION FINDINGS: EVENING STAR

Nomenclature

The Evening Star site has an intact ore bin, headframe, and associated structural timber framing. The structure is laid out on an approximate north–south axis (the parking area is assumed to be north of the structure), with the headframe located on the west side of the structure, near the south end (Figure 34). The ore bin has three framing bents, while the headframe and supporting tower are composed of four framing bents, for a total of seven bents. Each bent of the ore bin is composed of sills, columns, hopper girders, braces, and joists. The other bents have sills, columns, braces, and tie beams. For the wood condition assessment, the bents were numbered from north to south; the column lines were numbered from east to west.



Figure 34: Evening Star mine structure with ore bin in foreground. View from the northeast.

General Observations

The Evening Star headframe was originally constructed in 1943 and is generally in good condition with a few exceptions. The primary mechanism of deterioration of timbers above ground level is weathering; however, unlike conditions at Live Oak, many of the timber sills and columns at Evening Star rest on concrete foundations or piers (Figure 35). Not all foundation timbers remain above grade due to debris build-up, and those timbers in ground contact tend to exhibit deterioration due to wood decay fungi (Figure 36). Overload conditions during operation may have caused structural failure in one of the headframe timbers supporting the sheave (Figure 37). One timber girt on the second level of the north side of the structure is hanging from a connection (Figure 38). Some evidence of deterioration due to wood boring insects (likely termites) was also identified on a few timbers comprising the ore bin; it is unknown if the insect damage is from an active infestation. Steel plate clamps have been placed on some of the timbers for an unknown reason (possibly in an effort to control checking) (Figure 39). These clamps have been shimmed with plywood or OSB, which will retain moisture; therefore, they should be removed to prevent additional deterioration due to wood decay fungi and/or insect attack that is associated with high moisture contents.



Figure 35: Concrete foundation under the ore bin; view to the south.



Figure 36: North-south sill beam along column line 1 after excavation, showing decay pocket in the end grain.



Figure 37: A failure in a column supporting the sheave in the headframe at the southwest corner of the structure.



Figure 38: Hanging girt that is a fall hazard; view from the west.



Figure 39: Metal plate clamps, shimmed with plywood, that trap moisture against the wood; view to the north.

Species Identification

Samples were removed from structural member types (columns, braces, sills, etc.) and non-structural elements (ore bin planks) of interest to the assessment team and examined under the microscope to identify the species or species group. The wood species used in the construction of the Evening Star mining site, as identified by the samples that were removed, is Douglas-fir (*Pseudotsuga menziesii*). Table 2 shows the location of samples removed from the Evening Star site for species identification.

Table 2. *Wood Species Identified from the Evening Star Site*

Sample #	Member ID	Species
1	bent 1, ore bin hopper girder	Douglas-fir (*Pseudotsuga menziesii*)
2	N-S sill	Douglas-fir
3	bent 1, column 3	Douglas-fir

Sample #	Member ID	Species
4	bent 2, hopper joist	Douglas-fir
5	ore bin floor plank, west elevation	Douglas-fir
6	bent 5, sill	Douglas-fir
7	bent 7, sill	Douglas-fir
8	bent 7, column 1	Douglas-fir
9	bent 6, column 1	Douglas-fir
10	bent 7, tie beam 2	Douglas-fir
11	bent 7, south diagonal brace	Douglas-fir
12	bent 4, column 3	Douglas-fir
13	bent 4, 6" x 6" brace, level 2	Douglas-fir
14	riser, level 2, west elevation	Douglas-fir

Lumber Grade

Knots tend to be the grade-limiting defect for lumber in older structures, i.e., the size of the knots determines how the lumber can be classified. Some of the structural timbers used in the construction of the Evening Star mining structure do not contain large knots and can be assigned a relatively high structural grade, while others have knots or slope of grain that preclude them from a high structural grade.

Based on in-situ grading of the lower (level 1) structural elements, the structural elements of the mining structure can be assigned the grade of Douglas-fir No. 2 within the current *National Design Specification for Wood Construction* (NDS). Approximately 98 percent of the structural

framing meets or exceeds the grade of Douglas-fir No. 2. It should be noted that approximately 85 percent of the structural framing members meet or exceed the grade requirements for Douglas-fir No. 1.

Wood Moisture Content

Moisture content measurements of structural members were taken in a number of locations; timbers prone to moisture intrusion (such as those in ground contact or below grade) were the focus of the moisture diagnostics. Moisture contents at the Evening Star site ranged from 9 percent to 12 percent above grade. Higher moisture content readings were found in timbers that are partially or wholly below the current grade; typical moisture contents in excavated timbers ranged from 15 to 19 percent, and one sill was found to have a moisture content of 26 percent.

Wood Condition

Based on visual inspection, probing, resistance drilling, and moisture content readings, the wood used to construct the Evening Star mining structure appears to be, in general, in good condition, and the majority of wood is suitable to remain in service. However, only the timbers supporting the lower level of the structure were investigated. Areas of deterioration due to moisture intrusion occur primarily in timbers that are in ground contact or are below the current ground level. The primary mode of deterioration for elements above ground is weathering.

Bents 1 through 3 (Ore Bin). Most of the large structural timbers of the ore bin are in excellent to good condition (Figure 40), with a few exceptions. The north-south sill beam that runs along column line 1 has become partially buried by debris build-up over time and has visible deterioration of the end grain (viewed from the north elevation – see Figure 36). Based on resistance drilling results, the deterioration does extend into the beam but is limited to the east and bottom faces where it is in ground contact. Columns and hopper girders were found to have minimal or no deterioration when resistance drilled.



Figure 40: Timber columns on the west elevation of the ore bin in good to excellent condition.

Bent 4. Bent 4 consists of three timber columns that bear on concrete pad foundations. The bases of each column were resistance drilled and inspected for visual signs of deterioration. Column 1 has visible decay on the east and west faces and was found to be deteriorated on the north face based on resistance drilling results (Figure 41). The deterioration makes up 50 percent of the cross section at the drilling location. The two other columns were found to have no deterioration at the base.



Figure 41: Column 1, bent 4, viewed from the northwest, showing visible deterioration on the excavated west face.

Bent 5. Bent 5 consists of four timber columns and two diagonal column braces that bear on a timber sill. The timber sill rests on a concrete foundation; however, debris build-up on the north side of the sill has resulted in below-grade conditions. All four of the column bases were resistance drilled; of those, column 1 had limited deterioration on the east face, where debris build-up is the most extensive; the deterioration does not extend more than 2 inches into the column at the drilling location. The sill beam, however, was found to have large voids along its length and is a candidate for replacement (Figure 42).



Figure 42: Column 1 and the sill beam of bent 5 showing the build-up of debris that has resulted in significant deterioration of the sill. View from the northwest.

Bent 6. Bent 6 consists of a large 12 x 12 column and a smaller sister column that bear on a concrete pier, in addition to the north headframe tie beam and diagonal braces. The column, although not a single member, extends to the highest point of the structure, as does the west diagonal brace; the wood assessment, however, was limited to the lower level of the structure. The braces were not resistance drilled but were visually inspected. The short east diagonal brace has surface deterioration at the connection with the tie beam and the foundation for the column; this deterioration may have been caused by crushing while the mine was in operation. The long west diagonal brace is weathered at the connection with the tie beam but appears to be in good condition. The tie beam was found to have deterioration at the east end with only a thin shell of sound wood remaining (Figure 43). The small sister column is solid at the base; however, the larger 12 x 12 column has extensive deterioration at the base and only a thin shell of sound wood. This deterioration is limited to the bottom few inches of the column and is likely the result of water pooling on the top of the pier and at the base of the column (Figure 44). Resistance drilling results conducted at 14 inches above the base found no voids in the column (Figure 45).



Figure 43: Tie beam, bent 6, deteriorated at the east end.



Figure 44: Column 1, bent 6, and the sister column, showing the concrete encasing the base of the larger column that allows for moisture entrapment.



Figure 45: Column 1, bent 6, with a large internal void at the base of the column.

Bent 7. Bent 7 consists of four timber columns and two diagonal timber braces that bear on a timber sill (Figure 46). Column 4 (one column west of column line 3) has a slender sister column, similar to the sister column on bent 6. The timber sill rests on a concrete foundation. To the west is a horizontal tie beam and diagonal braces for the headframe. The sill, columns 1 and 4, and the sister column were resistance drilled and no deterioration was found. The tie beam and diagonal braces of the headframe were not resistance drilled but were visually inspected; the tie beam is deteriorated at the bolted connection on the east end (Figure 47). Both braces are weathered but do not appear to have deterioration at the connections to the tie beam.



Figure 46: South elevation of the Evening Star structure showing bent 7.



Figure 47: Deterioration at the east end, east face, of the tie beam, bent 7.

SUMMARY OF THE WOOD INVESTIGATION

The structural wood elements of both mining sites are, generally, in good to fair condition. The primary areas of deterioration occur in structural elements in contact with the ground or those that have become covered by debris. The primary mechanism of deterioration for timbers in ground contact is the growth of wood decay fungi facilitated by moisture absorption and poor drainage conditions. Damage by wood boring insects is a secondary concern; most wood boring insects prefer wood with high moisture content and/or the presence of active wood decay. At the Live Oak site, the primary mechanisms of deterioration for timbers and structural wood elements that are not in contact with the ground are decay, crushing, and weathering. For the Evening Star site, the primary mode of deterioration for above-grade timber is weathering. Based on a limited number of samples, most of the structural wood elements were constructed of Douglas-fir, a moderately durable wood species. The wood, particularly when not in ground contact, has performed fairly well at both mining sites in the relatively dry climate of the Mojave Desert.

The findings of the wood assessment can be summarized as follows:

- Based on a limited number of samples, most of the structural elements of the Live Oak site are constructed of Douglas-fir (*Pseudotsuga menziesii*), a moderately durable wood species. Other species identified from samples taken from the Live Oak structure include spruce (*Picea* spp.) and redwood (*Sequoia sempervirens*).
- Weathering, crushing, and wood decay fungi are the primary mechanisms of deterioration.
- Deterioration by wood decay fungi tends to be limited to structural elements in ground contact or those that have become covered with debris. Damage by wood-boring insects is a secondary concern.
- Bent 1 of the Live Oak site is in structural distress and is a high priority for repair.
- The hopper girders of the Live Oak ore bin exhibit crushing from overload and require repair or replacement.
- The foundation elements of the Live Oak site and a few foundation elements of the Evening Star site that are in ground contact have deterioration due to poor drainage conditions and debris build-up.
- The sill of bent 5 and column 1 of bent 6 at the Evening Star site have extensive deterioration and require repair.

STRUCTURAL ASSESSMENT

The field data in this report provide the information needed to conduct a preliminary structural analysis based on known wood conditions, wood species, and grade of the structural framing.

LIVE OAK

Four braced bents support a radial track that was used to convey mine carts to dump ore down a supported chute into a large heavy timber ore bin. Portions of the Live Oak structure exhibit significant distress but they are all repairable to achieve preservation as a non-operating structure. The ore bin has moved out-of-plumb and bent 1 is partially collapsed resulting in the dropping of the top end of the ore chute and the ends of the stringers supporting the floor deck and track between bents 1 and 2. The collapse of the bent may have been initiated by movement of the ore bin to the south (apparently the combined result of the decay of substructure elements and crushing of hopper girders) and/or loss of lateral support due to deterioration of the stringers at the drift pin connections, causing the top of the bent to move to the south. Significant loss of wood fiber has occurred in the crushed and weathered ends of the hopper girders. The easternmost hopper girder is significantly deteriorated along its length. Deflection of the heavy timber top plate in the ore bin substructure occurs beneath the southeast corner of the ore bin. Wood decay occurs in sills, bottoms of columns, and ends of braces in contact with the ground. Many of the dimension lumber braces and waling strips have failed at bolted connections due to deterioration associated with weathering; recovery of connection capacity through repair or replacement of deteriorated members is essential to the axial stability of the trestle.

Jacking and returning the ore bin to a plumb position, and repairing bent 1 and the stringers and girts that brace it, will result in a stable structure. Replacing the decayed sill and repairing decayed columns of the framed substructure that support the ore bin are required to support the bin in a plumb position. While the top plate of the substructure frame is deflected beneath the southeast ore bin column, the beam is adequate to continue to support its portion of empty ore bin. As a part of re-plumbing the bin, the southeast ore bin column will be re-aligned to bear over the supporting beam, rather than primarily over the cantilevered end of the eastern hopper girder. New timber bearing plates can be installed behind the existing beam to provide additional support of the southern ends of the hopper girders.

The long timber braces at the south end of the ore bin are essential to maintain the stability of the bin; scarf repairs at the bases of decayed members and strengthening of upper connections are required to recover capacity lost to deterioration. The integrity of the hopper girders is also essential in order to support the ore bin, particularly on the south; scarfed end repairs will be suitable to restore axial strength on three of the hopper girders. The easternmost hopper girder should be replaced due to excessive deterioration over its entire length.

Replacement of decayed sills in trestle bents and repair of decayed column bases are necessary to return trestle caps and the floor deck they support to their original positions. Deterioration of the ends of stringers that brace the bents can be addressed with scarfed splices and dutchman inserts at stringer-cap connections. Deterioration in trestle caps at tops of bents can be addressed with dutchman inserts at stringer-cap connections. Deteriorated timber rail ties need not be replaced; there is adequate redundancy and continuity of rail such that they may remain. Light dimension lumber braces can be replaced in kind.

EVENING STAR

Three massed towers of varying height were used to separate ore; the tallest tower is towards the south. The south and center towers are braced and connected by trusses. The lower tower is a sheathed ore bin. A long braced conveying system brought the ore from the mine to an overhead sheave at the top of the tallest tower.

In general, the Evening Star structure is in good structural condition, with distress limited to a few structural elements, which are repairable. In the frame supporting the sheave assembly (and against which the headframe terminates), one column (north) is fractured and the other column (south) is extensively deteriorated; both can be scarf repaired. The sill at bent 5 is decayed and requires replacement. The 12 x 12 column at bent 6 is embedded in a concrete pier and the column is decayed to a height of <14 inches above the top of the pier. An 8 x 8 that sisters the 12 x 12 column, and is a part of the conveying system, bears on concrete and is not decayed. New through-bolts can be installed along the height of the 8 x 8 and 12 x 12, and new clip angles connected from the base of the 8 x 8 with epoxy anchors to the concrete pier. The steel clamps previously installed at tower columns should be removed. They appear to have been installed to control checking of timber, but they currently trap water, creating conditions that are likely to promote decay of the columns. During the site visit, there was no observed checking which indicated through splits or loss of structural capacity in the columns.

STABILIZATION / PRESERVATION STRATEGIES

In managing and maintaining the mine sites, the park is broadly guided by the Secretary of the Interior's Standards for the Treatment of Historic Properties. Because of the historical and technological significance of the structures, the project team has been additionally guided by the ICOMOS Principles for the Preservation of Historic Timber Structures, and the ISCARSAH Principles and Guidelines.[16]

In proposing stabilization options, thought was given to preservation goals as they apply to existing fabric, the original structural configuration of the mine structures, and the craft practices that were used to produce the structures. When fully exposed to weather, wood is an ephemeral material. For exposed structures, replacement in kind is typically included as a repair strategy, and preservation goals in these circumstances are frequently focused on retention of the historic structural configuration and the traditional craft practices involved in making replacements. The team also considered access and the obstacles to routine maintenance of the structure.

The Evening Star Mine has not been in use since the 1980s, and the Live Oak Mine similarly has not been in use since the 1990s, so the mine structures no longer function in their original capacity. Park goals for the mine sites include interpretation and pedestrian access, so that recovering the original structural capacity (for mining activities) is not essential. Recommendations for treatment of the two mine structures are focused on stabilization and based on funding restrictions and the desires of the park. For Live Oak, the strategy includes extensive repair recommendations required to restore original structure geometry and is intended to prevent further loss due to collapse. For Evening Star, the headframe and sorting structure are in generally good condition. The project team is proposing a stabilization strategy based primarily on maximizing the retention of historic material while stabilizing those members that have decayed or failed. Repair recommendations for both structures are intended to result in an acceptable level of structural stability for a period of 50 years or more.

STABILIZATION STRATEGIES: LIVE OAK

Live Oak is in danger of collapse largely due to settlement of the ore bin that terminates the trestle run. Loss of support on the south side of the ore bin has resulted in rotation of the bin

[16] International Council on Monuments and Sites (ICOMOS) and the International Scientific Committee on the Analysis and Restoration of Structures of Architectural Heritage (ISCARSAH)

around the north sill, partially collapsing trestle bent 1, the ore chute, and the floor deck between bents 1 and 2. The stabilization strategy proposed by the project team is focused on shoring bent 1, the ore chute, and the floor deck, dismantling the ore chute and deck so that the bin and trestle bent can be returned to plumb, repairing the substructure supporting the ore bin, and returning the ore chute and floor deck to their original positions.

Shoring will be on structural staging set up in the bays between the ore bin and trestle bent 2. Once the ore chute and roadway have been supported, they can be disconnected, partially disassembled, and stored for reinstallation.

The ore bin is several inches out of plumb due to settlement of the substructure related to decay of the sill and column bases, and crushing of the hopper girders (see Figures 20, 21, and 22). Repair options include:

- Replacement of the sill, either in-kind or with pressure treated timber. In-kind replacement should be accompanied by installation of borate rods or gel, periodic inspections, and reinstallation of borate as needed. It should be noted that the north ore bin sill was treated with a preservative (while the mine was in operation) and is less extensively decayed, so there is a precedent for the use of treated timber in this context. Replacement of the sill will provide an opportunity to reposition the substructure with respect to the ore bin so that load paths are properly aligned.
- Scarfed repair of the substructure columns where they are decayed at their bases. This will maximize retention of historic wood.
- While the top plate of the substructure is deformed at several of the hopper girder locations, the timber is capable of supporting current loads without repair (so long as there is no ore in the bin).
- New ends can be scarfed onto hopper girders where they cross the top plate; this will reduce the potential for decay associated with the crushed ends in their current condition. The easternmost girder is deteriorated along its entire length and should be replaced in kind.
- Bearing plates (of treated wood) can be installed on the ledge below hopper brace – hopper girder connections to transfer brace loads to the ground and eliminate bending in the girders.
- Long timber braces on the ore bin were installed while the mine was in operation; decayed portions at grade can be repaired by scarfing in new timber.

Returning the ore bin to its original position with respect to plumb will eliminate buckling in trestle bent 1 because the horizontal member near the center of the bent (which is the hinge in the assembly) is braced against the bin (Figure 48). Damage at bolted connections can be

repaired by reattaching broken portions of the members, replacing lost relish with dutchman inserts or captured plates, or scarfing in new wood.

Trestle bents 2 through 4 are in reasonably good condition with the exception of wood in contact with the ground. Repairs include replacing sills and bearing blocks, and splicing new wood into decayed columns. It will be necessary to replace the sill in each of the trestle bents, either in-kind or with pressure-treated timber. Moisture contents of the sills were uniformly high, and replacement sills will be exposed to moisture levels conducive to decay. It is expected that the use of pressure-treated timber for replacement sills will result in reduced inspection and maintenance requirements and significantly longer service life.



Figure 48: Rotation of the ore bin caused bent 1 to buckle at the intermediary horizontal member.

In most of the trestle bents, column bases are decayed where they have been in contact with the ground (see Figures 25, 27, 29, and 31). For large dimension timber, new column bases can be scarfed into the historic wood using traditional scarf forms. For dimension lumber columns, new wood can be half-lapped and glued into the existing members provided half-lap joints are staggered and reinforced with spacers and through bolts (Figure 49). As a matter of maintenance, debris build-up (since the time of construction) should be routinely removed to prevent damage to replacement members.

Trestle caps at bents 3 and 4 are decayed and may require dutchman inserts in order to restore capacity to the stringer-cap connections (see Figures 30 and 32).

Timber stringers support ties, deck planking, and rails, and along with waling strips (longitudinal braces), restrict lateral movement of the trestle bents. It is expected that some of the stringers have decay pockets that are hidden below the rest of the floor system. Only half of the original member depth is required to support current loads. Repair options for members with insufficient capacity include installation of dutchman inserts to fill decay pockets and scarfed splices to replace decayed material at the ends of members.

Many of the ties are decayed, but are very minimally loaded; they support only the deck planking and rails, and typically loads are shared by several members. The floor deck cannot be made safe for pedestrian traffic under any of the stabilization scenarios, and under most circumstances ties will not be repaired or replaced.

For Live Oak repair locations, see Appendix B.

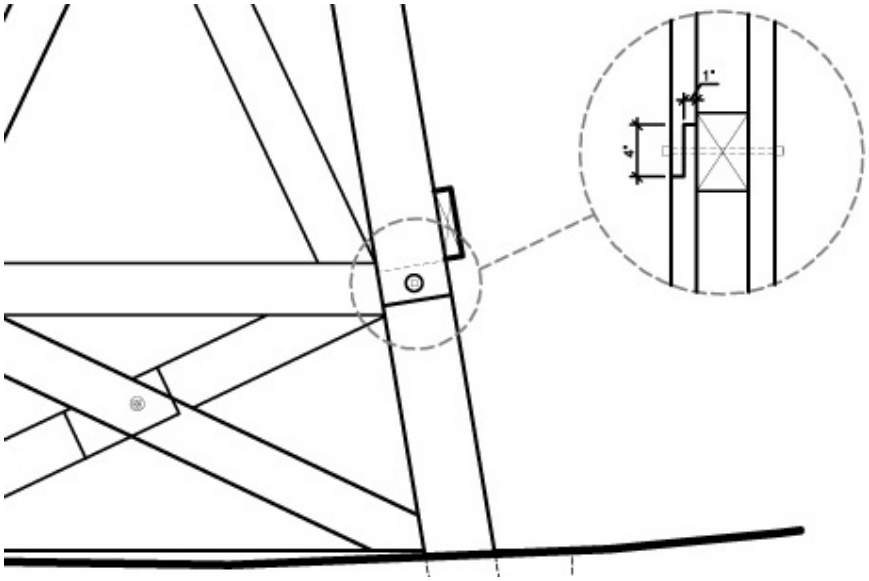


Figure 49: Proposed half lap scarf repair in a dimensioned lumber bent.

STABILIZATION STRATEGIES: EVENING STAR

At the Evening Star Mine, tall columns on the southwest that support the sheave above the headframe are decayed where sheave frame joinery, braces, and tiebacks meet. One column has failed and the other is approaching failure (see Figure 37). Without intervention, the

columns, sheave, and sheave framing will fall. The best option for repair is the scarfing (or splicing) of new wood into the columns 3 to 6 feet above the ore bin plate. This will require scaffolding the headframe and equipping the staging with a hoist for lifting the sheave assembly. The iron sheave and most of the sheave framing can be salvaged for installation on the replacement column ends. Surface-mounted brackets can be fabricated for capturing tiebacks, eliminating the need for holes through the columns (where the failure appears to be focused).

A sill supporting a row of columns in the tallest part of the structure (bent 5, immediately behind the headframe and one bay north of the south perimeter framing) is nearly entirely decayed (see Figure 42). A shell ≤2 inches thick covers the decay void, making the deterioration difficult to detect without resistance drilling. At present, the sill is providing no support for the four columns and the braces that terminate there. The best option for repair is replacement of the sill. Because a substantial portion of the replacement sill will be below grade and subject to decay, the replacement sill can be pressure-treated to increase service life. Alternatively, an in-kind replacement sill can be treated with borate rods or gel to slow decay. This will require annual inspection of the sill and periodic replacement of the rods to ensure there is no break in preservative protection.

A 12 x 12 column supporting the sheave assembly (column 1, bent 6, one bay north of the southwest corner) is decayed where the bottom of the column is embedded in a concrete pier (see Figures 44 and 45). Settlement of the column is prevented by an 8 x 8 column bearing on the pier and bolted to the larger column. Treatment alternatives include:

- Repair of the 12 x 12 column, which will require partial demolition of the pier, scarfing of new wood at the base of the column, and repair of the concrete pier. This will result in a repair that will be subject to the same process of deterioration, since the replacement end will be encased in concrete;
- The 8 x 8 column will reliably support the larger column provided that connections between the two members adequately transfer load from one column to another (requiring 8 to 10 through-bolts above the decay zone), and a connection is created between the bottom of the smaller column and the pier capable of resisting lateral loads (wind, seismic). This connection might consist of a steel angle or fin bolted to the column and anchored to the pier.

Diagonal braces terminating against 8 x 8 columns in bents 6 and 7 are fastened (with drift pins) to decayed tie beams terminating at a pier in bent 6 (see Figure 43) and a foundation wall in bent 7 (see Figure 47). The condition of the wood around the pins is such that the connections

have lost most or all of their original capacity. Options for treatment include: 1) in-kind replacement of the tie beams. The tie beams are made up of two timbers each, scarfed along their length. Replacement would be of the timbers on the east only; 2) alternatively, the braces could be fastened to foundation concrete using steel angles or fins as for the column connection described above.

Steel plate clamps are a recent addition to many of the historic timber members, presumably to control checking of the members (see Figure 39). Drying checks seldom result in reductions in capacity, and the clamps are unnecessary. The clamps are shimmed with plywood, which holds moisture and will help to promote decay and insect attack in the columns. We recommend that the clamps be removed.

An 8 x 8 girt on the north side of the structure at the top of level 2 is dangling from a single bolt through a plate timber on the west (see Figure 38). Originally, this girt was supported on columns at either end, and provided support for level 3 deck joists. The columns have fallen (one is in the debris pile on the west side), allowing the girt to swing free of the east plate. In its current condition, the girt is in danger of falling. Options for repair include:

- Re-erecting the columns (the surviving column can be repaired and reinstalled) and supporting the girt and plate timbers on them;
- The cantilevered plate timbers can support the girt (without columns) so long as there are bolted connections at both ends of the girt (as there were originally). The damaged plate timber on the west can be repaired by reattaching the broken portion with glue and screws, and the girt can be reattached at either end with bolts and structural washers.

For Evening Star repair locations, see Appendix C.

REPAIR TECHNIQUES

Because of the historic significance of the mine structures, the park and project team collaboratively determined that any intervention should conserve as much of the historic wood as possible while recovering the historic structural system to achieve stabilization goals. If we consider the tradition of heavy timber framing, of which the mine structures are certainly examples, then in this context scarfed splices and dutchman inserts can be considered traditional means of construction and repair; scarfed splices appear in the original construction of the Evening Star structure. In addition, they constitute a means by which a substantial portion of the surviving historic material can be retained, preserving the resource and improving visitor safety.

SCARFED SPLICES

Traditional scarf forms can be used to splice new timber into deteriorated members. These repairs are not invisible, but the visual impacts are not obtrusive or unattractive, and the joinery is interesting to look at. Limited replacement of decayed portions of members using traditional joinery has the advantages of preserving the salvageable portions of historic elements as well as the historic craft tradition that originally produced the structures.

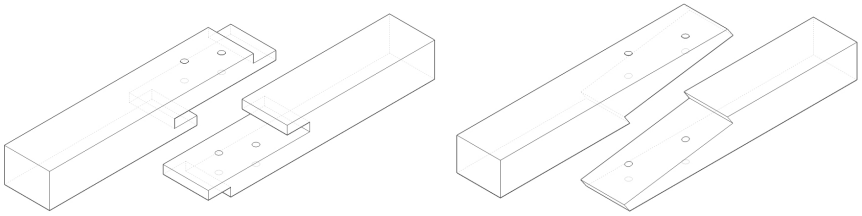


Figure 50: Two forms of scarfed splices: half lap with nose (left) and splayed (right).

DUTCHMAN INSERTS

Wooden dutchman inserts can be let into deteriorated portions of historic elements where decay is limited in extent. Dutchman inserts can be used to improve the bearing area of deteriorated members, improve the performance of connections, and to fill recesses and cavities that might otherwise collect water. Using wood to make the repairs has the advantage of introducing repair materials that have physical and mechanical properties that are similar to the original material while maintaining aesthetic continuity.

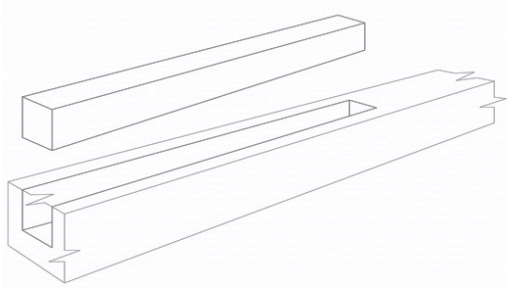


Figure 51: Typical dutchman repair. The decayed portion of the existing member (bottom left) is removed, and a new piece (top) is cut to fit tightly into the void. The repair may be secured with mechanical fasteners and/or an adhesive.

REPLACEMENT IN KIND

Some of the structural timber is so thoroughly deteriorated that the only way to recover adequate capacity is by replacing the original member. In replacing the wood elements of an historic structure, guidelines often urge the use of material matching the original in species and of at least equal quality. While high-quality timber was not used in every instance in the original construction of the mine structures, an argument can be made for using it in the repairs. High-quality materials will have greater structural capacity and improved durability, meaning that for a given repair the investment in making the repair will yield better performance and longer-lasting results.

In addition to the craft-related aspects of the repair work, there are also logistical problems to be solved. One challenging aspect of the project will be moving crew and material to the site. Daily travel between the nearest available accommodations and the site may be impractical, especially for the Live Oak site. An alternative would be to have the crew camp onsite, with food, water, and shelter brought in by park and crew vehicles (Evening Star) or by pack animals and helicopter (Live Oak). Materials and equipment can be trucked to the Evening Star site, but will be brought in by helicopter to the Live Oak site. It is anticipated that work at the Live Oak site will require a single mobilization episode and a single demobilization episode, limiting the use of the helicopter to two (partial) days.

Most of the timbers used in the repair of the mine structures will be large and heavy, so that finding appropriate solutions to material handling challenges will be essential to completing the work in the short timeframes available. Heavy machinery can be brought in to assist with the removal of deteriorated timber and the re-setting of repaired / replaced members and assemblies at Evening Star, but for the Live Oak site, the remoteness of the site and the

difficulty of the terrain will make the use of large machinery or equipment impractical. A variety of tools and techniques can be employed to support lumber during removal and repairs, as well as move lumber around the site, including cribbing, rollers, and hand tools such as screw jacks, chain hoists, and come-alongs. Some of the smaller tools can be brought by pack animals, though most of the equipment (including rollers, jacks, and material for cribbing) will need to be brought in by helicopter with the repair lumber.

Because of the short timeframes available for repair, some use of power tools for cutting, mortising, boring, and surfacing will be necessary. This is not a problem at Evening Star, requiring nothing more than a generator to power the equipment. The Live Oak site is in a wilderness area where the use of power tools is discouraged. While power tool use will be relatively infrequent (the crew will be relatively small and because of the precarious condition of the structure, the majority of the time will be spent on shoring, disassembly, and reassembly) and can, perhaps, be restricted to certain hours of each day (mornings might be used for cutting and afternoons for assembly, for example), eliminating the use of power tools altogether will substantially increase the time required for making repairs, necessitating revision of the scope.

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APPENDIX A

RESISTANCE DRILLING RESULTS

and

DRILLING AND SAMPLE LOCATIONS

Table A-1. *Live Oak Resistance Drilling Results*

Drill #	Elevation /Structure	Member	Location	Drilling Direction	MC	Comments
D1	south, ore bin	column	westernmost column, at current grade, mid-width	S-N		no void
D2	south, ore bin	brace – column,	second column from west, at current grade, mid-width	S-N		drilled below bolt, no void in either member
D3	south, ore bin	column	third column from west, 2" above sill beam, mid-width	S-N		excavated at base, deteriorated
D4	south, ore bin	column	third column from west, 6.5" above sill beam, mid-width	S-N		1.5" solid, then void
D5	south, ore bin	column	third column from west, 14" above sill beam, mid-width	S-N		5" intermittent internal voids
D6	south, ore bin	column	fourth column from west, 2" above grade, mid-width	S-N		no void
D7	south, ore bin	column	fifth column from west, 2" above sill beam, mid-width	S-N		minor deterioration at drilling location
D8	south, ore bin	column	easternmost column, 3" above sill beam, mid-width	S-N		minor deterioration on north face

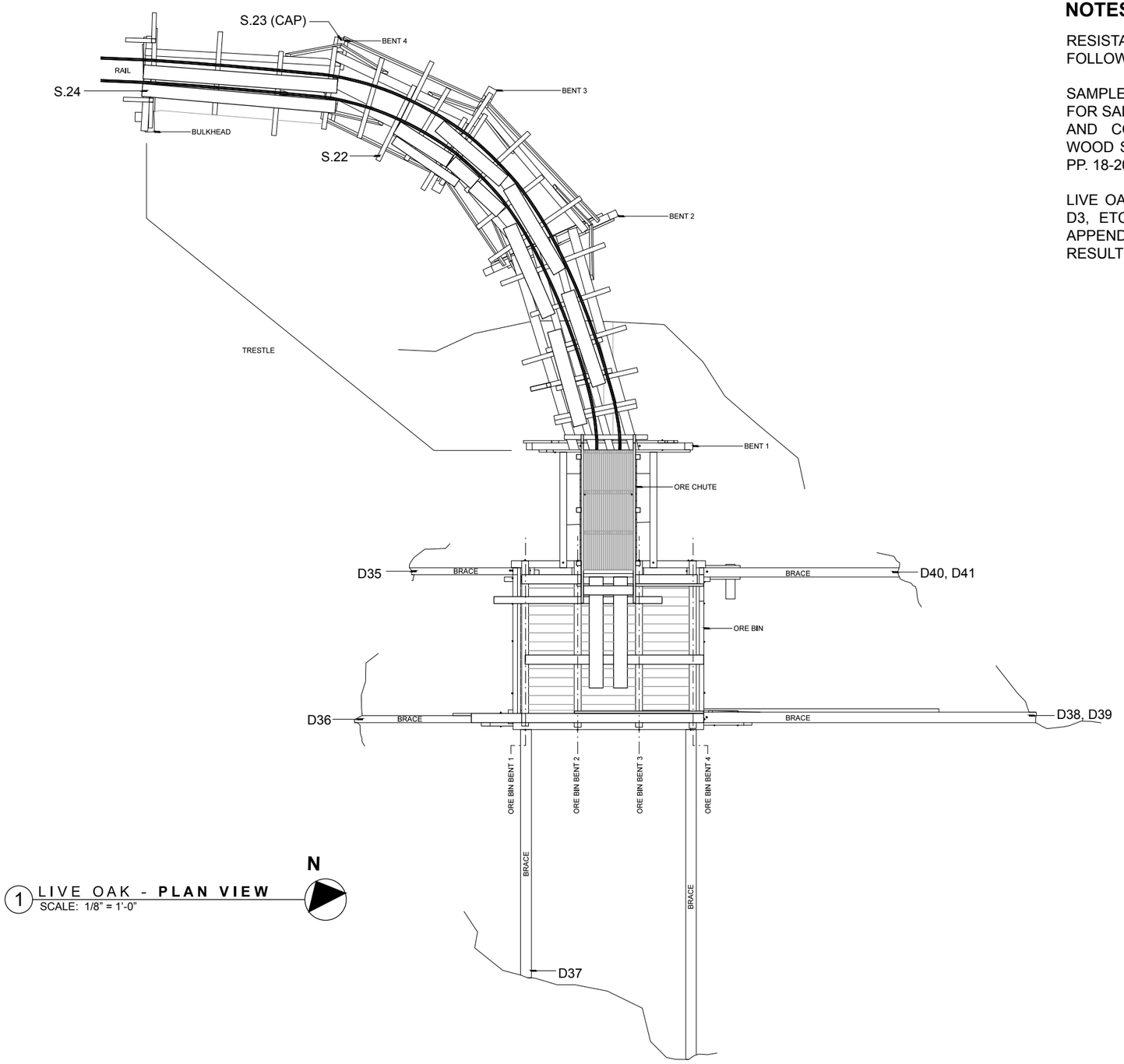
Drill #	Elevation /Structure	Member	Location	Drilling Direction	MC	Comments
D9	south, ore bin	sill	3" from top, below center of easternmost column	S-N		in check, nothing detected
D10	south, ore bin	sill	2" from top, below and slightly east of center of easternmost column	S-N		2.5" solid, then void
D11	south, ore bin	sill	6" west of easternmost column, mid-width	from top		2" solid then void
D12	south, ore bin	brace	east diagonal brace, 90" from east end, mid-width	from bottom		8" solid, then deterioration; the top face, where the deterioration is present, has about 1" of decay
D13	south, ore bin	brace	east diagonal brace, 120" from east end, mid-width	from bottom		7.5" solid then void, top face has 1" of decay
D14	south, ore bin	column	second column from west, 2" below beam, mid-width	W-E		through local crushing, due to overload, no void
D15	south, ore bin	column	ore bin bent 2, 2" above level 2 base, mid-width	W-E		no void
D16	east, ore bin	north sill - east	10" from east end, mid-width	S-N	13%	no void

Drill #	Elevation /Structure	Member	Location	Drilling Direction	MC	Comments
D17	east, ore bin	north sill - east	40" from east end, under column at ore bin bent 4, mid-width	S-N	14%	no void
D18	east, ore bin	hopper girder at ore bin, bent 4	6" from north end, 2" from bottom	E-W		beam is split through center from crushing, channel of deterioration at top, but no void at drilling direction
D19	east, ore bin	column at ore bin, bent 4 - north	2" from bottom, mid-width	E-W	9%	no void
D20	east, ore bin	hopper girder at ore bin, bent 3	6" from north end, 2" from bottom	E-W		minor decay at end grain and very slight crushing on north end, no void at drilling location
D21	east, ore bin	hopper girder at ore bin, bent 2	7" from north end, 2" from bottom	E-W	12%	visibly deteriorated with 50% loss of section at the north end grain, no void at drilling location, minor crushing under column
D22	north, ore bin	column at ore bin, bent 2	2" from bottom, mid-width	E-W		no void

Drill #	Elevation /Structure	Member	Location	Drilling Direction	MC	Comments
D23	north, ore bin	west sill	6" east of C1 - north, mid-width	from top		old RR tie has total void at drilling location, which is about 12" below grade on east side; bottom of hopper girder beam has 1" of deterioration (it is not in contact with the tie)
D24	north, ore bin	west sill	2" from D24	from top		total void; hopper girder beam has surface deterioration, possibly from termites, but can't be penetrated by an awl in most places
D25	west, ore bin	column at ore bin, bent 1 - north	2" above base, mid-width	E-W	14%	first half solid, then hit something
D26	west, ore bin	column at ore bin, bent 1 - north	1" from D25, 2" above base	E-W		no void
D27	east, bent 1	east column	13" above sill beam, above current grade, mid-width	W-E	12%	22% MC below grade; 1" intermittent voids, base has insect damage and decay
D28	west, bent 1	west column	4" below current grade, mid-width	S-N	19%	brace is deteriorated, no void in column

Drill #	Elevation /Structure	Member	Location	Drilling Direction	MC	Comments
D29	west, bent 1	west column	6" above current grade, mid-width	S-N	9%	above grade, no void
D30	west, bent 2	west column	2" above base, mid-width	W-E		dug down to sill or horizontal brace below grade, no void
D31	east, bent 2	east column	2" above base, mid-width	W-E		1" deterioration then solid for 6" then deteriorated below current ground line
D32	east, bent 2	east column	24" above base, mid-width	W-E		no void
D33	east, bent 2	sill	4" west of east column, mid-width	from top		deteriorated
D34	na, bent 2	sill	midway between east and west columns	from top		3" solid wood, 5.5" deep
D35	west, ore bin	north diagonal brace	at rock line, mid-width	from top		no void
D36	west, ore bin	south diagonal brace	at current grade, mid-width	S-N		no void
D37	south, ore bin	west diagonal brace	at current grade, mid-width	E-W		6" internal void, some crushing on top surface, awl penetration below ground line

Drill #	Elevation /Structure	Member	Location	Drilling Direction	MC	Comments
D38	east, ore bin	south diagonal brace	at rock line, mid-width	S-N		3" internal void
D39	east, ore bin	south diagonal brace	24" above rock line, mid-width	S-N		no void
D40	east, ore bin	north diagonal brace	at current grade, mid-width	S-N		5" solid, then void, back/north face where the deterioration is present is imbedded in the ground
D41	east, ore bin	north diagonal brace	24" above current grade, mid-width	S-N		no void



1 LIVE OAK - **PLAN VIEW**
SCALE: 1/8" = 1'-0"

NOTES:

RESISTANCE DRILL LOCATIONS ARE SHOWN AS FOLLOWS:

SAMPLE LOCATIONS ARE DENOTED BY S.1, S.2, S.3, ETC. FOR SAMPLE RESULTS, SEE THE WOOD INVESTIGATION AND CONDITION ASSESSMENT SECTION, TABLE 1: WOOD SPECIES IDENTIFIED FROM THE LIVE OAK SITE, PP. 18-20.

LIVE OAK DRILL LOCATIONS ARE DENOTED BY D1, D2, D3, ETC. FOR RESISTANCE DRILLING RESULTS, SEE APPENDIX A, TABLE A-1: LIVE OAK RESISTANCE DRILLING RESULTS, PP. 61-65.

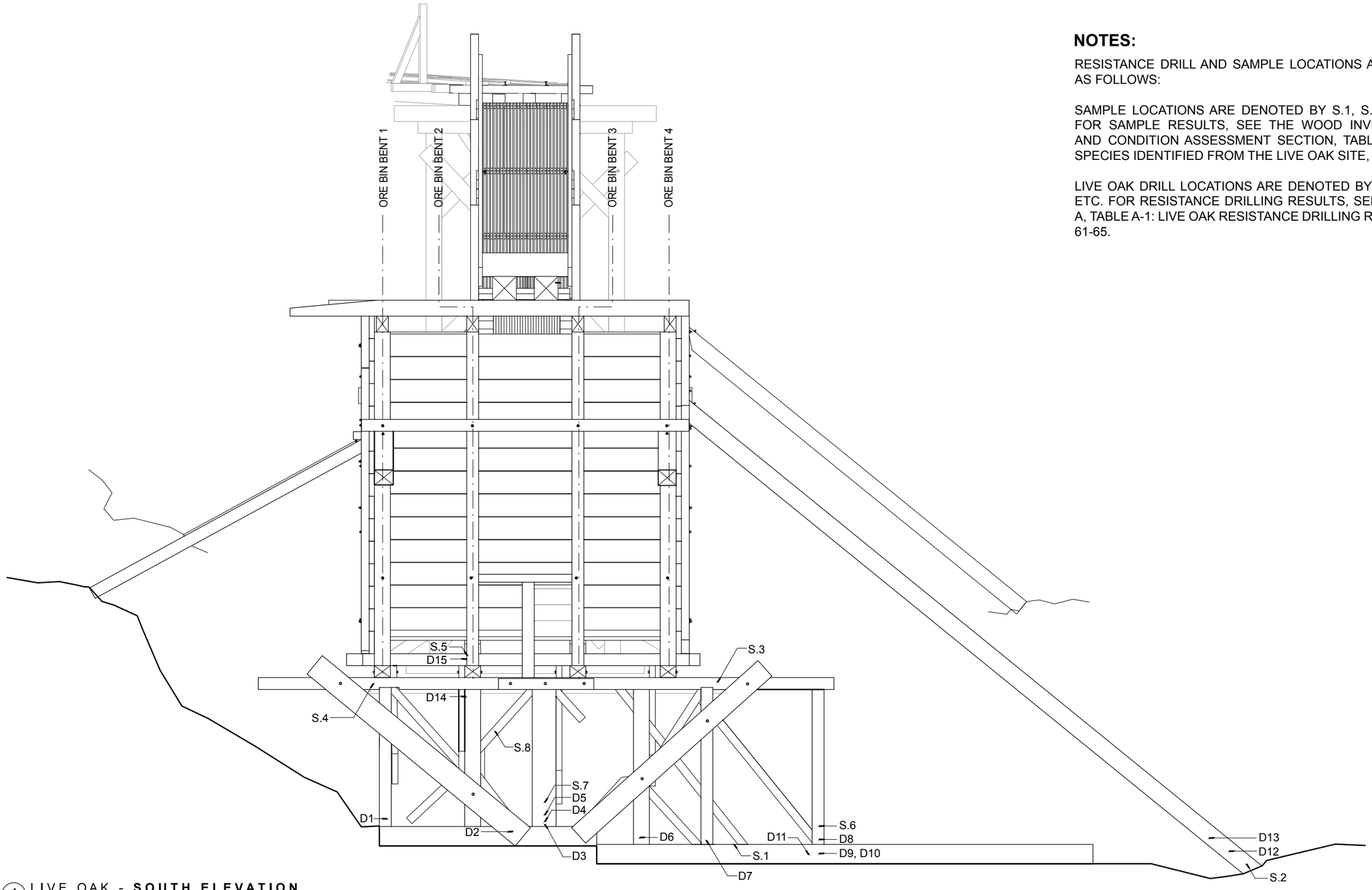
LIVE OAK MINE STRUCTURE - **RESISTANCE DRILL AND SAMPLE LOCATIONS**
SCALE: 1/8" = 1'-0"

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DRAWINGS PREPARED BY: KERI L. STEVENSON

LIVE OAK MINE STRUCTURE
CONDITION ASSESSMENT, STABILIZATION, AND REPAIR
KEYSTONE CANYON, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 03/07/14

RD1



1 LIVE OAK - **SOUTH ELEVATION**
SCALE: 1/4" = 1'-0"

NOTES:

RESISTANCE DRILL AND SAMPLE LOCATIONS ARE SHOWN AS FOLLOWS:

SAMPLE LOCATIONS ARE DENOTED BY S.1, S.2, S.3, ETC. FOR SAMPLE RESULTS, SEE THE WOOD INVESTIGATION AND CONDITION ASSESSMENT SECTION, TABLE 1: WOOD SPECIES IDENTIFIED FROM THE LIVE OAK SITE, PP. 18-20.

LIVE OAK DRILL LOCATIONS ARE DENOTED BY D1, D2, D3, ETC. FOR RESISTANCE DRILLING RESULTS, SEE APPENDIX A, TABLE A-1: LIVE OAK RESISTANCE DRILLING RESULTS, PP. 61-65.

LIVE OAK MINE STRUCTURE - **RESISTANCE DRILL AND SAMPLE LOCATIONS**
SCALE: 1/4" = 1'-0"

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KEYSTONE CANYON, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 03/07/14

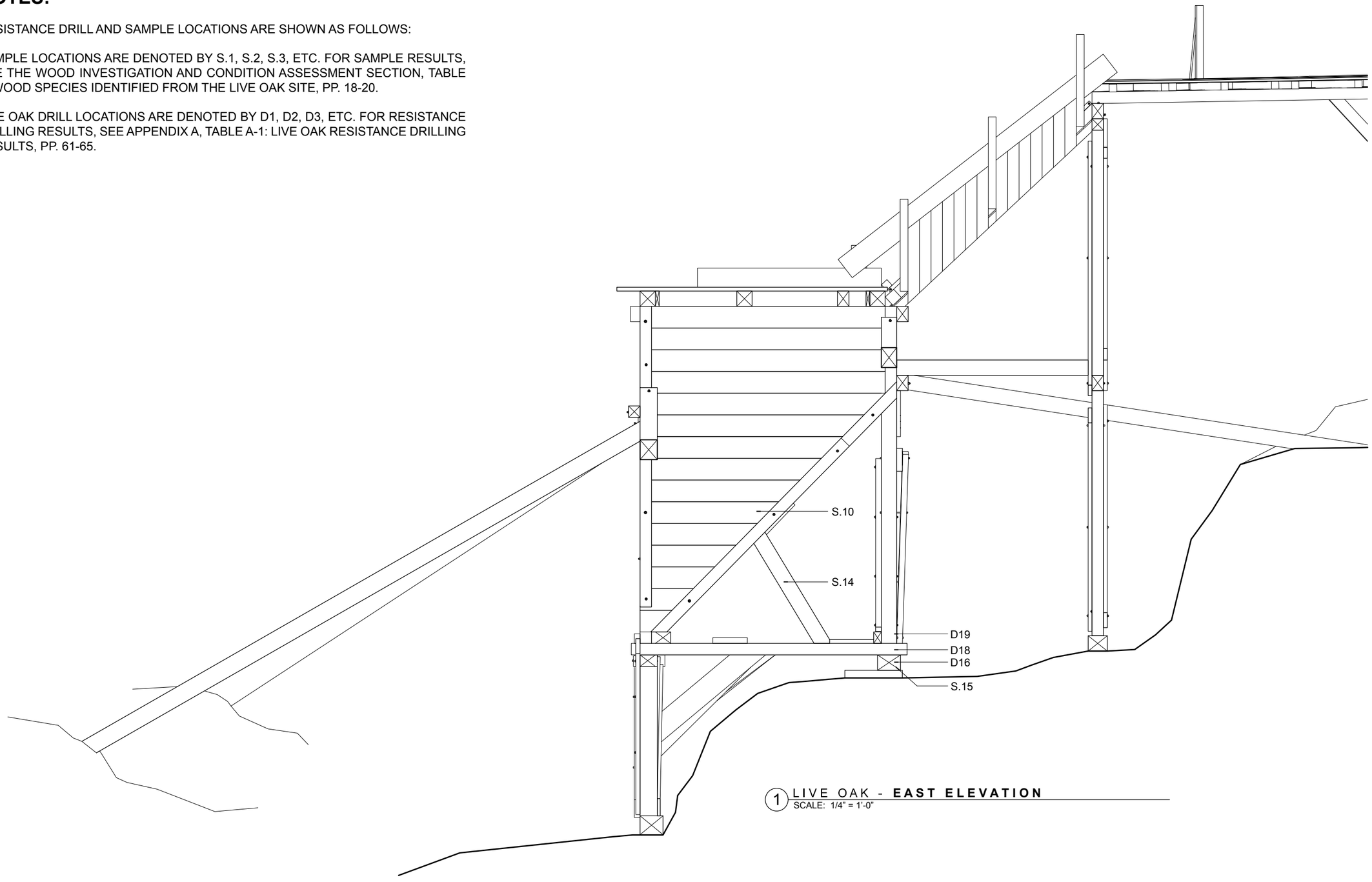
RD2

NOTES:

RESISTANCE DRILL AND SAMPLE LOCATIONS ARE SHOWN AS FOLLOWS:

SAMPLE LOCATIONS ARE DENOTED BY S.1, S.2, S.3, ETC. FOR SAMPLE RESULTS, SEE THE WOOD INVESTIGATION AND CONDITION ASSESSMENT SECTION, TABLE 1: WOOD SPECIES IDENTIFIED FROM THE LIVE OAK SITE, PP. 18-20.

LIVE OAK DRILL LOCATIONS ARE DENOTED BY D1, D2, D3, ETC. FOR RESISTANCE DRILLING RESULTS, SEE APPENDIX A, TABLE A-1: LIVE OAK RESISTANCE DRILLING RESULTS, PP. 61-65.



1 LIVE OAK - **EAST ELEVATION**
SCALE: 1/4" = 1'-0"

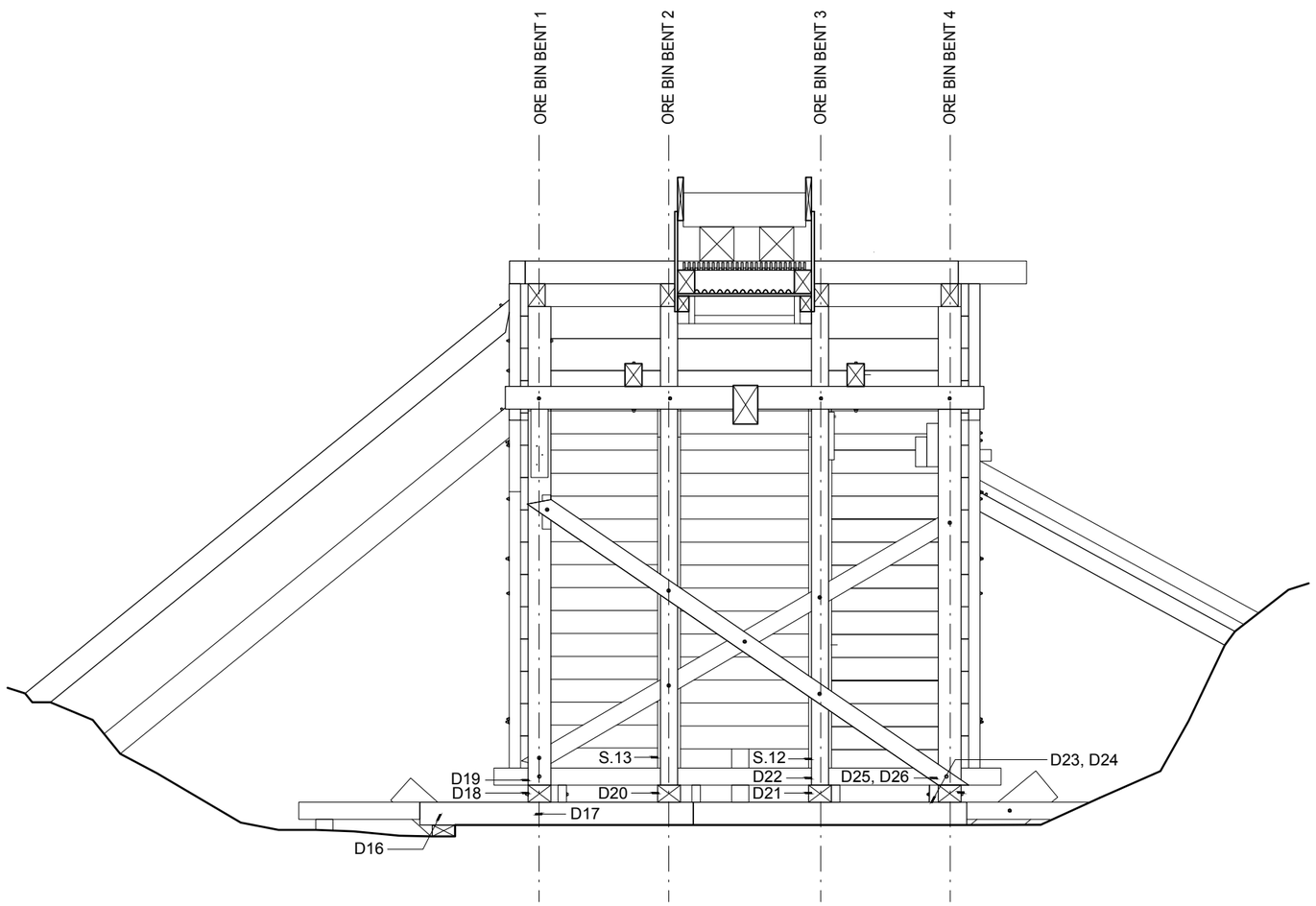
LIVE OAK MINE STRUCTURE - **RESISTANCE DRILL AND SAMPLE LOCATIONS**
SCALE: 1/4" = 1'-0"

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KEYSTONE CANYON, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 03/07/14

RD3



1 LIVE OAK - **ORE BIN - NORTH ELEVATION**
SCALE: 1/4" = 1'-0"

LIVE OAK MINE STRUCTURE - **RESISTANCE DRILL AND SAMPLE LOCATIONS**

SCALE: 1/4" = 1'-0", OR AS NOTED

NOTES:

RESISTANCE DRILL AND SAMPLE LOCATIONS ARE SHOWN AS FOLLOWS:

SAMPLE LOCATIONS ARE DENOTED BY S.1, S.2, S.3, ETC. FOR SAMPLE RESULTS, SEE THE WOOD INVESTIGATION AND CONDITION ASSESSMENT SECTION, TABLE 1: WOOD SPECIES IDENTIFIED FROM THE LIVE OAK SITE, PP. 18-20.

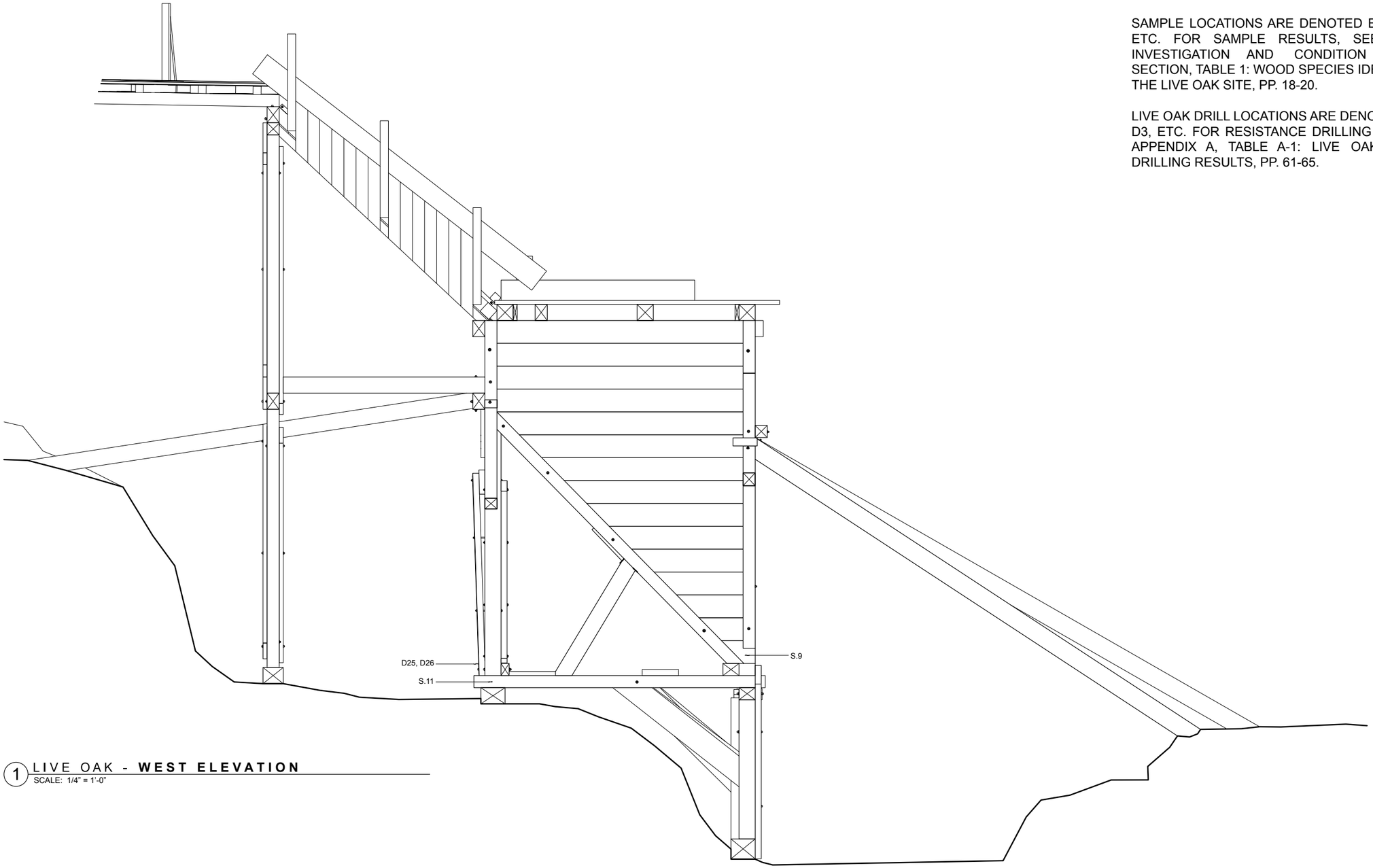
LIVE OAK DRILL LOCATIONS ARE DENOTED BY D1, D2, D3, ETC. FOR RESISTANCE DRILLING RESULTS, SEE APPENDIX A, TABLE A-1: LIVE OAK RESISTANCE DRILLING RESULTS, PP. 61-65.

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DATE: 03/07/14

RD4



1 LIVE OAK - **WEST ELEVATION**
SCALE: 1/4" = 1'-0"

NOTES:

RESISTANCE DRILL AND SAMPLE LOCATIONS ARE SHOWN AS FOLLOWS:

SAMPLE LOCATIONS ARE DENOTED BY S.1, S.2, S.3, ETC. FOR SAMPLE RESULTS, SEE THE WOOD INVESTIGATION AND CONDITION ASSESSMENT SECTION, TABLE 1: WOOD SPECIES IDENTIFIED FROM THE LIVE OAK SITE, PP. 18-20.

LIVE OAK DRILL LOCATIONS ARE DENOTED BY D1, D2, D3, ETC. FOR RESISTANCE DRILLING RESULTS, SEE APPENDIX A, TABLE A-1: LIVE OAK RESISTANCE DRILLING RESULTS, PP. 61-65.

LIVE OAK MINE STRUCTURE - **RESISTANCE DRILL AND SAMPLE LOCATIONS**
SCALE: 1/4" = 1'-0"

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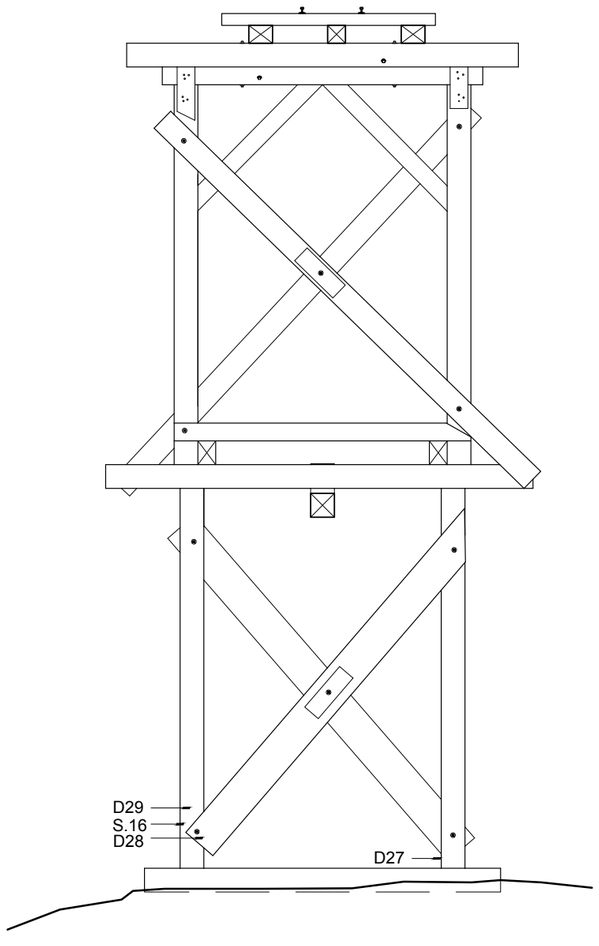
RD5

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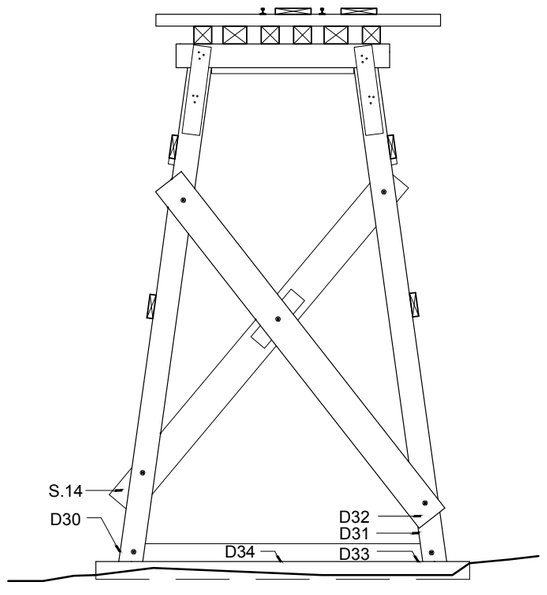
RESISTANCE DRILL AND SAMPLE LOCATIONS ARE SHOWN AS FOLLOWS:

SAMPLE LOCATIONS ARE DENOTED BY S.1, S.2, S.3, ETC. FOR SAMPLE RESULTS, SEE THE WOOD INVESTIGATION AND CONDITION ASSESSMENT SECTION, TABLE 1: WOOD SPECIES IDENTIFIED FROM THE LIVE OAK SITE, PP. 18-20.

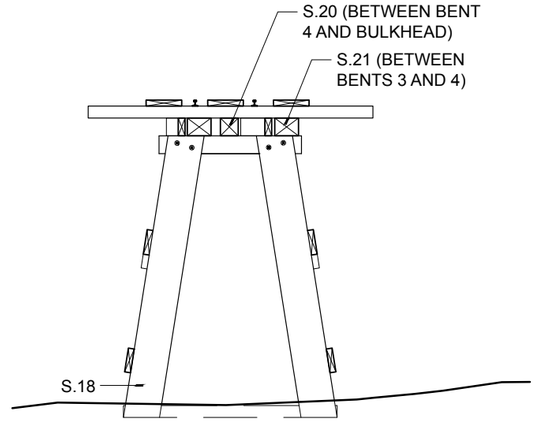
LIVE OAK DRILL LOCATIONS ARE DENOTED BY D1, D2, D3, ETC. FOR RESISTANCE DRILLING RESULTS, SEE APPENDIX A, TABLE A-1: LIVE OAK RESISTANCE DRILLING RESULTS, PP. 61-65.



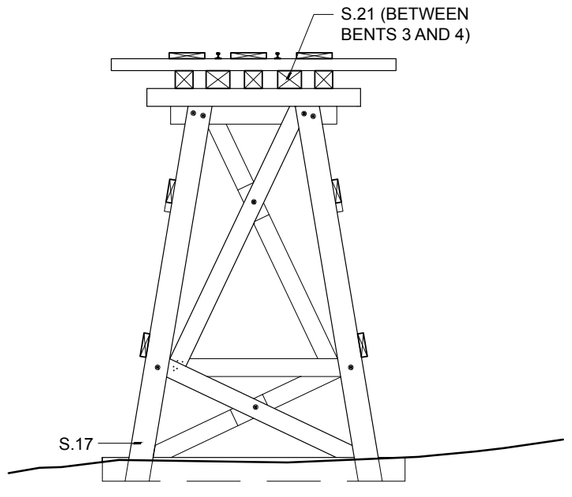
1 LIVE OAK - **BENT 1 - NORTH ELEVATION**
SCALE: 1/4" = 1'0"



2 LIVE OAK - **BENT 2 - SOUTH ELEVATION**
SCALE: 1/4" = 1'0"



4 LIVE OAK - **BENT 3 - NORTHWEST ELEVATION**
SCALE: 1/4" = 1'0"



3 LIVE OAK - **BENT 3 - NORTHWEST ELEVATION**
SCALE: 1/4" = 1'0"

LIVE OAK MINE STRUCTURE - **RESISTANCE DRILL AND SAMPLE LOCATIONS**

SCALE: 1/4" = 1'0"

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DATE: 03/07/14

RD6

Table A-2. *Evening Star Resistance Drilling Results*

Drill #	Bent	Member	Drilling Location	Drilling Direction	Comments
E1	1	N-S sill, column line 1	ore bin sill under C1, mid-width, 10" from north end	W-E	8.5" solid, then deteriorated
E2	1	hopper girder	17" from east end, 3" from bottom	N-S	no void
E3	1	column 2	2" from bottom, 4" from north side	W-E	no void
E4	1	column 3	2" from base, mid-width	W-E	no void
E5	2	column 3	2" from base, mid-width	W-E	possible 2" of deterioration
E6	3	column 3	2" from base, mid-width	W-E	no void
E7	2	column 2	2" from base, mid-width	W-E	no void
E8	2	hopper girder	2" from base, below C1	N-S	no void
E9	2	N-S sill, column line 1	2" from concrete, below hopper girder 2	E-W	8" solid, then void (12" wide member)
E10	3	hopper girder	2" from concrete, below C1	N-S	no void
E11	3	N-S sill, column line 1	2" north of C1, mid-width	From top	east face of sill is visibly deteriorated, 5" solid then void
E12	4	column 1	2" above concrete, mid-width	N-S	6" solid then void or check

Drill #	Bent	Member	Drilling Location	Drilling Direction	Comments
E13	4	column 1	2" above concrete, off-center	N-S	6.5" solid then void
E14	4	column 2	2" from concrete, mid-width	N-S	7" solid, then unknown - hit something
E15	4	column 2	2" above concrete, off-center	N-S	8" solid, then unknown - hit something
E16	4	column 1	3" from north face, 2" from bottom	W-E	no void
E17	4	column 1	3" from south face, 2" from bottom	W-E	9" solid, then void, visible decay on west and east faces where covered with debris
E18	4	column 2	4" from south face, 2" from bottom	W-E	no void
E19	4	column 3	2" from concrete, mid-width	N-S	no void
E20	5	E-W sill	2" from concrete, 10" west of C1	N-S	total void
E21	5	E-W sill	2" from top, 10" west of C1	N-S	1" internal void
E22	5	N-S sill	6" west of C2, 2" from concrete	N-S	total void
E23	5	E-W sill	6" west of C2, 2" from top	N-S	5" solid, then deteriorated

Drill #	Bent	Member	Drilling Location	Drilling Direction	Comments
E24	5	E-W sill	2" from concrete, below C4, mid-width	N-S	2" deterioration on buried south face, otherwise solid
E25	7	E-W sill	2" from concrete, 10" from east end of sill	N-S	no void
E26	7	E-W sill	2" from concrete, 11" from west end of sill	N-S	no void
E27	7	column 1	2" above base, 4" from west face	N-S	no void
E28	7	column 4	2" above base, 4" from east face	N-S	no void
E29	6	column 1	3" from east face, 2" above concrete	N-S	8.5" internal void
E30	6	column 1	3" from south face, 2" above concrete	N-S	7.5" internal void
E31	6	column 1	4" from west face, 2" above concrete	E-W	8.5" internal void
E32	6	column 1	4" from east face, 2" above concrete	E-W	9" internal void
E33	6	column 1	4" from west face, 14" from concrete	E-W	no void
E34	6	column 1	4" from south face, 14" from concrete	N-S	no void
E35	6	tie beam	12" from east end of tie beam, 2" from concrete	N-S	1" shell then void

Drill #	Bent	Member	Drilling Location	Drilling Direction	Comments
E36	6	tie beam	12" from east end of tie beam, mid-width	N-S	1" shell then void
E37	5	E-W sill	2" above concrete, directly below C3	N-S	1" shell then void
E38	5	E-W sill	2" from top of sill, directly below C3	N-S	3.5" solid, then void
E39	5	column 1	3" from east face (previously buried), 2" from sill	W-E	9.5" solid then deteriorated at east face
E40	5	column 1	2" from west face, 2" from sill	W-E	no void
E41	5	column 2	2" above sill, mid-width	N-S	no void
E42	5	column 3	2" above sill, mid-width	N-S	0.5" internal void
E43	5	column 4	2" above sill, mid-width	N-S	no void
E44	7	sister column to column 4	at angle, 2" from concrete, mid-width	SW-NE	no void
E45	6	sister column to column 1	2" from concrete, mid-width	W-E	no void

NOTES

RESISTANCE DRILL AND SAMPLE LOCATIONS ARE SHOWN AS FOLLOWS:

SAMPLE LOCATIONS ARE DENOTED BY S.1, S.2, S.3, ETC. FOR SAMPLE RESULTS, SEE THE WOOD INVESTIGATION AND CONDITION ASSESSMENT SECTION, TABLE 2: WOOD SPECIES IDENTIFIED FROM THE EVENING STAR SITE, PP. 37-38.

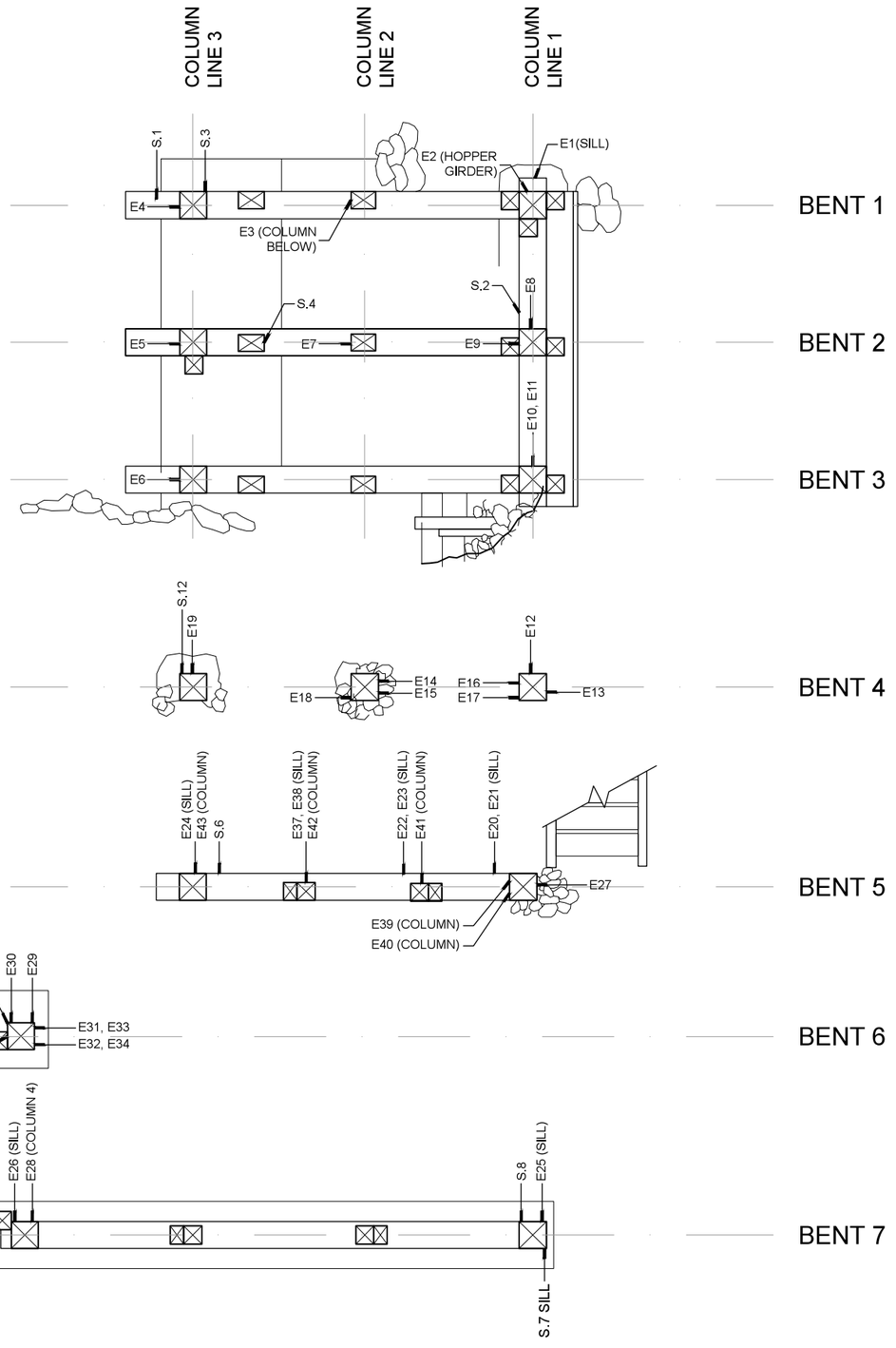
EVENING STAR DRILL LOCATIONS ARE DENOTED BY E1, E2, E3, ETC. FOR RESISTANCE DRILLING RESULTS, SEE APPENDIX A, TABLE A-2: EVENING STAR RESISTANCE DRILLING RESULTS, PP. 66-69.

SAMPLE LOCATION S.5 IS A FLOOR PLANK ON THE EAST ELEVATION OF THE ORE BIN (NOT SHOWN).

SAMPLE LOCATION S.13 IS A 6" X 6" BRACE ON THE WEST SIDE OF THE SECOND LEVEL OF BENT 4 (NOT SHOWN).

SAMPLE LOCATION S.14 IS THE FIRST STAIR RISER ABOVE THE SECOND LEVEL FLOOR DECK, BETWEEN BENTS 3 AND 4 (NOT SHOWN).

ORE BIN COLUMNS IN BENT 1-3 ARE NUMBERED ACCORDING TO COLUMN LINE. COLUMNS IN BENTS 4-7 ARE NUMBERED FROM EAST TO WEST.BY BENT.



EVENING STAR MINING STRUCTURE - PLAN
DRILL AND SAMPLE LOCATIONS
SCALE: NOT TO SCALE

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DRAWINGS PREPARED BY: KERI L. STEVENSON

EVENING STAR MINE STRUCTURE
CONDITION ASSESSMENT, STABILIZATION, AND REPAIR

IVANPAH DISTRICT, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 03/12/14

RD1

APPENDIX B

LIVE OAK REPAIR DRAWINGS

LIVE OAK MINE STRUCTURE
MOJAVE NATIONAL PRESERVE, CALIFORNIA



1 LIVE OAK MINING STRUCTURE - **SITE PLAN**
SCALE: 1" = 40'-0"



MAP IMAGE FROM GOOGLE MAPS, 2013

2 VICINITY MAP
N.T.S.



MAP IMAGE FROM GOOGLE MAPS, 2013

3 LOCATION MAP
N.T.S.

SHEET INDEX

01	COVERSHEET AND SITE PLAN
02	PLAN AND ELEVATION
03	OVERALL ELEVATIONS
04	ORE BIN ELEVATIONS
05	ORE BIN ELEVATIONS
06	ORE BIN ELEVATION AND ORE CHUTE DETAIL
07	ORE BIN ELEVATIONS
08	ORE BIN SECTION
09	TRESTLE BENT ELEVATIONS
10	TRESTLE BENT ELEVATIONS AND HANDRAIL DETAIL
11	TRESTLE BENT ELEVATIONS

GENERAL NOTES

DOCUMENTATION FOR THIS PROJECT WAS COMPLETED BY DOUG PORTER (UNIVERSITY OF VERMONT), KERI STEVENSON (UNIVERSITY OF VERMONT), MIKE CONTRONEO (HOUSEJOINER, INC.), RON ANTHONY (ANTHONY + ASSOCIATES), KIM DUGAN (ANTHONY + ASSOCIATES), AND ERIC STOVER (CRITICAL STRUCTURES). DRAWINGS IN THIS SET ARE BASED ON FIELD MEASUREMENTS TAKEN IN NOVEMBER 2013.

ALL DRAWINGS DEPICT THE 'AS-BUILT' STATE OF THE LIVE OAK MINE STRUCTURE AS INFERRED FROM SURVIVING FEATURES. EXISTING CONDITIONS SHOULD BE VERIFIED IN FIELD. THIS DRAWING SET WAS PRODUCED BY THE UNIVERSITY OF VERMONT FOR MOJAVE NATIONAL PRESERVE AND THE NATIONAL PARK SERVICE IN DECEMBER 2013.

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DRAWINGS PREPARED BY: KERI L. STEVENSON

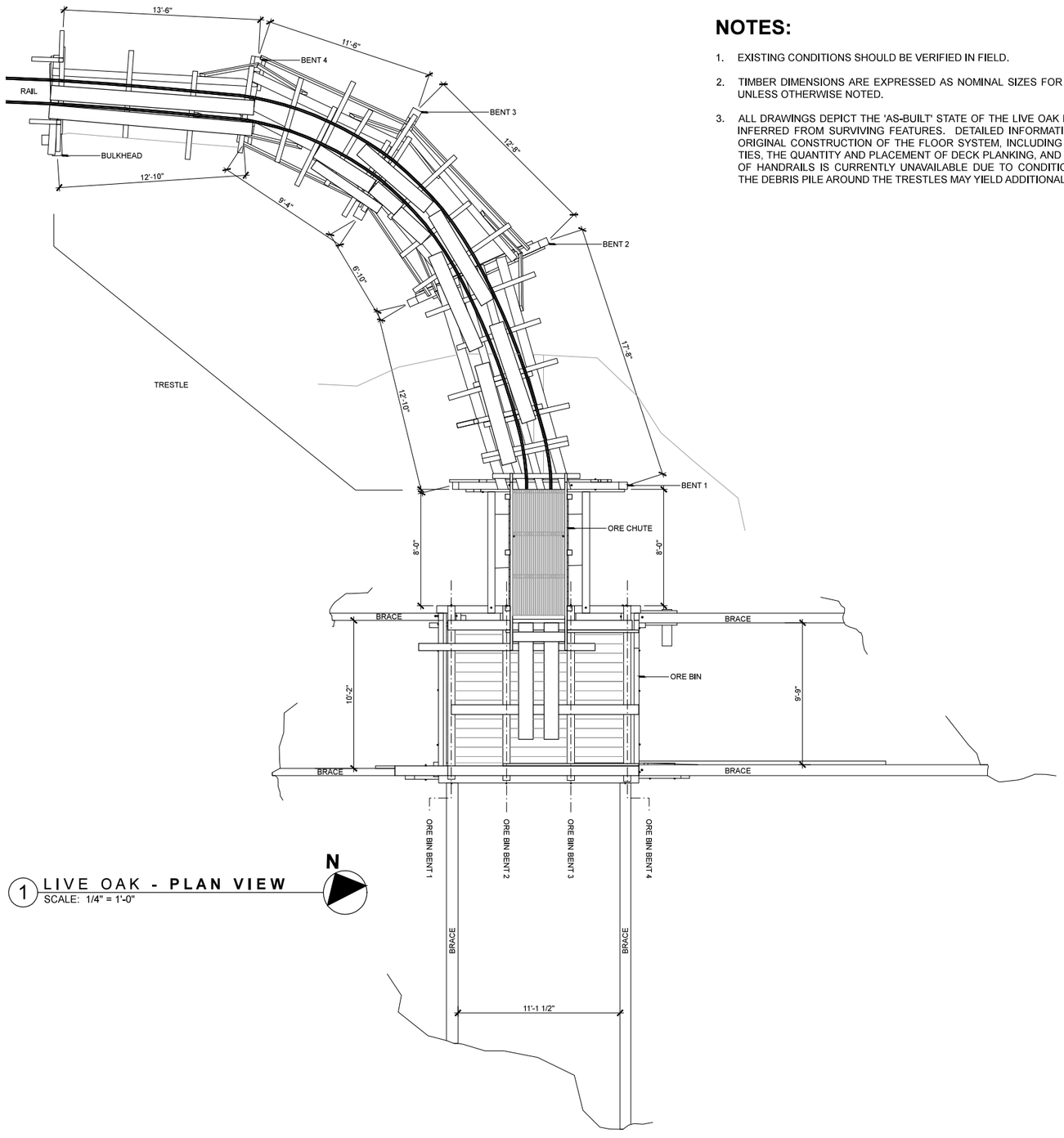
LIVE OAK MINE STRUCTURE
CONDITION ASSESSMENT, STABILIZATION, AND REPAIR
KEYSTONE CANYON, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 03/07/14

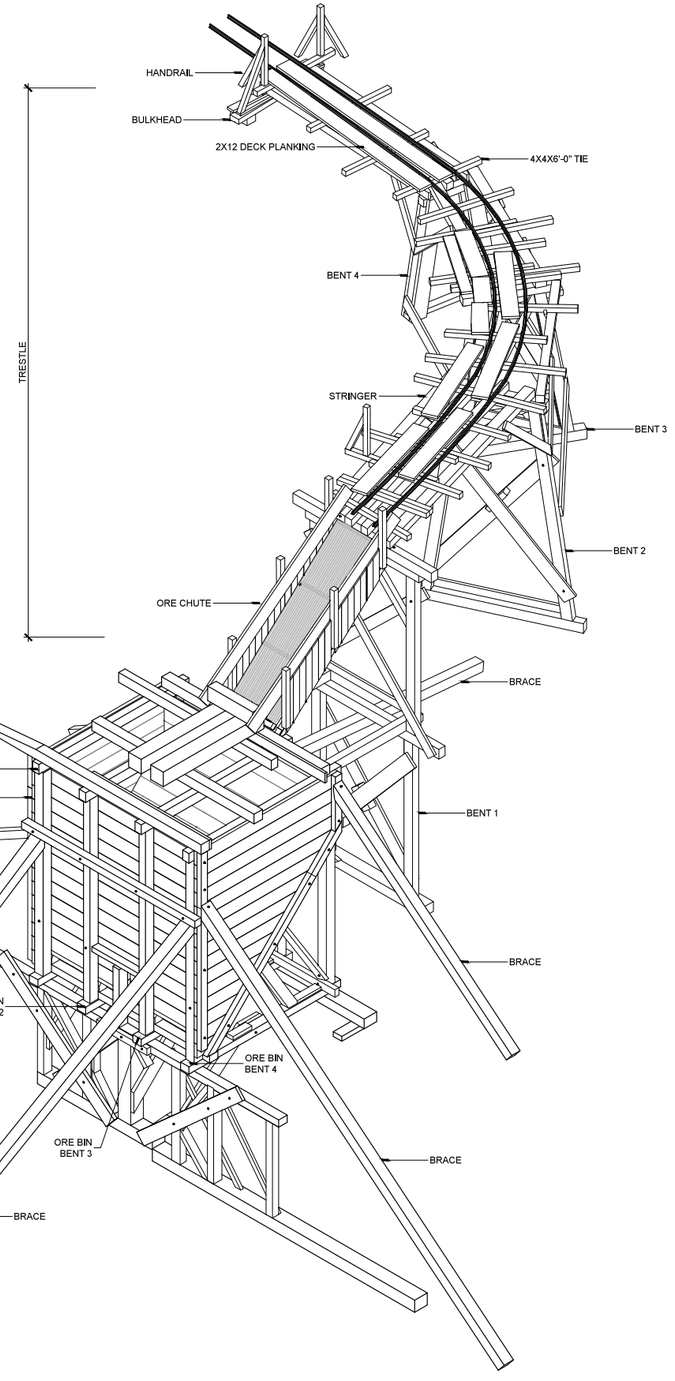
01

NOTES:

1. EXISTING CONDITIONS SHOULD BE VERIFIED IN FIELD.
2. TIMBER DIMENSIONS ARE EXPRESSED AS NOMINAL SIZES FOR ROUGH CUT TIMBER UNLESS OTHERWISE NOTED.
3. ALL DRAWINGS DEPICT THE 'AS-BUILT' STATE OF THE LIVE OAK MINE STRUCTURE AS INFERRED FROM SURVIVING FEATURES. DETAILED INFORMATION REGARDING THE ORIGINAL CONSTRUCTION OF THE FLOOR SYSTEM, INCLUDING PLACEMENT OF THE TIES, THE QUANTITY AND PLACEMENT OF DECK PLANKING, AND THE CONFIGURATION OF HANDRAILS IS CURRENTLY UNAVAILABLE DUE TO CONDITION. EXAMINATION OF THE DEBRIS PILE AROUND THE TRESTLES MAY YIELD ADDITIONAL INFORMATION.



1 LIVE OAK - **PLAN VIEW**
SCALE: 1/4" = 1'-0"



2 LIVE OAK - **SOUTH EAST ISOMETRIC**
SCALE: 1/4" = 1'-0"

LIVE OAK MINE STRUCTURE - **PLAN AND ELEVATION**

SCALE: 1/4" = 1'-0"

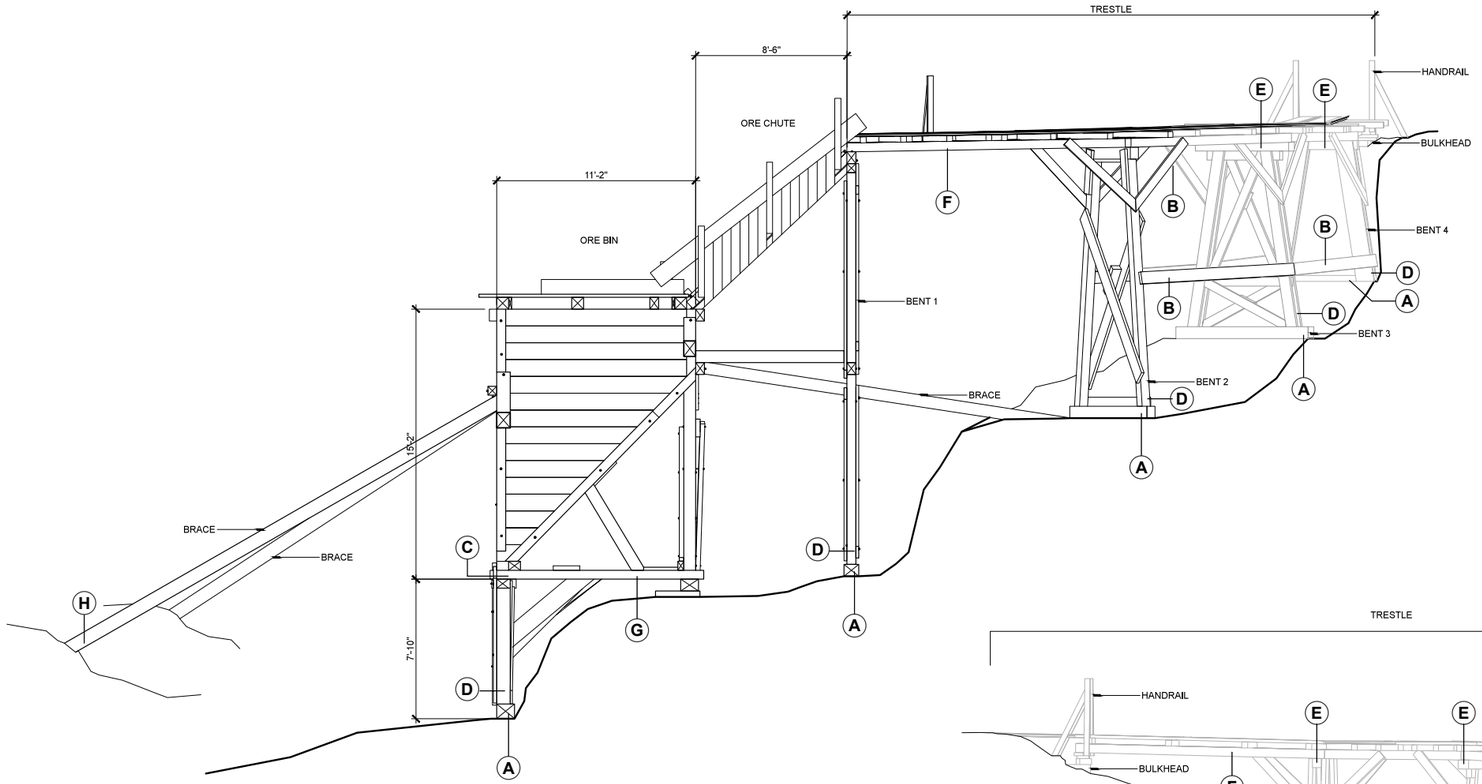
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DOUG PORTER, PRINCIPLE INVESTIGATOR
DRAWINGS PREPARED BY: KERI L. STEVENSON

LIVE OAK MINE STRUCTURE
CONDITION ASSESSMENT, STABILIZATION, AND REPAIR

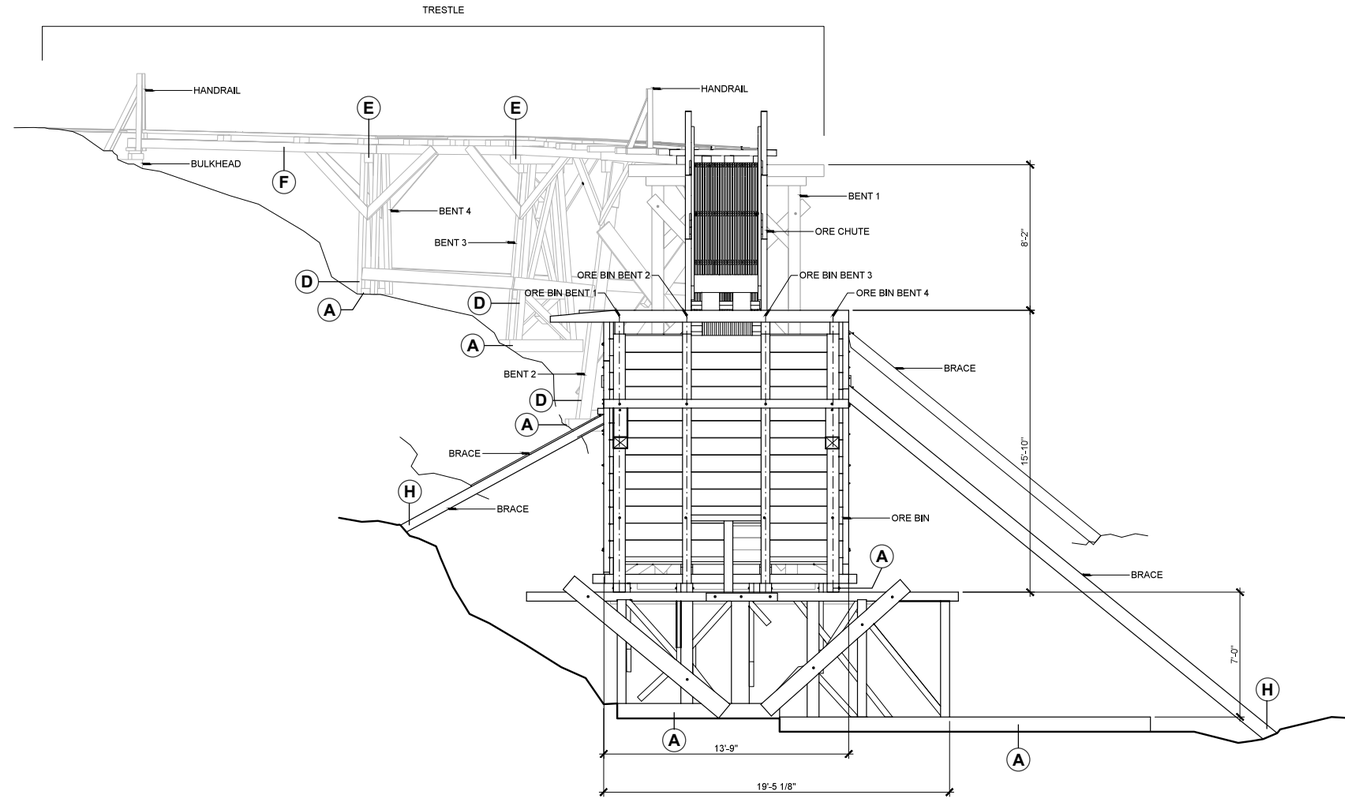
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DATE: 03/12/14

02



1 LIVE OAK - **EAST ELEVATION**
SCALE: 1/4" = 1'-0"



2 LIVE OAK - **SOUTH ELEVATION**
SCALE: 1/4" = 1'-0"

NOTES:

1. EXISTING CONDITIONS SHOULD BE VERIFIED IN FIELD.
2. ALL TIMBER MEASUREMENTS ARE NOMINAL FOR ROUGH CUT TIMBER UNLESS OTHERWISE NOTED.
3. REPAIR LOCATIONS

   A. REPLACE DECAYED SILL IN KIND OR WITH PRESSURE-TREATED WOOD (TO EXTEND SERVICE LIFE). TREAT IN-KIND REPLACEMENT SILL WITH BORATE TO DELAY THE ONSET OF DECAY (PP. 54-55).

   B. REPAIR DAMAGE AT BOLTED CONNECTIONS BY REATTACHING BROKEN PORTIONS, REPLACING LOST RELISH WITH DUTCHMAN INSERTS OR CAPTURED PLATES, OR SCARFING IN NEW WOOD (PP. 54-55).

   C. SCARF NEW WOOD INTO DAMAGED HOPPER GIRDERS AT ENDS WHERE THEY CROSS THE TOP PLATE (P. 54)

   D. SCARF NEW WOOD INTO DAMAGED COLUMNS AT BASES (PP. 30, 40, 43-44, 55).

   E. REPAIR DECAYED TRESTLE CAPS AT BENTS 3 AND 4 WITH DUTCHMAN INSERTS (PP. 43, 45, 55).

   F. REPAIR DECAYED TIMBER STRINGERS (WHERE LOSS OF ORIGINAL SECTION > 50%) USING DUTCHMAN INSERTS AND/OR SCARFED SPLICES (PP. 43, 45, 46).

   G. INSTALL BEARING PLATES ON THE LEDGE BELOW HOPPER BRACES (P. 54).

   H. SCARF NEW WOOD INTO DECAYED PORTIONS OF LONG TIMBER BRACES AT GRADE, AND REINFORCE CONNECTIONS TO ORE BIN (PP. 28, 36-37, 54).

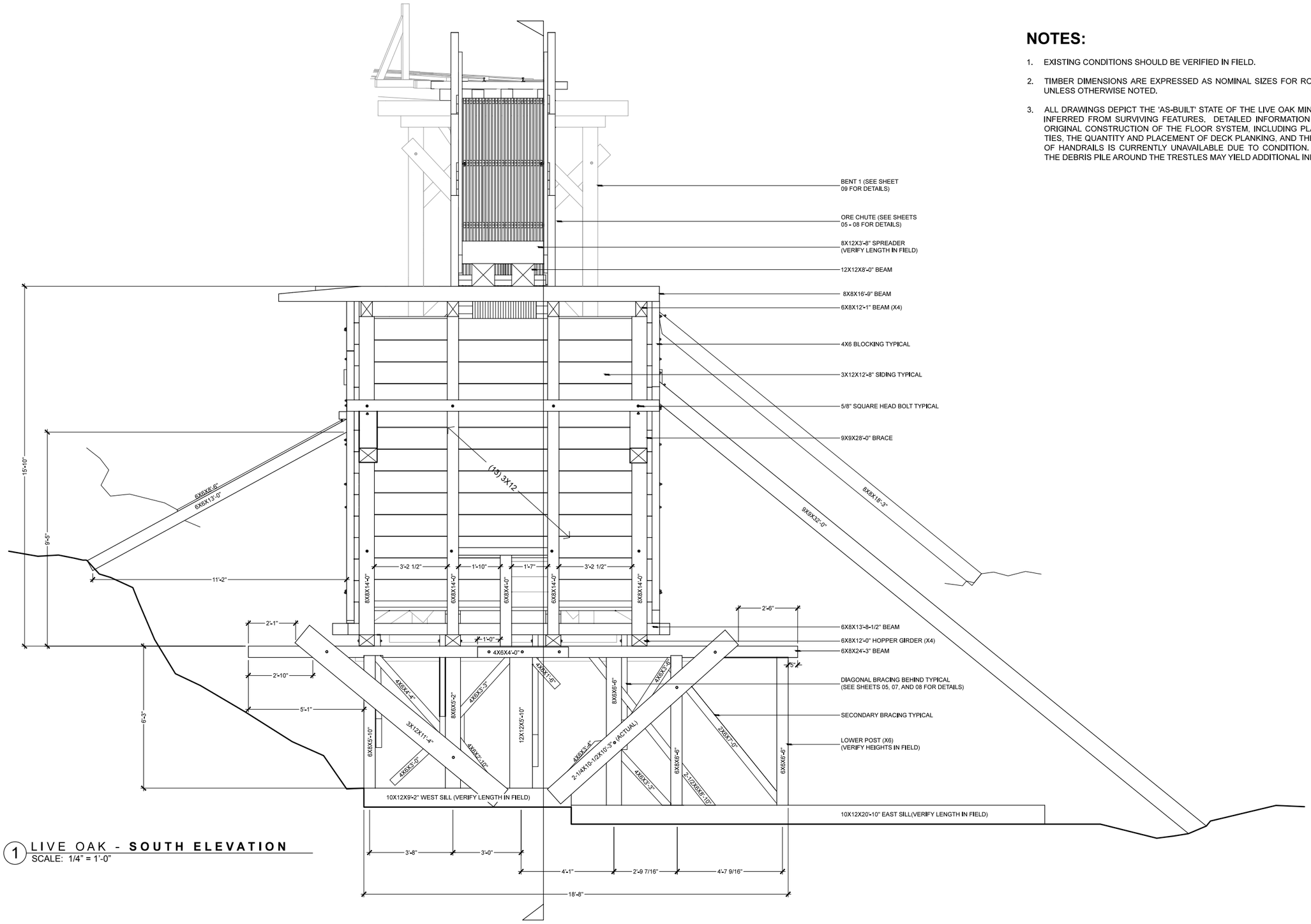
LIVE OAK MINE STRUCTURE - **OVERALL ELEVATIONS**
SCALE: 1/4" = 1'-0"

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DRAWINGS PREPARED BY: KERI L. STEVENSON

LIVE OAK MINE STRUCTURE
CONDITION ASSESSMENT, STABILIZATION, AND REPAIR
KEYSTONE CANYON, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 03/12/14

03



1 LIVE OAK - **SOUTH ELEVATION**
SCALE: 1/4" = 1'-0"

NOTES:

1. EXISTING CONDITIONS SHOULD BE VERIFIED IN FIELD.
2. TIMBER DIMENSIONS ARE EXPRESSED AS NOMINAL SIZES FOR ROUGH CUT TIMBER UNLESS OTHERWISE NOTED.
3. ALL DRAWINGS DEPICT THE 'AS-BUILT' STATE OF THE LIVE OAK MINE STRUCTURE AS INFERRED FROM SURVIVING FEATURES. DETAILED INFORMATION REGARDING THE ORIGINAL CONSTRUCTION OF THE FLOOR SYSTEM, INCLUDING PLACEMENT OF THE TIES, THE QUANTITY AND PLACEMENT OF DECK PLANKING, AND THE CONFIGURATION OF HANDRAILS IS CURRENTLY UNAVAILABLE DUE TO CONDITION. EXAMINATION OF THE DEBRIS PILE AROUND THE TRESTLES MAY YIELD ADDITIONAL INFORMATION.

LIVE OAK MINE STRUCTURE - **ELEVATIONS**
SCALE: 1/4" = 1'-0"

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DRAWINGS PREPARED BY: KERI L. STEVENSON

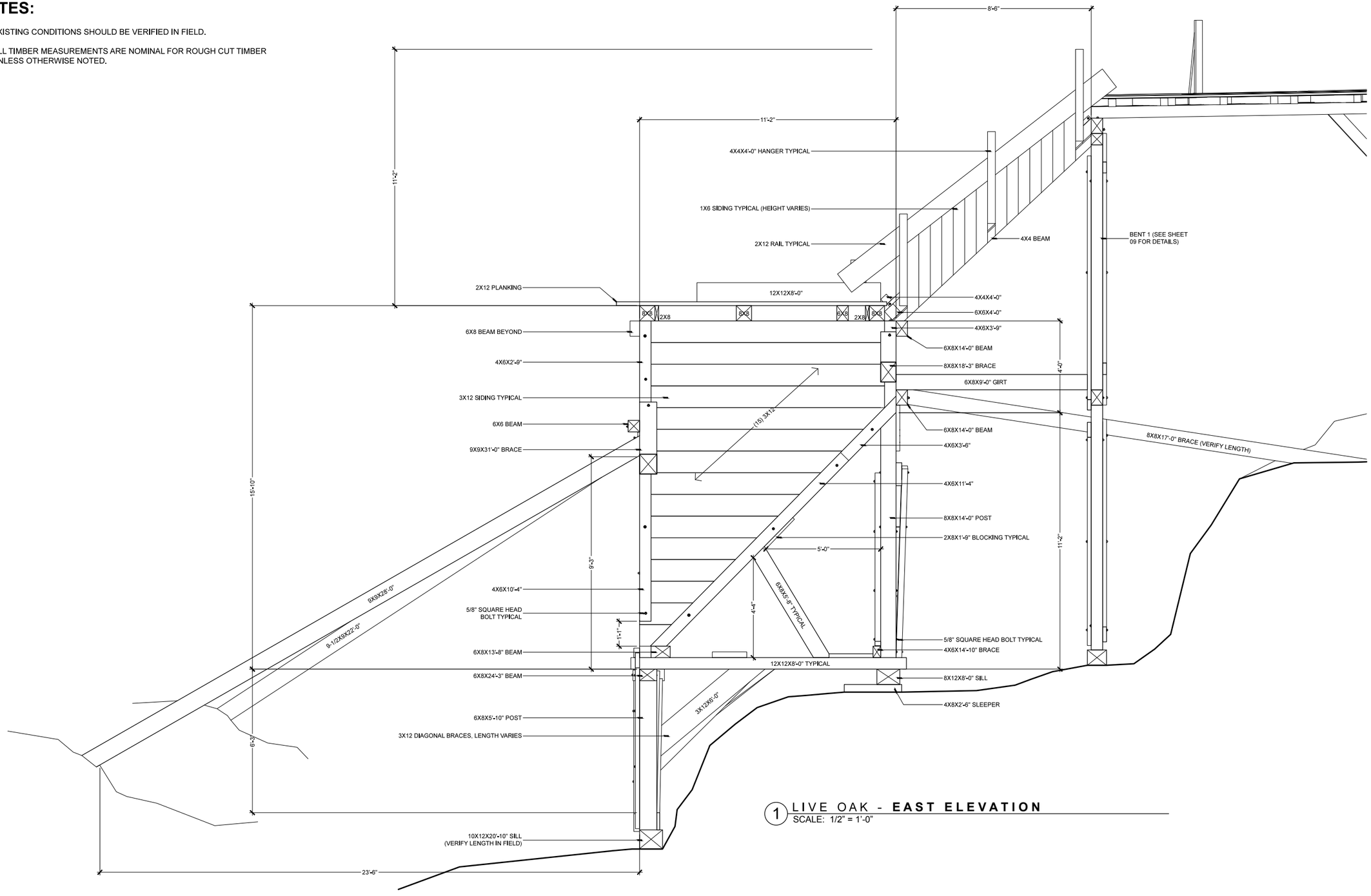
LIVE OAK MINE STRUCTURE
CONDITION ASSESSMENT, STABILIZATION, AND REPAIR
KEYSTONE CANYON, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 03/07/14

04

NOTES:

1. EXISTING CONDITIONS SHOULD BE VERIFIED IN FIELD.
2. ALL TIMBER MEASUREMENTS ARE NOMINAL FOR ROUGH CUT TIMBER UNLESS OTHERWISE NOTED.



1 LIVE OAK - **EAST ELEVATION**
SCALE: 1/2" = 1'-0"

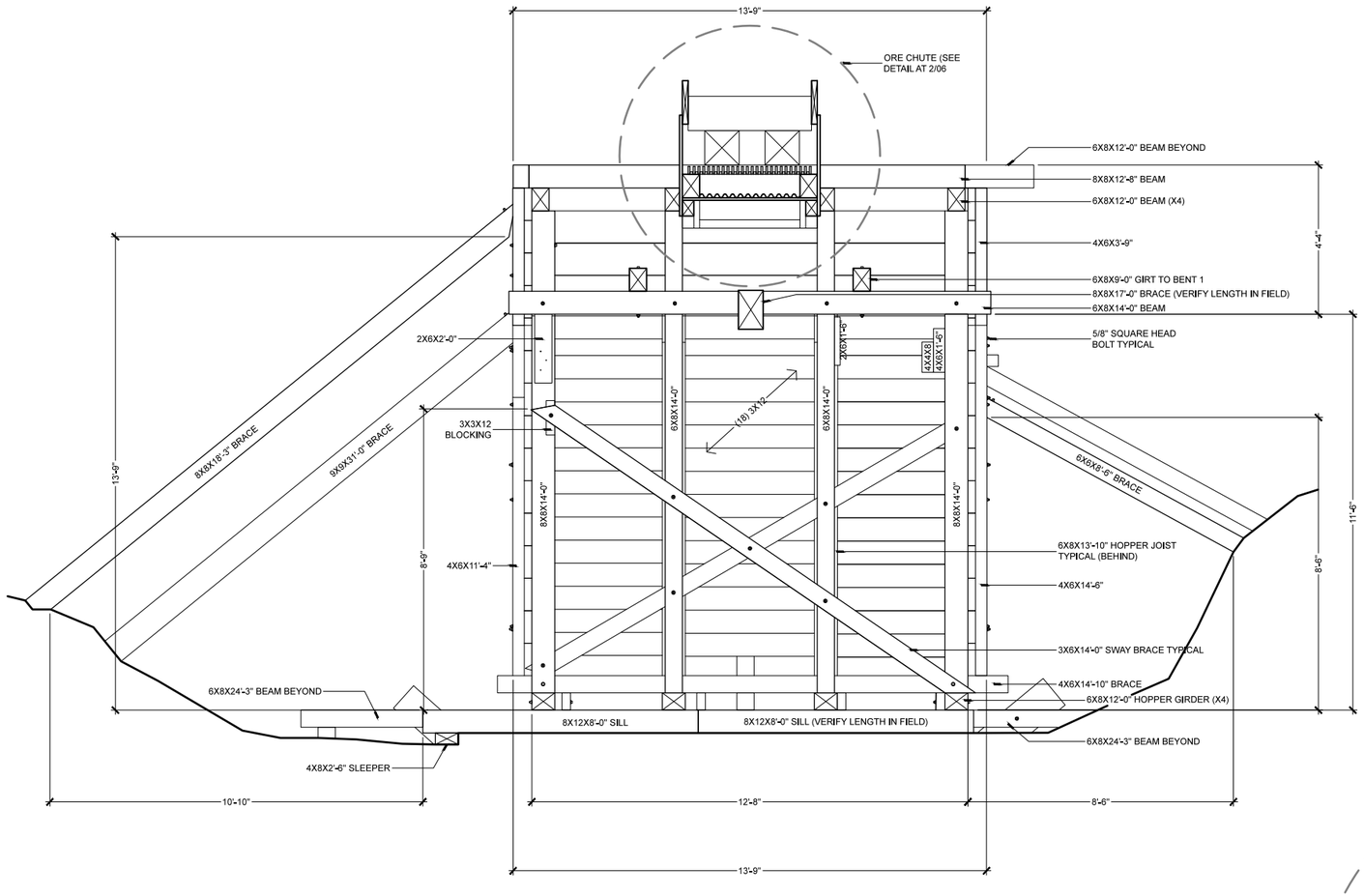
LIVE OAK MINE STRUCTURE - **ELEVATIONS**
SCALE: 1/4" = 1'-0"

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LIVE OAK MINE STRUCTURE
CONDITION ASSESSMENT, STABILIZATION, AND REPAIR
KEYSTONE CANYON, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 03/07/14

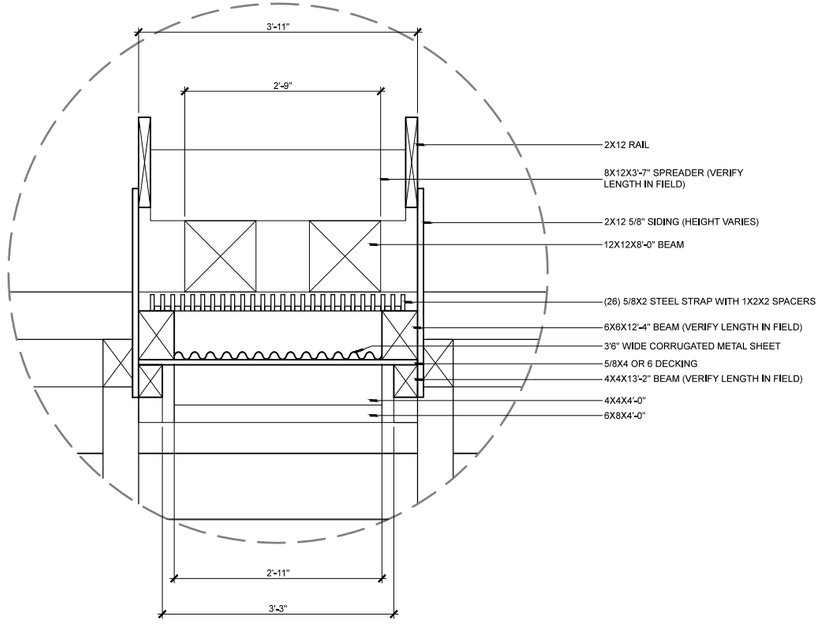
05



1 LIVE OAK - **ORE BIN - NORTH ELEVATION**
SCALE: 1/4" = 1'-0"

NOTES:

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2 LIVE OAK - **ORE CHUTE - EAST-WEST SECTION**
SCALE: 1/2" = 1'-0"

LIVE OAK MINE STRUCTURE - **ELEVATIONS**
SCALE: 1/4" = 1'-0", OR AS NOTED

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DRAWINGS PREPARED BY: KERI L. STEVENSON

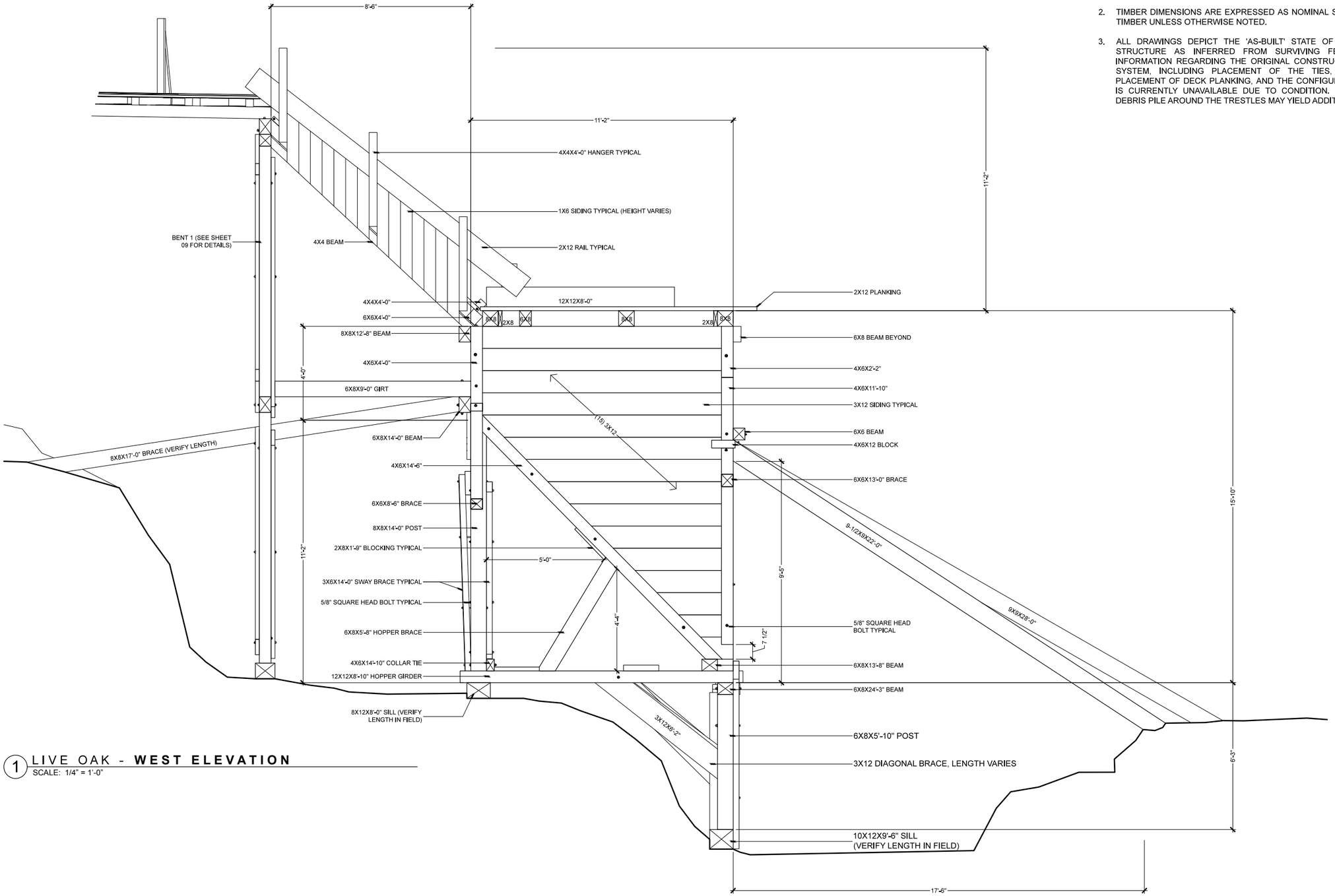
LIVE OAK MINE STRUCTURE
CONDITION ASSESSMENT, STABILIZATION, AND REPAIR
KEYSTONE CANYON, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 03/07/14

06

NOTES:

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1 LIVE OAK - **WEST ELEVATION**
SCALE: 1/4" = 1'-0"

LIVE OAK MINE STRUCTURE - **ELEVATIONS**

SCALE: 1/4" = 1'-0"

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DRAWINGS PREPARED BY: KERI L. STEVENSON

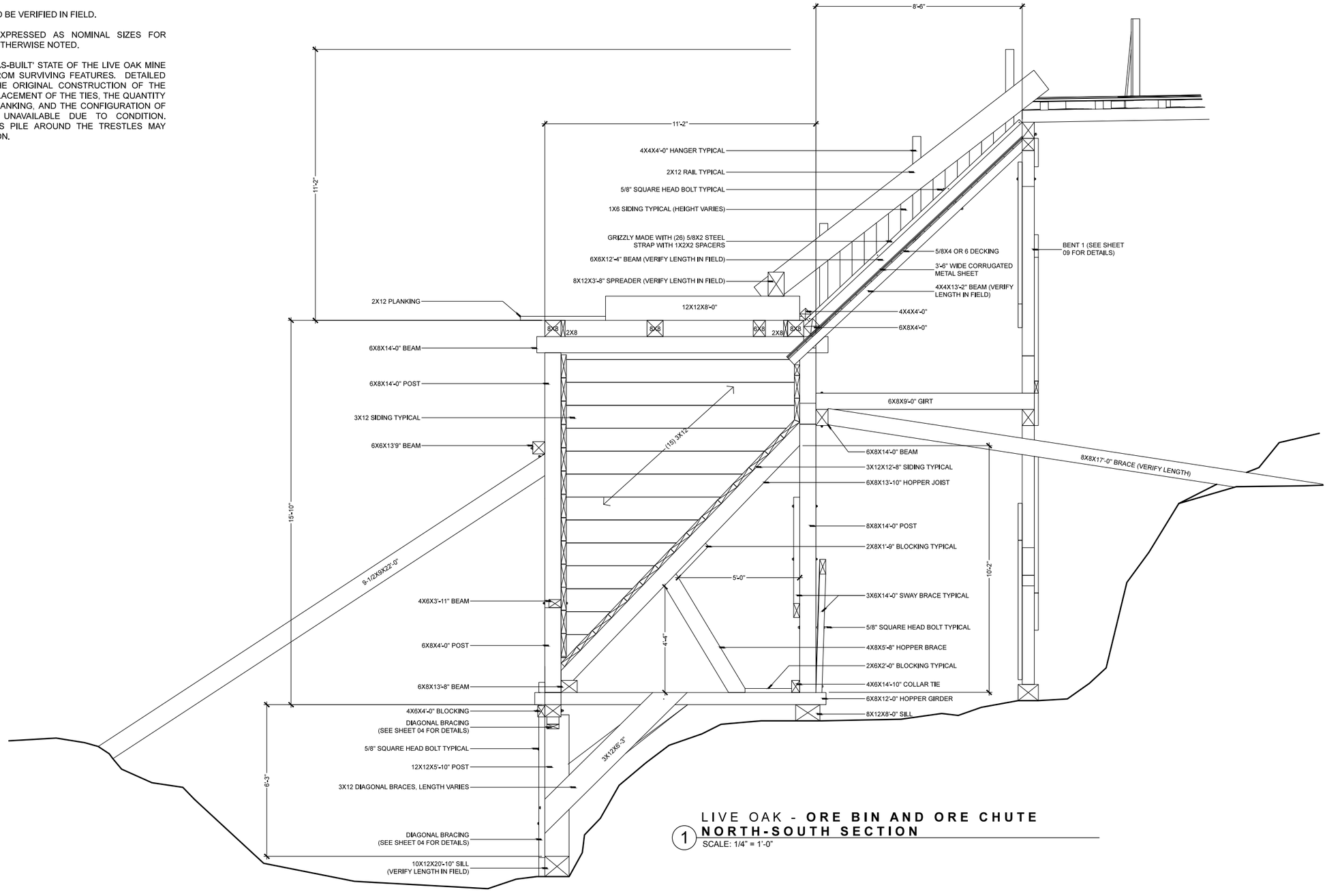
LIVE OAK MINE STRUCTURE
CONDITION ASSESSMENT, STABILIZATION, AND REPAIR
KEYSTONE CANYON, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 03/07/14

07

NOTES:

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1 LIVE OAK - **ORE BIN AND ORE CHUTE NORTH-SOUTH SECTION**
SCALE: 1/4" = 1'-0"

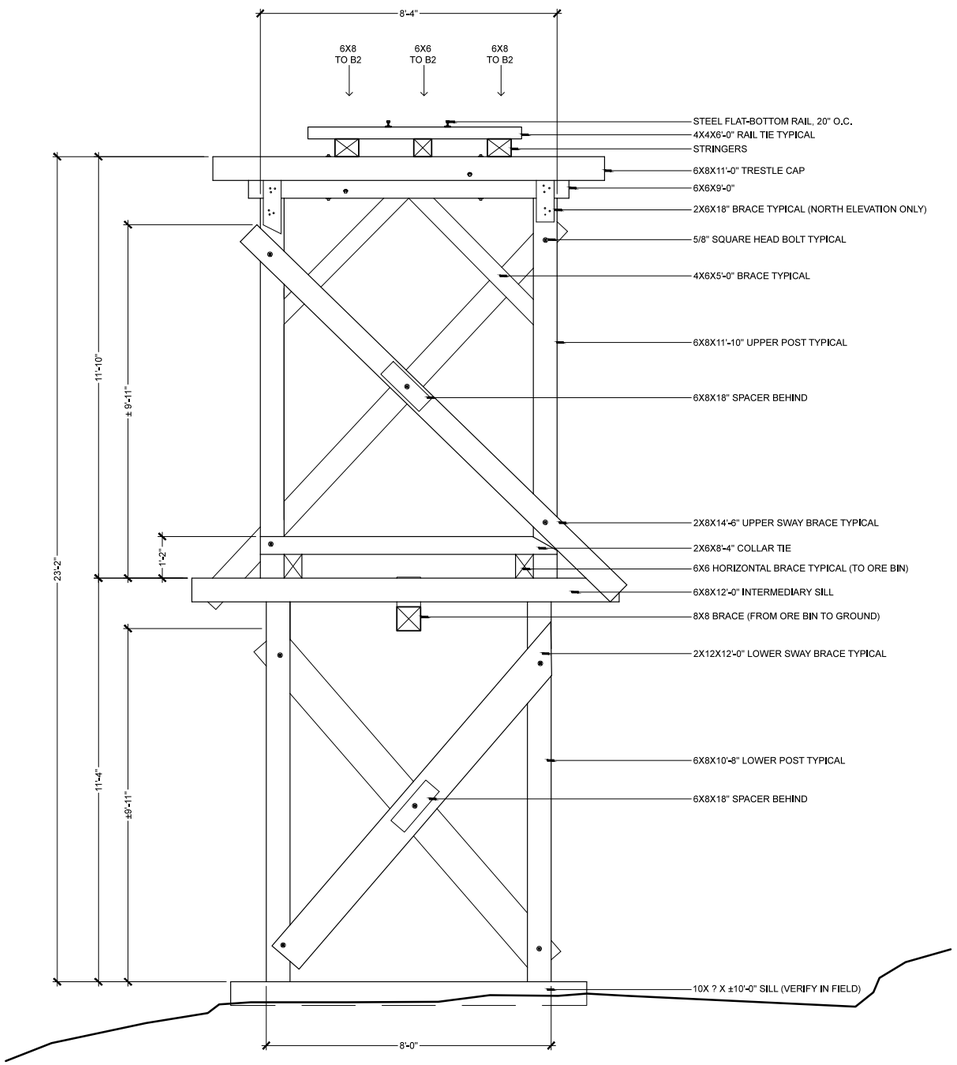
LIVE OAK MINE STRUCTURE - **SECTION**
SCALE: 1/4" = 1'-0"

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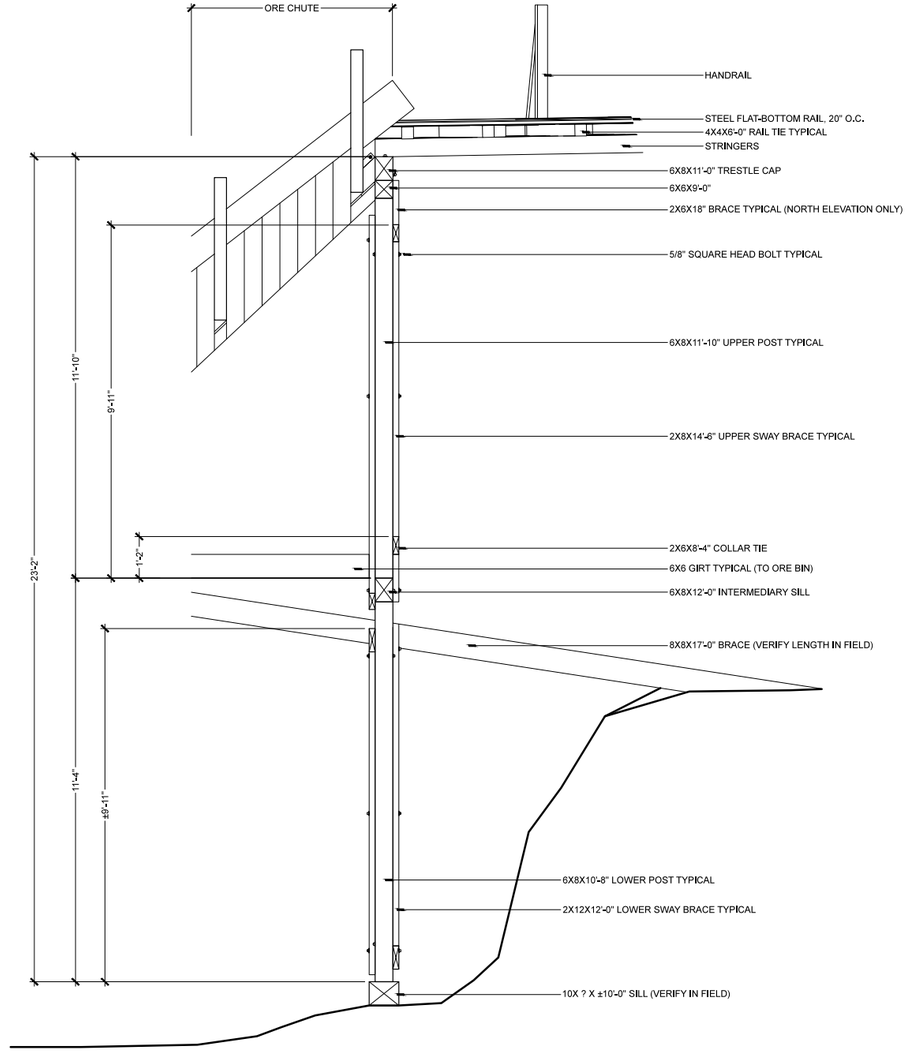
LIVE OAK MINE STRUCTURE
CONDITION ASSESSMENT, STABILIZATION, AND REPAIR
KEYSTONE CANYON, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 03/07/14

08



1 LIVE OAK - **BENT 1 - NORTH ELEVATION**
SCALE: 1/4" = 1'0"



2 LIVE OAK - **BENT 1 - EAST ELEVATION**
SCALE: 1/4" = 1'0"

NOTES:

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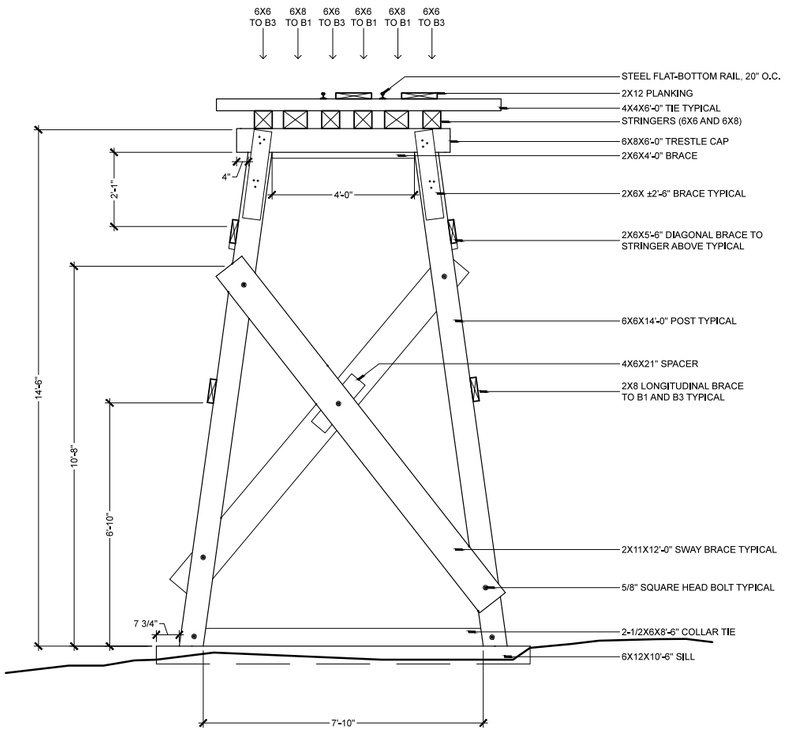
LIVE OAK MINE STRUCTURE - **ELEVATIONS**
SCALE: 1/4" = 1'0"

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DRAWINGS PREPARED BY: KERI L. STEVENSON

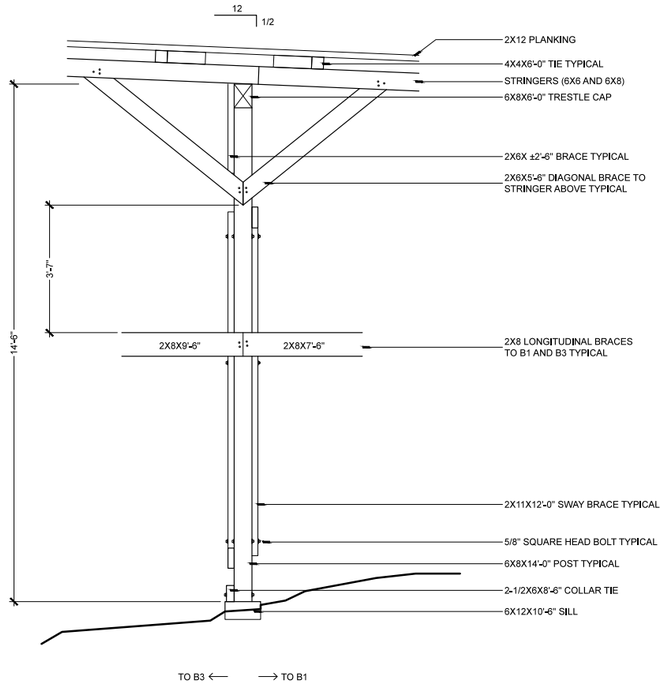
LIVE OAK MINE STRUCTURE
CONDITION ASSESSMENT, STABILIZATION, AND REPAIR
KEYSTONE CANYON, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 03/07/14

09



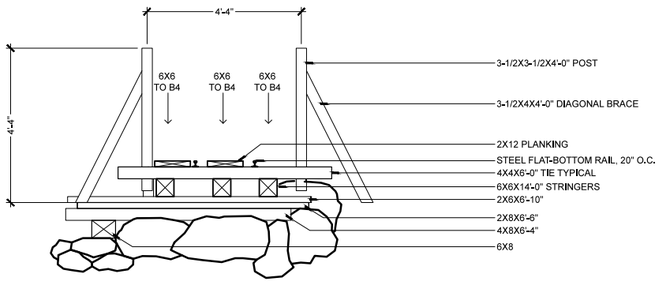
1 LIVE OAK - **BENT 2 - SOUTH ELEVATION**
SCALE: 1/4" = 1'0"



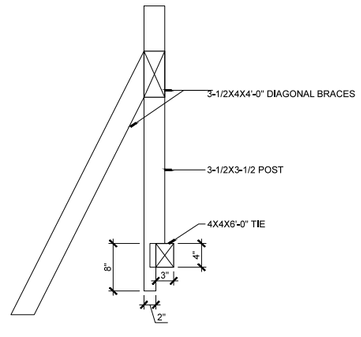
2 LIVE OAK - **BENT 2 - WEST ELEVATION**
SCALE: 1/4" = 1'0"

NOTES:

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3 LIVE OAK - **BULKHEAD - EAST ELEVATION**
SCALE: 1/4" = 1'0"



4 LIVE OAK - **HANDRAIL DETAIL**
SCALE: 1/2" = 1'0"

LIVE OAK MINE STRUCTURE - **ELEVATIONS AND DETAILS**

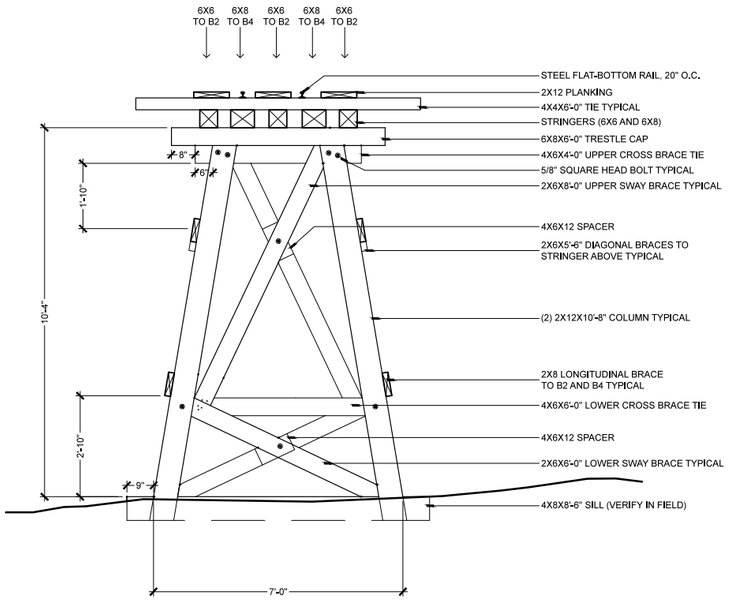
SCALE: 1/4" = 1'0", OR AS NOTED

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DOUG PORTER, PRINCIPLE INVESTIGATOR
DRAWINGS PREPARED BY: KERI L. STEVENSON

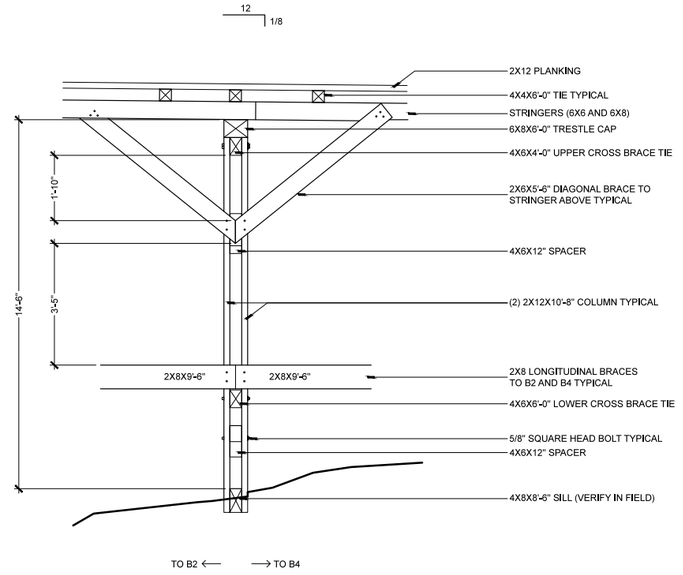
LIVE OAK MINE STRUCTURE
CONDITION ASSESSMENT, STABILIZATION, AND REPAIR
KEYSTONE CANYON, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 03/07/14

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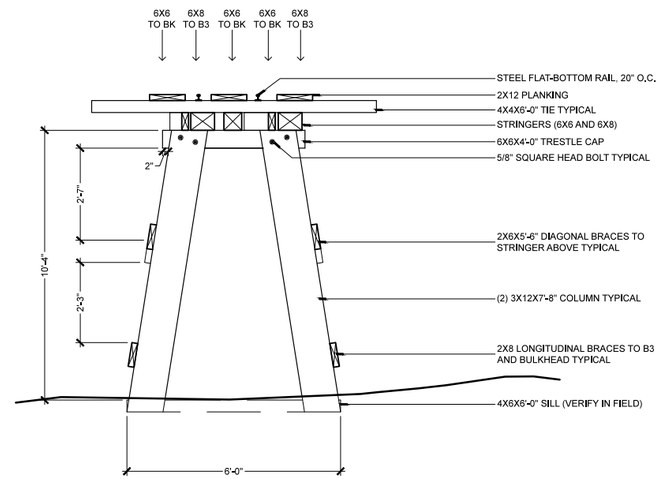
1 LIVE OAK - **BENT 3 - NORTHWEST ELEVATION**
SCALE: 1/4" = 1'0"



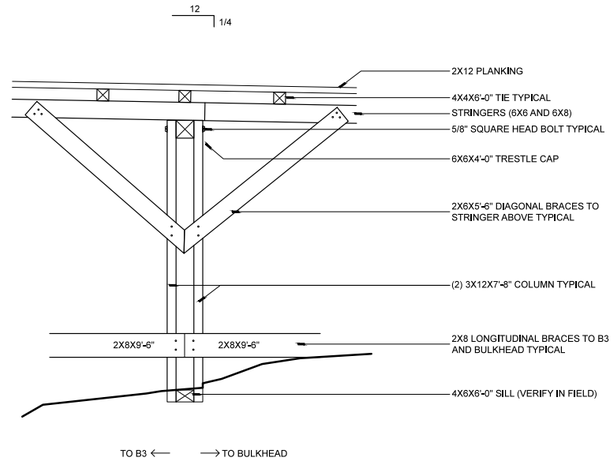
2 LIVE OAK - **BENT 3 - NORTHEAST ELEVATION**
SCALE: 1/4" = 1'0"

NOTES:

1. EXISTING CONDITIONS SHOULD BE VERIFIED IN FIELD.
2. TIMBER DIMENSIONS ARE EXPRESSED AS NOMINAL SIZES FOR ROUGH CUT TIMBER UNLESS OTHERWISE NOTED.
3. ALL DRAWINGS DEPICT THE 'AS-BUILT' STATE OF THE LIVE OAK MINE STRUCTURE AS INFERRED FROM SURVIVING FEATURES. DETAILED INFORMATION REGARDING THE ORIGINAL CONSTRUCTION OF THE FLOOR SYSTEM, INCLUDING PLACEMENT OF THE TIES, THE QUANTITY AND PLACEMENT OF DECK PLANKING, AND THE CONFIGURATION OF HANDRAILS IS CURRENTLY UNAVAILABLE DUE TO CONDITION. EXAMINATION OF THE DEBRIS PILE AROUND THE TRESTLES MAY YIELD ADDITIONAL INFORMATION.



3 LIVE OAK - **BENT 4 - NORTHWEST ELEVATION**
SCALE: 1/4" = 1'0"



4 LIVE OAK - **BENT 4 - NORTHEAST ELEVATION**
SCALE: 1/4" = 1'0"

LIVE OAK MINE STRUCTURE - **ELEVATIONS**

SCALE: 1/4" = 1'0"

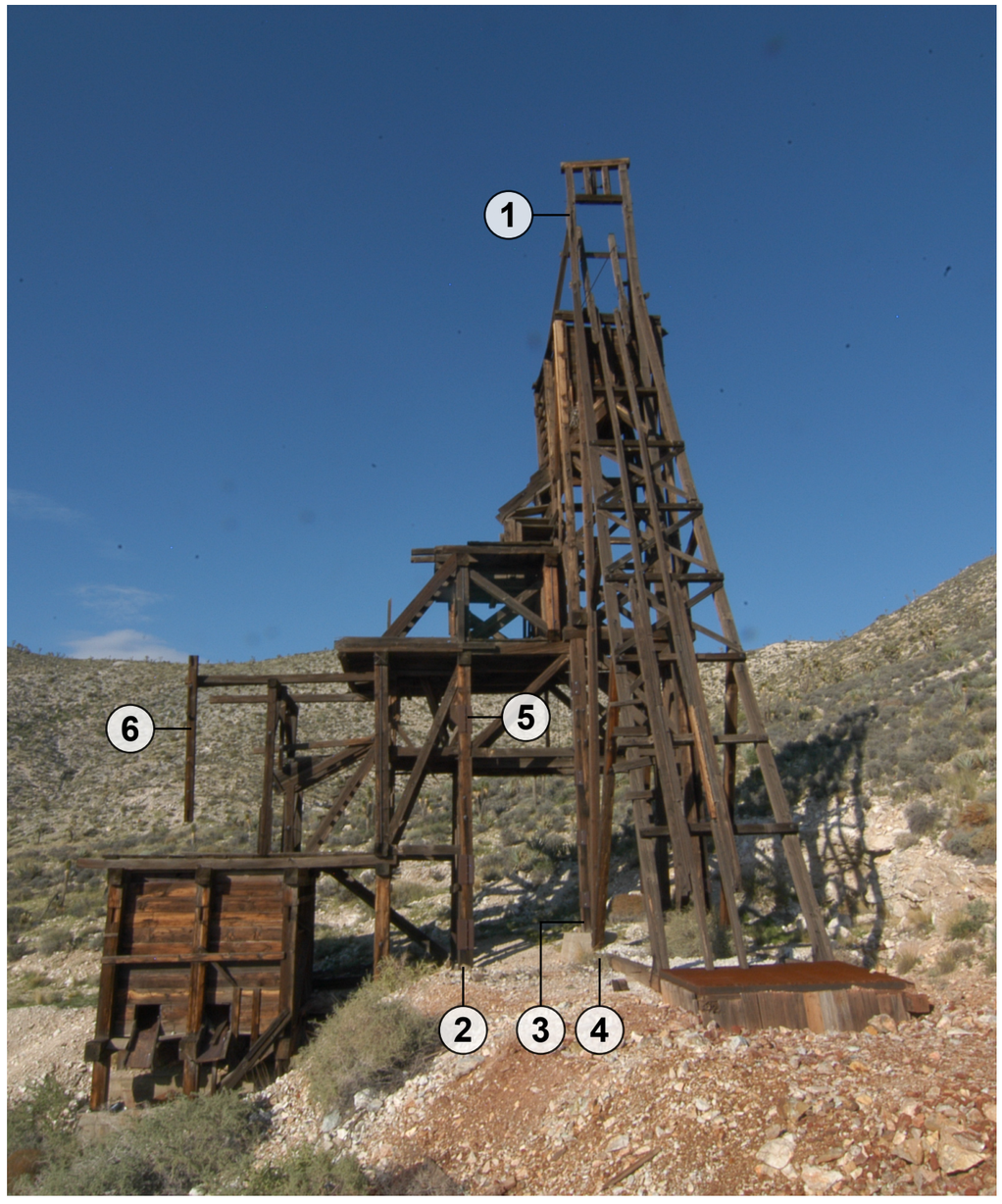
UNIVERSITY OF VERMONT
SCHOOL OF ENGINEERING
DOUG PORTER, PRINCIPLE INVESTIGATOR
DRAWINGS PREPARED BY: KERI L. STEVENSON

LIVE OAK MINE STRUCTURE
CONDITION ASSESSMENT, STABILIZATION, AND REPAIR
KEYSTONE CANYON, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 03/07/14

APPENDIX C

EVENING STAR REPAIR LOCATIONS



EVENING STAR - **REPAIR LOCATIONS**

SCALE: NOT TO SCALE

REPAIR NOTES:

1. Scarf new wood into damaged columns 3 to 6 feet above the ore bin plate. The iron sheave, and most of the sheave framing, should be salvaged for installation on the replacement column ends (pp. 17, 52).

2. Replace decayed sill in kind or with pressure-treated wood (to extend service life). Treat in-kind replacement sill with borate rods to delay the onset of decay (pp. 23, 52).

3. Stabilize decayed 12 x 12 column, installing through-bolts joining the column to the sistered 8 x 8 above the decay zone. Connect smaller column to the concrete pier, using clip angle connection anchored to the pier. Alternatively, repair decayed 12 x 12 column, requiring partial demolition of the pier, scarfing of new wood at the base of the column, and repair of the concrete pier (pp. 24-25, 52).

4. Replace decayed portion of timber tie and re-connect brace. Alternatively, connect the diagonal brace to the concrete pier using a clip angle anchored to the pier (pp. 24, 53).

5. Remove steel plate clamps (typical, entire structure) (pp.18, 53).

6. Repair damaged plate timber on the west and reattach the girt at either end with bolts and structural washers. Alternatively, re-erect missing columns and re-support the partially detached girt (pp. 17, 53).

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EVENING STAR MINE STRUCTURE

CONDITION ASSESSMENT, STABILIZATION, AND REPAIR

IVANPAH DISTRICT, MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

DATE: 02/04/13

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