Advantage

FERIC

Restricted to FERIC Members and Partners Vol. 6 No. 26 September 2005

Installation of a structural-plate corrugated-steel round culvert along a fish-bearing stream in Alberta

Contents

Author
Clayton T. Gillies,
Western Division

Abstract

The Forest Engineering Research Institute of Canada (FERIC) monitored and documented the installation of a culvert along a fish-bearing stream in Alberta. Detailed installation procedures and cost information are presented, as well as suggestions for implementation of future culvert projects.

Keywords

Stream crossing, Water crossing, Culvert, Fish habitat.

Introduction

Crossing fish-bearing streams along forest roads in Alberta has typically been accomplished with clear-span (bridge) structures, partly because of the regulatory and application processes associated with alternative structures such as culverts and arches. Because these alternatives require work within the watercourse during installation, the level of protection given to aquatic ecosystems—including fish habitat, fish passage, water quality, and continued navigability—is important. This protection is governed by provincial and federal legislation. Although the preservation of aquatic resources is paramount when working in or near streams, installing a closed-bottom stream-crossing structure while maintaining and protecting the water quality and riparian resources is feasible.

Alberta-Pacific Forest Industries Inc. installed a closed-bottom structural-plate corrugated-steel round culvert along a fish-bearing stream in its Forest Management Agreement (FMA) area following best management practices while working in and near the stream. FERIC was on-site at the beginning and end of the construction phase of this project. Lengthy delays due to wet weather postponed the completion of this project more than once and for up to two weeks at a time.

Objective

The purpose of this study was to provide FERIC's members with information about the procedures and costs of installing culverts along fish-bearing streams.

Background and site description

Piche Road was built during the summer and fall of 2004 and leads into the eastern portion of Alberta-Pacific's FMA area. The road location was planned and preliminarily mapped in advance of ground-truthing and lay-out in the field. The road was built to a Class 3 standard: a permanent road for use up to 20 years, built with an 8-m-wide running surface, with a cleared right-of-way from 25 to 30 m (Alberta-Pacific 2003). Large amounts of fill were required to accommodate the vertical alignment of the road through the depression at the water crossing (Figure 1).

Figure 1. View of the wetland depression and right-of-way clearing on far side of crossing.

Figure 2. Upstream of the crossing showing meandering channel through grassy wetland (photo courtesy of Alberta-Pacific).

The road was built across an unnamed fish-bearing stream containing brook stickleback, with a meandering channel through a muskeg/grassy wetland containing water year-round. The main stream channel was braided through much of the wetland area near the crossing. Numerous beaver dams had flooded portions of the wetland and beaver activity was evident adjacent to the main channel. The width of the main branch of the stream varied from 1.65 to 2.50 m, and the depth varied from 25 to 62 cm. Pool areas away from the crossing location were wider and deeper, at 3.10 and 0.75 m, respectively. The stream had a sandy, silty bottom with few cobbles, and a natural gradient close to 1%. The width of the wetland at the crossing location was 25 to 30 m. The wetland is comprised of grasses, taller sedges, and dead or dying spruce trees (Figure 2). The distinct division between the grasses and taller sedges indicated a 3- to 5-year flood event boundary.

Planning and design

Bridges are typically the Alberta-Pacific's road engineers' first choice for crossing fish-bearing streams (Alberta-Pacific 2003). However, the width of the wetlands meant a bridge would need to be close to 30 m in length. The road engineers also considered alternative structures such as a closed-bottom culvert. A culvert was expected to cost less than a bridge and would be a two-lane crossing (compared to a single lane for a bridge), thus increasing road safety. For a closed-bottom structure, a structural-plate culvert would be more rigid and better suited to the fill requirements at the site compared to a helical (spun) culvert. A thickness of 4 mm was suggested for the structure and may not have been available for a helical (spun) culvert.

To proceed with building a closed-bottom structure along a fish-bearing stream, federal authorizations and provincial notifications were required. Alberta-Pacific applied for and received an authorization from Fisheries and Oceans Canada for the "harmful alteration, disruption, or destruction (HADD) of fish habitat" arising from the culvert installation, pursuant to subsection 35(2) of the Fisheries Act (DJC 1985). Such an application also triggers an environmental review of the proposed activities on the resource in question under the Canadian Environmental Assessment Act, which concluded that the project was not likely to cause significant adverse environmental effects. Both approvals were subject to the mitigation (erosion and sediment control) and compensation (fish-habitat enhancement) measures

Forest Engineering Research Institute of Canada (FERIC)

Find us Online!
www.feric.ca

Eastern Division and Head Office
580 boul. St-Jean
Pointe-Claire, QC, H9R 3J9

☎ (514) 694-1140
📠 (514) 694-4351
💻 admin@mtl.feric.ca

Western Division
2601 East Mall
Vancouver, BC, V6T 1Z4

☎ (604) 228-1555
📠 (604) 228-0999
💻 admin@vcr.feric.ca

Disclaimer

Advantage is published solely to disseminate information to FERIC's members and partners. It is not intended as an endorsement or approval of any product or service to the exclusion of others that may be suitable.

© Copyright 2005. Printed in Canada on recycled paper.

ISSN 1493-3381

specified in the application. In-stream work activities were scheduled to avoid migration, spawning, and incubation periods of resident fish species.

Liland Engineering Ltd. of Sexsmith, Alberta surveyed the stream 300 m both upstream and downstream of the crossing location, and prepared the designs. The survey established the gradient of the natural channel and cross-sections of the channel were measured at 100-m intervals (3 upstream and 3 downstream). A cross-sectional view was established for the road crossing itself, showing the existing ground, the proposed road surface, and the placement of the culvert superimposed below the proposed road grade. This last view also showed 5 m of fill over the top of the culvert. The designed gradient for the culvert was 0.8%. All designs were signed and sealed by a member of the Association of Professional Engineers, Geologists, and Geophysicists of Alberta.

Hydrological planning for wetland areas can be uncertain, in part due to the wetlands' holding/storage capacities during high rain events and the delayed passage of water through a wetland. Unlike a lake where the storage capacity can be easily viewed and estimated, a wetland's capacity is partially hidden below ground. In this case, hydrological designs for the crossing were generated by analyzing the data from a nearby stream gauge, and extrapolated to suit the target stream's drainage area (11.4 km^2). The crossing was designed to allow passage of the 1:50 year flood event (Q50) of 10 m^3/s. The culvert is also expected to pass the 1:100 year flood event (Q100) of 16.5 m^3/s (flow velocity of 2.7 m/s) without overtopping the road. The 1:10 year flood event (Q10) was calculated as 1.1 m^3/s, corresponding with a three-day delay from the actual event.

Erosion control plans for the site included geotextile fences across the stream and diversion channel at various strategic locations, and across the ditchlines entering the crossing location. Fibrous matting was to be placed along ditchlines and staked down. Hand seeding of exposed soils with a local reclamation mix was to be done concurrent with the construction of the crossing. Alberta-Pacific's road engineer and/or biologist were to visit the site during construction to observe and document any sediment-related concerns.

Materials and equipment

The closed-bottom structural-plate corrugated-steel round culvert was supplied unassembled by Atlantic Industries Ltd. Once assembled, the culvert measured 3.36 m in diameter and 50 m long, and had a wall thickness of 4 mm and corrugation profile of 152 × 51 mm. The end area of the culvert was 8.86 m^2 and each end was fabricated with a step-bevel. The culvert will accommodate the weights of loaded off-highway logging trucks (approximately 68 tonnes gross vehicle weight). Maximum recommended cover over this structure is approximately 20 m (AISI 1995).

The primary equipment used during construction were a John Deere 230 LC excavator and a John Deere 450 crawler tractor. John Deere 270 and 330 excavators were also used. An articulating and a tandem end-dump truck delivered pit-run and crushed aggregate and retrieved excavated material.

Other equipment and supplies included the following:

- survey equipment: level with tripod, rod, stakes, and flagging tape
- dewatering equipment: Honda GX240, 6-kW (8-hp) pump with 9-cm (3.5-inch) intake hose, geotextile, 60 m of corrugated metal pipe (600-mm diameter)
- embedding equipment: Bobcat 773 front-end loader, sheets of plywood
- compaction equipment: jumping-jack hand-held compactor, Ingersoll Rand 203-cm vibrating-drum pad-foot roller, lengths of 2 × 4 dimensional lumber
- erecting crew: compressor and air ratchet, torque-wrench, scaffolding, truck with crane

- sediment and erosion mitigation: geotextile and wooden stakes, fibrous matting, reclamation seed mixture

Site preparation

The site preparation is presented in the following steps: stream diversion, tote road, excavation, bedding preparation, and surveying.

Figure 3. Looking downstream along the open diversion trench (before the decision was made to use round culverts).

Figure 4. Fence made of geotextile near the outlet of diversion trench.

Figure 5. Tote road which allowed equipment to pass the culvert installation site. Arrow shows the abrupt and distinct boundary between the wetland area and forested area (photo courtesy of Alberta-Pacific).

Stream diversion

At the beginning of the construction, the excavator prepared a diversion trench on the camp side of the stream crossing through the edge of the wetland area (Figure 3), connecting the downstream end to a backwater/meander of the stream. The upstream side of the trench was not connected to the main stream at this time. The diversion trench had filled with water due to the high water table and seepage associated with the wetland area. Two fences made of geotextile were constructed downstream to slow water movement and promote the settling of fines (Figure 4). The excavation was to be used as a gravity-fed open-trench bypass for the stream.

The dewatering plan was altered to a closed gravity-fed system to allow equipment to travel over the bypass section during construction and to lessen any sediment delivery to the open trench. The original open trench was utilized by placing a series of 600-mm-diameter corrugated metal pipes along the length of the trench to carry the stream flow. The pipes were joined together by couplers and then covered with fill. Also, the open trench at the outlet of the diversion pipe was lined with geotextile to separate soil from the water flow. The total length of the diversion was approximately 50 m.

Tote road

A tote road was built so machinery could pass and continue roadbuilding past the crossing (Figure 5), and to give heavy equipment access to both sides of the culvert during installation.

Excavation

Two excavators worked in tandem during the initial excavation. One removed the earth through the length of the dewatered stream section and placed this material uphill. The second then moved this material one boom-swing further from the construction site. The uphill excavator placed the material in a peaked pile. The excavated material was placed along the edge of the right-of-way on both approaches to the crossing.

Bedding preparation

The bedding for the culvert was prepared by a series of lifts. First, the excavator removed an additional 1 m of soil below the target elevation and spread pit-run aggregate along the length of the excavation. This "bottom" lift added additional support for the culvert and established the initial flat working surface. This lift was compacted with a vibrating-drum pad-foot roller (Figure 6). Approximately 10 cm of sandy material was then spread on top of the compacted lift as the final bedding for the culvert (Figure 7). This lift was not compacted, but left loose to allow the culvert to "settle" itself into the material.

Surveying

The majority of the surveying and field referencing took place during the bedding preparation. A benchmark was established and a level and tripod were used to accurately gauge the gradient/vertical alignment of the culvert. Due to the meandering nature of the stream and the wetland in general, the horizontal positioning of the culvert through the proposed road was somewhat forgiving. In fact, during the installation the supervisor/foreman positioned the culvert at a slightly different skew through the wetlands compared to the original plan. The purpose of the change was to position the outlet at a better location.

Installation

The installation is presented in the following steps: culvert delivery and assembly, backfilling, infilling, stream channel blending/reconnection, stream connection, armouring and reclamation, and compensation works.

Culvert delivery and assembly

The culvert was delivered unassembled. The plates and buckets of bolts were unloaded and stored along the road (Figure 8) on the camp side of the crossing, approximately 40 m from the excavation.

Figure 6. Vibrating-drum pad-foot roller used for compaction during various stages of construction.

Figure 7. Sandy bedding prepared to a level surface (photo courtesy of Alberta-Pacific).

Figure 8. Unassembled culvert plates and buckets containing bolts (photo courtesy of Alberta-Pacific).

The erecting crew for the culvert consisted of 5 members, and was on-site for 4 days for a total of 40 hours per crew member. Up to three plates were joined together on the road, away from the excavation, where there was ample room to work. These pre-assembled sections (connected plates) were then transported to the construction site on a truck equipped with a crane and lifted into place (Figure 9). The bolts were kept loose until the entire assembly was complete to allow

Figure 9. Truck with extended crane to lift pre-assembled sections into place during construction. Note the sections on the back of the truck (photo courtesy of Alberta-Pacific).

Figure 10. Assembled culvert showing clay material placed next to the culvert and above the lowest bolt holes (photo courtesy of Alberta-Pacific).

Figure 11. End-dump truck delivering backfill material (photo courtesy of Alberta-Pacific).

Figure 12. Crawler tractor spreading backfill material. Note the large pile of excavated material on the far side of the culvert (photo courtesy of Alberta-Pacific).

for plates to be aligned properly. Once assembled, the erecting crew used an air ratchet to cinch the bolts tight and a torque wrench to check the torque-force on a large sample of bolts. Scaffolding, which ran on wheels along the bottom of the culvert, gave access to areas that were unreachable from the ground.

Backfilling

Compaction of the initial backfilling under the haunches of the culvert was done first by hand using lengths of 2 × 4 dimensional lumber followed by a jumping-jack style compactor. All compacted lifts measured approximately 30 cm in height. Shortly after the haunches were compacted, rainy weather delayed the construction for three weeks. Clay soil was placed at a water-shedding angle next to the culvert above the lowest bolt holes (Figure 10) during this prolonged shutdown. This hand-placed material helped to keep water from entering the culvert through the bolt holes, and to shed water away from the compaction below the haunches.

Backfilling around the outside of the culvert continued once the rainy weather had changed, and the threat of construction-related erosion and suspended sediment had been reduced. Backfill material was delivered next to the culvert by the end-dump trucks (Figure 11) and was spread by the crawler tractor (Figure 12). The material within one metre of either side of the culvert was compacted using a jumping-jack style compactor, while the remaining width of the lift was compacted using the vibrating drum roller. The backfilling and compaction were completed after 5 shifts (3 day and 2 night), with an average compacted height of 60 cm per shift.

The roadbuilding crew employed a local technique to help prevent any eventual stream flow from piping along the outside of the culvert. Clay from the original excavation was placed around the culvert at each end to act as an impermeable "plug" to water flow. As an alternative, geotextile can be placed under and around the culvert to form a curtain on either side (Gillies 2003).

Once the material around and over the top of the culvert had been compacted, additional fill material was delivered to build the road to grade. Up to three scrapers moved the large amount of fill required for the entire road construction. A geogrid (plastic mesh) was placed between upper lifts, but below the final road grade, to reinforce the road and give it additional lateral strength to help resist sloughing. The geogrid, through confinement and its inherent tensile strength, helps to resist the lateral movements promoted under load. Sloughing was a concern considering the height of fill above the culvert. The final measured height of fill was close to 5 m above the culvert and close to 8.5 m above the original ground level on either side of the culvert. The running surface of the road was approximately 8 m wide.

Infilling

The design for infilling the culvert prescribed a minimum of 600 mm depth of Class 1 rock riprap to be placed along the entire length of the culvert. The measured actual depth of infill material was 600 to 800 mm, and the rock was 200 to 550 mm in diameter. This rock will offer resting areas, in the form of velocity shadows, for fish during migration through the culvert and promote the settling of sand and gravel. Hydrological tables show that a flow event with a mean velocity of approximately 3.9 m/s would be necessary to transport the smaller rock from within the culvert. This can be considered an extremely high flow event. The infill material is considered part of the compensation measures required for this closed-bottom structure.

Infilling started once the backfill had reached the top of the culvert, but before the road was built to design grade. The design depth for the infill material was measured and spray painted along the inside wall of the culvert to help guide the placement of material. A Bobcat front-end loader delivered the infill material through the length of the culvert. The primary excavator placed the infill material into the front-end loader's bucket (Figure 13). A staging area just outside of the culvert was prepared by placing wooden pallets for the loader to work on. These pallets kept the staging area from becoming excessively muddy, and kept the majority of the soil material from being carried into the culvert on the loader's tires. Plywood was placed through the length of the culvert to protect the loader's tires from bolts, and was eventually removed once it was no longer required.

The loader travelled forward into the culvert to deliver the rock riprap infill material, and reversed out of the culvert. Two workers inside the culvert rolled and manipulated the rock to cover the bottom of the culvert evenly from side to side. The infilling of the culvert took 12 hours to complete.

Stream channel blending/reconnection

In order for the stream to enter the culvert without making an abrupt turn, a section of stream channel was reconstructed. One meander upstream of the culvert was isolated from the main flow path and a straight section of channel was constructed. Geotextile was laid along the streambanks of this straightened channel and rounded rock similar to that used inside the culvert was placed on top as armouring. The reconstructed section of stream blended in to the natural stream approximately 15 m from the inlet, and a 15–30 cm difference in streambed elevation occurred which resulted in a riffle characteristic (Figure 14).

Figure 13. Excavator placing infill material into the bucket of the front-end loader during the infilling of the culvert (photo courtesy of Alberta-Pacific).

Figure 14. Inlet of culvert showing length of reconstructed stream channel, size and amount of rock, and stream-riffle section near the end of the armoured streambanks.

Figure 15. Arrow points to un-vegetated and ravelling bank.

Figure 16. Outlet of culvert showing streambank armouring.

Figure 17. Outlet of culvert showing fillslope armouring and geotextile fencing.

Eliminating the flow in the upstream meander will lower future sediment inputs to the stream because the meander was eroding the toe of a steep and un-vegetated ravelling bank (Figure 15). The meander may still function as a backwatering/refuge area for aquatic wildlife.

The stream channel downstream of the culvert also had some modifications. Although the outlet of the culvert was purposefully positioned to flow into a downstream meander of the stream, a short redirection of the channel was necessary. The streambank along this redirection, and portions of the original streambank, were armoured using rounded rock (Figure 16).

Stream connection

During the final armouring of the streambanks along the upstream side of the culvert, the main channel of the stream was redirected through the culvert. The excavator placed fill material to block the stream's flow through the meander area, forcing the flow through the newly created channel. Rock armouring was also placed over this fill. During the reconnection, the stream elevation dropped as the flow entered the new channel. To help alleviate this difference in elevation, the excavator placed sand within the riffle section to promote a more gradual transition.

Armouring and reclamation

Fillslopes were armoured above and around the culvert at both the inlet and outlet. The armouring extended to just below the road surface and up to 3 m on each side of the culvert (Figure 17). Geotextile fencing was installed around the entire armoured areas. The bottoms of the geotextile fences were placed in a hand-dug trench, and wooden support stakes were placed at 2-m intervals. The fillslopes above the culvert were 15–20 m in length and had an average gradient of 40%.

Ditchlines immediately entering the wetlands area were protected against further erosion by use of fibrous matting (Figure 18). Geotextile fences were also constructed in this area to slow water velocity and promote deposition of sediment. Rounded cobbles and boulders were placed along one of the ditchlines as armouring because of its steeper slope. The exposed soils were seeded with a reclamation mix at the completion of the project.

Compensation works

To compensate for the destruction and/or alteration of fish habitat, specific conditions were directed by Fisheries and Oceans Canada within the authorization document that was initially presented by the proponent of the project. Specified compensation works were correlated to the predicted area of lost habitat (150 m^2) and, in this case, primarily made reference to the placement of root wads upstream and downstream of the culvert crossing. The root wads were strategically placed to offer shade and bank-scour protection. They will also offer protection for fish from overhead predation, add habitat diversity, and give micro-habitat flow characteristics (Figure 19).

Project costs

FERIC's estimate of project costs is shown in Table 1. The purchase and delivery of the culvert accounted for approximately 46% of the total installation cost, while the delivered aggregate accounted for approximately 14%. The remaining 40% was accounted for in the cost of the heavy equipment, labour, and the other materials.

The costs presented also include building the road up to grade approximately 20 m on either side of the culvert. If the complete road approach to the crossing site was included (50 m on either side of the culvert), an additional $70 000 in roadwork costs would be included. This cost would be generated primarily by the scraping and delivery of fill material, and its spreading and compaction.

Figure 18. Fibrous matting and geotextile fences placed across ditchline (photo courtesy of Alberta-Pacific).

Figure 19. Root wads placed upstream of culvert within main channel of stream.

Cost comparison for alternative product

During the planning stage, the road engineer considered different products for crossing the stream. The professional advice given to the road engineer regarding a culvert was that its walls should be at least 4 mm thick. To meet this criteria, a structural plate product was chosen, as the thickest wall for a helical (spun) corrugated-steel culvert was 3.5 mm. Although product tables present wall thickness for helical culverts up to 4.2 mm, this thickness is rarely sold and is difficult to obtain.

If a thinner wall thickness was acceptable, a comparable product would have been a helical corrugated-steel round culvert. For example, a culvert with the same length and corrugation profile as the one used in this installation, but with a slightly larger diameter at 3.4 m and a slightly thinner wall thickness of 3.5 mm (with a maximum cover over structure of approximately 12 m), would be delivered in 4 sections on 4 separate trucks and would require 3 couplers

Table 1. Estimate of project costs

Cost category	Quantity	Unit cost ($)	Total cost ($)
Materials			
structural plate culvert (delivered)	50 m	1 800	90 000
delivery of culvert	1 delivery	2 000	2 000
delivered pit-run aggregate (bottom lift)	270 m^3	22	5 940
delivered 2-cm minus crushed (backfill)	300 m^3	42	12 600
delivered rounded field stone (infill, stream channel, and armouring)	200 m^3	50	10 000
geotextile fence	450 m^2	1.5	675
geogrid for road	2 rolls	1500	3000
fibrous matting	5 rolls	110	550
wooden stakes	50 pieces	1	50
plywood sheets	20 sheets	25	500
lumber	10 pieces	12	120
Equipment			
excavator (20–25 t) (John Deere 230)	160 h	130	20 800
excavator (35–40 t) (John Deere 330)	32 h	155	4 960
articulating end-dump truck	32 h	140	4 480
tandem end-dump truck	32 h	130	4 160
crawler tractor (5–10 t) (John Deere 450)	40 h	110	4 400
drivable compactor	16 h	105	1 680
Bobcat loader	12 h	95	1 140
jumping-jack compactor	4 wk	250	1 000
pumps and hoses	4 wk	250	1 000
Labour			
site survey	16 h	30.5	488
mapping (site plan)	8 h	30.5	244
culvert erecting crew (5 people and equipment)	4 d	5 000	20 000
forest worker(s) (culvert infill, geotextile fences)	76 h	30.5	2 288
supervision/foreman (also surveyor)	20 d	300 [a]	6 000
Total			198 075

[a] Supervisor/foreman rate shown is approximately one-half the total daily rate, because the supervisor/foreman spent time away from the stream crossing attending to other duties.

at $250 each. The freight to deliver the sections would be the same as the structural plate ($2000 per truck) and the price per metre for the culvert is approximately $800, totalling $48 800 for the culvert to be delivered. The helical culvert would therefore have a delivered price of $43 200 less than the structural plate. Additional savings may also have been realized during the placement of the culvert as there would not be the need for bolting plates together, although the time to secure couplers to large round culverts can take 1.5 hours each (Gillies 2003).

A thinner structural-plate culvert would also cost less. The next lower thickness available is 3 mm (with a maximum cover over structure of approximately 14 m) with the same diameter and corrugation profile as this installation. This would cost $1 375/m, as compared to $1 800/m for the 4-mm-thick structural-plate culvert. This lower cost equates to a savings of $21 250, when all other factors remain the same.

The cost of installing a single-lane bridge at this location was estimated to be similar to or higher than the structural-plate culvert.

The length of the bridge deck would have been approximately 30 m to span the entire wetland. It was unclear whether or not a short causeway could be built at each approach to shorten the bridge length; if permitted, this construction may require approvals to work within the watercourse area. A single-lane bridge was not desirable for this crossing. Factors such as engineering costs for the design, the desired vertical alignment for the road, and safety of a single versus two-lane crossing all played a role when making the final choice.

Conclusions and implementation

The 3.36-m-diameter, 50-m-long structural-plate round culvert was installed at a cost of $198 000. The road was built to a Class 3 standard. Large amounts of fill were placed along the approaches to achieve the vertical alignment typical of such crossings, and a two-lane crossing with excellent sightlines for driving resulted (Figure 20). A HADD was applied for and authorization was received for the construction of a closed-bottom culvert along a fish-bearing stream. The HADD specified compensation measures. The culvert was infilled with rounded rock to create habitat features within the culvert. The rock will also provide a roughness factor which will reduce water velocity and increase deposition within the culvert. Root wad structures were built within the main stream channel. Short sections of the stream channel were reconstructed to accommodate placement of a straight culvert along a meandering stream.

Observations were made on-site which may be useful during future installations:

- A culvert of this length cannot be delivered as one pre-assembled section. Two or three sections can be pre-assembled and delivered, but they would need to be transported on separate trucks. The pre-assembled option should be carefully considered when ordering a culvert of this size. The cost of additional delivery trucks may be justified when considering the cost of the erection crew and/or timing window. In this case, the culvert was delivered unassembled.
- When assembling the culvert on-site, connecting two or three sections before attaching them to the main portion of the culvert streamlined the process. Bolting culvert sections together away from the excavation was easier and more convenient than working with individual suspended sections.
- Air quality within the culvert can be compromised when operating diesel- or gas-powered machinery within the culvert. Workers should be advised and equipped for this risk, and the air quality should be monitored. If prolonged machinery use is anticipated, fans can be used to force air into or out of the culvert.
- Typically, the backfill material around a culvert is delivered by an excavator, one bucket of material at a time. By building a tote road, the dump trucks had access next to the culvert and time was saved during delivery of backfill material. The options for delivery of backfill need to be assessed for each site and volume required.
- Closed-bottom structures along newly built roads can be perceived to remove habitat from the riparian system. In this case, the habitat affected was commonly available upstream and downstream of

Figure 20. View of road surface across the installed culvert (photo courtesy of Alberta-Pacific).

the crossing. The introduction of cobbles and small boulders through the length of the culvert gave the stream new diversity, which may prove beneficial to the aquatic system. Root wads placed along the stream bank and pool areas also provided new features.

- The need for precise elevation readings was highlighted by the elevation difference between the reconstructed streambed and the natural streambed. In this case, a 15- to 30-cm drop created a riffle. A 50-cm drop in elevation would have been much more challenging to accommodate. To avoid large differences, a semi-permanent benchmark should be established at the site survey stage (e.g., while collecting data for the engineered design), and referenced frequently while surveying during the construction phase.
- The structural-plate culvert is not considered watertight due to the numerous bolt holes. If a watertight culvert is necessary, each bolt hole exposed to water flow may require a gasket. If a helical culvert is used, the couplers to the culvert should be sealed.
- When removing and storing large amounts of excavated fill, utilizing trucks to end-haul the material may be more efficient than excavators working in tandem.
- Excavated material should be well peaked (water shedding) or covered with a tarp if heavy rains are expected to reduce erosion of the pile and/or suspended sediment. Excavators can produce a well-peaked pile by continually placing material higher on a pile. Conversely, end-dump trucks can only produce individual piles correlated to a single end-dump of material.
- Compensation measures dictated within the authorization of a HADD were reasonable and proposed within the application. The crew built the root wad structures easily and quickly, and an abundance of root wads were available on-site. Compensation works are typically in line with Fisheries and Oceans Canada's mandate for a net gain (no net loss) in fish habitat across the country.
- All best management practices are worthy of attention, but none were as important in this case as the rainy-weather shutdown. Heavy rains combined with machinery activity would have created an unacceptable level of erosion and higher probabilities of sediment reaching the fish-bearing stream.

References

Alberta-Pacific Forest Industries Inc. 2003. Alberta-Pacific watercourse crossing manual. Boyle, Alta. 33 pp.

American Iron and Steel Institute (AISI). 1995. Handbook of steel drainage and highway construction products, Canadian edition. Washington, D.C. 411 pp.

Department of Justice Canada (DJC). 1985. Fisheries Act, Chapter F-14. Ottawa, Ont.

Gillies, C.T. 2003. Installation of an embedded pipe culvert: Lewis Lake tributary. FERIC, Vancouver, B.C. Advantage Report Vol. 4 No. 30. 11 pp.

Acknowledgements

The author expresses his appreciation to Dawn Safar, Tony Gaboury, Kevin Ledieu, and Roy Crawford of Alberta-Pacific Forest Industries Inc. for their cooperation and assistance during the course of this project. The author also thanks FERIC staff for report reviews, graphics and layout work, and final edit.