Trenchless Culvert Replacement Using a Horizontal Pipe-Driving System: Agness Road, Rogue-Siskiyou National Forest

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Background

Pipe ramming is one method of installing a culvert by driving an open-ended steel casing with a percussive hammer through an embankment. It is much like a steel pipe pile-driving operation, except that the pipe is driven horizontally. After the pipe has been driven, the soil in the pipe is removed by auguring, jetting, or compressed air. For large-diameter pipe, a small machine (a Bobcat or tunnel muck excavator) may be used. Although pipe ramming is relatively new in the United States, rapid advances in the technology are expected.

Pipe ramming generally is more costly than conventional cut-and-cover methods. For Forest Service culvert applications, pipe ramming can work well when:

- Social or political considerations rule out road closure, no reasonable alternate route exists, and providing a temporary traffic bypass, such as a shoe-fly road or bridge, would be too expensive.
- The risk of adverse environmental impacts from excavation are excessive, even when extraordinary mitigation measures are taken.
- A large amount of soil would be excavated using the traditional approach, or other factors make it expensive to remove fill, and a small-diameter pipe is adequate. For instance, a 24-inch-diameter culvert under 40 feet of fill, where the soil needs to be hauled to a stockpile site, would be a good candidate for pipe ramming.

Introduction

The project team replaced a 60-inch-diameter corrugated steel pipe on a tributary to Quosatana Creek that passes under Agness Road in the Rogue-Siskiyou National Forest near Gold Beach, in southwestern Oregon. A 120-inch-diameter, 197-foot-long steel casing, which met the 100-year stormflow requirement, replaced the original pipe. The pipe was not designed for fish passage because a fish barrier exists immediately upstream of the culvert. The culvert passes the stream under a two-lane paved road that is 45 feet above the streambed. Engineers chose a rammed pipe method to place the new pipe so that the road fill would not need to be excavated or replaced.

The Alternatives

Because the road provides access for the mountain community of Agness (population 138) and no acceptable alternate traffic route exists, the road needed to remain open during construction. The traditional alternative of excavating the fill and rerouting traffic over a temporary bridge would have cost about $200,000 less than ramming the pipe. However, because pipe ramming reduced potential environmental effects, it was preferred over traditional excavation. Less soil disturbance meant less risk of fine sediment affecting highly valued chinook, coho, and steelhead salmon habitat. All of these fish species spawn directly downstream from the project site.

The contract was awarded for about $1 million. Price negotiations were key to this project's economic feasibility. Future price negotiations may not be as favorable.

Project Summary

Access

The contractor drove the casing from the downstream side. The road was too narrow and unstable to transport the 60,000-pound hammer and the casing (which weighs 50,000 pounds per 30-foot section). A crane delivered these heavy pieces to the launch pad where the hammer was set up. To keep the crane off the traveled way, the crew drove nine 24-inch-diameter pipe piles and constructed a temporary platform at road level over the fillslope to accommodate the 175-ton, 23-foot-wide crane.

Stream Bypass

The crew installed the new pipe directly beside the old culvert and extended the existing pipe 100 feet to bypass the water beyond the pit where the launch pad was built. After the bypass was in place, resource specialists rescued 84 juvenile fish from the scour pool and moved them to safety. During the initial construction, steelhead could be seen spawning in Quosatana Creek only 200 feet below the launch pad. The crew placed heavy geotextile over the streambed as a separation layer followed by quarried rock to form the launch pad that supported the hammer.

A cofferdam constructed from sandbags kept the stream from washing back onto the launch pad. As the casing emerged on the upstream side, another cofferdam separated the streamflow from the newly disturbed streambank, and workers constructed the new inlet before rerouting the channel. Before water was allowed through the completed culvert, the crew removed the fill from the launch pad, armored the bank, restored the channel, and lined the new stream portions with cobbles and boulders. When the stream was released in its new path, the water downstream was cloudy for about 20 minutes, the only significant period when turbidity was noticed downstream. The crew took water samples daily and compared turbidity measurements to samples upstream. Figure 1 shows the view from the road.

Figure 1—View from the road: the stream bypass pipe, the access road, and the launch pad.

The Hammer Setup

A modified piledriver hammer with 6 million pounds of thrust drove the casing. This piledriver is designed for high-capacity piles, such as those used in offshore drilling platforms. The contractor modified the piledriver to operate horizontally by changing some of its materials to accommodate the increased friction between the sliding portion of the hammer and the bore. The hammer is powered by compressed nitrogen gas that supplies energy to slide the hammer when it expands. The dynamic force moves through a steel helmet (figure 2) and a specially designed metal cone (the shoe) that fits the hammer to the full circumference of the casing.

In typical large pipe-ramming projects, bentonite slurry is pumped to the outside and inside of the casing wall to ease the hammer's slide through the soil. The high-capacity hammer used at Agness Road did not need lubrication. In fact, the contractor estimated that this hammer used only about one-third of its capacity. During the actual driving, the hammer typically struck 30 blows per minute and the casing advanced about one-quarter inch per blow. The hammer operated for about 7 hours.

Figure 2—The hammer with red helmet attached to the end.

Hammer Size

Selecting the proper hammer capacity for a particular job is important. A hammer that is too large might cost more than a small hammer, but the extra expense could be far less than the cost of a ramming job that failed because the hammer was too small.

The Casing

The new culvert is composed of seven sections of 1.25-inch-thick steel casing. To ensure that the casing wasn't deformed during driving, the steel was ASTM A-36 with a minimum tensile strength of 60,000 pounds per square inch and yield strength of 35,000 pounds per square inch.

To minimize the use of welded joints, the crew used interlocking Permalok pipe sections. Permalok is a brand of computerized, numeric-controlled, machined, integral, press-fit pipe connections. For a more complete description of the Permalok joint system, see the Web site: *http://www.permalok.com*.

Because of the high dynamic forces delivered by the hammer, the contractor designed a modified joint. The new culvert's total weight is about 350,000 pounds.

Grade Control

Gravity can cause the end of a slender pipe driven a long distance through the soil to drop significantly, perhaps several feet. In addition, grade and alignment can be affected by large obstructions, such as boulders, logs, or stumps.

Unplanned deviations in grade and alignment also can cause problems. If the culvert is being driven upstream, a drop in the target elevation of the culvert's invert (the bottom of the culvert) would result in headcutting of the stream and associated problems. An unexpected drop at a pipe's outfall may reduce the culvert's flow capacity. An increase of the pipe's gradient also would make fish passage more difficult.

Controlling deviations in the casing's gradient and alignment can be difficult. The casing's tendency to drop at the end can be counteracted somewhat by modifying the configuration of the driving shoe. For instance, welding a steel band to the upper outside of the driving shoe may compress the soil along the upper leading edge of the casing and relieve the downward soil pressure on the casing as it is being driven through the ground. Because this type of effect varies with soil characteristics and other driving conditions, the performance is difficult to predict and may be impossible to modify during the driving process.

Sometimes, the project crew can access the casing's leading edge to remove an obstruction or to modify the drive shoe configuration by removing the soil plug inside the casing. However, excavating the soil may be too dangerous because of soil instability at the open face, the potential for ground movement into the casing, and unacceptable ground subsidence above the installation.

The Grade Control System

The Agness Road pipe-ramming project was the contractor's first full-scale test of his proprietary guidance system. Flaps built into the drive shoe adjusted the soil pressure near the casing's leading edge. The contractor, Specialty Contractors and Consultants, Inc., of Tampa Bay, FL, monitored the drive shoe elevation with a pressure transducer and a tube of water (a water level), which was carried forward as driving progressed. This system appeared to work well. The contractor drove the new pipe within 0.2 percent of the design gradient. More information on this process is available at the contractor's Web site: *http://www.sccitunnels.com*.

The Track System

A steel frame supporting two H-beams formed a track to align the hammer and support the weight of the casing. The casing rested on a cradle, which slid along the upper flanges of the H-beams when it was being driven (figures 3 and 4). To keep the casing from bouncing upward, the crew attached the trailing end of the casing to the track with ten 18-inch-diameter pipe piles, designed for soil and pipe friction.

Figure 3—The first section of casing is being lowered onto the cradle with the crane. The blue cone at the right is the shoe, which transfers force from the hammer to the casing.

Figure 4—This view shows the operation from the other side of Quosatana Creek. The green vibratory pile hammer is suspended from the crane as it drives pipe piles.

The Winch System

The crew used the large crane to place the hammer and the casing sections on their cradles. A winch mounted on the track slid the hammer assembly forward and pulled the hammer back to allow casing sections to be added. The crew drove two 24-inch-diameter pipe piles at the toe of the slope to support pulleys to winch the hammer forward. Because the cone that abuts the casing is merely pressed against the casing during driving, the winch must pull the hammer forward after every blow to maintain a snug fit. Figures 5 and 6 show the complete hammer set up and in operation. Figures 7 through 10 demonstrate the final phases of the project.

Figure 5—The hammer setup is complete. The first pipe section is in place before driving starts.

Figure 6—The hammer in action. The casing, shoe, helmet, and hammer are in place on the track. The winch is set up at the end of the track and takes up the slack in the system between hammer blows.

Figure 7—A tunnel excavator completes the job of cleaning out the new casting. It scoops up soil onto a belt between its tracks and transports the soil to the other end of the casing where the soil is loaded onto a truck.

Figure 8—Grouting the old pipe. Note its condition.

Figure 9—The new pipe's inlet. The grouted old pipe is just to the right.

Figure 10—The new pipe's outlet. The grouted old pipe is to the left.

Project Schedule Highlights (2003)

Date	Activity
March 6	Site preparation began
March 19	Water diverted
March 25	Launch pad completed
March 26	Crane being assembled
April 10	Crane platform completed
April 24	First section of casing on the launch pad
April 27	Driving started
May 9	Pipe driving finished
May 29	Demobilization completed
June 3	Water diverted into the new culvert
June 5	Concrete slurry pumped into the old culvert

Rob Piehl is preparing a summary of trenchless technology for Forest Service culverts that will be published by the San Dimas Technology and Development Center.