

# Tech Notes

NATIONAL PARK SERVICE  
U.S. DEPARTMENT OF THE INTERIOR  
WASHINGTON, D.C.



## LAMAR BARN Yellowstone National Park Wyoming

In the 1930s, Yellowstone National Park set out to revive the wild buffalo herd. To meet this important goal, the park set up a buffalo ranch on the northern edge of the Lamar Valley. The project saved the buffalo, but all that remains of the Lamar Buffalo Ranch are two residences, a bunkhouse (home of the Yellowstone Institute), and a horse barn.

Built in 1936, the horse barn is like thousands of other log structures constructed in the rustic style between the late teens and World War II. The two-story barn is made of Lodgepole Pine logs, daubed with mortar on the outside, chinked with wood on the inside, and set on a stone and concrete foundation. Typical of this type of building, the intersecting log wall crowns extend 12" to 28" from the corners of the building. The log rafters and purlins originally extended about 8" beyond the roof eaves and rakes, but were cut back years ago. Magnificent in its massive scale and bulky appearance, this simple barn presented a major preservation problem because of its distinctive design.

### Problem

An inspection of the Lamar Barn revealed few surprises. Wood protected by the roof was in good condition;

portions of the logs directly exposed to the weather were deteriorated. The culprit in every case was moisture. It was easy to predict where to find the greatest pockets of decay. Log crowns extending beyond the drip edge of the roof were in the worst condition. Sill logs, particularly on the north side of the building, were also badly deteriorated. The amount and depth of decay in both instances followed a pattern: the further out from the roof they extended, the greater the deterioration (*see figure 1*).

After about sixty years, decay had taken its toll. More than half of the extending crowns were so rotten that it was possible to pull large chunks of the heartwood out of the exposed ends. In some cases, the log crowns were almost totally gone. In others, the shells of the crowns had given way and the soft mulch-like interior had fallen out. In the most severe cases, the decay had penetrated beyond the notch where the logs intersected and had traveled into the log as much as ten to twelve inches. This impacted both the visual and the structural integrity of the walls and their appearance.

### Options for Repair

There are only a few ways to treat this type of deterioration: 1) replace the deteriorated logs; 2) stabilize or repair

## EXTERIOR WOODWORK NUMBER 3

### Log Crown Repair and Selective Replacement Using Epoxy and Fiberglass Reinforcing Rebars

**Harrison Goodall**  
Conservation Services

*Logs should be repaired rather than replaced in log structures whenever possible to preserve the historic structure's integrity and character.*



Figure 1. Typical deterioration of log crowns is seen at the Institute Building, adjacent to the Lamar Barn. This is the condition of many of the log crowns at the Lamar Barn prior to the repair and replacement work. Logs are notched at the corners. Photo: Harrison Goodall.

the deteriorated portion of the crowns; 3) remove the deteriorated crowns and splice on replacement crowns; or 4) saw off the deteriorated portion and leave as is.

In the past, the most expedient treatment was chosen. In an attempt to stop the rot, the decayed rafters and purlins were simply sawed off. It did not work. Unfortunately, this is the most frequently chosen treatment in such situations. The greatest problem with this technique is that it irreparably alters the architectural character of this type of building, which derives much of its appearance from these extending roof and corner elements. Their removal flattens the surface and dilutes the rustic qualities of the barn. For this reason, Option #4 was immediately rejected.

Option #1, replacement, was not a viable choice either. More than half of the logs in the building were deteriorated to some degree. Such extensive replacement would have raised serious questions about the physical integrity of the historic building. Intervention on this scale would also have created other problems. It would have required dismantling many features connected to the exterior log walls. These included interior stalls and walls, windows, doors, frames and jambs. The exterior appearance of the building afterwards, and the notching in particular, would have looked entirely different because it would not have been possible to obtain logs with

minimal taper like the original logs. Finally, replacing most of the logs in the building would have been costly as well as harmful to the historic character of the barn.

Option #2, patching, was also rejected. Repairing or patching decay in wood is possible only when there is enough sound wood on which to bond repair material. A good case in point is when the shell of a log is still intact. The decayed wood can be stabilized with an epoxy consolidant and filled with an epoxy patch material to make the repair. In the Lamar Barn, however, there was not enough sound wood for an epoxy patch in the extending crowns.

Option #3 involved cutting off the deteriorated log crowns at the area of greatest decay (the intersecting notches), and splicing on replacement crowns of the same size, configuration, and texture. This approach had several advantages:

- Only the deteriorated portions of the wall logs would be replaced, thus preserving sound historic material.
- There would be little disruption to the building because it would not be necessary to spread logs to withdraw or insert full replacement logs.
- The replacement crowns could be replaced when necessary (10-30 years), without further loss of material.

- Moisture would be prevented from migrating into the historic logs by incorporating a small gap into the replacement crowns.
- The replacement crowns could be blended visually into the existing wall surfaces, as the historic structure had been previously stained.
- The crown replacement system would be cheaper than extensive log replacement.

For these reasons, Option #3 was chosen over the other alternatives.

The treatment selected for the log crowns was to splice replacement sections onto sound portions of the wall logs. Additionally, one totally deteriorated sill log required replacement, a few wall logs needed facing, and some decay in checks or horizontal cracks required consolidation with a flexible epoxy. The rafters and purlins, previously cut back, were left untouched.

## Preparing for the Replacement Crowns

Each of the deteriorated log crowns was carefully photographed and documented. Diameter, length from the wall and surface configuration of the cut end of the log were recorded. Then the crowns were cut off, at an angle towards the notch (*see figure 2*). Next, the original logs were drilled back to the center line of the intersecting walls, using a plumber's bit (*see figure 3*). This gave a flat surface to begin the new crowns. The recessing with a flat surface to the center line of the wall was more difficult than first anticipated because the barn builder had anchored each log with four galvanized square spikes 8" x 3/8". These spikes had to be chiseled and sawn back to a flat surface so the new crowns could be properly anchored.

In a few cases, deterioration penetrated beyond the center line of the wall, and more material had to be cut back to reach sound wood. A rotary rasp, not unlike a king-size dental drill, was used to remove remaining decay at the center line. The sound wood surface was treated with an epoxy consolidant to encapsulate remaining soft absorbent wood, thereby retarding future decay. Where the decay had traveled into the log walls, sufficient wood was removed and the surface flattened to permit new faces to be attached to the logs (*see figure 4*). These new faces were notched to match the log surfaces removed.



Figure 2. Small chainsaws were used to cut off deteriorated log crowns. The darker portions of wood at the log ends are the soft punky deteriorated fibers. Photo: Harrison Goodall.



Figure 3. A plumber's bit was used to recess the crown back to the center line to create a flat surface for attaching the replacement crowns. Photo: Harrison Goodall.



Figure 4. In a few cases, the deterioration had penetrated beyond the center line of the log corners and portions of the wall face were removed. Photo: Harrison Goodall.

Due to a short work schedule, it was not feasible to treat the new wood with a wood preservative such as CCA (chromated copper arsenate). Such a treatment, however, would have been desirable. Pressure-treating with CCA in a salt solution would have left the wood tinted a light green, but with aging and an applied stain, it would have been unnoticeable. A surface-applied preservative was not considered, because it would not penetrate to the center of the 9"- to 12"-diameter logs. This is the area where deterioration is likely to occur first. The logs were, therefore, left untreated.

### Replacing the Log Crowns

The photographs of the deteriorated crowns were used to reconstruct the replacements. Each replacement log crown was cut and fitted until it matched the notch of the original. A wood framing not unlike cribbing was constructed at each corner to hold the replacement log crowns as they were marked, cut, and fitted in place from the bottom level up (*see figure 5*). As much as possible, checks in the wood were placed in a downward position to prevent water from collecting in the wood. As the crowns were extensions of the logs and not supported by the ground, it was necessary to provide temporary support until the replacement crowns were epoxied in place. The log crowns were not anchored until all had been stacked in place with all notching complete. They were then marked to ensure proper alignment when anchored.

The new crowns were anchored to the original logs by fiberglass reinforcing rebars (fiberglass rods that have spiral ridges to enhance bonding) embedded in epoxy bonded to the wood. Three fiberglass rebars were used for most of the connections: one long fiberglass rebar at the top of each new crown to resist the tension forces (from the weight), and two small fiberglass rebars used at the base to counteract any lateral movement. This made a three-point connection (*see sidebar*). Because buffalo sometimes rub against the building corners, an additional top tension rebar was used on the lower crowns.

The three materials making up the connection were the fiberglass rebars, the structural grade epoxy, and the pine wood of both the original wall logs and the new replacement crowns. The tensile strength of the fiberglass rebar is 80,000 psi (pounds per square inch), with the bonding shear strength



**Figure 5.** A framework or cribbing held the replacement crowns as they were fabricated. All the crowns had to be temporarily put in place to ensure a proper fit. Once stacked up, they were numbered to make sure they would be properly aligned at the time of anchorage.

Photo: Harrison Goodall.

of the rebar at 60,000 psi. The shear strength of the epoxy is 3000 psi; thus all the new synthetic materials are substantially higher in shear strength than the pine, which has a shear strength of only 60 to 90 psi. The wood was the weakest element of the connection. Since the crowns were in effect to be cantilevered from the main wall section, it was necessary to calculate the diameter and length of the reinforcing fiberglass rebars necessary to hold the ends in place and to keep the wood from shearing away from the epoxy.

The reinforcing rebars were intended to counteract the natural force of gravity pulling the crowns away from the wall, due to the weight of the crown itself, from the accumulation of snow and ice, or from lateral loads. With a 12"-28" long log crown 9" to 12" in diameter, it was determined that a 1/2" diameter reinforcing rebar set 12" into sound wood of the upper section of the wall log and 12" into the attached crown was necessary to combat the combined forces of shear, bending moment and vertical loading. (The drilled holes were slightly longer and wider to accommodate the reinforcing fiberglass rebar and the epoxy.) In addition, for horizontal or lateral movement, two 1/2" diameter fiberglass rebars were imbedded 4" into the lower sections of the log walls and a matching 4" into the crowns. The length, diameter, and the place-

ment of the rebars were based on calculations intended to keep the wood fibers from shearing away from the imbedded rebars. Another situation might require different dimensions.

Thus at the Lamar Barn, a 1/2" fiberglass rebar 12" deep on either side of the connecting wood was used in the tension zone (total of 24") and located within an inch of the top of the log. Two short fiberglass rebars 4" long on each side of the connection (total of 8") were used at the bottom of each log crown for lateral strength. The holes for the rebars and epoxy were 3/8" larger than the rebars, for a total of a 7/8" hole.

## Installation

The work area was protected with tarpaulins to keep the wood dry. The wood was allowed to dry out to less than 20% moisture content before the new crowns were installed.

The holes (7/8" diameter) for the 1/2" reinforcing fiberglass rebars were drilled into the original logs. Corresponding holes were drilled into the crowns. An 8" piece of flexible tubing was stapled onto the nozzle of a caulking tube in order to reach to the back of the long drilled hole. The caulking gun was filled with a high-strength structural two-part epoxy in a paste-like consistency, which was then injected into the original log. The cavity was filled two-thirds. The paste-like consistency of the epoxy kept it from draining out of the drilled hole. The precut rebar was then inserted using a twisting motion (see figure 6). The replacement crown was also filled two-thirds with epoxy, then aligned, inserted and left to cure (see figure 7).

Working with epoxy is difficult. Setting times depend on the type of formula and the ambient temperature. Some epoxies set up in less than 15 minutes; others can be formulated to dry over a three-day period. The epoxy for this job set in less than 45 minutes, and for that reason, only small amounts were mixed at a time, and work was not undertaken in the direct sun, as this further reduced the effective working time. Curing took place in about 24 hours at temperatures between 60 to 80°F. The cribbing construction supporting the crown ends was kept in place until all the crowns were fully cured.



**Figure 6.** A flexible tube was stapled onto a caulking gun in order to fill the 12"-12 1/2" deep holes that had been drilled into the sound end of the historic log. The individual hole was filled two-thirds with epoxy adhesive and a 1/2" diameter fiberglass reinforcing rebar was then inserted.

Photo: Harrison Goodall.



Figure 7. A 12 1/2" long hole was drilled into the new crowns. This hole was filled in the same manner as were the old logs. The crown was then immediately lifted into position and supported by the cribbing framework for several days until the epoxy cured. Photo: Harrison Goodall.

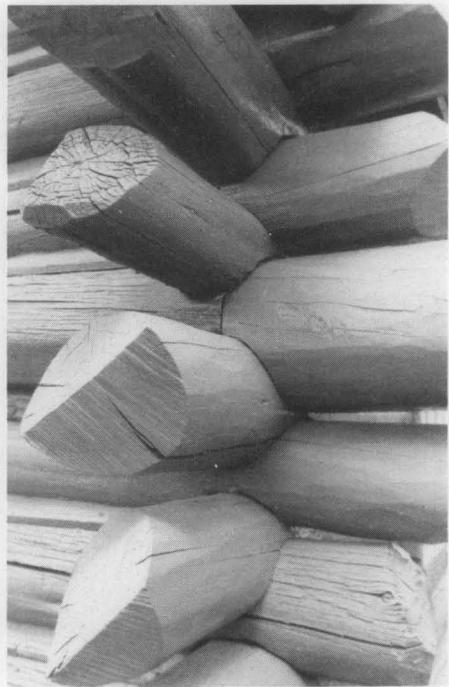


Figure 8. The joints between the historic logs and the new crowns are visible, but not disconcerting. The unsealed joint will help keep future decay isolated to the log crown. Photo: Rodd Wheaton.

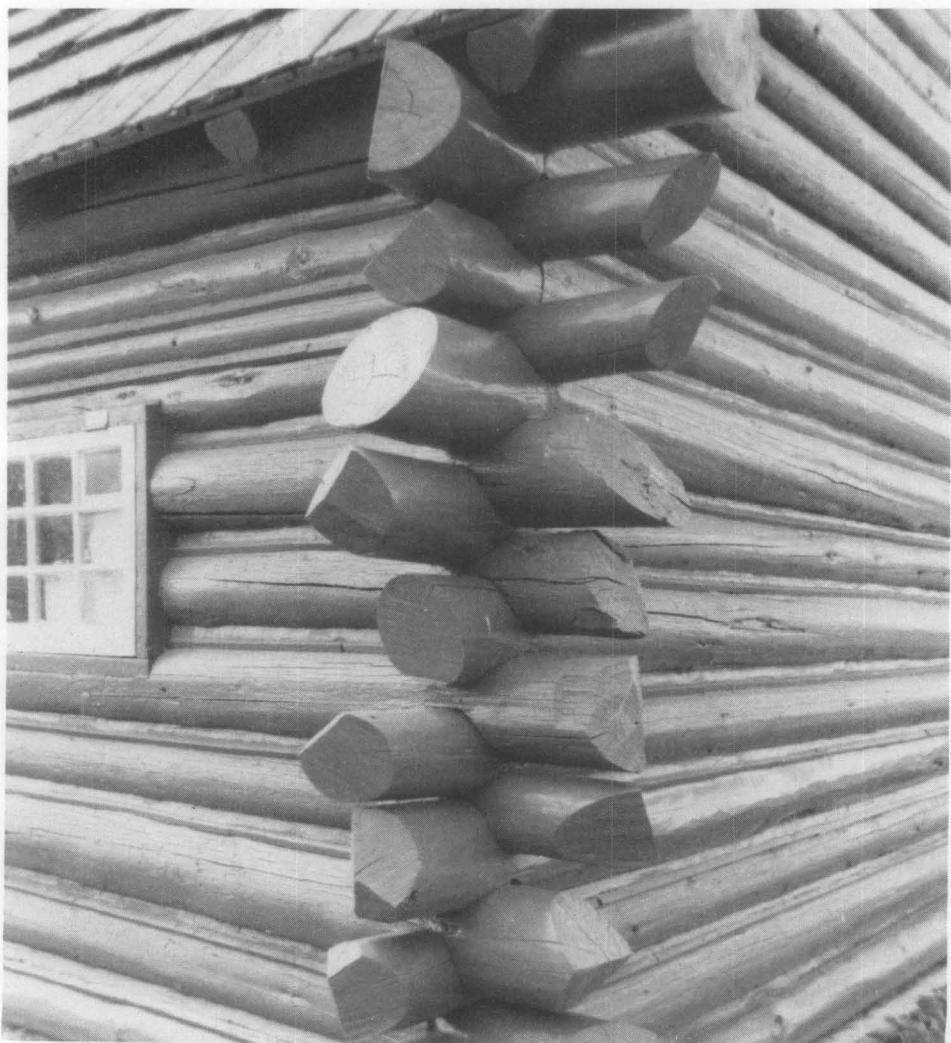


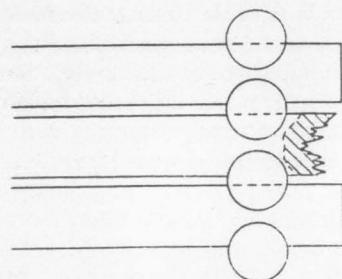
Figure 9. A repaired corner of the Lamar Barn. It is expected that the log crowns will need replacing in 10-30 years. Photo: Rodd Wheaton.

## Finishing

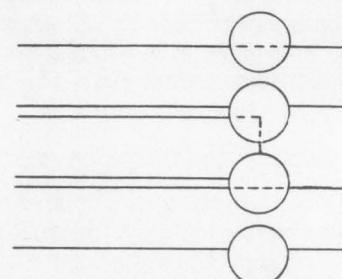
Once the epoxy cured and cribbing was removed, the log crowns were stained. A first coat of oil-based stain was used on the log crowns and eventually the entire building was stained. Had the new wood been treated with a salt-impregnated preservative solution, a full year of aging would have been required prior to staining. It is anticipated that every 3–6 years the building will need re-staining in addition to an annual coating of the new log crowns with a water repellent.

## Evaluation

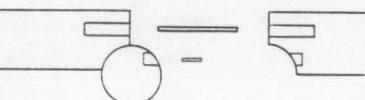
While there is a tendency to caulk the cracks in wood, it has been found that in many instances it is best to leave small checks open to let wood breathe naturally (*see figure 8*). For this reason the joints between the log crowns and the original log walls were also left open and not sealed. The new crown ends are expected to last between 10 and 30 years. The upper crowns directly under the roof runoff are likely to deteriorate first. These can be replaced as required. As with any completed preservation project, the better the routine maintenance the longer the work will last and the more cost-effective it will be in the long run (*see figure 9*).



Deteriorated log crown.



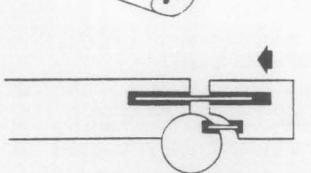
Remove deteriorated crown. Recess to the center line of the log wall. Remove all pockets of decay. Saturate the decay pockets with an epoxy consolidant.



Cut and prefit log crown replacement. Typical log crown applications require one or two 1/2" diameter fiberglass rebars embedded 12" deep in the top of the existing wall log and replacement crowns. Shorter 4" long rebars placed at the bottom of the log will make the log crown rigid by creating a 3-point support. Drill holes 1/4" to 3/8" larger than rebar to accommodate the epoxy. Maintain 1" of good wood between the hole and the edge of the log.



Fill holes with epoxy.



Assemble log crown replacement with fiberglass rebars. Support until epoxy has cured.



Completed log crown replacement.

This PRESERVATION TECH NOTE was prepared by the National Park Service. Charles E. Fisher, Preservation Assistance Division, National Park Services, serves as Technical Coordinator for the PRESERVATION TECH NOTES. Special thanks go to the following National Park Service Staff: Lee Nelson, FAIA, Sharon Park, AIA, Michael Auer, Brenda Siler, and Rodd Wheaton for their assistance with this Tech Note.

PRESERVATION TECH NOTES are designed to provide practical information on innovative techniques and practices for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures and standards. This

## PROJECT DATA:

### Building:

Lamar Barn  
Yellowstone National Park  
Wyoming

### Owner:

National Park Service  
Yellowstone National Park  
Wyoming

### Project Date:

Summer 1986

### Contractor:

Harrison Goodall  
Conservation Services  
Kinnelon, New Jersey

### Epoxy Supplier:

ConServ Epoxies  
Conservation Services  
Kinnelon, New Jersey

### Project Costs:

Total: \$39,706

Epoxy cost = \$375.00

Labor cost for log crown stabilization  
= 100 person days or approximately  
2.5 days per log crown.

### Project Included:

39 log crown replacements (wood supplied by the park)  
38 rafters stabilized  
69 lin.ft. sill log replacement  
90 lin.ft. wall log facing  
20 lin.ft. wall log epoxy stabilization  
50 lin.ft. foundation repair  
2 weeks log stabilization training

Approximately half of the contract involved log crown replacement

Tech Note was prepared pursuant to the National Historic Preservation Act Amendments of 1980, which direct the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

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