Advantage

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Contents

Closed-bottom corrugated-steel embedded culverts in British Columbia: overview of seven sites

Abstract

The Forest Engineering Research Institute of Canada (FERIC) and the B.C. Ministry of Forests' Resource Tenures and Engineering Branch surveyed users of closed-bottom corrugated-steel embedded culverts to find installations that generally conform to the Fish-stream Crossing Guidebook that was released in 2002 under the Forest Practices Code of British Columbia Act. This report describes seven sites that were visited, and includes the installation procedures and costs for each of the sites.

Keywords

Stream crossing, Water crossing, Embedded pipe culvert, Corrugated-steel pipe culvert, Fish habitat.

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Introduction

In some situations, closed-bottom corrugated-steel embedded culverts may be an appropriate and cost-effective alternative to conventional structures for stream crossings on forest roads in British Columbia. However, there is still little information available to potential forest industry users about the applications, installation procedures, and costs of closed-bottom embedded culverts. To address this gap, in 2002 the Engineering Section of the Resource Tenures and Engineering Branch (RTEB) of the B.C. Ministry of Forests (BCMOF) contracted with FERIC to compile an inventory and document selected installations throughout British Columbia (Gillies 2003a).

Almost all of the embedded culverts identified during this initial survey were installed prior to the release of the March 2002 Fish-stream Crossing Guidebook (BCMOF 2002). At the request of the BCMOF, the embedded culvert compendium was continued to include a selection of embedded culverts that generally conformed to this guidebook. Documenting these recent installations would allow for the dissemination of up-to-date techniques and costs associated with implementing the new guidebook.

FERIC re-surveyed the B.C. forest industry and the BCMOF RTEB surveyed Forest Region and District offices regarding closed-bottom embedded culverts installed after March 2002. Seven sites were chosen and described in more detail. This report includes individual descriptions for the seven installations (Appendix I).

Objectives

FERIC's objectives were to work in consultation with the BCMOF RTEB to:

- Re-survey major forest licensees and BCMOF Forest Region and District offices to identify the locations of existing closed-bottom embedded culverts that generally conform to the March 2002 version of the Fish-stream Crossing Guidebook.
- Conduct field inspections to collect additional information, including photographs, engineering designs, and construction methods, for embedded pipe culvert installations selected by the BCMOF.
- Prepare a report that summarizes the results of this study and that describes the embedded culvert installations that were field visited.

Methods

Major forest licensees and BCMOF District offices in each Forest Region were contacted to document closed-bottom embedded culverts that conform to the March

2002 Fish-stream Crossing Guidebook or that were not previously reported in the initial compendium (Gillies 2003a). Operations having such culverts were asked to complete a brief survey form for each installation within their operating area.

The following criteria were established by BCMOF to guide the selection of candidate installations for field inspection:

- natural stream and culvert gradients less than or equal to 6%
- culvert embedment depth of 40% of diameter for round pipes, and 20% of rise for pipe arches
- relatively uniform embedment depth (i.e., no bare areas through culvert)
- detailed design drawings prepared for the installation
- preferably in place for one freshet (i.e., in place for one year or longer)
- fish habitat at the crossing location is considered “Marginal”[1]
- installed during local fish window, or with Fisheries agency consultation for installation outside window
- examples of both round and arch culverts, but preferably a majority of round culverts
- broad geographical representation by Forest Region

During field inspections, data collection included the location, culvert and stream dimensions, design and construction details, and costs. Steel and nylon measuring tapes were used to record dimensional, depth, and distance measurements. An Impulse 200 laser[2] was used to determine gradients of the natural stream and the installed culvert, and maximum depth of fill over the culvert.

Results

A review of the survey responses resulted in the selection of seven sites for field review and documentation. Appendix I summarizes the features of the seven embedded culverts. Three of the culverts were installed prior to publication of the Fish-stream Crossing Guidebook (BCMOF 2002). The pre–March 2002 installations were guided by the working draft for 1997/98 of the Stream Crossing Guidebook for Fish Streams (Poulin and Argent 1997), as well as by B.C. Ministry of Water, Land and Air Protection guidelines in the form of “Timing windows and measures for the conservation of fish and fish habitat.”[3] The working draft for 1997/98 specified burial depths of “a minimum of 300 mm or 20% of the vertical rise for pipe arches, whichever is greatest, and a minimum of 300 mm or 20% of the vertical rise for round pipes, whichever is greatest” versus the current Fish-stream Crossing Guidebook criteria for round pipes of “40% of culvert diameter or 0.6 m, whichever is greater” and for pipe arches “at least 20% of the vertical rise.”

The seven sites illustrate examples of embedded pipe culverts covering a range of culvert types (round and arch), dimensions, infilling techniques, and site characteristics. These are considered informative examples for the purpose of describing installation techniques, costs, and requirements of embedded pipe culverts. The BCMOF was the proponent for all seven embedded culverts presented in this report.

The culvert presented in Appendix I, Site 1 was located within the Coast Forest Region, and those presented in Sites 2–7 were located within the Northern Interior Forest Region. No embedded culvert examples were selected from the Southern Interior Forest Region.

One of the installations was a round culvert, and six were pipe arches. The round culvert

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1 The definitions for “Marginal”, “Important”, and “Critical” fish habitat are given in BCMOF 2002. “Marginal” habitat has low productive capacity and contributes marginally to fish production.

2 Manufactured by Laser Technology Inc. of Centennial, Colo.

3 The purpose of these documents is to provide timing windows (windows of least risk) and measures for work related to stream crossings, to facilitate compliance with the Forest Practices Code of British Columbia Act. The documents were prepared by the designated environmental officials of the Ministry of Water, Land and Air Protection. Individual documents were prepared for either a BCMOF Forest Region, or a BCMOF Forest District.

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had a diameter of 2700 mm. The dimensions (span/rise) of the six pipe arches ranged from 1630/1120 mm to 4370/2870 mm. Culvert lengths ranged from 11 to 33 m. The average amount of infill material was 40% of diameter for the round culvert, and 10 to 38% of rise for the pipe arches.

The main differences among the field-inspected embedded culvert installations were in the depth of infill material within the culvert, and the methods of delivering and placing this material. Delivery of infill material was done manually using wheelbarrows, using powered machinery such as Bobcat loaders, and by natural infilling. Suggestions for alternative infilling techniques included tilting the culvert and partially filling it with an excavator before final placement, pushing the material through the culvert with a log, and using a conveyor system. Another suggestion was that culvert suppliers might manufacture closed-bottom culverts with removable sections or plates to allow excavators to deliver the material within the culvert once it is in place.

The placement of aggregate material during the construction of the simulated streambed varied by the size of the installed culvert. The larger culverts (Appendix I, Sites 1 and 2) were filled using Bobcat loaders. With the smaller culverts, the simulated streambed was typically constructed by delivering aggregate material using manual or natural infilling methods.

The source and size of material placed within the culverts also varied. Some installations were filled with drain rock purchased from building suppliers, while some used pit-run material containing various aggregate sizes. Other installations used a mix of both materials. Boulders and cobbles were placed on the surface, and/or within the depth of the delivered material for some installations. Natural deposition was promoted by the placement of boulders and cobbles along the corrugated surface of one culvert (Appendix I, Site 4). Natural infilling is not specifically excluded as an option for creating the simulated streambed, but this technique requires prior consultation with the Department of Fisheries and Oceans Canada.

De-watering techniques also varied. Some sites contained very low flows during the installation and did not require a large volume transfer, while other sites (Appendix I, Site 5) had full streambank volume requiring transfer around the construction site. The WaterGate™ dam by MegaSecure Inc. was used at Site 5, and on-site personnel thought the dam performed very well.

Conclusions and implementation

The re-survey identified closed-bottom embedded culverts within British Columbia that were not identified in the previous survey. Seven sites were field-visited and documented as examples of embedded pipe culvert installations. Three of the culverts were installed prior to 2002 and therefore were guided by the 1997/98 working draft of the Stream Crossing Guidebook for Fish Streams and local "Timing windows and measures for the conservation of fish and fish habitat." The remaining four culvert installations were installed after the publication of the March 2002 Fish-stream Crossing Guidebook.

The following suggestions should be considered for successful implementation of embedded culverts:

- Appropriate engineering design of embedded closed-bottom culverts can greatly enhance the ease of installation and help to ensure that the desired objectives are achieved. Positioning through the road, depth of embedment, size distribution of the aggregate to be used within the culvert, and gradient of the installation are all easily referenced on the designs.
- The use of appropriate survey equipment, such as a precise construction level and rod, during the installation will help achieve the design elevations and depths. BCMOF recommends the use of a precise construction level for profile site surveys and during installation of embedded culverts.
- Compared to conventional culverts, embedded closed-bottom culverts require additional excavation and typically require infilling with streambed material. The cost of this additional work should be budgeted when planning the installation and allocating machine time to the project.
- Installation works should be planned during the preferred fish windows and low stream flow periods to minimize the environmental risk. Emergency repairs and unforeseen circumstances may require culvert installations outside of the documented fish windows.

- Match the infilling technique to the size of the culvert. Small culverts may require manual infilling with wheelbarrows and buckets, while small motorized loaders may be effective for larger culverts. Other culvert features, such as baffles, may also influence the choice of infilling technique and equipment.
- Ensure the infill material is well graded and contains sufficient fines and sand to fill the voids in the streambed and maintain surface flow. If the infill material is too clean (without fines), fines and sand can be spread over the surface of the simulated streambed in the culvert and hosed down to drive the finer particles into the voids. Failure to seal the simulated streambed may result in a dry surface which could preclude fish passage. Backwatering the culvert by use of a downstream weir may help to promote fines to settle within the culvert. Larger rocks and boulders can be incorporated within the infill material to assist in anchoring the simulated streambed materials in the embedded culverts.
- Monitor the pumps frequently during installation to ensure they are working properly. Have a spare pump-and-hose set onsite in case one pump fails. The outlet of the hose/bypass should be positioned to allow the sediment-laden water to filter through the forest floor. Hay bales can be used to promote filtering.
- As an alternative precaution to a pump failure, consider installing a bypass culvert in addition to using a pump-and-hose setup for de-watering the installation site and maintaining streamflow during the installation of the embedded culvert. For installations that require more than one day to complete, a bypass culvert eliminates the need to monitor pumps overnight.
- Two installations which the BCMOF used as pilot projects have been documented in detail (Gillies 2002a, 2002b). These reports offer insights into installation procedures and costs, and present implementation suggestions. A third report in this series of case studies is also available (Gillies 2003b).

References

British Columbia Ministry of Forests (BCMOF). 2002. Forest practices code of British Columbia: Fish-stream crossing guidebook. Victoria, B.C. 68 pp.

Gillies, C.T. 2002a. Installation of an embedded pipe culvert: Hotfish Creek. FERIC, Vancouver, B.C. Advantage Report Vol. 3 No. 38. 11 pp.

Gillies, C.T. 2002b. Installation of an embedded pipe culvert: Stuart Lake tributary. FERIC, Vancouver, B.C. Advantage Report Vol. 3 No. 40. 8 pp.

Gillies, C.T. 2003a. Closed-bottom corrugated-steel embedded culverts in British Columbia: overview of twelve sites. FERIC, Vancouver, B.C. Advantage Report Vol.4 No. 29. 31 pp.

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

Poulin, V.A.; Argent, H.W. 1997. Stream crossing guidebook for fish streams: A working draft prepared for 1997/1998. Working draft of Forest Practices Code guidebook, prepared for B.C. Ministry of Forests; B.C. Ministry of Employment and Investment; B.C. Ministry of Environment, Lands and Parks; and Department of Fisheries and Oceans. Victoria, B.C. 94 pp.

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Appendix I

Description of 7 culvert sites

Note: The Forest Regions and Districts mentioned in this Appendix reflect the organizational structure of the BCMOF as it was prior to April 1, 2003.

Site 1

Embedded round culvert at an unnamed creek, Campbell River Forest District

Location

Coast Forest Region
Campbell River Forest District
Snowden Forest Service Road, km 8
Stream name: Unnamed

Proponent

BCMOF, B.C. Timber Sales Branch, Strait of Georgia Business Area, Campbell River Forest District

Table 1. Culvert, site, and installation data—Site 1

Culvert installation date	July 4–10, 2002
Field visit date	September 10, 2003
Culvert shape	round
Culvert dimensions	
Diameter (mm)	2 700
Length (m)	15
Installed culvert gradient (%)	0.4
Simulated streambed gradient (%)	1.1
Avg. depth of infill material (mm, % diam.)	1 070, 39.8
Avg. natural stream width and gradient (m, %)	2.1, 1.5
Stream classification	S3
Design flood event (m^3/s)	16.7
Site plan prepared	yes
Detailed design drawings prepared	yes
Cost estimates	
Planning & design ($)	1 215
Materials ($)	4 303
Delivered culvert ($)	8 109
Installation ($)	9 045
Environmental monitor ($)	1 830
Supervision ($)	2 215
Total ($)	26 717

Figure 1a. Looking towards inlet of embedded culvert.

Project description

- A wood-box culvert was a barrier to fish passage due to being very narrow (1 m wide) and constricting the natural channel. It had partially collapsed, and contained a sediment wedge at the inlet. It was replaced with a closed-bottom corrugated-steel embedded round culvert (Table 1, Figures 1a–c).

Habitat description/indicators

- The stream was not in its original location. Old railway grades (1940s) had forced the stream to flow along associated ditchlines which subsequently became the new stream channel.
- Electroshocking within the stream had determined that cutthroat trout were present.
- The natural stream has a sandy and organic streambed. Few cobbles or boulders are present within the stream channel. A deep pool exists approximately 10 m from the outlet of the culvert, and was one of the only areas containing water during the field visit. This pool was identified and noted on the design drawings as a habitat attribute (year-round rearing) to be left undisturbed.
- The stream habitat was in a transition zone between "Marginal" and "Important" habitat as noted by a Ministry of Water, Land and Air Protection ecosystem officer during the site visit.

Planning and design

- A site plan and a detailed design were produced by StoneCroft Project Engineering of Black Creek. An assessment of the existing drainage structure and replacement options in terms of impacts on fish habitat was prepared by Raven River Habitat Services of Quathiaski Cove.
- A semi-permanent benchmark was marked on an alder tree in the field for elevational reference. Approximate target culvert elevations were shown on the designs.

Pre-installation works

- Fish nets were installed upstream and downstream of the site to keep fish from entering the work area.
- Fish salvage was conducted between the nets using baited minnow traps and an electro-fisher.
- An earth dam was built immediately upstream to divert the stream flow along an already existing ditchline. Inlet and outlet sumps were prepared to collect sediment-laden seepage. Pumps and hoses delivered this water away from the

stream to be filtered through the forest floor.
- The puncheon and sill logs from the existing wood-box culvert were carefully removed.

Construction works

- A BCMOF contract construction specialist, Mike Browning of Larch Systems Inc., supervised the installation of the embedded culvert. Equipment included a Link-Belt 3400 excavator, Hitachi EX 150 excavator, and jumping-jack and plate compactors. A precise construction level was used onsite.
- D.L Bernard Contracting of Fanny Bay provided on-site environmental monitoring and fisheries consultation during the construction activities. The installation was done during the preferred in-stream work window.

Simulated streambed/embedment material

- Sand, gravel, and cobbles were all delivered to the site for use within the culvert. Boulders were salvaged nearby and were installed within and along the surface of the simulated streambed (Figure 1b).

Embedment method and time frames

- The culvert was infilled using a Bobcat loader. The Bobcat first placed rock lines within the culvert, and then pit-run aggregate was delivered to 30 cm below a reference 40% depth spray paint line. Rounded gravels and cobbles were placed to a depth of 20 to 30 cm along the surface of the simulated streambed.
- A hydro-seeding truck was used as a water source for hosing and sealing the surface of the simulated streambed. A low-flow channel was excavated using the force of the pumped water.
- Infilling the culvert took approximately 4 hours.

Additional information

- The culvert installation was compared to an adjacent (50 m away) 6.6-m slab girder bridge installed at the same time. The culvert was installed for approximately $12 500 less than the bridge.

Observations and simulated streambed comments

- Infill gravel within the culvert near the inlet has been displaced from one side of the culvert and has deposited along the opposite side (Figure 1c). The stream turns 90 degrees to enter the culvert, which forces flows along the scoured side of the culvert.
- The simulated streambed's distribution and size of material matches well with the natural streambed. The width of the simulated stream is similar to natural stream reaches immediately upstream and downstream. The natural channel has a distinct low flow channel, which is absent within the culvert. The absence of a confined channel within the culvert may result in lower water depths during typical flows (spread over entire surface).

Figure 1b. Looking towards outlet of culvert.

Figure 1c. Mound of gravel (white arrow) along one side of the culvert near the inlet.

Prepared design and assessments

StoneCroft Project Engineering. 2003. Snowden Road & Brewster Lake Road Junction. As-built design drawings prepared for BCMOF, Campbell River Forest District. 2 pp.

D.L. Bernard Contracting. 2002. Post construction environmental report: Snowden Forest Service Road wooden box culvert replacement. Report prepared for BCMOF, Campbell River Forest District. 13 pp.

Raven River Habitat Services. 2001. Stream drainage structure assessments. Assessment prepared for BCMOF, Campbell River Forest District. 4 pp.

For further information:

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Site 2

Embedded multiplate pipe arch at Little Wedeene River back channel, Kalum Forest District

Location
Northern Interior Forest Region
Kalum Forest District
Wedeene Forest Service Road, km 30.1
Stream name: Little Wedeene River, back channel

Proponent
BCMOF, Prince Rupert Forest Region
(pre-April 2003)

Project description
- A partially collapsed, 3.9-m-wide by 2.0-m-high wooden-box culvert was replaced with a closed-bottom corrugated-steel embedded multi-plate pipe arch culvert (Table 2, Figures 2a–c). The BCMOF Bridge Replacement Program funded the replacement.

Table 2. Culvert, site, and installation data—Site 2

Culvert installation date	February 2000
Field visit date	September 29, 2003
Culvert shape	pipe arch
Culvert dimensions	
Span (mm)	4 370
Rise (mm)	2 870
Length (m)	32.9
Installed culvert gradient (%)	0.5
Simulated streambed gradient (%)	0.5
Avg. depth of infill material (mm, % diam.)	570, 19.9
Avg. natural stream width and gradient (m, %)	3.9, 1.0
Stream classification	S3
Design flood event (m^3/s)	n/a
Site plan prepared	yes
Detailed design drawings prepared	yes
Cost estimates	
Delivered culvert, unassembled ($)	61 500
Total ($)	109 000 [a]

[a] No detailed costs were supplied.

Figure 2a. Embedded culvert showing natural woody debris within stream, and the height of road fill.

Habitat description/indicators
- The stream is a back-watering channel for the Little Wedeene River and is situated on the river floodplain. The back channel offers an abundance of rearing habitat for fish and is an important habitat feature of the river and floodplain system.
- Electroshocking during a stream assessment determined that rainbow trout were present at the time of sampling. Coho and Chinook salmon were also presumed to use the back channel during other times of the year.
- Stream sections with no surface flow and isolated pools were located approximately 25 m upstream from the culvert. Light currents in the pools through this section indicated subsurface flows.
- The natural stream has a silty/sandy and organic streambed. Numerous rounded cobbles are present along the surface of the streambed (Figure 2b). Sandy deposits are also present. The stream is bordered by typical deciduous floodplain vegetation.

Planning and design
- A site survey was conducted and a site plan produced by the BCMOF, Prince Rupert Forest Region. A detailed set of design drawings was produced by McElhanney Consulting Services Ltd. of Smithers.
- During the field survey, semi-permanent reference points were established for elevational reference during construction. Working points were shown on the designs for the embedded culvert's inlet and outlet invert elevations (relative to the field reference points). The survey table on the design contained horizontal distances and bearings from the reference points to the working points, which essentially could be used to control the horizontal alignment of the embedded culvert.
- The design specified culvert infill material to be placed to a nominal depth of 600 mm with the following particle size distribution: 40% less than 80 mm; 30% between 80 mm and 180 mm; and 30% between 180 mm and 300 mm.
- The average depth of infill material during the field visit was within 30 mm of the suggested depth, essentially achieving the design level.

Pre-installation works

- Stop nets were installed upstream and downstream of the site to keep fish from entering the work area. Fish were captured between the nets and relocated upstream.
- Upstream and downstream sumps were excavated to collect stream and seepage flow, and provide a de-watered work site. Pumps and hoses were used to remove water from the sumps.

Construction works

- Kalum Construction Ltd. of Terrace installed the embedded culvert under contract. Contract works did not include fish isolation from the work site or sampling/assessment. Equipment included two Hitachi 300 excavators, two plate compactors, a generator, and a pneumatic rammer (for haunch compaction). A precise construction level was used during installation.
- The culvert was assembled within the excavation. Scaffolding was used within the culvert, and ladders were used outside the culvert, during the assembly of the upper plates.
- Pumps were operated through the night to keep the site de-watered and to prevent sediment-laden water from entering the stream channel.
- The installation was done outside of the preferred in-stream work window. Consultation with the Department of Fisheries and Oceans, and notification of the timing of the works, were both done before works began.

Simulated streambed/embedment material

- Pit-run aggregate was delivered to the site for use as embedment material. The design stated that a heterogeneous mixture of specified material be placed in such a way as to seal the simulated streambed (see planning and design section).

Embedment method and time frames

- The culvert was infilled using a Bobcat loader. Infilling took approximately one day to complete.

Additional information

- The culvert predominantly functions to balance water levels on either side of the road and the typical water velocity through the culvert is minimal. Higher flow events do occur when the Little Wedeene River rises.
- The back channel is not conducive to measurable and/or predictable flood events, so a flood event volume (m^3/s) was not calculated. The culvert was designed to accommodate the average stream width.

Figure 2b. The natural stream bedload is comprised mainly of cobble size material. Note the alignment of the culvert with the stream.

Figure 2c. Embedded culvert showing finer, sandy material deposited along one side of the culvert's inlet. The opposite side is mostly bare.

Observations and simulated streambed comments

- Numerous small fish approximately 7 cm in length were observed during the field visit, both outside and within the culvert.
- Fine material has been deposited along one edge of the culvert at the inlet (Figure 2c). The opposite edge has had material displaced, creating a distinct deeper channel through this section. Through the centre and outlet of the culvert, the infill material is at a consistent depth from side to side.
- The simulated streambed's composition visually compares well with the fines component of the natural stream channel, but is lacking the abundant cobble-sized material found in the natural channel.

Prepared design

McElhanney Consulting Services Ltd. 1999. Wedeene FSR, km 30, Little Wedeene River back channel. Design drawings prepared for BCMOF, Prince Rupert Forest Region. 5 pp.

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Site 3

Embedded pipe arch at an unnamed creek, Skeena Stikine Forest District

Location
Northern Interior Forest Region
Skeena Stikine Forest District
Suskwa-Nichyeskwa Forest Service Road, km 1.2
Stream name: unnamed

Proponent
BCMOF, Prince Rupert Forest Region (pre-April 2003)

Project description
- A 1200-mm-diameter corrugated-steel round culvert had partially deteriorated and was undersized for the stream flow. It was replaced with a closed-bottom corrugated-steel embedded pipe arch culvert (Table 3, Figures 3a–d).

Habitat description/indicators
- Fish were observed during installation, and are presumed to be rainbow trout and/or bull trout.
- Fish habitat within the stream was not assessed according to the March 2002 Fish-stream Crossing Guidebook, and is therefore rated as unknown.
- The fast-flowing stream had an average depth of 11 cm at the time of the field visit. The natural stream substrate was predominantly gravels and cobbles. There were no obvious physical barriers to fish passage observed during the field visit.

Table 3. Culvert, site, and installation data—Site 3

Culvert installation date	1998
Field visit date	September 29, 2003
Culvert shape	pipe arch
Culvert dimensions	
Span (mm)	2 130
Rise (mm)	1 400
Length (m)	11
Installed culvert gradient (%)	1.3
Simulated streambed gradient (%)	0.9
Avg. depth of infill material (mm, % rise)	315, 22.5
Avg. natural stream width and gradient (m, %)	3.4, 3.0
Stream classification	S3
Design flood event (m^3/s)	unknown
Site plan prepared	yes
Detailed design drawings prepared	yes
Cost estimates	
Contract ($)	7 000
Delivered culvert ($)	4 500
Total ($)	11 500

- Approximately 15 m downstream, downed trees have spanned the stream and are a source of large woody debris. A gravel wedge is exposed in this area along the centre of the stream, creating a somewhat braided channel.

Planning and design
- A site survey was conducted and a site plan produced by McElhanney Consulting Services Ltd. of Smithers. A design drawing, utilizing the site plan, was produced by the BCMOF, Prince Rupert Forest Region. The design drawings showed plan and profile views of the proposed culvert.
- During the field survey, traverse hubs and reference trees were established for elevational and horizontal field reference. Working points were indicated on the designs for the inlet and outlet of the embedded culvert.
- The target infill depth was 20% of the culvert's rise. The average depth of infill material during the field visit was 315 mm, or 22.5% of the culvert's rise.

Pre-installation works
- The site was de-watered by use of a gravity-fed diversion channel.

Construction works
- The two-sectioned culvert and coupler materials were supplied by the BCMOF.
- Barb's Trucking of Telkwa installed the embedded culvert under contract. Contract works included the removal of the existing structure, production and delivery of backfill and infill material, installation of embedded culvert, and building the road to grade. Contract works did not include the purchase and the delivery of the culvert. All works were completed in one day.

Simulated streambed/embedment material
- Pit-run aggregate was delivered to the site for use as embedment material.

Embedment method and time frames
- The culvert was infilled by placing clean streambed material at the inlet of the culvert and having the natural stream flow move and deliver this material within the culvert. An excavator assisted with the placement of this material.

- Natural infilling was expected to complement the delivered material.

Additional information

- The stream parallels the road for approximately 25 m before entering the culvert. However, there is no obvious remnant channel to suggest the stream was redirected by the road.

Observations and simulated streambed comments

- The average natural stream width (3.4 m) was greater than the maximum width of the culvert.
- A mound of material (gravels and cobbles) had been deposited along one edge of the culvert at the inlet (Figure 3b). The opposite edge has had material displaced, creating a distinctly deeper channel through this section. The difference in depth is partly due to the stream turning sharply to enter the culvert (Figure 3c) resulting in scour on the one side and deposition on the other.
- Through the centre and outlet of the culvert, the infill material is at a relatively consistent depth.
- The simulated streambed material visually compares well with the natural streambed composition (Figure 3d).

Prepared design

McElhanney Consulting Services Ltd. 1998. Nichyeskwa FSR, km 1.5, unnammed creek, site plan - existing condition. Site plan prepared for BCMOF, Prince Rupert Forest Region. 2 pp.

For further information:

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Figure 3a. Looking towards inlet of embedded culvert, showing stream flow and cobble sized material.

Figure 3b. Inlet of embedded culvert showing uneven depth of aggregate partly due to the stream turning sharply into the culvert.

Figure 3c. Inlet of embedded culvert showing stream turning sharply into the culvert.

Figure 3d. Natural bedload material downstream of the culvert.

Site 4

Embedded pipe arch with baffles and a concrete headwall at Nichyeskwa Creek, Skeena Stikine Forest District

Location

Northern Interior Forest Region
Skeena Stikine Forest District
Suskwa-Nichyeskwa Forest Service Road, km 2.4
Stream name: Nichyeswka

Proponent

BCMOF, Prince Rupert Forest Region
(pre-April 2003)

Table 4. Culvert, site, and installation data—Site 4

Culvert installation date	1998
Field visit date	October 1, 2003
Culvert shape	pipe arch
Culvert dimensions	
Span (mm)	3 730
Rise (mm)	2 290
Length (m)	12.8
Installed culvert gradient (%)	2.6
Simulated streambed gradient (%)	2.0
Avg. depth of infill material (mm, % rise)	235, 10.3
Avg. natural stream width and gradient (m, %)	4.6, 3.0
Stream classification	S3
Design flood event (m^3/s)	unknown
Site plan prepared	yes
Detailed design drawings prepared	yes
Cost estimates	
Contract ($)	20 000
Delivered culvert, unassembled ($)	16 000
Fish baffles ($)	1 250
Total ($)	37 250

Figure 4a. Looking upstream showing the embedded culvert, stream flow, and one partially exposed baffle.

Project description

- A 1000-mm-diameter corrugated-steel round culvert had deteriorated, was perched at its outlet, and was undersized for the stream flow. It was replaced with a closed-bottom corrugated-steel embedded multi-plate pipe arch culvert with baffles (Table 4, Figures 4a–c).

Habitat description/indicators

- The stream is fish-bearing, although no fish were observed during the installation. The presumed species are rainbow trout and/or bull trout.
- This replacement project predated the March 2002 Fish-stream Crossing Guidebook. As such, fish habitat was not assessed according to the guidebook, and is therefore rated as unknown.
- There were no obvious physical barriers to fish passage observed during the field visit.
- The fast-flowing stream had an average depth of 17 cm at the time of the field visit. The natural stream substrate was predominantly gravels and cobbles.
- Upstream of the culvert, the stream banks on both sides are undercut for some distance. The predominant vegetation adjacent to these banks is alder.

Planning and design

- A site survey was conducted during 1992 and a site plan produced by the BCMOF, Prince Rupert Forest Region. A design drawing, utilizing the site plan, was produced by a BCMOF Professional Engineer during 1997. The design drawings included the proposed culvert being shown on the site plan, both in plan and profile view. The concrete headwall was also shown on the design.
- During the field survey, reference points and benchmarks were established for elevational and field reference. Invert elevations were given for the inlet and outlet of the proposed structure, resulting in a design gradient of 2.5%.
- The culvert was designed to be installed approximately 56 cm below the bottom of the streambed. After infilling, this would result in an embedment depth of approximately 24%. The observed embedment depth was measured at 10.3%.
- Infilling was specified on the design to include placing fifty rocks, 20 to 30 cm in diameter, at random intervals within the culvert.

Pre-installation works

- A dam consisting of sand- and gravel-filled livestock feed bags was built to isolate the work site from stream flow. A pump and hose were used to deliver water downstream below the worksite.
- A sump was dug by the excavator at both the inlet and outlet of the culvert. Pumps and hoses were used to disperse sediment-laden water onto the forest floor.

Construction works

- Barb's Trucking of Telkwa installed the embedded culvert under contract. Contract works included the removal of the existing structure, production and delivery of backfill and infill material, installation of the embedded culvert, preparation and construction of the concrete headwall, and building the road to grade.
- The culvert materials were supplied by the BCMOF.
- The concrete headwall was poured in place after the culvert had been installed and after the backfill had been compacted.

Simulated streambed/embedment material

- The simulated streambed is comprised of natural bedload material which has migrated and deposited in the culvert.

Embedment method and time frames

- Cobbles and boulders were carried/rolled into the bottom of the installed culvert and placed at random intervals.
- The cobbles and boulders placed within the culvert acted to slow bedload movement and promote deposition. The diameter of this material was observed to be similar to the largest 10% of the natural streambed.

Additional information

- A 2-m-wide and 1-m-deep pool at the immediate outlet of the original perched culvert was partially filled with aggregate in order to install the culvert to design grade. This area is now a riffle.
- The concrete headwall at the inlet allowed the length of the culvert to be shortened and kept fillslope material from reaching the stream. A concrete headwall can also function during high flows to contain water levels which are above the top (obvert) of the culvert.

Figure 4b. Inlet of embedded culvert showing concrete headwall and riprap armouring along the stream bank.

Figure 4c. Outlet of embedded culvert showing riprap armouring on the right, riffle area near the outlet, and shallow road fill above the culvert.

Observations and simulated streambed comments

- The average natural stream width (4.6 m) was greater than the maximum width of the culvert.
- Ample accumulation and deposition of natural streambed material was observed, allowing the entire width inside the culvert to be covered (no exposed areas).
- All but one of the baffles was completely covered with bedload material. The baffles helped retain material within the culvert, though the intent of the embedded system is to design and retain streambed material without requiring baffles.

Prepared design

BCMOF, Prince Rupert Region 1998. Suskwa-Nichyeskwa FSR, 2.4 km, unnammed creek, site plan. Design drawing. 1 p.

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Site 5

Embedded pipe arch at an unnamed creek, Prince George Forest District

Location

Northern Interior Forest Region
Prince George Forest District
Moldowan Forest Service Road, km 7.6
Stream name: unnamed

Proponent

BCMOF, Prince George Forest Region (pre-April 2003)

Project description

- A 450-mm-diameter corrugated-steel round culvert was undersized for the stream flow and had become blocked with ice during spring breakup. This resulted in the stream flowing over the road. An emergency repair was necessary as residents required the road. The replacement structure was a closed-bottom corrugated-steel embedded pipe arch culvert (Table 5, Figures 5a–c).

Table 5. Culvert, site, and installation data—Site 5

Culvert installation date	April 24, 2003
Field visit date	October 15, 2003
Culvert shape	pipe arch
Culvert dimensions	
Span (mm)	1 630
Rise (mm)	1 120
Length (m)	12.3
Installed culvert gradient (%)	2.4
Simulated streambed gradient (%)	3.2
Avg. depth of infill material (mm, % rise)	430, 38.4
Avg. natural stream width and gradient (m, %)	0.8, 2.0
Stream classification	S4
Design flood event (m^3/s)	unknown
Site plan prepared	no
Detailed design drawings prepared	yes
Cost estimates	
Planning and design	onsite
Culvert ($)	3 365
Backfill & infill material ($)	4 782
Labour ($)	1 980 [a]
Heavy equipment ($)	5 015
Compactors and pumps (rental) ($)	810
Other ($)	183
De-watering (Water-Gate™)	n/a [b]
Total ($)	16 135

[a] No cost for supervision was supplied.
[b] The Water-Gate™ dam was loaned for this installation. The purchase price for this sized product was approximately $4 200 including the diverter tunnel. Water-Gate is a trademark of MegaSecur Inc. of Victoriaville, Que.

Habitat description/indicators

- The stream had not previously been classified, and was defaulted to an S4 classification due to time constraints. The stream is assumed to contain rainbow trout.
- Fish habitat within the stream was rated as "Marginal" as per the March 2002 Fish-stream Crossing Guidebook. The stream did not contain any surface water during the field visit.
- The natural stream near the crossing site had shallow banks (approximately 15 to 30 cm) and was difficult to discern. The stream's natural substrate was predominantly sand with minor amounts of gravel.

Planning and design

- Due to time constraints, the design was completed onsite by a BCMOF Professional Engineer. A construction level was used for accurate elevation measurements. All elevations were in reference to a locally established benchmark.
- The stream was surveyed for approximately 30 m upstream and downstream from the crossing location. This survey identified the stream's natural gradient, which then determined the embedded culvert's gradient and elevation.
- A downstream rock weir was built approximately 1 m from the outlet. Its function was to create a backwater, extending approximately three-quarters through the culvert during flow conditions.
- As-built drawings were prepared for the installation, showing the inlet and outlet invert elevations, the height of fill, and the stream profile.

Pre-installation work

- The site was de-watered using a Water-Gate™ dam and its associated overflow diverter tunnel (Figure 5b). Four pumps with hoses were also used. The diverter tunnel delivered water downstream below the installation site. Hay bales were positioned around the outlet of the diverter tunnel to help capture sediment exiting the tunnel.
- Two sumps were excavated to capture seepage. One was immediately downstream of the dam (Figure 5b) and the other was near the outlet of the culvert.

Construction work

- Dahl Grading and Excavation Ltd. of Prince George installed the embedded culvert under hourly hire. Work included the removal of the

existing structure, delivery of pit-run aggregate, installation of the embedded culvert, and building the road to grade.
- The pipe arch culvert was supplied by the BCMOF.
- Equipment included a Caterpillar 315 excavator, a gravel truck, three plate compactors, four sets of pumps and hoses, and the de-watering dam described above.

Simulated streambed/embedment material

- Purchased aggregate (2-cm-minus washed gravel) and pit-run material were hauled to the site for use as infill material. Riprap was also delivered for stream bank and fill slope armouring (Figure 5c).

Embedment method and time frames

- The two culvert sections were each infilled while on the road, before they were each individually installed. Gravel-sized pit-run aggregate was placed inside the culvert from both ends using shovels and rakes. Infilling one section took approximately 2 hours, for a total of 4 hours for the whole culvert.
- Once the culvert sections were in place and backfilled, washed gravel was placed along the upstream stream bank adjacent to the inlet of the culvert to help prevent fine soil movement into the stream. Some of this gravel has migrated into the culvert during higher stream flows, including during the release of the dam.

Additional information

- The excavator prepared the installation site while the culvert sections were being infilled away from the excavation. The excavator was near its maximum lifting/placement capacity when handling an infilled section. Ten-centimetre-wide lifting straps were used when lifting and placing the sections.
- The Water-Gate™ dam and diverter tunnel worked well to de-water the site. Sandbags could be used along the front bib making dismantling faster and easier than when using loose aggregate. The pumps and hoses were primarily used before the diverter tunnel was attached to the dam.

Observations and simulated streambed comments

- The weir helps to backwater the culvert allowing fines (sand/silt) to deposit. Where fines have deposited within the culvert, the washed gravels are completely covered. The result visually compares well with the natural streambed. Washed gravel is visible within the culvert near the inlet.

Figure 5a. Looking towards outlet of embedded culvert showing surface cobbles and gravel.

Figure 5b. Water-Gate™ dam with the overflow diverter tunnel (photo courtesy of BCMOF).

Figure 5c. Inlet of embedded culvert.

Prepared design

BCMOF, Prince George Region. 2003. Moldowan FSR, km 7.6, As-built of culvert installation. 1 p.

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Site 6

Embedded Pipe Arch at an unnamed creek, Prince George Forest District

Location
Northern Interior Forest Region
Prince George Forest District
Moldowan Forest Service Road, km 8.8
Stream name: unnamed

Proponent
BCMOF, Prince George Forest Region (pre-April 2003)

Project description
- A 500-mm-diameter corrugated-steel round culvert was undersized for the stream flow and had become blocked with ice during spring breakup. This resulted in the stream flowing over the road surface. An emergency repair was necessary as residents required the road for access. The replacement structure was a closed-bottom corrugated-steel embedded pipe arch culvert (Table 6, Figures 6a–c).

Table 6. Culvert, site, and installation data—Site 6

Culvert installation date	May 1, 2002
Field visit date	October 16, 2003
Culvert shape	pipe arch
Culvert dimensions	
Span (mm)	1 630
Rise (mm)	1 120
Length (m)	12
Installed culvert gradient (%)	1.0
Simulated streambed gradient (%)	1.0
Avg. depth of infill material (mm, % rise)	200, 17.9
Avg. natural stream width and gradient (m, %)	1.0, 2.0
Stream classification	S4
Design flood event (m^3/s)	unknown
Site plan prepared	no
Detailed design drawings prepared	no
Cost estimates	
Planning and design	onsite
Culvert ($)	3 365
Backfill & infill material ($)	3 533
Labour ($)	1 305 [a]
Heavy equipment ($)	8 515
Other ($)	1 364
Dam materials ($)	267 [b]
Total ($)	18 349

[a] No cost for supervision was supplied.
[b] "Dam materials" does not include the cost of the diversion pipe.

Habitat description/indicators
- The stream had not previously been classified, and was defaulted to an S4 classification due to time constraints. The stream is assumed to contain rainbow trout.
- Fish habitat within the stream was rated as "Marginal" as per the March 2002 Fish-stream Crossing Guidebook. The stream did not contain any surface water during the field visit and may typically be dry for 2 or 3 months of the year.
- Upstream of the crossing, the streambanks ranged in height from approximately 30 to 40 cm. Downstream of the crossing the stream had shallow indistinct banks (approximately 10 to 25 cm, Figure 6c). The stream's natural substrate was predominantly sand with minor amounts of gravel and cobbles.

Planning and design
- Due to time constraints, the design was done onsite by a BCMOF Professional Engineer. A construction level was used for accurate elevation measurements. All elevations were in reference to a locally established benchmark.
- The stream was surveyed for approximately 30 m upstream and downstream from the crossing location. This survey identified the stream's natural gradient, which then determined the embedded culvert's gradient and elevation.
- A downstream rock weir was built approximately 1 m from the outlet. Its function was to create a backwater, extending approximately halfway through the culvert during flow conditions.

Pre-installation work
- The site was de-watered using a gravity-fed diversion. First, a dam of sandbags was built and the containment side was lined with a sheet of plastic. Large rock was placed near the base of the dam to secure the plastic to the ground.
- An 800-mm plastic diversion pipe (typical Big-O without perforations) was used as a bypass. The pipe was laid in a trench parallel to the proposed culvert location, through the road, extending approximately 10 m downstream of the culvert outlet.
- Hay bales were placed downstream of the bypass outlet across the full stream width to capture sediment.

- Sumps were excavated near the outlet area of the culvert to capture seepage. A pump delivered the sediment-laden water onto the forest floor away from the stream channel.

Construction work

- Dahl Grading and Excavation Ltd. of Prince George installed the embedded culvert under hourly hire. Work included the removal of the existing structure, delivery of pit-run aggregate, installation of the embedded culvert, and building the road to grade. The pipe arch culvert was supplied by the BCMOF.
- Equipment included a Caterpillar 315 excavator, a gravel truck, plate compactors, and a pump and hose.

Simulated streambed/embedment material

- Purchased aggregate (2-cm-minus clean gravel) and pit-run aggregate were hauled to the site as infill material.

Embedment method and time frames

- Each of the two culvert sections were infilled on the road, before they were individually installed. A mix of pit-run and washed gravel was placed inside the culvert from both ends using shovels and rakes. Material could be thrown and/or raked close to the centre of the culvert section. At times, workers would enter the culvert to place or move material. Infilling one section of the culvert took approximately 2 hours, for a total of 4 hours for the whole culvert.

Additional information

- The excavator prepared the installation site while the culvert sections were being infilled away from the excavation. The excavator was near its maximum lifting/placement capacity when lifting and placing the sections.

Observations and simulated streambed comments

- The weir helps to backwater the culvert allowing fines (sand/silt) to deposit. Where fines have deposited within the culvert, the infill material is partially covered, somewhat matching the natural streambed. Cobbles are visible within the culvert near the inlet.

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Figure 6a. Looking towards inlet of embedded culvert showing sandy bottom with surface cobbles and gravels.

Figure 6b. Looking towards outlet of embedded culvert showing cobble-sized bedload.

Figure 6c. Looking towards the outlet of the embedded culvert, showing flat terrain and shallow stream banks (dashed line indicates the approximate centre of the stream channel).

Site 7

Embedded Pipe Arch at an unnamed creek, Fort St. James Forest District

Location

Northern Interior Forest Region
Fort St. James Forest District
Leo-Trembleur Forest Service Road, km 8.8
Stream name: unnamed

Proponent

BCMOF, Prince George Forest Region (pre-April 2003)

Project description

- Two 500-mm-diameter corrugated-steel round culverts positioned one above the other, were considered undersized. The culverts became blocked with ice during spring breakup, resulting in the stream flowing over the road surface. An emergency repair was necessary as residents of the Dzitl'ainli First Nations community required the road for access. A temporary bridge was installed providing access until a replacement structure, a closed-bottom corrugated-steel embedded pipe arch culvert (Table 7, Figures 7a–c), was installed.

Table 7. Culvert, site, and installation data—Site 7

Culvert installation date	August 18, 2002
Field visit date	October 16, 2003
Culvert shape	pipe arch
Culvert dimensions	
Span (mm)	1 880
Rise (mm)	1 260
Length (m)	16
Installed culvert gradient (%)	1.2
Simulated streambed gradient (%)	1.8
Avg. depth of infill material (mm, % rise)	295, 23.4
Avg. natural stream width and gradient (m, %)	1.3, 2.3
Stream classification	S4
Design flood event (m^3/s)	unknown
Site plan prepared	yes
Detailed design drawings prepared	no
Cost estimates	
Site plan ($)	1 400
Culvert ($)	4 350
Backfill & infill material ($)	1 600
Labour ($)	1 200
Heavy equipment ($)	10 800
Other ($)	300 [a]
Total ($)	19 650

[a] Includes 30 m of geotextile, hay bales, and grass seeding.

Habitat description/indicators

- The stream was assumed to contain rainbow trout. Fish habitat within the stream was rated as "Marginal" as per the March 2002 Fish-stream Crossing Guidebook. The stream is typically dry starting near the middle of July and remains dry for 2 to 3 months each year.
- Immediately downstream of the crossing, the site appeared to have been disturbed by heavy machinery during a recent powerline installation. A pool adjacent to the outlet is approximately 5 m wide and measured 28 cm deep during the field visit. Further downstream of the pool, the stream averaged 1.4 m wide and had an incised channel which averaged 25 cm in depth. Upstream widths averaged 1.2 m and average channel depths were similar to those upstream, although they were up to 61 cm deep. Water depths during the field visit averaged 6 cm.
- The stream's natural substrate was predominantly gravel and cobbles. Organic material was also present along the streambed.

Planning and design

- A site plan was prepared before the installation. Due to time constraints, the design was done onsite by a BCMOF Professional Engineer. A construction level was used for elevation measurements. All elevations were in reference to a locally established benchmark.
- The stream was surveyed using a level for approximately 30 m upstream and downstream from the crossing location. This survey identified the stream's natural gradient and relative elevation, which then determined the embedded culvert's gradient and elevation.
- A weir was built of boulders and gravel approximately 3 m downstream from the outlet. Its function was to create a backwater through the culvert. The weir was completely covered by water during the field visit.

Pre-installation work

- The site was naturally dry during the culvert installation. A sump was prepared at the inlet to collect subsurface seepage. During the course of the installation, the sump was emptied twice using a pump and hose.

Construction work

- Lakeview Holdings Ltd. of Fort St. James installed the embedded culvert under hourly hire. Works included the removal of the existing structures (i.e., both the temporary bridge and failed culvert), delivery of pit-run and riprap aggregate, installation of the embedded culvert, and building the road to grade. The entire installation took 8 hours to complete. The pipe arch culvert was supplied by the BCMOF.
- The road was rebuilt with fill to a 0% grade, eliminating the old dip (4%) in the road at the crossing location.
- Equipment included two Hitachi EX200 LC excavators, two gravel trucks, plate compactors, and a pump with a hose.
- Workers used 2 × 4 wood to compact backfill material below the haunches of the culvert. Shovels, rakes and the backhoe bucket were used to smooth each uncompacted backfill lift before running a plate compactor over the surface.

Simulated streambed/embedment material

- Two loads of pit-run aggregate (sandy-gravel with trace of fines) were hauled 6 km to the site as infill material. One load of riprap (35 to 80 cm diameter) was hauled 35 km to the site for use as infill material and for armouring the stream bank and fillslopes.

Embedment method and time frames

- The two culvert sections were each separately infilled on the road before they were installed. Each section was filled with pit-run aggregate using shovels and wheelbarrows (taking approximately 2 hours each).
- Larger riprap was placed amongst the infill material at various levels and along the surface of the simulated streambed.

Additional information

- The infill material was sourced from a pre-evaluated pit. The aggregate was deemed appropriate as it contained a large component of sand, which would help to fill any voids.
- Emergency transport vehicles were parked on the village side of the construction site, which would allow the vehicles access to the village if needed.

Observations and simulated streambed comments

- The simulated streambed was predominantly under water, except for a mound of material near the inlet. The infill material appeared to match well with the natural streambed with respect to size and distribution.

Figure 7a. Looking towards outlet of embedded culvert, showing predominantly gravel substrate. Spray paint lines, as indicated by the arrow, along the culvert's wall indicate target infill depth plus 5 cm.

Figure 7b. Outlet of embedded culvert showing water depth during field visit and subsurface material.

Figure 7c. Looking towards the outlet of the embedded culvert showing flat terrain and shallow stream banks. Arrow indicates centre of braided stream channel through the powerline clearing.

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