Case Study 19. Mill Creek Embedded Box Culvert Vented Ford

Location

Southeast Missouri. Mark Twain National Forest; Houston-Rolla Ranger District. Southeast of Rolla, south of Interstate 44, off of State Road P: Forest Road 1576. Mill Creek, tributary of Little Piney Cr, Gasconade River basin.

Crossing Description

The current structure was built in 1994 in a State-designated wild trout management area. Traffic access is required year-round for private residences and recreation; fish passage is also required. The structure is a set of three box culverts that overtops at least once per year on average. The boxes are embedded about 1 foot so that the natural streambed is continuous through the structure (figure A121). The supports slope up toward the deck to facilitate large debris riding over the structure rather than damming it during overtopping flows.

Figure A121. Looking upstream at Mill Creek box culvert vented ford, 2002.

Setting

Ozark Highlands Section (222-A). Gasconade River Hills. Soils are rocky and thin over carbonate and sandstone bedrock and large springs are characteristic of the karst geology (Draft Descriptions of Missouri Ecological Subsections, USDA Forest Service Mark Twain National Forest, 1999). Elevation is 748 feet. Mill Creek flows through a long, gently sloping valley generally around ¼-mile wide. Vegetation is mostly grass and riparian hardwood forest. The valley is bordered by rounded, forested ridges about 150 feet high.

Appendix A—Case Study 19

Why Was This Structure Selected?

This structure was selected because it:

- Allows passage of fish, other aquatic organisms, and large woody debris.
- Is less likely than the previous structure to be damaged by large woody debris and therefore has reduced maintenance costs.
- Was less expensive to build than a bridge.
- Provides greater public safety and fewer traffic interruptions than previous structures, due to fewer overtopped days.

Crossing Site History

Most road crossings in this area are vented or unvented concrete slab fords, which are inexpensive and easy to replace. The original crossing structure at the Mill Creek site, a slab, was replaced in 1976 with a low-water bridge, probably in response to fisheries concerns. However, the bridge was very low and its piers were closely spaced. It trapped woody debris, and not only was debris removal required after every large storm, but the piers scoured and erosion occurred around the ends.

Road Management Objectives

This road accesses recreation facilities, grazing allotments, and private residences. It is gravel-surfaced road managed for passenger cars (maintenance level 3). During hunting season—the peak season—traffic is approximately 100 vehicles per day. Traffic interruptions are undesirable; an alternative access route exists, but it is less convenient and may be impassable during high water flood events.

Stream Environment

Hydrology: Low flow in Mill Creek is sustained by Wilkins Springs, a spring that supports Mill Creek's important cool water fishery. High flows are quite flashy in this area of thin soils and historically channelized streams (figure A122). Most of the 45 to 50 inches of precipitation in the area falls in the spring, and peak runoff usually occurs from drenching rains between March and May. Summer thunderstorms also produce flashy peaks. Drainage area above the site is approximately 37 square miles.

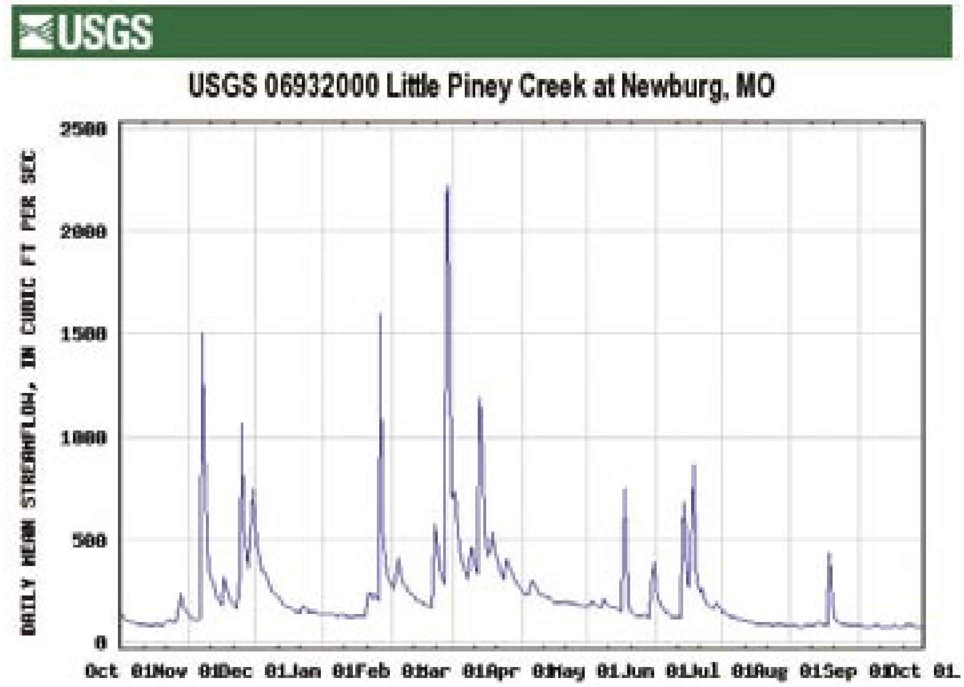

Figure A122. Little Piney Creek at Newburg. The hydrograph for water year 1997 illustrates how flashy high flows are in this area. From USGS National Water Information System Web site: http://nwis.waterdata.usgs.gov/nwis/sw. Newburg is about 3 miles north of the Mill Creek crossing site. Watershed area for the Little Piney Creek gauge is 200 square miles.

Figure A123. Looking downstream on Mill Creek from the box culvert ford.

Channel Description: This reach of Mill Creek is a pool/riffle, gravel bed stream with an estimated gradient of 2 percent. It is about 40 feet wide away from the widened section at the crossing, and banks are 2 to 3 feet high (figure A123). The well-vegetated flood plain is about 3 feet below the wooded terrace that forms the broader valley floor. The channel appears to be vertically stable, but has at least moderate potential to migrate laterally. The crossing is on a slight bend, and crosses a gravel bar on the right bank (bar is on left side of figure A121). Historical land use in this area of the Ozarks, especially riparian grazing and stream channelization, affected streams by removing riparian vegetation and inducing bank erosion. This mobilized large volumes of gravel, and streams responded by widening and shallowing (Jacobson and Primm, 1997). Bank erosion is prevalent on some reaches of Mill Creek.

Aquatic Organisms: Rainbow trout were introduced between 1880 and 1890. Mill Creek is now one of only five creeks in Missouri with a self-sustaining population, and the State of Missouri has classified Mill Creek as a wild trout management area. Passage for trout is considered important; no other aquatic organism passage needs have been identified. Fish can be seen using the structure for cover.

Water Quality: This structure protects water quality by keeping traffic out of flowing water. Also, since it passes most debris and only slightly constricts the bankfull channel, it is unlikely to cause bed or bank erosion.

Structure Details

Structure: This current structure has three boxes, with sloping wings designed to sweep debris up and over the deck. Open area under the deck approaches bankfull cross section area, but is being reduced by gravel accumulation on the right bank (foreground, figure A124). The interior openings of the boxes are 14 feet wide and 5 feet high, and they are embedded 1 foot into the streambed so that the natural streambed is continuous throughout. The design is a standard Missouri Department of Transportation design that is available on the Internet. See Concrete Triple Box Structure drawing 703.81F for sample plans (http://www.modot.org/business/standards_and_specs/currentsec700.htm).

Bank stabilization and approaches: Concrete approaches slope slightly down into the center of the structure, and have solid wing walls resting on 2-foot-wide by 1-foot-high footings. The approaches obstruct flood-plain flow, but there is very little evidence of downstream scour, perhaps because gravel loading is so high in the stream. Some riprap is used to stabilize the banks immediately adjacent to the structure (figure A124a).

Figures A124a and A124b. Downstream side of the box culvert crossing. Between 2003 and 2006, gravel bar enlarged to block one box.

Cost: $95,300 in 1994.

Safety: This crossing has curbs. It does not currently have safety signing, and the road is not closed during storm runoff.

Flood and Maintenance History

The structure overtops annually, sometimes more than once per year, but generally no maintenance is required. In May 2002, the region received 18 inches of rain in 18 days, causing the largest flood over the structure to date. Woody debris and sediment were deposited on the deck and approach slabs and had to be removed but, except for the tension cracks described below, there was no damage to either the structure or the channel. USDA Forest Service personnel generally remove large woody debris 1 or 2 times each year. Prior to the current structure, such activity occurred monthly.

The bridge inspection in 2003 found what appeared to be tension cracks in the top of the deck between the piers. For similar structures, designers should check to ensure there is enough steel reinforcement in the tension zones.

Summary and Recommendations

The structure's length approximates bankfull channel width in straight, undisturbed reaches, but the walls, curbs, and approach slabs are enough of an obstruction to flood flows that sediment deposition is altering the site somewhat. Gravel is accumulating both on the bar and on the riffle upstream. Flow constriction and the resulting accelerated water velocity have caused some bed scour in the box furthest from the gravel bar. These changes do not appear to have reduced the structure's effectiveness for aquatic organism passage, but they may impede traffic by causing more frequent overtopping. The approaches do obstruct flood-plain flows, but no scouring is apparent on the banks or the well-vegetated flood plain. In general, the structure appears to be working well in a challenging environment of flashy flows and high sediment loads.

Larry Furniss, forest fisheries biologist; Amy Sullivan, forest hydrologist; and Lori Wilson, transportation planner, on the Mark Twain National Forest provided information and photos for this case study. Scott Groenier, engineer at the USDA Forest Service Technology and Development Center in Missoula, MT supplied information about the 2003 bridge inspections, which he conducted.

Similar Structures In Other Locations

Forests in the middle part of the United States and in the southeast are increasingly using low-profile embedded box culverts as crossing structures on roads where brief traffic interruptions are tolerable. Unlike the Mill Creek structure, some are designed to overtop several times every year. The Long Creek structure (described at the end of case study 14) is an example on the Ouachita National Forest. The Kinkaid Lake low-water crossing on the Shawnee National Forest is another example.

Forest Road 772 on the Shawnee National Forest is an unimproved native surface road that accesses about 1,000 acres of hilly National Forest System land and some private land used for fall hunting. The embedded box culvert crossing is located where the road crosses Little Kinkaid Creek, a perennial tributary of Kinkaid Lake.

The previous crossing structure was a concrete slab ford (figure A125). Silty sediment and woody debris routinely accumulated on it during high water, frequently making it impassable. The slab collapsed when the stream undercut it on one side. The soil at the site has difficult engineering properties. It is a poorly-drained silt loam characterized by a seasonally high water table, frequent winter flooding, and stream bank erosion. Severe erosion of the 4-foot to 5-foot high banks around the ford is apparent in figure A125.

Figure A125. Looking upstream at failed Kinkaid Creek crossing, 2000. Stream slope is 0.3 percent.

Sustained concentrated rainfalls of several inches per day cause peak flows in this area, and peaks on Little Kinkaid Creek are very flashy. Since traffic use is low and would be interrupted only a few hours during any one runoff event, a low-water crossing was a desirable and cost-effective solution here. However, the design had to account for the unstable, erodible banks and tendency for debris and bedload plugging. The designer selected a very low-profile structure to encourage woody debris to go over the top and to avoid large changes in flow width that would put pressure on the banks at bankfull and higher flows. The structure is a set of four 5-foot-wide concrete boxes with metal-grate decking that can be removed to clear the boxes. The box walls slant out and down, as at Mill Creek, to help debris slide over the top (figures A126 and A127).

Figures A126a and A126b. Kinkaid crossing just after construction in 2001. A126a. Close up of embedded boxes; A126b. View along vented ford showing riprap.

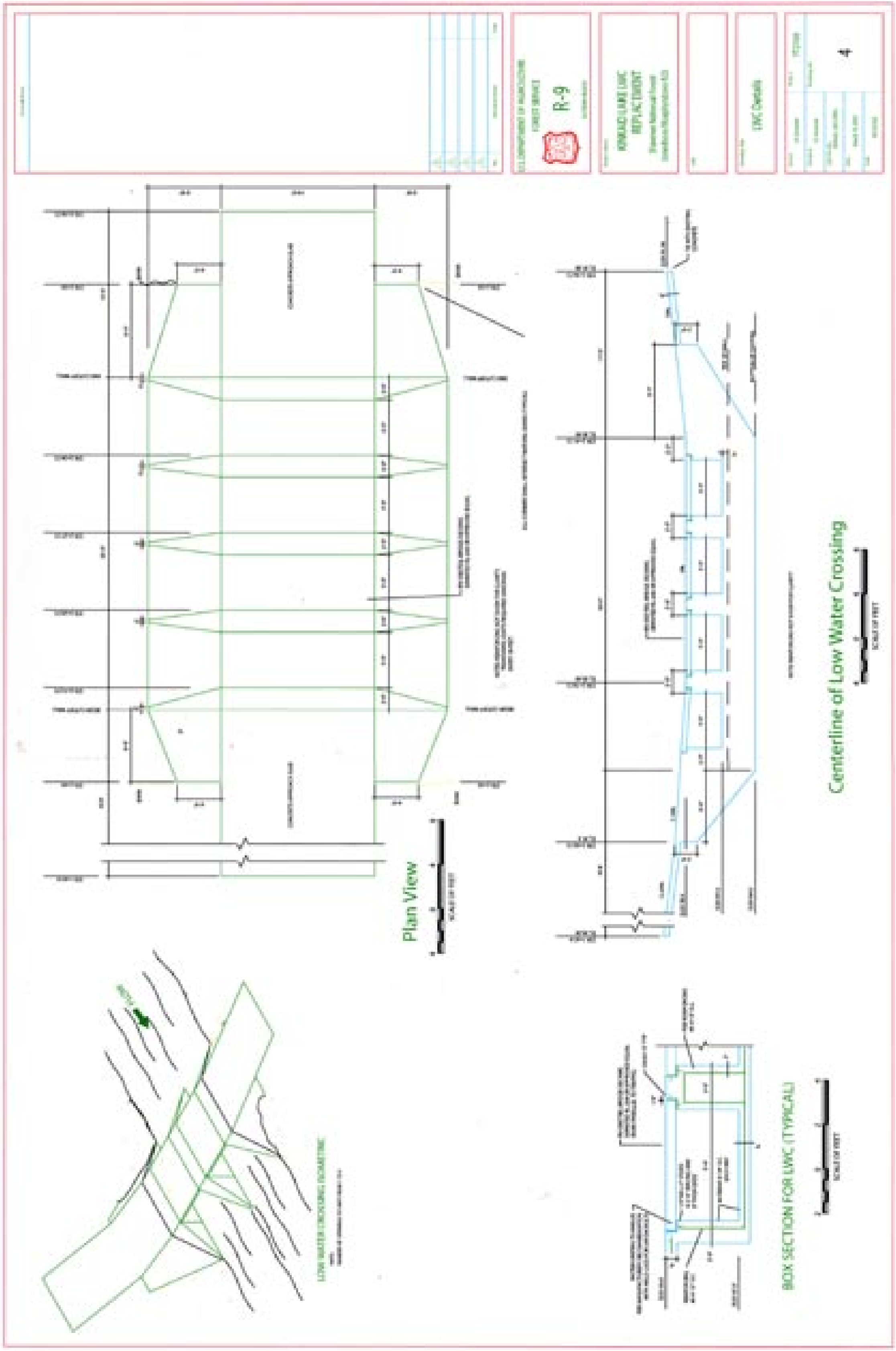

Figure A127—Plans for Kinkaid low water crossing replacement, 2001. A full size drawing may be found on the CD included in the back of this publication.

The 3-foot-high boxes are embedded about 1 foot into the streambed for fish passage (figure A126a). The boxes were allowed to fill naturally with streambed material, and in this case the streambed was mobile enough (medium to coarse gravel) and the sediment supply high enough that no headcut resulted. The streambed in the boxes has maintained itself successfully through two approximately normal rainfall years.

The new structure was designed to pass the mean annual flow underneath the deck at a depth of 6 to 8 inches, and it is submerged at frequent high flows (3 to 4 times per year). Approach slopes are steep at 10 to 12 percent but at a site where the natural banks are nearly vertical, the structure had to be somewhat wider than the channel. Riprap provides erosion protection upstream and downstream of the cutoff walls (figure A126b). The structure cost $23,000 to install in 2003.

Two years after installation, the structure is functioning well. Traffic is not interrupted by sediment and wood deposition as with the old slab structure. The new one does require removal of woody debris after high flows, but no other maintenance has been needed. Fish successfully pass the structure and the adjacent streambanks are stabilizing.

Scott Groenier, east zone structural engineer, (Northeast Region (R9) Technical Skills Team, now at Missoula Technology and Development Center), and Anthony Kirby, Mike Welker, and Steve Widowski of the Shawnee National Forest provided information and photos on the Kinkaid crossing.