A Large Diameter Culvert vs. an Engineered Rock Drain for a Temporary Stream Crossing

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Background

In open pit mining, a substantial portion of the mining costs are incurred by the movement of the waste that covers the ore body. In basic terms, open pit mining is the construction of a very large hole in the ground. Moving the waste involves lifting it from within the hole, and transporting it to a point outside of the pit. In order to minimize the cost of waste movement, engineers try to shorten both the horizontal and vertical movement of excavated material. Following this logic, once the material has reached the outside limit of the pit, it is most cost effective to dump it immediately, into a conveniently located void. During open pit mining in mountainous terrain such a void is often present in the form of a stream or river valley. A complication in this situation can be the presence of the water course that will be impacted as the valley is filled with waste rock. It was partly in order to take advantage of this opportunity to reduce mining costs, that engineered rock drains were developed. By stripping the topsoil and placing large competent boulders in the water course, prior to establishing a waste rock dump, water can continue to flow down the water course with minimal impact while the valley is filled with waste rock and overburden. This approach is really only appropriate in headwater situations as passage of organisms outside of invertebrates can be restricted. A secondary benefit of the rock drain concept is that it provides a durable stream crossing, allowing very large mining equipment to travel across a water course. A further development of this concept has been the use of rock drains for temporary crossings utilized by large scale mining equipment.

As the size of open pit mining equipment has increased, the traditional bridge crossings of rivers and streams have most often been replaced by large diameter steel culverts. Culverts are far more cost effective than the traditional bridge at the scale required. The length and diameter of the culvert required is dependent on the volume of water to be conveyed, the grade of the affected streambed, the desired width of the road surface and the fill required to raise the streambed elevation to road grade. Most often culverts for mining in mountainous topography are hundreds of feet long. Installation of a culvert requires replacing the streambed with a straight and stable base. This usually entails destroying the existing meandering stream bed to allow a perfectly straight culvert to be installed. During construction and removal of a culvert the stream is usually either pumped or diverted around the installation site.

Situational Comparison

Construction

At the Gregg River Mine near Hinton, Alberta, two similar streams in adjacent valleys were crossed during mining. The Drinnan Creek valley was crossed using a temporary rock drain. The Sphinx Creek valley was crossed using a large diameter horizontal elliptical culvert. In October of 2000 the mine was permanently closed and the reclamation process was undertaken. Both crossings were restored to open channel configurations allowing a comparison of observable results and impacts during both installation and removal of both types of crossing.

In 1996 a 2.87 meter high by 4.37 meter wide horizontal elliptical culvert, 133 meters long was constructed in Sphinx Creek. It was sized to pass a 1:100 year flood event and to support 18 meters of fill material. A system of steel baffles was installed in the culvert to reduce water velocity and facilitate fish passage. Riprap was placed at the inlet and outlet to protect against erosion. The culvert was placed on the inside of a small diameter curve in the creek. Each end of the culvert was placed so that construction of a short section of engineered channel was required to connect to the existing streambed. In effect, the culvert straightened out a large curve in the watercourse. Prior to culvert installation a 0.6 meter bed of compacted granular material, 11.7 meters wide was constructed as a base. After culvert placement a series of 0.15 meter compacted layers of granular material were placed simultaneously up each side of the culvert to avoid culvert distortion and provide support for the fill material. During the backfill portion of the construction process the original creek channel adjacent to the culvert was destroyed to allow room for the equipment to work placing and compacting the fill material. Construction of the crossing was completed by adding subsequent lifts or layers of material to reach final road design criteria.

During 1999 the South Drinnan Creek rock drain was constructed to allow equipment to access a new mining area. It was designed using criteria and experience developed during the installation of 6 permanent rock drains at the mine. A key difference in this design was that it was to be a temporary structure left in place for a maximum of 5 years. Design criteria allowed passage of a 1:20 year storm event. The rock drain consisted of 2 zones dependent on rock size. The core zone consisted of competent sandstone sized at 50% greater than 0.6 meters; a second buffer zone was built with competent sandstone sized at 50% greater than 0.4 meters. The cross sectional areas of the 2 zones were 326 m^2 and 147 m^2 respectively. 42,800 m^3 of sandstone rock was selectively quarried to achieve these design specifications. Prior to construction of the rock drain, the affected ground area was stripped of organic material and clays. A 5 meter zone on each side of the creek was left undisturbed in order to minimize sediment in the creek after the rock drain was in place. To place the rock core, the quarried sandstone was dumped from an 11 meter height above the creek bed. The 11 meter height allowed natural size segregation to occur over the dump face. The larger rocks rolled to the bottom 5 meters of the dump with the middle 2.3 meters forming the buffer zone. Any finer material naturally remained in the upper portion of the dump face. In order to avoid disturbance of the creek bed and ensure that the rock drain design criteria was met, a backhoe was used to place some of the largest coarse rock directly into the creek, prior to end-dumping from the dump face. This work was undertaken during February to utilize the snow and ice cover for watershed protection during construction. This is a period of very low water flows ensuring that the number of fish that might potentially be trapped above the rock drain would be minimized. Fish over wintering pools were constructed immediately up and downstream of the rock drain as part of the installation.

Removal

The Drinnan Creek rock drain was removed during the winter of 2000. A large long reach backhoe and trucks were used to excavate the 11 meters of waste rock so that it could be hauled away. The material was removed in a series of shallow lifts until the creek bottom and valley floor were within easy reach. At this point all of the fill material was removed from the west side of the creek and a temporary Geotextile lined channel was built to divert the water around the rock drain. The backhoe was then able to remove the rock drain core from the creek channel with out impacting water quality. As the large diameter boulders were removed, the original substrate, and the 5 meter buffer zones that were left on either side of the channel were exposed. The skill of the backhoe operator was such that boulders could be lifted from the topsoil exposing the willows that had been growing on the undisturbed portion of the creek bank. Little evidence of the rock drain remained in the creek bed when the hoe work was finished. The project was completed by removing the remaining fill material, returning the creek to the natural channel, reclaiming the temporary channel, and retreating out of the valley with recontouring and topsoil placement. The area was immediately seeded with a light annual rye covercrop, our standard reclamation seed mixture was applied later in the spring, reforestation continues.

The Sphinx Creek culvert removal was undertaken in the winter of 2002. Initially the approach was very similar to that used in Drinnan Creek. A backhoe and trucks were used to excavate a series of lifts to remove the 18 meters of waste over the culvert. When the waste level reached the top of the culvert, the material was removed down to the valley floor on the west side. This allowed the construction of the new engineered Sphinx Creek open channel located to the west of the culvert. Flow was maintained in the culvert while the channel was excavated to grade, sized riprap was placed in the creek bed and topsoil was placed on the east creek bank. The creek was then diverted into the new channel allowing the removal of the culvert and the reclamation of the west side of Sphinx Creek. Reclamation then continued by recontouring and replacing topsoil on the culvert access road. The area was seeded and reforested in a similar manner to Drinnan Creek.

Results

At project completion, Drinnan Creek was returned to its natural configuration. Resulting channel length and grade were unchanged from the original. From an observational point of view, rock drain construction and removal had minimal impact on water quality, partially due to capitalizing on the seasonal nature of creek flow rates. The headwaters location of the crossing eliminated most of the concern around the blockage of fish passage. Fish were never observed in the over wintering pools.

The construction of the Sphinx Creek culvert in a fairly narrow mountain valley eliminated the original creek bed. The removal of the culvert required the construction of a new channel having different length, grade and location. Riprap material to rebuild the stream bed was brought in from a nearby quarry. Although every effort was made to minimize impact, the resulting reclaimed creek channel was substantially different from the original channel. Reestablishing the creek in its initial location and configuration would have been extremely difficult and expensive to accomplish without impacting water flow and quality.

Comparison of construction, environmental and reclamation impacts of each crossing method, for these particular, similar situations, reflects favorably on the use of temporary rock drains. When the crossing of the headwaters of some mountain streams is required, a rock drain crossing is worth serious consideration.