TREATMENT REPORT: STABILIZATION OF THE LIVE OAK MINE

MOJAVE NATIONAL PRESERVE, SAN BERNARDINO COUNTY, CALIFORNIA

PREPARED FOR THE NATIONAL PARK SERVICE

by

THE SCHOOL OF ENGINEERING

UNIVERSITY OF VERMONT

April 2015

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
THE SCHOOL OF ENGINEERING

UNIVERSITY OF VERMONT

APRIL 2015

PROJECT TEAM

University and Professional Partners

Douglas Porter, Principal Investigator, UVM.
Mike Cotroneo
Scott Ernst
Chris Patton
Keri Stevenson

National Park Service

Stephanie Dubois, Superintendent, Mojave National Preserve
David Nichols, Park Archaeologist, Mojave National Preserve
Randall Skeirik, Vanishing Treasures Historical Architect

Cover photo: The Live Oak mine structure after completion of repair work, 2015

Figure 1: The Live Oak site prior to treatment, 2014

EXECUTIVE SUMMARY

The Live Oak mine site in Mojave National Preserve (MOJA) contains historic timber structures erected by mining companies in the early- to mid-20th century. The site is located in the New York Mining District in the northeastern area of the preserve, and surviving structures include a timber ore bin along with a timber trestle supporting a rail track which originally supplied the bin with ore.

The National Park Service and the School of Engineering at the University of Vermont collaborated in the condition assessment, repair design, and pilot treatment of the primary mine structures. A site visit by the assessment team in late 2013 focused on documentation of the structure and development of stabilization strategies. It was immediately apparent that the ore bin itself was out of plumb, as were the ore chute and rail deck, due to the partial collapse of the trestle bent below them. Repairs to the Live Oak mine structure took place over the course of the fall and spring of 2014/15.

This report outlines the subsequent treatment and repair of the Live Oak Mine structure and is divided into six parts: a description of the mine structure with a brief consideration of its history and significance, a summary of the condition assessment[1], presentation of preservation strategies, a description of the repair work completed at the site, and a section outlining recommendations for future work.

[1] For a more detailed description of condition assessment at the Live Oak mine, please see Porter, et al., *Condition Assessment and Treatment Recommendations: Live Oak and Evening Star Mines, Mojave National Preserve, San Bernardino County, California*, 2014.

HISTORY AND SIGNIFICANCE

The Bronze-Live Oak Mining Camp is 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 site was claimed in 1896, and was likely worked until sometime in the 1920s, though sporadically at that point. 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 unique view of early 20th-century small-scale mining technology in the region. The camp is also singular in that it captures the entire process of ore extraction through its surviving structures. The relative completeness of the fabric record is likely due to its remote location.

The New York Mining District was formed in 1870, and mining began two years later. These early mines were responsible for 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 slump in silver prices. However, the construction of the San Pedro, Los Angeles, and Salt Lake Railroads in the early 20th century helped reinvigorate the development of mining sites in the region. [2]

Seven claims were made on the site over the course of its life, but the only record of production was in 1912, detailing one ton of extracted material which contained 10 percent lead and 24 ounces of silver. It was around this time that new veins of silver were discovered in existing mines, spurring further prospecting throughout the district. The First World War plunged the region into recession, and the Live Oak site is believed to have ceased operating shortly afterwards. 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.

[2] Ibid, p.4.

INVESTIGATION AND CONDITION ASSESSMENT

INVESTIGATION OF WOODEN ELEMENTS

Prior to the condition assessment of the ore bin and trestle at Live Oak, the species, condition, and structural grade of the timbers used in their construction were unknown. The out-of-plumb condition of the ore bin and partial collapse of one of the trestle bents appeared to be at least partially the result of the crushing of supporting members, but it was not known to which extent deterioration in the structure was the result of decay fungi and/or wood-boring insects. The assessment focused on evaluation of structural geometry, connection capacity, and material quality in order to make a determination as to whether the members in the structure were (a) unfit to remain in service, (b) deteriorated and in need of repair or (c) in sound condition.

The general conclusion was that the structural wood elements were in good to fair condition, and that primary areas of deterioration occurred in structural elements which were in contact with the ground or had been covered by debris. The primary mechanism of deterioration for timbers in ground contact was growth of wood decay fungi facilitated by moisture absorption and poor drainage conditions. Damage by wood boring insects was a secondary cause of damage, as wood boring insects prefer wood with high moisture content and/or the presence of active wood decay. Deterioration of timbers and structural wood elements not in contact with the ground was primarily due to weathering. Based on a limited number of samples, it was determined that most of the structural wood elements were composed of Douglas Fir, a species characterized by moderate durability, and as such performed fairly well in the relatively dry climate of the Mojave Desert.

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

- Based on limited sampling, most of the structural elements of the Live Oak site are constructed of Douglas Fir (*Pseudotsuga menziesii*). Other species identified include spruce (*Picea* spp.) and redwood (*Sequoia sempervirens*).
- Weathering, crushing, and wood decay fungi were the primary mechanisms of deterioration.
- Deterioration by wood decay fungi tended to be limited to structural elements in ground contact or those that had been covered by debris, which encouraged an influx of wood-boring insects as a secondary decay vector.
- Bent 1 of the Live Oak trestle was in structural distress and was a high priority for repair.
- The girder beams of the Live Oak ore bin hopper exhibited crushing from overloading of the bin, necessitating repair or full replacement.

STRUCTURAL ASSESSMENT

A preliminary analysis of the Live Oak site's structural integrity was conducted based on the framing's condition, species, and grade. Four braced bents support a radial track used to convey mine carts to dump ore down a supported chute into a heavy timber bin. Portions of the structure exhibited significant distress, but were in sufficiently good condition to make possible the preservation of the structure, exclusive of its original intended use. The ore bin had moved out-of-plumb and bent 1 was partially collapsed, resulting in the dropping of the upper end of the ore chute and the ends of the stringers supporting the floor deck and track between bents 1 and 2 (see Figure 2). The collapse of the bent may have been initiated by shifting of the ore bin to the south (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. Additionally, significant loss of wood fiber had occurred in the crushed and weathered ends of the hopper girders, and the easternmost hopper girder was significantly deteriorated along its length. Deflection of the top timber plate occurred beneath the southeast corner of the bin's substructure, and wood decay occurred in sills, bottoms of columns, and ends of braces in contact with the ground. Many of the dimension lumber braces and waling strips had failed at bolted connections due to deterioration associated with weathering; recovery of connection capacity through repair or replacement of deteriorated members was essential to the axial stability of the trestle.

Recommendations based on the structural assessment were to:

- Jack and return the ore bin to a plumb position in tandem with repairs to bent 1, and repair their associated bracing in order to reestablish stability in the structure.
- Replace the decayed sill and columns of the substructure supporting the ore bin in order to fix the bin in a plumb position. While the top plate of the substructure frame was deflected beneath the southeast ore bin column, the member was believed to be sufficiently adequate as a support for the now-empty container.
- Install reinforcing timber bearing plates onto the existing bin substructure to provide additional support to the southern ends of the hopper girders.
- Remove decayed material at the bases of the timber braces at the south end of the ore bin and strengthen upper brace connections.
- The integrity of the hopper girders was also essential in order to support the ore bin, particularly on the south; scarfed end repairs were recommended to restore axial strength on three of the hopper girders. It was proposed that the easternmost hopper girder be replaced due to excessive deterioration over its entire length.

- Replacement of decayed sills in trestle bents and repair of decayed column bases to restore trestle caps to their original positions, and consequently the floor deck they support.
- Deteriorated timber rail ties did not need to be replaced, as they were considered redundant to the structural integrity of the road surface,
- Damaged or light dimension lumber braces could be replaced in kind.

Figure 2: Rotation of the ore bin (bottom right) caused bent 1 to buckle at the intermediary horizontal member, leading to partial collapse of the bent (tall structure left of center), dropping of the ore chute (at center), and dropping of the ends of the stringers supporting the roadway (top left).

STABILIZATION / PRESERVATION STRATEGIES

In managing and maintaining its mine sites, Mojave National Preserve is broadly guided by the Secretary of the Interior's Standards for the Treatment of Historic Properties, and the project team has been additionally guided by the ICOMOS Principles for the Preservation of Historic Timber Structures, and the ISCARSAH Principles and Guidelines.[3]

For structures normally exposed to view, replacement in kind is typically included as a repair strategy, and preservation goals are frequently focused on retention of the historic structural configuration and the traditional craft practices involved in fabricating replacement elements. The team also included future considerations such as ongoing access to the site for visitors, and ease of conducting later repair work.

The Live Oak Mine has been disused for some considerable time and no longer has a feasible role in its original intended function, but the park's goals for the site include providing access and interpretation for pedestrian visitors. Given these factors, it was not essential to recover the structural capacity for mining activities, and for this reason, along with budgetary constraints, the scope was limited to restoration of the structure's original geometry and preventing further loss due to collapse. The project team proposed a stabilization strategy based on maximizing the retention of historic material while stabilizing those members that had decayed or failed. Repair recommendations for the structure were intended to result in an acceptable level of structural stability for a period of 50 years or more.

STABILIZATION STRATEGIES

Live Oak was in danger of collapse largely due to settlement of the ore bin at the end of the trestle structure's run. Loss of support on the south side of the ore bin had resulted in rotation of the bin 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 focused on shoring each substructure, after which the ore chute and deck would be dismantled so that the bin and trestle bent could be returned to plumb. The substructure supporting the ore bin would then be repaired, after which the ore chute and floor deck would be restored to their original positions. Shoring was set up on structural staging erected in the bays between the ore bin,

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

trestle bent 1, and trestle bent 2 (see Figure 3). Once the ore chute and roadway were properly supported, they could be partially disassembled and stored for reinstallation.

Figure 3: Structural staging was erected to support the structure.

In addition to the out of plumb condition of the ore bin and trestle bent 1, some of the other bents had deteriorated due to decayed column bases and sills. Stringers and ties in the roadway were also in disrepair, but to a lesser extent. New wood was scarfed into several of the column bases, and most of the sills were replaced. Stringers and ties in the roadway no longer have to support loads beyond their own weight, and were consequently left intact.

REPAIR TECHNIQUES

SCARFED SPLICES

Traditional scarf forms were used to splice new timber into deteriorated members. If we consider the tradition of heavy timber framing, of which the mine structures are certainly a part, scarfed splices can be considered a customary yet substantial means of construction and repair which allows for the retention of a considerable quantity of original timber. These repairs are not invisible, but the visual impacts are relatively unobtrusive. Limiting replacement to decayed portions of members using traditional joinery had the advantages of preserving the salvageable bulk of historic elements while employing craft traditions contemporary with those that originally produced the structures.

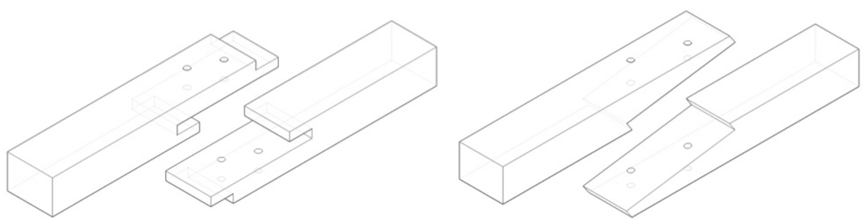

Figure 4: Two forms of scarfed splices: half lap with nose (left) and splayed (right).

REPLACEMENT IN KIND

Some of the structural timbers are so deteriorated that the only way to recover adequate capacity is through total replacement. In replacing wooden elements of an historic structure, guidelines often urge the use of materials that match the original in both species and quality. While high-quality timber was not used in every instance in the original construction of the mine structure, an argument can be made for using it in repair work. 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.

Due to the mass and size of the timbers required for the completion of repairs, and the remoteness of the site itself, finding appropriate solutions to logistical challenges was essential to completing the work. This remoteness and difficulty of the surrounding terrain ruled out the use of large machinery or heavy equipment. A variety of tools and techniques were employed to support the structures during removal and repairs, as well as to transport lumber around the site, including cribbing, rollers, and hand tools such as screw jacks, chain hoists, and come-alongs. A variety of smaller power tools, powered by a portable generator, were also used for shaping and joining the timbers.

REPAIR WORK

ORE BIN OVERVIEW

The ore bin was 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. Repair work on the ore bin included replacing the sill in kind, scarfing repairs into some of the substructure columns and in kind replacement of others, replacement in kind of the southern half of the top plate, replacement in kind of two of the hopper girders, and removal of decayed portions of the long timber braces located at the corners of the ore bin. When heavily deteriorated or absent timbers required replacement, dimensions were based on surviving material, existing hardware locations, and weathering and exposure patterns on remaining wood. Replacement members were set in place by hand, or through a combination of rollers, cribbing, and rigging, and were secured using existing hardware when possible; otherwise by custom-made replacements.

ORE BIN SUBFRAME

Settlement of the subframe and the resulting tilt of the bin itself contributed to many of the other areas of concern for the mine structure. As such, repair of the subframe and replumbing of the bin were necessarily some of the first items addressed in the repair work. After removal of the ore chute, which was at a high risk for collapse, the ore bin was supported using temporary beams bearing on structural staging located on the bin’s south side. Once the weight of the ore bin had been lifted off of the subframe (Figure 5), repairs could be made to the sill, columns, and the cap timber located at the top of the subframe, while allowing an opportunity to reposition the substructure with respect to the ore bin so that load paths through the base of the structure could be properly aligned.

Figure 5: The south end of the ore bin was lifted using a combination of structural staging, cribbing, and screw jacks, allowing for repairs and plumbing of the subframe

The cap timber in the substructure was deformed at several of the hopper girder locations, but it was hoped that it would nonetheless be capable of supporting the reduced loads of the empty bin. However, after disassembly of the surrounding structure and closer inspection of the cap timber, it was deemed necessary to replace its entire eastern half, the timber being originally composed of two sections joined by through-bolted wooden backing plates.[4] The original hardware was used to secure the half-lapped replacement section, and the backing plates were replaced in kind. Additionally, the supporting column beneath the cap was repaired and supplemented by an additional support for the cap timber, addressed in a later section below.

HOPPER GIRDERS AND BRACES

It was originally suggested that new ends be scarfed onto the hopper girders where they cross the top plate, in order to reduce the potential for decay associated with the girders' already crushed ends. The easternmost hopper girder was deteriorated along its length, and full replacement was anticipated, but further inspection also showed a high level of deterioration in the neighboring girder. As such, they were replaced as a pair. The ends of the two westernmost hopper girders were in better condition than previously thought and deemed sufficiently intact to

---

[4] This may have been the result of an earlier repair, or more likely, based on the piecemeal nature of the rest of the structure, the most economic way to make the span with the timber on hand.

support their respective loads. The hopper braces were found to be in poorer condition and were all replaced in kind.

Figure 6: Replacing the braces between the hopper girders and the ore bin subframe. The two easternmost hopper girders were deteriorated along their length, and were replaced in kind (ends visible above the subframe).

Figure 7: The replacement sill for the ore bin subframe was moved into place using ABS plastic pipe rollers

Following replacement in kind of the east section of the cap timber and the two easternmost hopper girders, the ore bin was returned to a plumb position using a combination of jacking and shoring. This allowed the subframe to be lifted enough for the installation of a new sill.[5] The replacement sill, which weighed several hundred pounds, was moved across site using a dimensional lumber roadway and ABS plastic pipe rollers (see Figure 7). The area under the subframe was partially excavated in order to lay a base of dry stacked stone, which will facilitate drainage and help slow future deterioration (see Figure 8). The sill was then moved into position, and the subframe and ore bin lowered to rest on it.

Figure 8: Stone from the area around the base of the ore bin was dry stacked to provide a foundation for the replacement sill. This will facilitate drainage and help to slow future deterioration.

[5] At the time of the condition assessment, inspection suggested that the sill for the subframe was composed of two pieces with a difference in elevation of approximately eight to ten inches. This may have been the result of a repair, or was part of the original method of construction. Excavations to admit the replacement sill uncovered very little material remaining of the west section, and a significantly deteriorated east section. In order to provide greater stability for the rest of the structure, it was decided to install one continuous piece for the replacement sill, rather than two.

The two western posts in the subframe were also replaced in kind due to an advanced level of decay (see Figure 9), along with some of the diagonal bracing used to stabilize this portion of the structure, much of which had deteriorated significantly either around their hardware, or where the ends lay in contact with the ground (see Figure 9). During the second repair visit, new wood was scarfed into the 12x12 supporting column at the center of the subframe, and a secondary column was added just to the right of it to carry the end of the half-lapped replacement cap timber (see Figure 10). Moisture content of the existing sills throughout the mine structure were uniformly high, and replacements will be exposed to moisture levels conducive to decay. Ongoing maintenance should focus on this area, among others.

Figure 9: Setting the replacement post, second from the west, in the ore bin subframe. The first and second posts from the west were deteriorated along their lengths and were replaced in kind.

Figure 10: The completed subframe. The east half of the cap timber was replaced in kind, as were the two westernmost posts, and diagonal braces. New wood was scarfed into the end of the center post, and a column was added to the right to help support the end of the replacement cap timber.

Ore Bin Bracing

Long timber bracing to the ore bin had been installed while the mine was in operation; decayed portions at grade were removed and the posts were reset (see Figure 11).

Figure 11: Resetting the ore bin braces after the bin was returned to a plumb condition.

TRESTLE BENT 1

Returning the ore bin to its original position with respect to plumb eliminated buckling in trestle bent 1, because the horizontal member near the center of the bent is braced against the bin. Additionally, all bracing between the two structures was then reset. However, the intermediary sill of trestle 1 had deteriorated and suffered damage associated with prior buckling of the bent, and was replaced in kind (see Figure 12). In tandem with the process of replacing the intermediary sill, the bent itself was returned to plumb.

Many of the smaller braces on the bent were broken, partially lost to decay, or badly deteriorated around their fasteners. Broken or damaged braces were repaired either by reattaching undamaged portions of the existing members, or replacing in kind. Repairs were reattached using a combination of original hardware or custom reproductions in cases where the originals were damaged or lost.

Figure 12: The intermediary sill in bent 1 was replaced in kind (below the diagonal bracing). Three of the diagonal braces, the diagonal brace spacers, and all of the vertical braces were also replaced in kind and reattached using either original hardware or custom reproductions.

ORE CHUTE

The ore chute originally carried ore from carts on the roadway into the bin for storage, and as such bridges the two structures. The chute itself is composed of one inch boards surrounded by a timber frame, with sheet iron and corrugated metal at the base, along with a metal grizzly, a heavy ore-sifting device. Settlement and rotation of the ore bin and the buckling of bent 1 had brought the to near-collapse. At the time of the wood investigation, the uppermost end of the chute was largely supported by a single bolt which had snagged on the eastern diagonal brace of upper bent 1. To alleviate the risk of complete collapse, the chute was removed prior to repair work and stored for later reinstallation. Removal was accomplished using structural staging, cribbing, and rigging.

Figure 13: A view of the metal grizzly sorter in the ore chute prior to repair work. The grizzly is composed of iron straps and spacers bolted together.

Repairs made to the ore bin subframe and the trestle bents brought structure as a whole back to an even and plumb condition, allowing for reinstallation of the ore chute. Some parts of the chute, such as siding, were missing, and others had been either lost to decay or damaged as a result of partial collapse. Enough of the chute was rebuilt to brace bent 1 using a selection of original timbers, and much of the remainder of the chute was replaced in kind. The original sheet iron and corrugated metal were reinstalled at the base of the chute (see Figure 14). The original angle of the ore chute as it descends from the roadway to the ore bin was inferred by evaluating existing evidence at the site.

Figure 14: The completed ore chute. Enough of the ore chute was rebuilt to brace bent 1, and several members were in good enough condition to be reused. Surviving remnants were copied to sheath the sides.

Due to the stresses on the structure which would be inflicted by the iron grizzly ore sorter, as well as possible safety concerns for the public, it was determined that the grizzly would not be reinstalled in the chute, and would instead be stored on site.

TRESTLE BENTS 2 THROUGH 4

Trestle bents two through four were in reasonably good condition with the exception of wood in contact with the ground. Repairs included replacing sills in kind and splicing new wood into decayed columns. Moisture content of the existing sills was uniformly high, and replacement sills will be exposed to moisture levels conducive to decay.

Sills were replaced and column bases repaired on bents 3 and 4 (see Figures 15 and 16). Combined with sill replacement on bent 1, this returned all the bent caps to parallel and the road grade to even along its length. For dimension lumber columns, new bases were scarfed into the historic wood using traditional forms and reinforced with spacers and through-bolts.

Figure 15: Scarfed repairs in bent 3. Lower cross bracing and the sill were replaced in kind. Spacers were added between the dimensional lumber posts between the scarfs to support the repairs.

It was originally thought that cap timbers in the trestle bents might also require repair or replacement. Further inspection showed the members to be in reasonable condition and capable of supporting their own weight as well as that of the roadway. Since these constitute the limit of the demands made on the structure going forward, the original cap timbers were left in place.

Figure 16: Scarfed repairs at trestle bent 4. The sill was largely lost to decay and replaced in kind. Spacers were added between the dimension lumber posts to support the repairs.

BENT TO BENT BRACING

The trestle portion of the mine structure is strengthened and stabilized with longitudinal bracing between bents and diagonal bracing between bents and the roadway. At the time of the initial inspection, several of these members were missing, broken, or partially detached. During repair, members in good condition were secured in place, and missing or broken bracing was replaced in kind (see Figure 17). Bracing was fastened using corrosion resistant structural screws.

Figure 17: Much of the diagonal and longitudinal bracing between the trestle bents was damaged or missing. Braces were replaced in kind when they could not be salvaged or reattached securely.

STRINGERS AND TIES

Working in concert with the bracing between bents, timber stringers help support ties, deck planking, and rails as well as limit longitudinal movement of the trestle structure. It was expected that some of the stringers would have decay pockets that were concealed from view by the floor system, despite being in generally serviceable condition. However, because the roadway is no longer functional and required to support loads associated with carts and ore, it was not necessary to repair or replace any stringers at this time. Similarly, many of the ties are decayed, but are very minimally loaded, supporting only the deck planking and rail. Ties were not repaired or replaced, preserving the roadway in its abandoned condition.

RECOMMENDATIONS FOR ADDITIONAL REPAIR WORK AND ONGOING MAINTENANCE

EVENING STAR

The original goals of assessing and improving the condition of the Live Oak site have been realized. Through a detailed inspection and assessment of the surviving woodwork, a repair plan was implemented that stabilized and strengthened the structure to a level sufficient for its intended future use, while also carefully conserving as much of the original material as possible.

Figure 18: The Evening Star mine site, 2014.

The initial condition assessment and treatment recommendation report also outlined recommended repairs at the Evening Star mine; time and budget constraints, along with priorities established by the Preserve prevented completion of that work during this phase. Implementation of repair work at the mine itself should be considered the highest priority for the next phase of the project, and the projected costs of that work are detailed in Appendix A of this report. In the mine structure, tall columns that support the sheave above the head frame are decayed at their connections with several other timbers. One column has failed and the other is approaching failure (see Figure 19); their collapse will result in the loss of the sheave assembly.

Figure 19: One of the columns supporting the sheave at the top of the structure has failed.

The best option for repair is the splicing of new wood into the columns several feet above the top of the ore bin. This will require scaffolding the head frame, 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 row of columns in the tallest part of the structure is supported by a sill at ground level which is now nearly entirely decayed (see Figure 20). The internal decay voids are hidden from view, however, making resistance drilling the only recourse to determining the full extent of deterioration. At present, the sill is providing no support for the four columns and the braces that terminate there, and must be replaced. Because a substantial portion of the replacement will be below grade and at a heightened risk for decay, stewards can consider treatment of the replacement sill with a borates-based wood preservative.

Figure 20: The interior of this sill has decayed, and leaves it providing little to no support for the columns and braces above.

A 12x12 column in the head frame assembly is decayed where the bottom of the column is embedded in a concrete pier (see Figure 21). Settlement of the column has been slowed by a sistered timber bearing on the concrete.

- Repair of the primary column will require removal of damage and scarfing of new wood at its base, including partial demolition and subsequent 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 embedded in concrete.
- The 8 x 8 sister will reliably augment the larger column and prevent its subsidence provided that connections between the two members adequately transfer load from one column to the other, which will be accomplished through the installation of several through-bolts.

Figure 21: The base of the larger (12x12) column is decayed where it is embedded in the concrete pier. The diagonal brace terminating in the pier is deteriorated around its connection and has lost most or all of its original capacity.

A diagonal brace terminating against the same pier is fastened with a drift pin to a decayed tie beam beneath it (see Figure 21). The condition of the wood around the pin is such that the connection has lost most or all of its original capacity. Options for treatment include in-kind replacement of the tie-beam (which is already in two segments, one of which could be left in place), or setting the end of the brace in a steel support anchored to the pier.

Figure 22: Steel plate clamps installed on columns will result in decay of the columns.

Steel plate clamps are a recent addition to many of the historic timber members, presumably to control checking of the wood (see Figure 22). Since drying checks seldom result in a reduction in capacity, the clamps are unnecessary, and instead contribute to the decay of the columns. Removal of the clamps is recommended, and an inspection of the underlying timbers conducted.

Figure 23: An 8x8 girt on the north side of the structure is partially detached and is at risk for falling (far left).

An 8 x 8 girt on the north side of the structure at the second level is supported on a single bolt through a plate timber on the west side (see Figure 23). This girt was originally supported on columns at either end, and provided support for 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) to provide support for the girt and plate timbers.
- 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, and the girt reattached at either end with bolts and structural washers.

MAINTENANCE, INSPECTIONS AND WOOD TREATMENT

At the Live Oak mine, timber structures should be inspected annually following in the spring, and after heavy rains or flood conditions. Inspectors should be particularly alert to undermining of the sills under the ore bin subframe or the trestle bents, and movement of trestle members due to subsidence. All of the sills, including replacements, must be regularly checked for adequate drainage and cleared of debris.

Most of the timber used in the construction of the mine structure is large dimension material, so that section losses due to decay are unlikely to significantly affect capacity in the short term. Inspectors should watch for signs of decay at or near grade, and where contact between two or more members inhibits drying after a rain. A sharp pick (like an icepick or awl) will help to probe areas with incipient decay. As has been noted, minimally damaged wood has been left in place, particularly and road level; the presence of decayed areas in some of the historic members does not necessarily indicate an approaching collapse. Inspectors should be alert to settlements and other changes in the structure that might indicate the development of new areas of deterioration.

Weathering is typically not a significant factor in the failure of wood components and the collapse of structures; significant damage is more often due to wood decay or wood-boring insects. However, severe weathering can reduce the capacity of bolted connections on braces and other members that are relatively small in cross section; loss of relish at these connections allow for settlements and rotations that result in additional structural stresses.

Because those members of the structure in contact with the ground are more prone to decay and deterioration, it is recommended that sills and column bottoms be treated with a borate preservative. In exposed conditions, it is typically recommended to install borate rods in the members, as opposed to applying topical preservatives that are re-dissolved and washed away when exposed to repeated wet / dry cycles.

SOURCES

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

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.

ICOMOS. (1999). *Principles for the Preservation of Historic Timber Structures.* Adopted by ICOMOS at the 12th General Assembly, in Mexico, October 1999.

ISCARSAH. (2003). *ICOMOS Charter - Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage.* Ratified by the ICOMOS 14th General Assembly, in Vicoria Falls, Zimbabwe, October 2003.

Western Wood Products Association. (2004). *Standard Grading Rules for Western Lumber*. Portland, Oregon.

Jaramillo, George S. (2012). "A Determination of Eligibility for the Bronze-Live Oak Mining Camp, Mojave National Preserve, San Bernardino County, California." Government Report. National Park Service. P. 3.

Porter, et al. (2014). *Condition Assessment and Treatment Recommendations: Live Oak and Evening Star Mines, Mojave National Preserve, San Bernardino County, California*. Government Report. National Park Service.

APPENDIX A: COST ANALYSIS FOR FUTURE REPAIR WORK AT EVENING STAR

Evening Star Repair Budget

Timber frame labor	
Sheave columns	$4,800
Sill replacement	$2,400
Column–column bolts	$800
8x8 kickers	$3,200
Girt repair	$1,600
Plate clamps	$800
Mob / demob	$6,400
Subtotal	**$20,000**
Travel	
Air (4- round trips @ $800)	$3,200
Local (truck, fuel)	$1,000
M&IE (camping expenses)	$2,000
Housing	n/a
Subtotal	**$6,200**
Supplies	
Timber (previous purchase)	n/a
Hardware	n/a
Shipping	$1,200
Printing	$400
Rigging	$1,000
Drilling supplies	$600
Subtotal	**$3,200**
Contract services	
Helicopter	$12,000
Scaffolding	$15,000
Subtotal	**$27,000**
SUBTOTAL	$56,400
University indirect (17.5%)	$9,870
TOTAL	**$66,270**

APPENDIX B:

ANNOTATED IMAGES OF REPAIR WORK

Figure 24: The Live Oak mine structure in 2014, prior to repair work. View from the southwest.

Figure 25: View from the southeast, 2014.

Figure 26: Rotation and subsidence in the ore bin had caused the tallest bent in the trestle, bent 1, to buckle at its intermediary sill.

Figure 27: Setting up structural staging and cribbing in front of the ore bin. This framework supported the structure during repair work and provided access to different parts of the structure.

Figure 28: Structural staging and cribbing was also installed between the ore bin and bent 1 and bents 1 and 2.

Figure 29: A view of the cribbing supporting the trestle roadway during repair work.

Figure 30: A temporary ledger was installed on the south side of the ore bin. Posts were set against the ledger and raised using screw jacks, lifting the south side of the ore bin. This allowed for repair work to the ore bin subframe and corrected the bin's out of plumb condition.

Figure 13: Using screw jacks to correct the alignment of the ore bin.

Figure 32: The eastern half of the subframe's cap beam was damaged and replaced in kind. The members strengthening the joint between the two cap beam halves were also replaced in kind (both sides of the beam). Here, holes are drilled into the replacement members so hardware can be reinstalled.

Figure 33: Hardware is installed through the cap beam and the brace on the far side.

Figure 34: Hardware for the repairs was a combination of existing pieces and custom-made reproductions

Figure 35: After the ore bin was repositioned, the long timber braces at the southeast and southwest corners were reset.

Figure 36: the bottoms of the braces had decayed from prolonged contact with the ground. Decayed portions were removed and the ends were reset in stone.

Figure 37: The ore bin subframe sill was largely lost to decay, and was replaced in kind. Here, remnants of the sill are removed.

Figure 38: Digging out the remains of the subframe sill.

Figure 39: Two small concrete footers were uncovered during the removal of the decayed sill, and may have been used to provide additional support to the sill. The footers were left in place. See Appendix B, sheet XXX for approximate locations of the footers.

Figure 40: A dry stacked stone foundation was constructed under the subframe prior to the installation of the replacement sill. The stone will facilitate drainage and help to slow deterioration.

Figure 41: Installing the replacement sill. The replacement was moved into position under the subframe using a dimensional lumber roadway and ABS plastic pipe rollers,.

Figure 42: Positioning the replacement sill under the subframe.

Figure 43: The two westernmost posts in the subframe were badly decayed and had lost significant portions of their length. The posts were replaced in kind after installation of the new sill. Here, the second post from the west is moved into position.

Figure 44: The three eastern posts in the subframe did not require repair and were reinstalled.

Figure 45: The center post was decayed at its bottom. The decayed material was removed and new wood was scarfed into the bottom of the post. A smaller post, just visible to the right of the scarfed repair, was installed to help support the end of the east half of the cap beam. This work was completed during the second repair visit.

Figure 46: The two eastern hopper girders in the ore bin were decayed along their lengths and were replaced in kind.

Figure 47: All four of the braces connecting the hopper girders to the subframe were in poor condition and were replaced in kind.

Figure 48: Much of the smaller diagonal bracing (at front) in the subframe was also decayed or damaged. Members were either reattached or replaced in kind.

Figure 49: Subsidence and rotation in the ore bin had caused bent 1 to buckle. Structural staging and cribbing stabilized it so repair work could be completed.

Figure 50: Staging provided access to both sides of the bent and to the intermediary sill located halfway up the structure.

Figure 51: After the bent was stabilized, the intermediary sill could be removed.

Figure 52: A new sill was cut using the old timber as a template and set on top of the lower posts.

Figure 53: The upper posts were moved into position on top of the replacement sill, correcting the buckle in the bent.

Figure 144 Once the replacement intermediary sill was installed, braces could be reset or replaced when damaged.

Figure 55: Three diagonal braces and all of the vertical braces connecting the cap beam and the upper posts and the intermediary sill and the lower posts were damaged and were replaced in kind.

Figure 56: Taking down structural staging at the completion of work on bent 1 during the first repair visit.

Figure 57: During the second repair visit, the sill for bent 1, which had been largely lost to decay, was replaced in kind.

Figure 58: Diagonal and longitudinal bracing in the trestle provide stability in this portion of the mine structure. Many of the braces had partially or completely detached, and were damaged or decayed at their ends. Those braces that could not be securely reattached were replaced in kind.

Figure 59: Attaching a replacement diagonal brace between bent 3 and the stringers above. Bracing was attached using corrosion-resistant structural screws.

Figure 60: Replacement diagonal and longitudinal bracing installed between bents.

Figure 61: The sills at bents 3 and 4 had been largely lost to decay due to prolonged debris build-up

Figure 62: New wood was scarfed into the columns of bents 3 and 4 and their sills were replaced in kind. Spacers were placed between the repairs in the dimensional lumber posts and through-bolted. See Appendix B, sheet XXX for details of the repairs.

Figure 63: The lower set of cross bracing in bent 3 was decayed and was also replaced in kind.

Figure 64: The ore chute, removed at the beginning of the repair work, was reinstalled during the second repair visit. The team was able to reuse several of the existing members to rebuild the base of the chute.

Figure 65: The reinstated ore chute viewed from the northwest.

Figure 66: Once the repairs were completed, the hardware at the mouth of the ore bin, including a movable chute and lever, was reinstalled.

Figure 67: The remoteness of the site and the difficulty of the terrain necessitated the use of a helicopter to transport bulky equipment, timber, and supplies.

Figure 68: The Live Oak mine structure after completion of repair work