Forestry Note:

DESIGNING AND CONSTRUCTING LARGE ROCKED FORDS ON FOREST STREAMS

This Forestry Note describes design and construction techniques applicable to rocked fords on streams in the Ouachita Mountains of Oklahoma with watersheds of the general size range of 2,000 to 6,000 acres and moderate to steep topography and channel slopes.

Introduction

For road crossings on forest streams of medium size, rocked fords are an alternative to concrete slabs and bridges (Figures 1 and 2). Fords offer the advantages of lower construction cost and are comparable to or less in maintenance costs than concrete slab or bridge crossings. Where boulders of adequate size for the end wall are available on-site, construction costs are likely to be ¼ or less of the cost of a concrete ford or timber bridge. On many Ouachita Mountain watersheds, loose surface rock of suitable sizes for fill and end walls is plentiful.

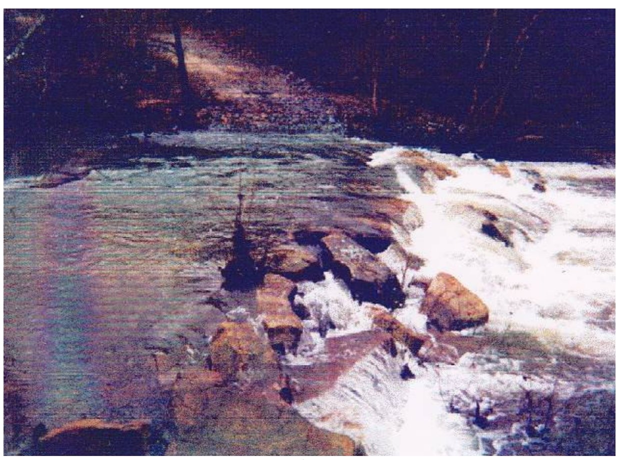

Figure 1. Typical large rocked ford

Rocked fords also have the important advantage over a concrete slab or bridge of easier and less costly reconstruction to adjust to natural changes in the channel.

Rocked fords can be designed for a wide range of stream sizes and stream channel and road conditions. This publication presents design and construction guidelines based on the construction of two fords on the Caney Mountain Trail Demonstration Road in the Ouachita Mountains in southern Pittsburg County. The fords were constructed on Clear Creek and Caney Creek, having watershed areas of approximately 3,000 and 5,500 acres respectively.

Figure 2. Vented concrete ford (slab)

Ford locations and design requirements on mountain streams of the size range represented by these demonstration examples will differ in channel type, soil and rock materials in the channel sides and bottom, channel slope and depth and velocity of high flows. The two demonstration fords differ substantially in most of these conditions. The two fords are representative of the frequently occurring conditions of (1) steep-sided, relatively deep channels and (2) relatively wide, shallow channels.

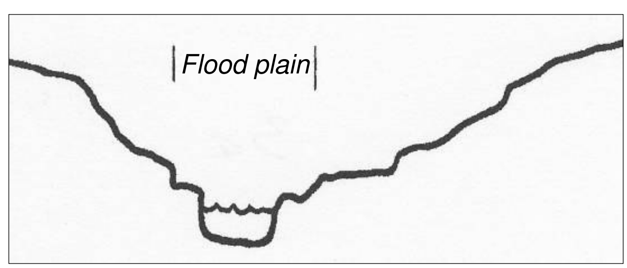

Figure 3a. Caney Creek channel profile, a steep-sided, relatively deep channel

The design and construction guidelines presented in this Forestry Note are directly applicable to the streams in the Ouachita Mountains with watersheds of the general size range of 2,000 to 6,000 acres, and moderate to steep topography and channel slopes. They are applicable to other parts of the state where the channels are rocky and lying on or near bedrock.

They also can be applied to streams or gravelly or silty channel sides and bottoms, with modifications of the end walls and apron. The principal limitations in such locations are likely to be the availability and cost of the large boulders.

Applications to streams on steep mountain watersheds larger than the recommended range would require large boulders and more care in selection of boulder shapes and placement. For mountain streams in the size range of 5,000 acres or larger, further demonstration and testing is recommended.

Design and construction guidelines for rocked fords on small mountain streams in the approximate size range of 10 to 50 acres in watershed size are presented in a separate publication, *Constructing Small Rocked Fords on Forest and Farm Roads in Oklahoma*. The three principal differences in design and construction associated with increasing stream size lie in the increasing sizes and amounts of rock needed in the end walls, in the selection and placement of boulders in the lower end wall, and increasing need for an upper end wall.

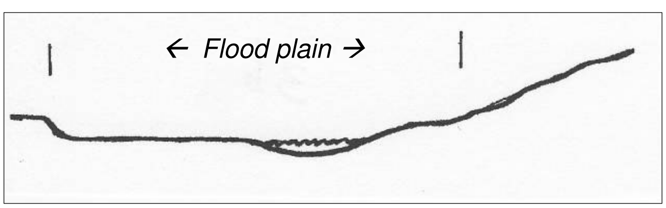

Figure 3b. Clear Creek channel profile - a relatively wide, shallow channel

Construction of the Caney Creek Ford: Deep Valley and Channel

Location

For reasons of cost, stability of the channel, and minimizing any effect of the ford on natural stream channel changes, the ford should be located in a riffle segment of the stream. Generally, locations across a pool should be avoided. The approaches to the ford should be at right angles to the channel. Considerations of road location as affected by local topography and overall system design may sometimes conflict, and less than ideal locations may be necessary. In any case, protection of the natural stream dynamics should have high priority.

The Caney Creek ford location is in a narrow, steep-sided valley with little or no flood plain (Figure 3a). The ford location is near the lower end of a riffle. The channel bottom above the ford is bedrock and large boulders. The channel is about twenty feet wide, with nearly vertical sides three to five feet in height.

Sloping the Banks

Both banks were cut down for approaches to the ford. Because of the steep slope of the valley, a short steep approach on one side was unavoidable.

Rock Fill

Normally, the end walls should be constructed before filling the channel with rock. However, the Caney Creek ford was previously constructed by building a square crib of creosoted pole timbers and filling the crib with local surface rock. An end wall of a single row of boulders was placed at the toe of the cribbed rock. The ford provided ten years of service, but the top tier of the poles and some of the fill was washed away by high water (Figure 4a).

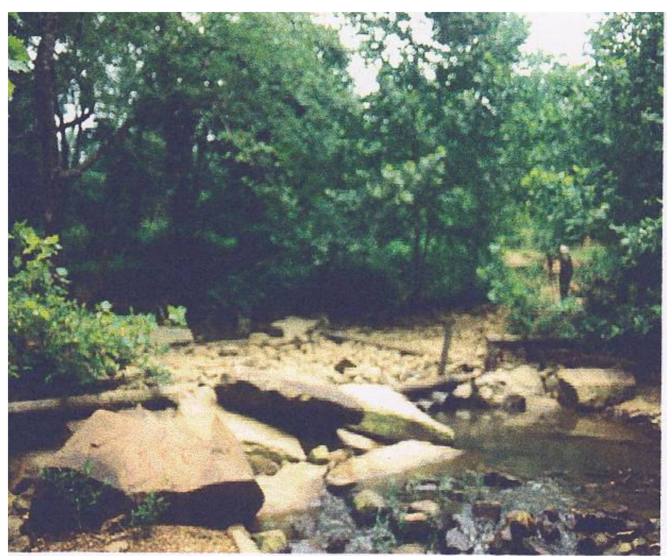

Figure 4a. Washed-out part of previous rocked ford on Caney Creek (note the pole cribbing)

To prepare for placing the end walls, the washed-out rock was pushed back into place with a dozer (Figure 4b).

Figure 4b. Dozer beginning Caney Creek ford reconstruction

End Walls

The lower end wall was constructed by placing large boulders along the toe of the rock fill. The boulders were pushed to the site by dozer, over distances up to 300 feet. These initial boulders were placed with a log loader (Figure 5). The upper and lower end walls were completed by pushing boulders in place with the dozer (Figure 6).

Figure 5. Log loader places boulders in Caney Creek ford end wall

Boulder sizes and shapes and how they are placed are major factors in end wall stability during high flows. The needed boulder sizes and stability are governed by the ability of high water to move boulders downstream. This ability is determined by flow depth and velocity, which in turn are determined mainly by the size and steepness of the watershed and width and slope of the channel.

Figure 6. Dozer pushing and placing boulders on Caney Creek ford end wall

Place boulders with generally square or round shapes in the bottom layer of the wall. Elongated boulders are needed to form the top layer (or layers) of the wall. They should be placed lengthwise, parallel to the stream flow. The long boulders should be tilted downwards in the upstream direction and extending partly under the layer above (Figure 7).

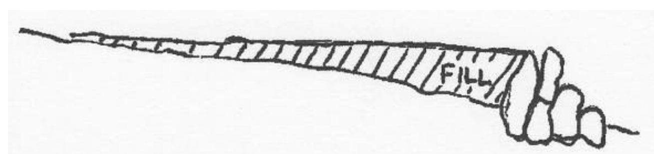

Figure 7. Typical boulder placement on lower end wall

For end walls of fords in this stream size range, the boulders should be at least two feet in average diameter, or eight feet at the smallest circumference. Examine the channel above and below the crossing as a guide to the size of boulders needed. Engineering formulas and tables for rip-rap sizes for rock-lined open channels may be helpful in determining the boulder sizes needed. However, such information is based on assumptions of uniform channel conditions. Ouachita Mountain streams vary greatly along the channel in cross-section, slope and necessary roughness coefficient. The stream flow energy for moving boulders therefore varies substantially in short distances and at different depths of flow. As noted, shape and placement of boulders will affect stability. Local observations and additional demonstrations and testing are needed.

In general, smaller streams will allow the use of smaller boulders. In demonstration fords described in a companion Forestry Note, *Constructing Small Rocked Fords on Forest and Farm Roads in Oklahoma*, boulders 12 to 18 inches in average diameter were found to be adequate for fords constructed on steep watersheds up to 40 acres in size.

Where feasible, the ford surface should be at the same elevation as the channel bottom. However, in a deep channel, the ford surface may need to be elevated with a fill of rock in order to reduce the slopes of the approaches.

Surfacing

Both approaches were surfaced with crusher-run rock of 8 inches maximum diameter (Figure 8a). A surface of gravel was then placed on the steep approach to increase traction. Additional rock was placed on the ford roadway to provide a solid bottom (Figure 8b).

Figures 8a (above) and 8b (below). Rock surfacing of steep approach to the Caney Creek ford

Figures 9a and 9b show the completed ford.

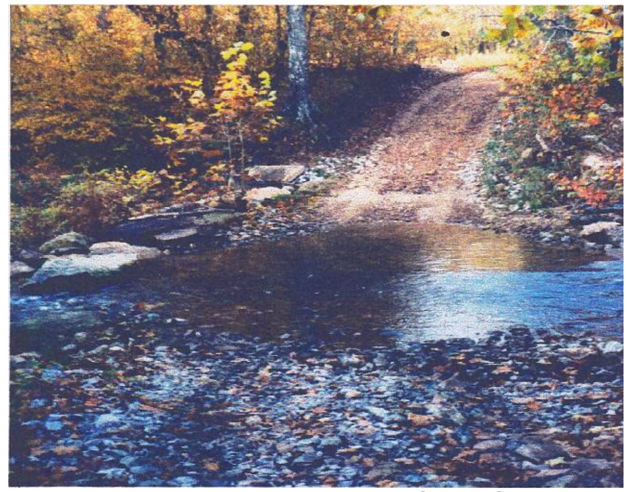

Figure 9a. North approach to completed Caney Creek ford with rock and gravel surface

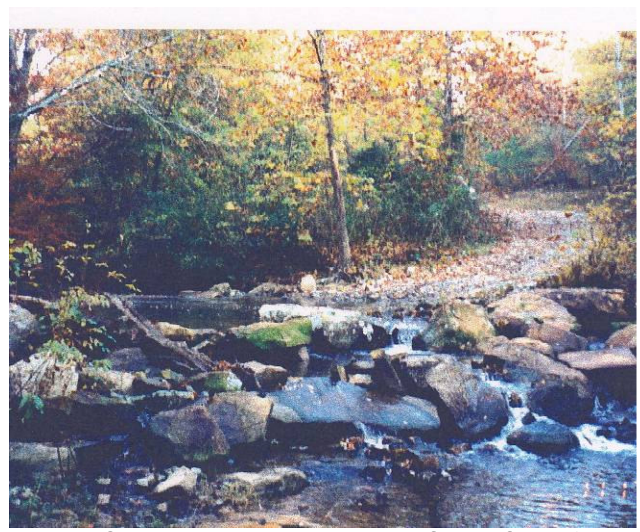

Figure 9b. South approach to completed Caney Creek ford showing the lower end wall downstream from the roadway

Design and Construction of the Clear Creek Ford: Shallow Channel Site

Location

The location of the ford on Clear Creek is controlled by the local topography and the Buck Creek and Clear Creek stream channel locations. The location is less than ideal, being on a shallow channel that may change over time. It is also located at a point where the flood plain narrows, causing increased velocities and turbulence during high flows. However, the ford was very low in cost and has no appreciable effect on the natural flow through the riffle.

The two ford locations differ in potential for natural shifting of the channels. The valley of Caney Creek at the ford location is narrow and steep-sided with little or no flood plain. The ford is located at the lower end of a long riffle with bedrock bottom and lined on the sides with large boulders. The Clear Creek valley at the ford location is wide and shallow with the channel bottom and sides composed of soil, gravel and rock of cobble size that can be easily moved by high flows. The channel can be expected to change in lateral location and depth, possibly requiring some ford reconstruction within the next 50 years.

Sloping the Banks

Because of the wide valley and shallow channel at the ford location, only minor bank sloping was needed (Figure 10). The west approach is 75 feet in length with a slope of 9 percent. The east approach from the channel to the elevation of the flood plain is 102 feet in length and five percent in slope.

Figure 10. Clear Creek ford prior to construction

End Walls

The location is near the lower end of a riffle of about 300 feet in length. The channel lies on a bed of rock ranging from small gravel to cobble in size, several feet in depth. The lower end wall was constructed by first excavating the bed material to allow placement of the boulders so that the top of the end wall was elevated approximately 8 inches above the original channel surface. The initial completed wall consisted of a single line of boulders. Boulders flat in shape were selected in order to minimize depth of excavation.

Rock Fill

A pool had formed in the original crossing. The pool recently increased in depth and width because of log truck traffic. Before the center boulders were placed, rock from the channel below was pushed by dozer to fill the pool and form the roadway.

The initial design did not include an upper end wall. Because considerable shifting of the rock in the roadway surface occurred during high flows following the initial construction, an upper end wall was added (Figure 11). Additional flat boulders were also added below the initial lower end wall. The completed ford is shown in Figure 12.

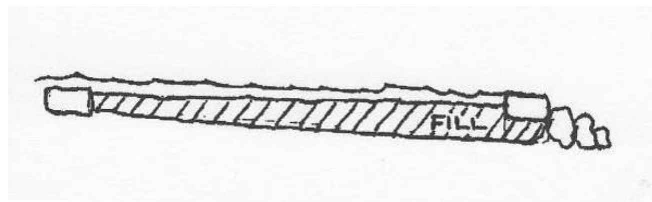

Figure 11. Design of a shallow channel ford with upper end wall

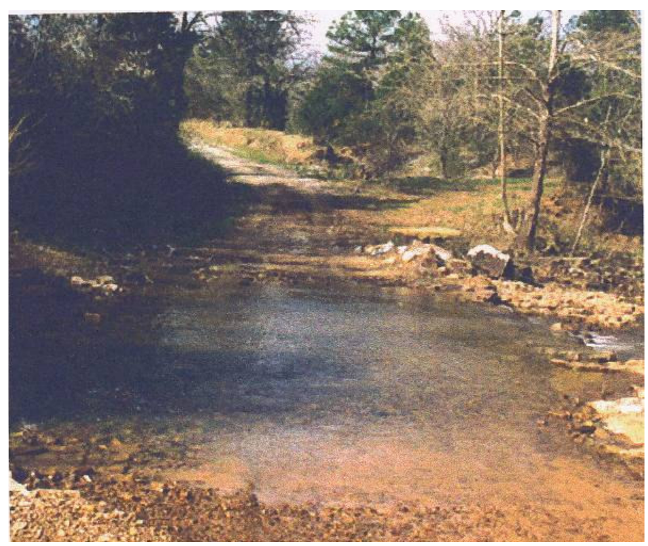

Figure 12. Completed Clear Creek ford with upper and lower end walls (looking toward the south approach)

Ford Construction Costs

Construction inputs and cost estimates are presented in Table 1. The per-unit cost rates of machine and materials are estimated as typical contractor rates for individual landowners, for mountain locations. They do not represent actual costs of construction, which was carried out with crews and equipment provided by Forestry Services, by a logger on the site and forest industry.

The total estimated construction costs were $2,090 for the Caney Creek ford and $595 for the Clear Creek ford. These totals include the costs of rock and gravel surfacing of the approaches, consisting of $850 for the Caney Creek ford and $355 for the Clear Creek ford. These surfacing costs would be incurred for any of the alternatives in crossing types. The total construction costs minus the approach surfacing costs, or $1,115 for the Caney Creek ford and $240 for the Clear Creek ford, should be used in comparing these costs to the construction costs of alternate types of crossings. In this connection also, constructing the approach is part of road subgrade construction and need not be included in making alternative crossing cost comparisons.

The differences between the two locations in rock and gravel per unit cost estimates are due to the additional 1.25 miles of rough mountain road for delivery of rock and gravel to the Caney Creek site from the crusher. Location of a gravel source near a crossing site may reduce gravel costs considerably.

Table 1. Estimated Construction Costs on Caney Creek and Clear Creek Fords (at time of installation in 1998)

		Estimated Costs ($)	
Input	*Total Inputs*	*Per Unit*	*Total*
Caney Creek Ford			
Dozer	7 hours	$50	$350
Log Loader	2.5 hours	40	100
Local Rock	25 tons	12	300
Crusher-run Rock	70 tons	17	1,190
Gravel	10 tons	15	150
		Total Cost	**$2,090**
Clear Creek Ford			
Dozer	3.5 hours	$50	$175
Local Rock	15 tons	12	180
Gravel	20 tons	12	240
		Total Cost	**$595**

The only labor inputs occurred in constructing the initial crossing on Caney Creek, as described above. These costs are included in the estimated cost rate for local rock.

Since rock and gravel make up most of the costs of a rocked ford, landowners may be able to reduce total costs considerably by using their own equipment, hiring labor and finding sources of rock and gravel near crossing locations.

It should be noted that the costs of installing concrete slab fords or concrete box bridges in large timber company operations would be substantially lower, because of the efficiency gained from the experience of many installations, and much-reduced materials hauling costs because of the relatively high standard of company roads.

Maintenance Costs

Following completion of the two fords, two exceptionally high storm flows occurred, with maximum depths of about 12 feet at the Caney Creek crossing and 10 feet at the Clear Creek crossing.

Some shifting of three of the boulders in the Caney Creek end wall occurred. To minimize further shifting, as many as four additional boulders are needed, with tilting and wedging placement as described in Figure 7. There was no loss of roadway surface rock other than in the area where the boulders shifted.

At the Clear Creek crossing, some washing of the roadway surface occurred because of turbulent flow around a small sycamore tree growing on a high point at the west edge of the channel (Figure 12). To correct this situation, the tree should be removed and the upper end wall extended about ten feet. Following these repairs, very little maintenance needs are expected.

Summary

Large rocked fords offer a cost-effective, low-maintenance alternative to expensive concrete slabs and bridges on heavily used forest roads in moderate size watersheds in the Ouachita Mountains of Oklahoma. They are most feasible where large surface boulders and loose rock are found close to the crossing location, and where the landowner has equipment and hand labor readily available to facilitate construction. Following the guidelines in this Forestry Note, landowners should be able to construct a stable, “all-weather” crossing that will last for many years with minimal maintenance at comparatively little out-of-pocket expense.

Acknowledgements

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Other Information Sources

This Forestry Note is one in a series on stream crossings and forest road Best Management Practices (BMPs) produced by the Oklahoma Department of Agriculture, Food, & Forestry - Forestry Services Division. Other Forestry Notes include:

- Introduction to Road Stream Crossings
- How to Install a Forest Road Culvert
- Constructing Small Rocked Fords on Forest and Farm Roads in Oklahoma
- A Handy Gauge for Forest and Farm Road Construction Measurements

Additional information on this and other forest road BMPs is available in videos produced by Forestry Services and in the OSU Extension handbook *Best Management Practices for Forest Road Construction and Harvesting Operations in Oklahoma* and a publication by the USDA Natural Resources Conservation Service, *Woods Roads*. These materials may be available at local offices of Forestry Services, the OSU Cooperative Extension Service and the Conservation Districts.

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