Fish Habitat Compensation Projects along Yukon Highways

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ABSTRACT

Under the Fisheries Act, highway construction projects that result in harmful disruption or destruction of fish habitat require replacement habitat. At Yukon Highways & Public Works we have developed successful compensation projects together with the Department of Fisheries and Oceans, and in many cases with the help of consultants.

This paper describes three Yukon examples. The first project describes the re-establishment of fish passage through two large culverts that were elevated. This was done back by backwatering the culvert inlets, constructing a riffle, and by installing baffles in one of the culverts. For the second project we will be creating over-wintering habitat for grayling in a small fresh water stream by excavating small side channels. The last project describes how we will be connecting two old gravel pit lakes with a large glacially fed river system. This will provide year-round fish habitat and a refuge for fish in summer to escape from turbid river water.

1.0 Introduction

In Yukon the human footprint on the overall landscape is still relatively small and many of our highways and bridges cross pristine wilderness. Under the federal Fisheries Act, highway construction projects that result in harmful disruption or destruction of fish habitat require development of replacement habitat. Consequently, in situations where we are required to find replacement habitat, we spend considerable effort investigating possible projects. Regardless of the challenge, Yukon Government Department of Highways & Public Works (HPW) has developed several fish habitat compensation projects in recent years.

This paper provides an overview of three representative projects in Yukon. The descriptions include information on each site, the reasons for the project, design, construction, and overall cost.

2.0 Marshall Creek Fish Passage

2.1 Site Information

The first project involves re-establishing fish passage at Marshall Creek where it crosses the Alaska Highway. The creek crossing is located at km 1562, which is about 16 km east of Haines Junction. The Marshall Creek watershed drains an area of 264 km^2 and flows south into the Dezadeash River, a major tributary to the Alsek drainage. The Alaska Highway crosses the lower portion of Marshall Creek, five km upstream from the mouth.

There are at least five different species of fish living in Marshall Creek. Arctic grayling and slimy sculpin are the most common and round whitefish, Dolly Varden, and rainbow trout are encountered occasionally. Most of these fish likely spend their summers in Marshall Creek and their winters downstream in the Dezadeash and Alsek Rivers.

In 1967, a bridge spanning Marshall Creek was replaced with two 5 m wide closed bottom multi-plate arch culverts. Over time, scouring of the outlet pools resulted in a significant drop at the outlet and the culverts were became a barrier to fish. In 2002 for instance, hundreds of Arctic grayling were observed attempting, unsuccessfully, to enter the culverts (1).

2.1 Reason for this Project

In general, the creek has a high habitat value and is an important local fishing destination. The elevated culverts were considered to be a sore point with both DFO and the local community. The importance to the community was illustrated by the fish capture and release work done by the local wildlife steward. For several years he caught fish downstream of the culverts and moved them across the culverts in an attempt to maintain upstream fish populations. Figure 2 shows this work in action.

There was no initial trigger under the Fisheries Act for HPW to improve the Marshall Creek situation. But, when DFO deemed the habitat replacement for a different highway project inadequate, improving the Marshall Creek site became the obvious choice. Meanwhile, HPW was planning highway reconstruction adjacent to the creek and funding was made available for the Marshall Creek Fish Passage project.

2.2 Culvert Barrier

The background studies, design and monitoring work for this project were completed by Environmental Dynamics, Inc (1, 4) in 2004. The information presented in this and the following design sections are a summary of their work.

Observed problems with fish passage through the culverts were confirmed by measured velocities. Velocities in both culverts were limiting passage by juvenile and sub-adult fish. For instance, the average velocity during relatively low flow conditions in October (Table 2) was around 1.1 m/s. At this flow, a juvenile rainbow trout (<125 mm) would need 17 minutes at a burst speed of 1.13 m/s to migrate through a 30.5 m long culvert (calculated from Table 3). This burst speed can only be maintained for less than 3 minutes, which is not enough time for the fish to pass through the culvert.

While no swimming capability data exists for juvenile grayling or Dolly Varden, it is likely that the water velocity in the culverts prevented upstream passage by these species. This is based on a comparison of the adult swimming abilities where rainbow trout are better swimmers than Arctic grayling.

The fish passage problems were due not only to the velocities, but also to the drop i.e. the jump at the outlet. The pool directly below the culverts had a maximum depth of 0.65 m (Table 2). An adult Arctic grayling could jump up to 0.52 m (calculated from Table 3 - pool depth should be 1.25 times the jump height) with a measured pool depth of 0.65 m. The perch height was slightly more (0.55m) so a strong adult could have made it. However, even if the pool depth was increased 1.25 times, the height of the drop would likely still be too high for adult and juvenile grayling, whitefish, and Dolly Varden (assuming rainbow trout are generally considered better jumpers than these species and the maximum jump height for a 120 mm rainbow trout is 0.6 m).

Although there is no data on the combined effect of the jump required to get into the culvert and the high velocities in the culvert, the combination of these factors likely prevented upstream passage by most fish species and life stages residing in Marshall Creek.

Culvert location looking downstr.	Perch height (m)	Outlet pool depth (m)	Length (m)	Height (m)	Width (m)	Inlet invert elevation (m)	Outlet invert elevation (m)	Gradient (%)	Average water velocity October2003 (m/sec)
Right	0.60	0.25-0.60	30.5	3.2	5.0	650.935	650.244	2.3	1.1
Left	0.55	0.65	30.5	3.2	5.0	650.872	650.175	2.3	1.2

Table 2. Marshall Creek stream crossing culvert attributes prior to restoration in 2003 (1).

Species	Life Stages	Maximum Jump Height / Min. Pool Depth Required (m)	Maximum Burst Speed[1] (m/sec)	Maximum Prolonged Speed[2] (m/sec)
Rainbow trout	Adults Juveniles (125 mm) Juveniles (50 mm)	1.5 / 1.88 0.6 / 0.75 0.3 / 0.38	1.8-4.3 0.75-1.13 0.3-0.45	0.9-1.8 0.38-0.75 0.15-0.3
Arctic grayling	Adults	1.0/ 1.25	2.1-4.3	0.8-2.1
Whitefish	Adults	1.0/ 1.25	1.3-2.7	0.4-1.3

Table 3. Swimming capabilities of fish species present at Marshall Creek (1, 8).

[1] Burst Speeds are the swimming velocities for escape and feeding that can be sustained for up to 165 seconds.
[2] Prolonged speeds are the swimming velocities that can be maintained for up to 200 minutes through difficult areas.

2.3 Design

Our objective was to (re)create year-round fish passage through the culverts. This meant developing a design that eliminated the elevated culvert and reduced the velocities in the culverts.

We met the objective by backwatering the culvert and creating a deeper pool on the outlet with a Newbury riffle (section 2.3.1). This design decreased the jump height into the culvert and increased the pool depth below the culvert. The velocities were reduced by installing baffles in one of the culverts (section 2.3.2).

2.3.1 Newbury Riffle

Newbury and Gaboury (5) describe methods of constructing riffles in streams lacking habitat complexity to enhance pools, recruit gravel, re-aerate flows, and assist fish passage. Figure 3 outlines the general design concept used for these riffles, which have become a common method to backwater culverts. One reason for this is that the slope of the riffle (made out of rock) can be designed to have a diversity of hydraulic conditions (small pools and pockets of slow water) making it more easily navigable by fish (compared to drops with weirs). In addition, the slope or face of the riffle can be designed to mimic natural riffle slopes within the stream.

For this project, the downstream face of the Newbury riffle was designed to mimic a natural riffle that occurs in Marshall Creek with a maximum slope of 5% (1). The crest of the riffle was built 16 m away from the outlet which created a large resting pool. To backwater the culvert to the outlet (rather than inlet), with a 5% gradient, the riffle required a crest that was approximately 1 m high and 25 m long. The site plan (Figure 4) and the structure profiles (Figure 5) show the design details.

The riffle was designed slightly higher than what is required to backwater to the culvert outlet elevation. This allowed for settling after installation. Even if the Newbury riffle does settle more than 0.1 metre, fish passage should still be achieved as long as the drop below the culvert does not exceed the jumping abilities of the fish. To help the riffle seal more quickly, the design included placing washed gravel in the riprap voids.

A natural seasonal high water channel was kept in the design (Figures 4 and 5). Allowing some of the water to flow down this channel during high flows relieved hydraulic pressure on the Newbury Riffle in the primary channel. The smaller channel likely exhibits slower water velocities than the main channel during high flows and may provide refuge habitat for fish as well as a migration corridor. The design included a smaller Newbury riffle at this location with a crest elevation 0.25 m higher than the primary channel Newbury riffle.

2.3.2 Baffles

By backwatering to the culvert inlet, rather than to the outlet, we could have taken care of the high velocities in the culvert. However, there were several reasons why this wasn't done:

1. The height of the Newbury Riffle would have to be almost 0.6 metres higher, so it would be extremely difficult to seal up and get the water to flow over this riffle.
2. The creek banks would have to be raised to a very high elevation.
3. Backwatering the entire culvert would significantly decrease the flow capacity of the culverts, which could in turn cause flooding problems upstream.

This meant that another method was required to address the high water velocities within the culverts since fixing the perch wasn't enough to ensure fish passage. We used baffles to modify the velocities. Baffles in culverts either interrupt the flow pattern and provide fish with a series of resting areas or create a continuous zone or route of controlled velocities through which the fish can swim. However, baffles reduce the hydraulic efficiency and capacity of the culvert. Using baffles in one of the two culverts instead of in both ensured that velocities were within acceptable levels, without compromising the overall capacity of the two culverts too much.

There are different types of baffles available and we used a modified version of a Wildstone baffle insert from Atlantic Industries Limited (7). The design included nine baffles with 4 m spacing.

2.4 Construction

The baffles were installed in the winter of 2006. There was no flow in the culvert at that time, but a large amount of ice had accumulated in the bottom (Figure 8). The contractor hired for the work set up propane heaters and melted the ice out at each section where a baffle needed to be installed. The baffles were supposed to be bolted in place. However, the prescribed type of bolt couldn't be installed in the frozen soil surrounding the pipe, so the baffles were welded to the bottom instead.

Ice at the site complicated the construction of the Newberry riffle so this work was postponed until later in summer. Tender prices came back too high through our regular contract tendering process, so instead we hired a small local contractor through our equipment rental program. When projects are constructed this way, it means that HPW inspection staff is actually directing the contractor how to do the work. Since no contractors in Yukon have experience with constructing riffles, this was probably the best way to ensure the final product was according to design and done for a reasonable price. Also, in an environmentally sensitive area it's particularly important to construct as directed. Figure 6, 7, and 8 show the site after completion of the construction.

Follow-up monitoring in 2007 (4) showed that the fish passage restoration structures were functioning as designed. The Newbury Riffle backwatered the culverts during all observed flow levels and the baffles provided resting areas (i.e. – lower velocities) within the culvert for migrating fish. While velocities over the baffles may limit migration of juvenile fish through the culverts during high flow levels, it appeared juvenile fish were getting by (likely opportunistically, i.e. during some flow levels). The lower section of the primary riffle appeared steeper than designed and should be monitored in future to find out if it requires modification.

2.5 Project Cost

Most of the work was contracted out to local small contractors. The site inspection during construction was done in-house. Riprap costs were reasonable because it was produced as part of nearby road construction and the pit was only 100 m from the project site. The entire project cost was $128K with a breakdown listed below.

Year	**Type of work**	**Approx. cost**
2003/04	Design and background studies	$14K
2005	Riprap production	$10K
2006	Baffle installation	$38K
2006	Riffle construction	$51K
2006	Construction monitoring (environmental)	$10K
2007	Follow-up monitoring	$5K
Total		**$128K**

Table 1. Project Cost

Figure 1. Culverts prior to restoration works. Photo D. Stillwell (YG HPW).

Figure 2. Community wildlife steward captured fish in spring in culvert outlet pool and released them upstream of the culverts. Photo T. Omtzigt (YG HPW).

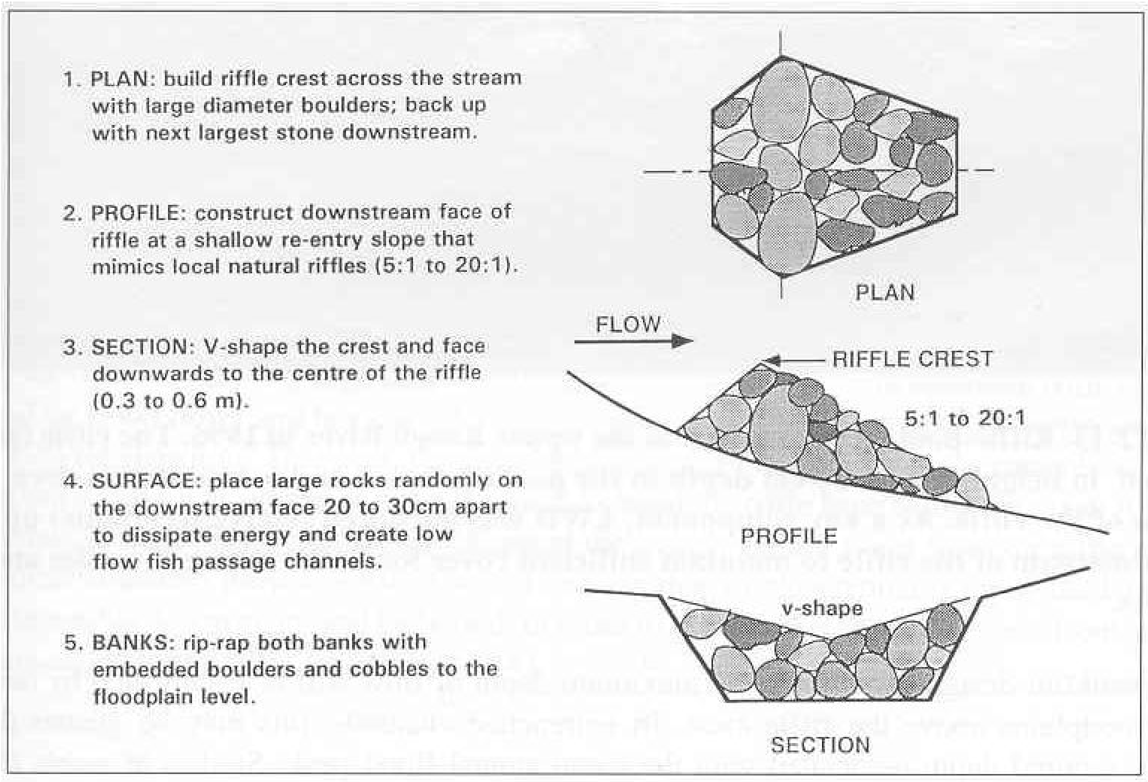

Figure 3. Schematic construction drawing of a Newbury Riffle (adapted from Newbury et al., 1997 in EDI 2004).

Figure 4. Project site plan (1).

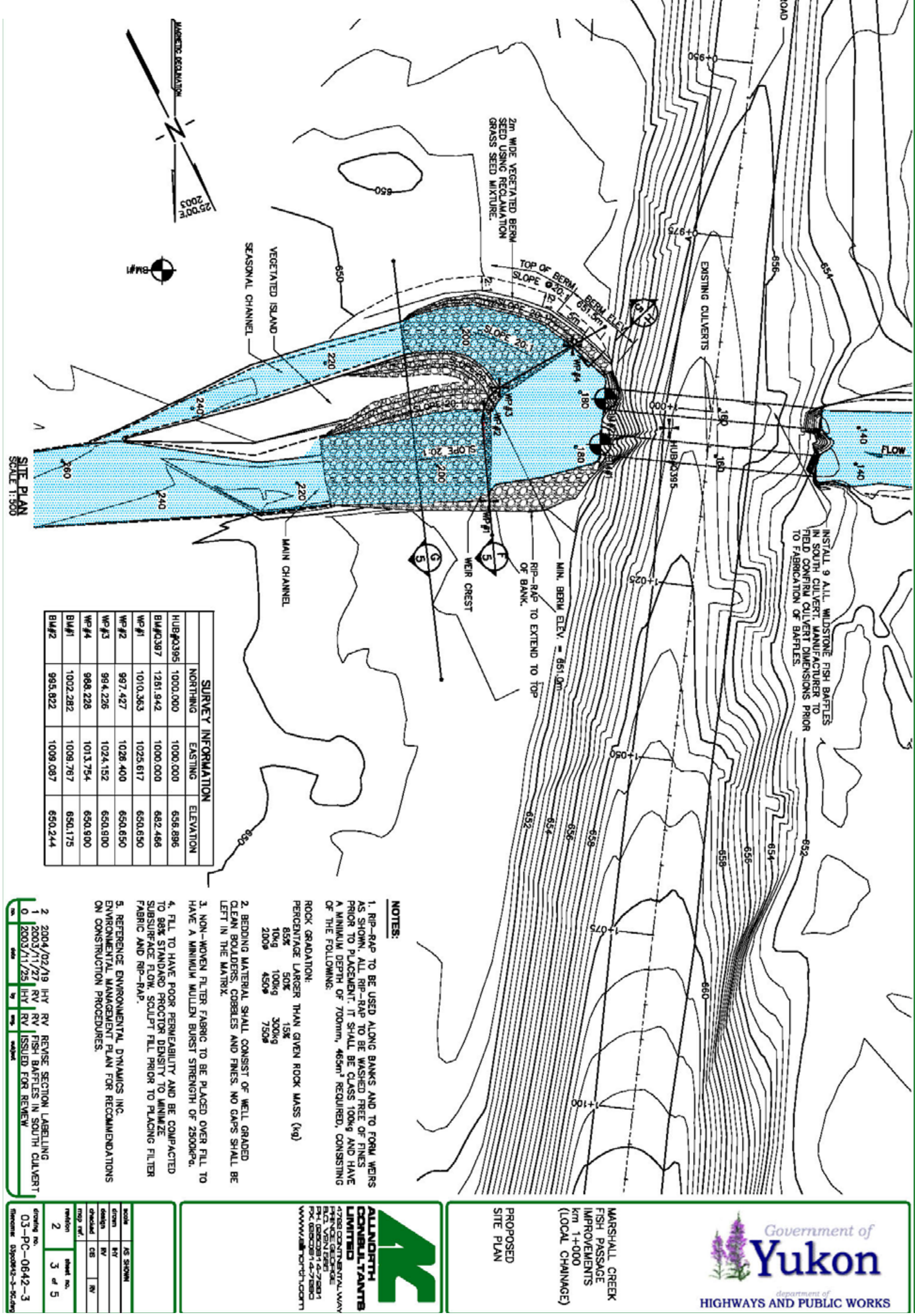

Figure 5. Structure profiles (1).

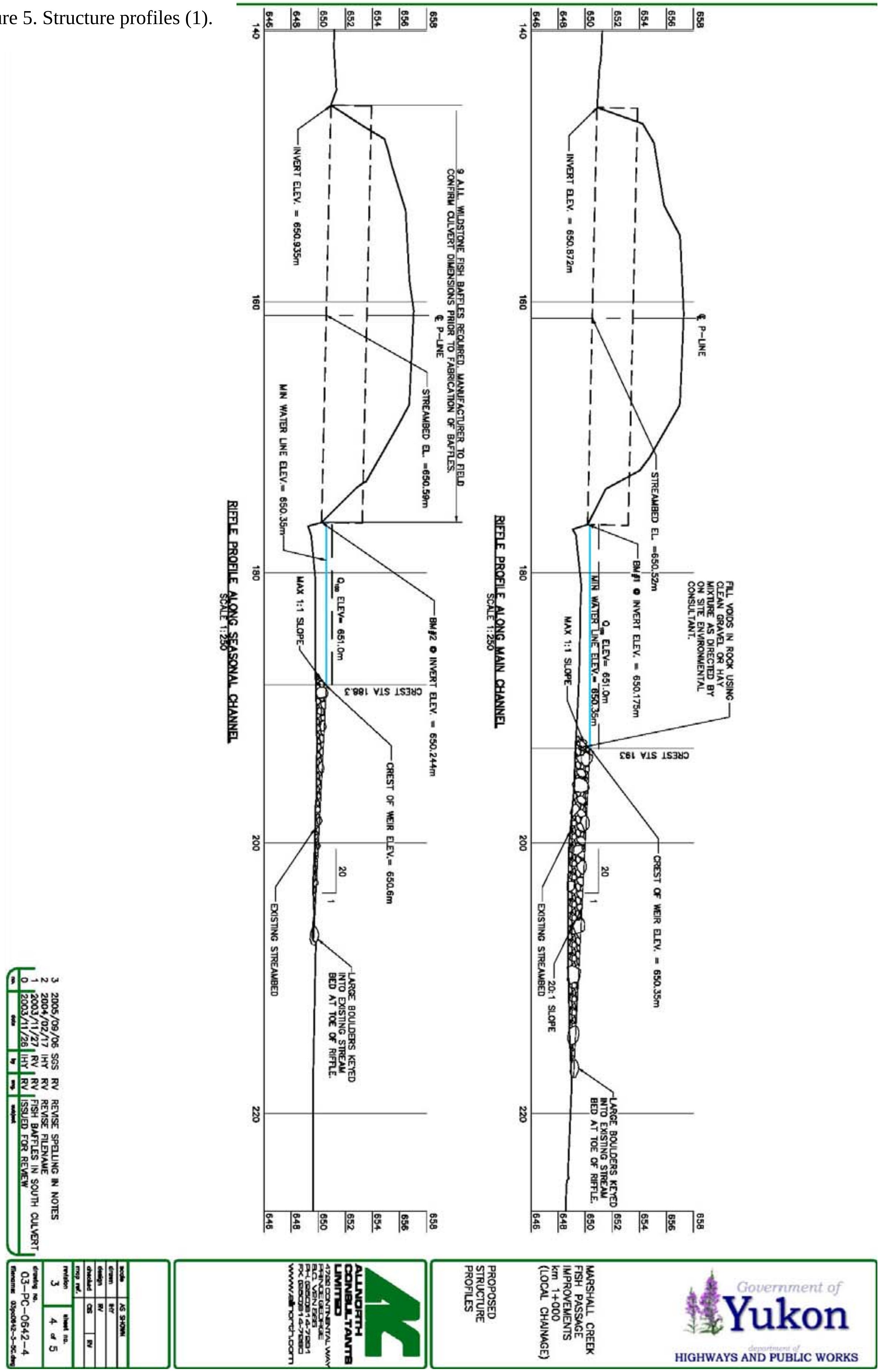

Figure 6. Culverts post construction. Photo T. Omtzigt (YG HPW)

Figure 7. View of Newbury Riffles in July (left) and during low water levels (right October 2007). Photos EDI.

Figure 8. Culvert on left received the baffles; note ice in culverts. The picture on the right shows the baffles in place. Photos T. Omtzigt (YG HPW)

3.0 Christmas Creek Over-Wintering Habitat

3.1 Site Information

The second project example involves creating new over-wintering habitat at Christmas Creek. Christmas Creek crosses the Alaska Highway at km 1630, about 10 km from its mouth at Kluane Lake. It drains several streams north of the Kluane Range including Boutellier Creek and Hungry Lake. The total catchment area is 112.5 km^2. For years the wooden culvert at the road crossing was elevated and a partial barrier to fish. Passage was re-established with the installation of a fish passage pipe in 2001.

Christmas Creek flows year-round and much of the water source is believed to be from groundwater. Much of the area surrounding the creek is muskeg with thick marsh grass, standing water and dead standing spruce. Fish species found at the highway crossing are Arctic grayling and slimy sculpin. The creek has several smaller side channels which provide good rearing habitat for juvenile fish. In addition, the creek provides important over-wintering areas for fish.

At the crossing with the highway the stream is about 2 m wide. In general it has a complex of pool, riffle and glide habitat, moderate flows, some gravel for spawning and good cover (6). The average flow during the open water season (summer and fall) is 0.535 m^3/s with a peak flow of 5.16 m^3/s (6). Overall the creek is considered to be of high value to fish.

3.2 Reason for this Project

The Christmas Creek project provides fish habitat compensation for infilling in Kluane Lake that occurred due to widening of the Alaska Highway in that location. It also provides compensation for planned infilling in the Slims River, next to Kluane Lake, for a replacement bridge across the river. The new bridge will be a shorter crossing than the old bridge with additional river training works in the river, both resulting in infilling of fish habitat.

The Christmas Creek compensation project is small (max. 70 m^2 of habitat created) compared to the infilled areas (Kluane Lake infilling 1.4 ha and Slims 1 ha). One reason for this is that the displaced habitat is of poor quality and the compensation project is of very high quality. Moreover, due to the heavy sediment load from the glacially fed Slims River, the authorized infilling for the road widening at Kluane Lake is now no longer in the wet for most of the year. This further reduced regulatory pressure to develop a large compensation project.

After years of highway reconstruction and several fish passage improvement projects in the general area, possible habitat restoration or enhancement projects in or near the highway corridor were hard to find. HPW spent considerable effort searching for compensation options by meeting with the local First Nations, local experts, and DFO as it turned out to be a challenge to find a suitable compensation project. With most reasonable options exhausted, DFO suggested to try out creating new over-wintering habitat at Christmas Creek. If this project is a success, it will likely be adopted elsewhere in the territory.

3.3 Christmas Creek Compensation Plan

The goal of the compensation plan is to increase pool areas and over wintering habitat for fish (primarily Arctic grayling) adjacent to the culvert crossing with the Alaska Highway.

Just upstream of the culvert the creek forks into the main stem of the creek and one short feeder that drains a muskeg area (Figure 10). The main stem of the creek will be left undisturbed, but along the feeder stream we will excavate small finger channels. We plan on excavating four to seven of these channels which will be as long as the reach of the excavator used to do the work. If the work is done under frozen soil conditions we might be able to drive equipment farther onto the site and make the channels longer. The channels will be between 2-5 m long and about 1.5 to 2 m wide. The total area of added fish habitat will be between 50 and 70 m^2.

The channels will be dug well below (about 0.5 m) the elevation of the main channel so pools will form at each finger channel. They are expected to fill up with groundwater. Once the channels are complete and filled with water, they will be connected with the second fork of the creek. Figure 9 shows the site details.

The material that's dug up will be spread above the high water mark, on the adjacent road right-of-way. This area is currently sparsely vegetated and will be seeded with locally collected native seed. Willow cuttings will be planted along the water edge of the new channels and the culvert inlet channel.

3.2 Project Cost

The project is scheduled for construction in October 2008. As mentioned before, we had to search for projects and used the help of a consultant for which we spent $8K. The design was done in-house for around $3K. The projected construction cost is estimated around $10K.

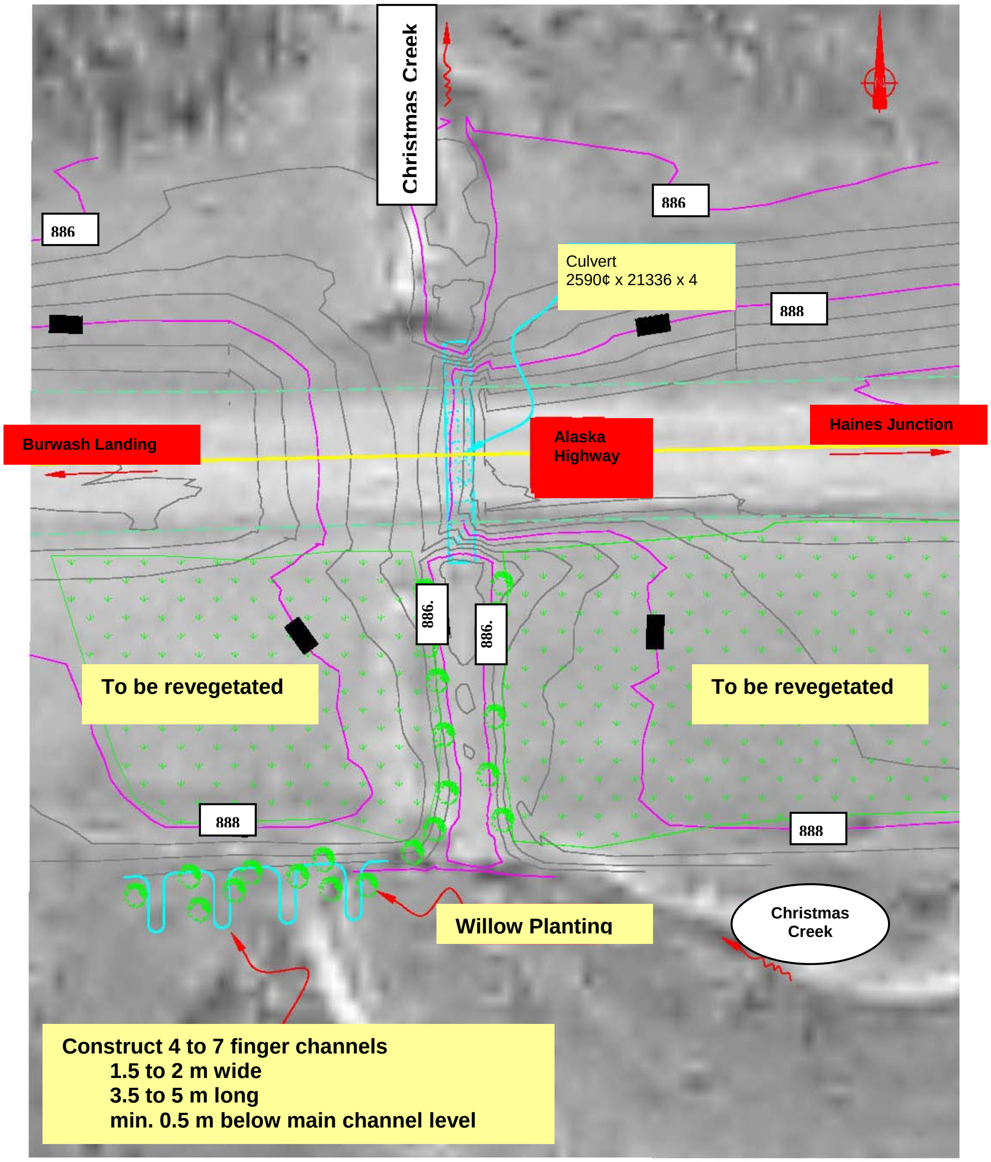

Figure 9. Site plan with location of finger channels.

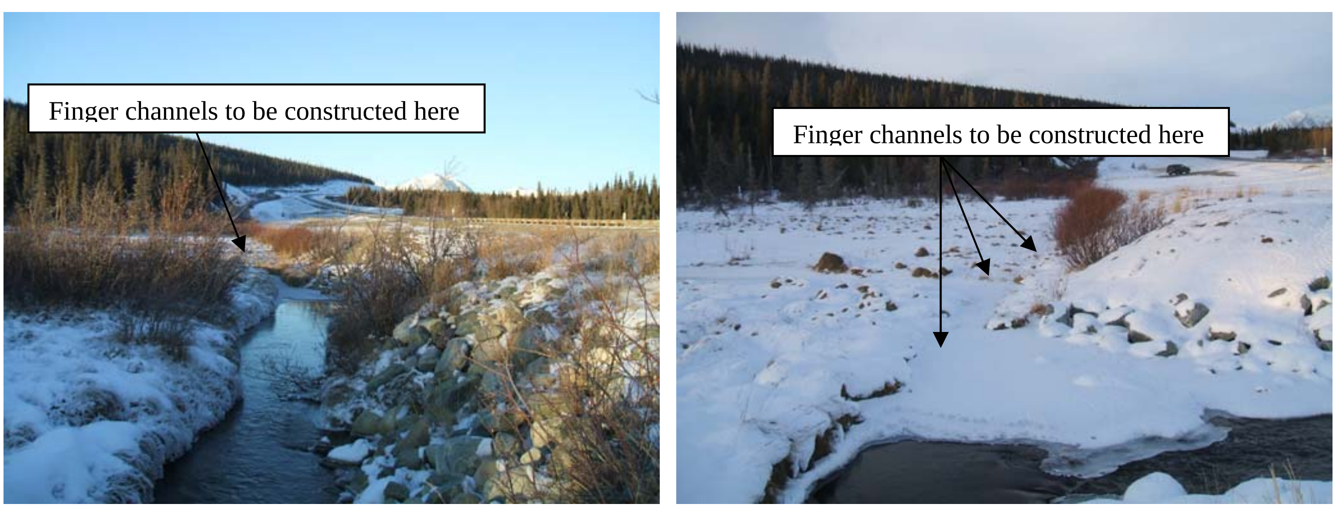

Figure 10. Christmas Creek, looking downstream, just before it bends toward the culvert. (Photo T. Omtzigt, YG HPW)

4.0 Donjek Gravel Pit Lakes

4.1 Site Information

The third compensation project involves developing new fish habitat at two lakes that were created as a result of past gravel extraction. The lakes are located adjacent to the Donjek River and are groundwater fed. Neither lake currently has fish.

The first lake is located near km 1818 of the Alaska Highway. The size of the lake is 11.2 ha with a maximum depth of 8 m. The second lake is located at km 1820 Alaska Highway. It is 3.4 ha with a maximum depth of approximately 5 m (Figure 11).

The sites are located next to the Donjek River which is a large and braided river typical of a stream that originates from extensive glacial headwaters. The river has a wide floodplain with numerous channels that shift frequently within this area. Fish species found in Donjek in the vicinity of the lakes include Arctic grayling, round whitefish, lake chub and slimy sculpin.

The mainstem river is quite turbid during the summer months due to the glacial melt. The presence of fish in this area of the Donjek River during the winter, spring and fall months and absence during the summer months indicates that the mainstem river habitat is being used during periods when the water level is low to moderate and conditions are more favourable to the fish (i.e. lower turbidity) (2).

4.2 Reason for this Project

The Donjek Gravel Pit Lakes project provides compensation for infilling that occurred during the replacement of two bridges, one across the Duke River and the other across the Donjek River. The infilling was required because both bridges now include shorter crossings and additional river training works compared to the old structures.

4.4 Compensation Plan

The objective of this project is to create new fish habitat by connecting both lakes to two small side channels of the Donjek River (Figure 11). The connecting channel at each site will be dug to the same elevation as the side stream to ensure proper flow. The channel at the km 1818 site will be 66 m long and 10 m wide; the connecting channel at km 1820 site will be only 20 m long and also 10 m wide. In addition, the sites will be revegetated with a native grass mix in the flat areas around the lakes and willow cuttings along the edges (2).

The newly created habitat will contain clear water which fish seek out in summer when the glacially fed Donjek River is very turbid. Measurements of winter oxygen level showed the km 1818 lake is potentially suitable for over-wintering habitat (3). This means that once the lake is connected to the Donjek side channel, it can provide year-round fish habitat. The km 1820 lake is shallower, but it may be possible that fish can over winter here as well. As it is closer to the Donjek River (Figure 12) there may be some groundwater movement in the winter. Regardless, even if the lake only provides habitat during high flows it will be valuable habitat as a high water fish refuge.

4.2 Project cost

Consultant fees for the background studies and draft compensation plan were $8K. The design was done in-house for around $5K. The project is scheduled for construction in September 2008 with projected construction costs around $25K.

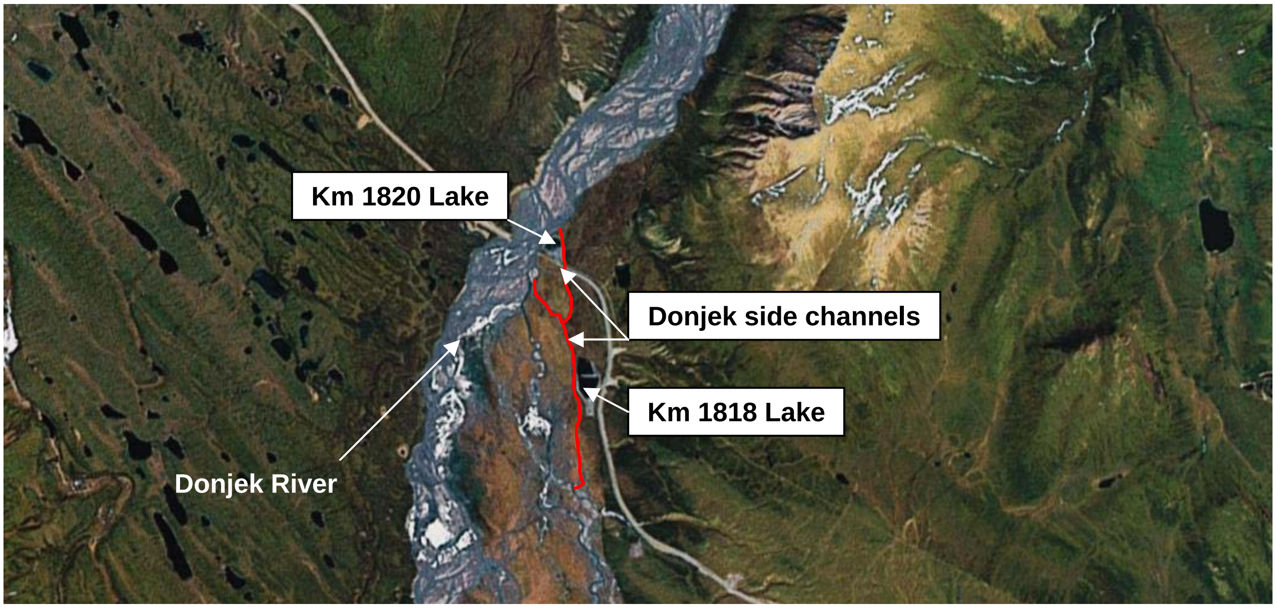

Figure 11: Location of gravel pit lakes near the Donjek River (Photo: Google Earth)

Figure 12: Km 1820 Aerial overview of site and location of new connecting channel. Note color of water in the lake and in the river. (Photo: Google Earth).

Conclusion

By describing three examples, I showed in this paper that HPW has been able to develop and implement successful habitat replacement projects that meet DFO's requirements. The projects were designed with local expertise and were or will be completed by local contractors. And finally, the project costs are probably considered reasonable.

References

(1) Environmental Dynamics, Inc. July 2004. Fish Passage Design and Environmental Management Plan for the Alaska Highway Crossing of Marshall Creek. Prepared for: Transportation Engineering, Highways & Public Works, Government of Yukon.

(2) Environmental Dynamics, Inc. October 2004. Donjek River Bridge Fish Habitat Compensation Plan - DRAFT. Prepared for: Transportation Engineering, Highways & Public Works, Government of Yukon.

(3) Environmental Dynamics, Inc. April 2005. Letter report: Winter Water Quality at Lake 1818.4. Sent to: Transportation Engineering, Highways & Public Works, Government of Yukon.

(4) Environmental Dynamics, Inc. November 2007. 2007 Marshall Creek Fish Passage Monitoring. Prepared for: Transportation Engineering, Highways & Public Works, Government of Yukon.

(5) Newbury and Gaboury. 1993. Stream Habitat Analysis and Fish Habitat Design, A Field Manual. Newbury Hydraulics. Co-published by Manitoba Natural Resources.

(6) LGL Limited. December 1999. Final Report. Fisheries Assessment: km 1664.5 to km 1780 Alaska Highway, Yukon. Prepared for: Transportation Engineering, Government of Yukon.

(7) Atlantic Industries Limited. http://www.ail.ca/

(8) Parker M.A. Fish Passage – Culvert Inspection Procedures. 2000. Watershed Restoration Technical Circular No. 11. Ministry of Environment, Lands and Parks, British Columbia http://www.env.gov.bc.ca/wld/documents/wrp/wrtc_11.pdf