Huwer Groundwater Channel Feasibility Study

04.Sh.04

Final Report

Prepared for:
Whitevalley Community Resource Centre Society

Prepared by:
Thomas Minor, BSc, CET

Prepared with financial support of:
B.C. Hydro Bridge Coastal Fish and Wildlife Restoration Program

Executive Summary

The Huwer groundwater feasibility study examined the potential of improving the habitat value of an existing 4 km pond/creek complex by increasing the groundwater flow. While there has been extensive work done in the Middle Shuswap to increase salmon spawning and rearing habitat, this would be the first complex that was completely groundwater fed.

Eight monitoring wells were dug at various locations on the property in May and static groundwater levels measured from pre-freshet to early January. The groundwater levels were compared to the river and pond water surface levels. Temperature and dissolved oxygen levels were also recorded.

The results of the study indicate that there is sufficient head between the groundwater level at the monitoring wells and the pond surface to increase the flow from to approximately of 6 ft^3/s by installing infiltration galleries. This increase in flow would improve rearing habitat values by increasing water depth in the pond and creek and by increasing the moderating influence of the groundwater on the stream temperature. It would also increase the potential for spawning especially for kokanee and coho by increasing the flow and velocity in riffle areas.

Table of Contents

List of Figures

List of Tables

Introduction

Interior Fraser coho have been on the decline since the 1960's and have been listed by COSWEC as endangered. In the Middle Shuswap River, coho recruitment has dropped from 3500 in the early sixties to a low of 20 in 1993 (Flynn, per. com.). In 1998, the Shuswap hatchery began to raise coho from stock taken from both the Middle Shuswap and Bessette Creek, the main tributary to the Middle Shuswap River.

In chapter 12, volume 2, of the Bride Coastal Restoration Program (BCRP) Strategic Plan, the limiting factors for coho and kokanne production below the Wilsey dam are identified as lack of suitable gravel between Wilsey Dam and Bessette Creek, reduction of side channel habitat, reduction of productivity and dewatering due to fluctuations in the river level from power outages and dam operations. Other limiting factors to coho rearing in the main stem cited in the plan are lack of nutrients and stranding due to sudden drops in the river level.

Fisheries and Oceans Canada (DFO) and Whitevalley Community Resource Centre (WCRC) have constructed several off-channel spawning and rearing complexes in both the Middle Shuswap and the Bessette Creek watershed. These projects have largely been funded by first B.C. Hydro and later by BCRP. To date, all of the constructed side channels in the Middle Shuswap have been constructed by diverting river water into constructed or remnant channels. The Huwer pond and stream complex is distinctive in that it is the only system with a flow made up entirely of groundwater (except during freshet when the river rises enough to flood a remnant channel). This has several benefits.

The first advantage to an all-groundwater channel is that the temperatures are moderated. Warmer winter temperatures and cooler summer temperatures would provide habitat within the temperature range of 12 – 14 ^{0}C considered optimal for coho growth and survival (Brett 1952). In a study based on the Coldwater and Nicola Rivers, Swales et al (1986) found that three of the overwintering habitat characteristics that attract coho salmon are low water velocity, abundant cover, and a high water temperature relative to the main river. Because of the narrower preferences for winter habitat, lack of suitable winter habitat may be the ultimate limiting factor to coho in rearing areas. (Chapman 1996, Mason 1979, Chapman and Kmudsen 1980, Mcmahon 1983, Mickelson et al 1992). Swales and Levings (1989) attributed the greater growth of juvenile coho overwintering in off channel ponds compared to the mainstem of the Coldwater River to the higher winter water temperature and abundance of food. Also, swimming ability decreases with temperature. Juvenile salmonids become less active (Mason 1966) making them more susceptible to predation.

A second benefit of an all-groundwater flow is that the creek level is not subject to the sudden fluctuations that occur in the river caused by tripping events at the Shuswap Dam. When there is a power outage anywhere on the grid fed by the power generating station 8 kms upstream, the generators shut down and water stops running through the penstocks. At certain low flow periods (early winter through spring) any water making it past the dam is passing through the generation station. When the generators trip, there is no water making it past the dam until the reservoir behind the dam is able to fill and then flow over the spillway. This no-flow period may last long enough to strand juveniles, de-water redds downstream and/or freeze the incubating eggs.

Goals and Objectives

The objective of this study is to see if the groundwater flow to the system can be increased to restore adequate flows for spawning and enhance over 3 km of rearing habitat, particularly for kokanee and coho.

A preliminary survey property showed that there was over a meter of head between the Shuswap River 200 m upstream of the beaver pond and the pond water level. There was some discussion between DFO, WCRC and the landowner about an open channel connecting the Shuswap to the remnant channel but this idea was dismissed for several reasons:

1. The pond and stream lie within the flood plain. Building an open channel to connect the pond and stream to the river could potentially create a pilot channel that could cause excessive erosion and river movement during an extreme flood such as occurred in 1997 or 1972.
2. Access for the open channel would have to be through a densely treed riparian area that provides some stability to the riverbank. Accessing the river would require removing some of these trees. It would also require large amounts of rock for riprapping the banks around an intake.
3. Even with the bank stabilized with riprap, it is possible for the river to move back to a former channel and leave the current one dry in low flows.
4. The river water level is influenced by Wilsey Dam. Power outages can cause sudden drops in the river level that could affect channel levels if directly connected.
5. Finally, river water temperatures reach the upper 20's during the summer and drop below 0 in the winter. Groundwater temperatures are more constant, around 9 ^{0}C.

According to the owners, the small creek was heavily used by kokanee for spawning when they first purchased the property 30 years ago. However, the flow in the creek has decreased and only a few kokanee still spawn here. Increasing the flow in the creek would restore it as a spawning area.

The pond and creek is currently used as rearing habitat by juvenile salmonids. While there have been no coho observed spawning in the creek for years, the Shuswap River floods a remnant channel that flows into the creek and pond complex during freshet, usually in late May. During this high-water period, juvenile coho and chinook are carried into the complex. The majority of chinook fry migrate downstream during the latter part of July. Early spring sampling has shown that both coho and rainbow overwinter in the creek. However, the water quality suffers from livestock use.

Study Area

The site is located on the Huwer property along the Middle Shuswap River approximately 8 km downstream of the Wilsey Dam (Figure 1). The Huwer family owns approximately a section (640 acres) of land at this site. They use it for pasturing and for winter-feeding cattle. Approximately 140 acres is cleared and the remainder has been selectively logged by previous owners.

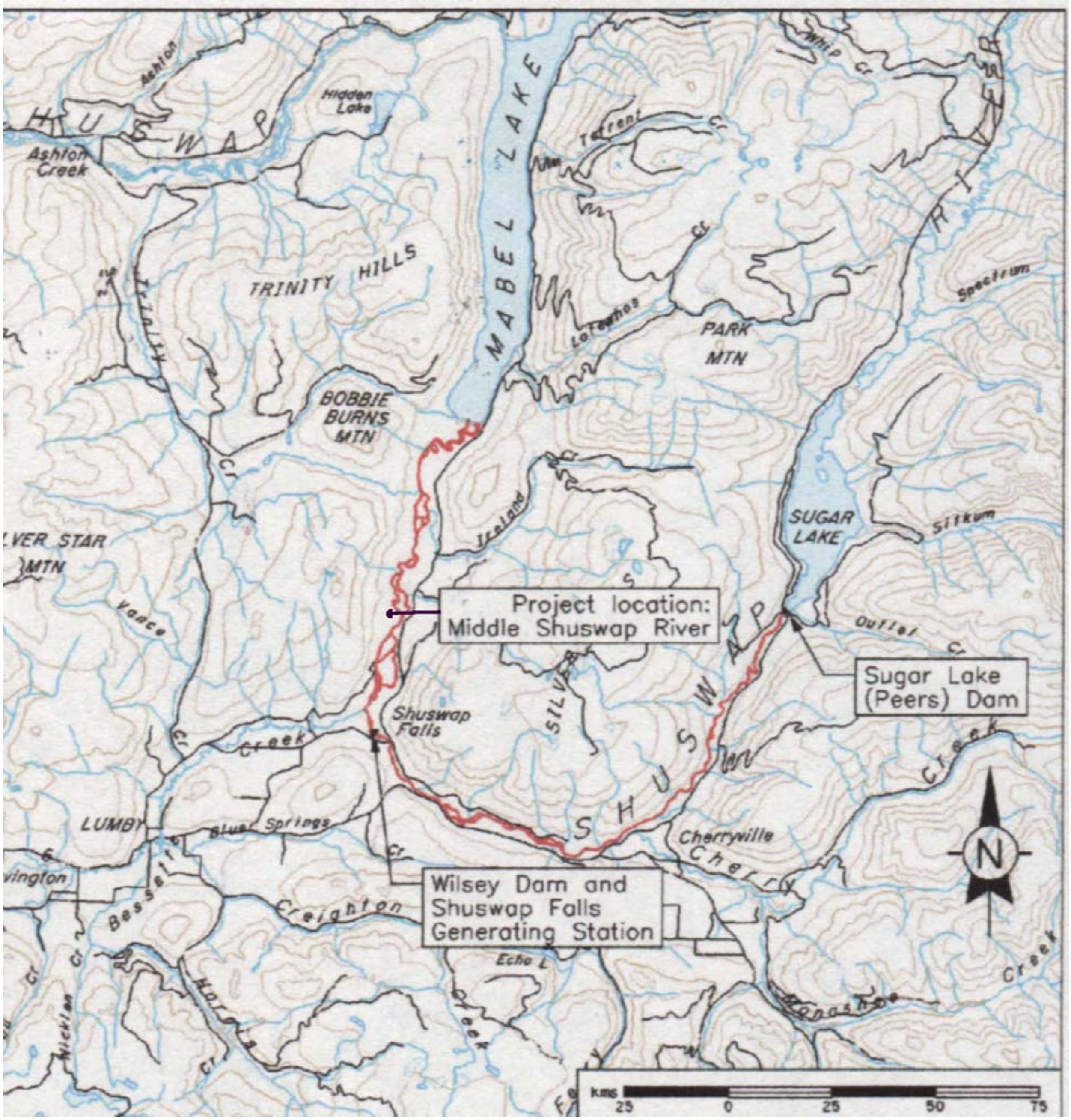


Figure 1: The Huwer property is located downstream approximately 8 kms downstream of the Wilsey Dam and 7 kms downstream of Bessette Creek, the main tributary of the Middle Shuswap River.

The Huwer groundwater complex consists of a 1500 m intermittent creek, an 8000 m^2 pond that feeds a small year-round creek approximately 3 km long. The flow in this system is comprised entirely of ground water except during freshet (June) when the river is high enough to enter into a remnant channel and flow into the creek below the pond outlet. For the rest of the year, the only connection to the river is the outflow of the creek at the north end of the property. The creek has a fairly constant flow of 1 to 2 ft^3/s.

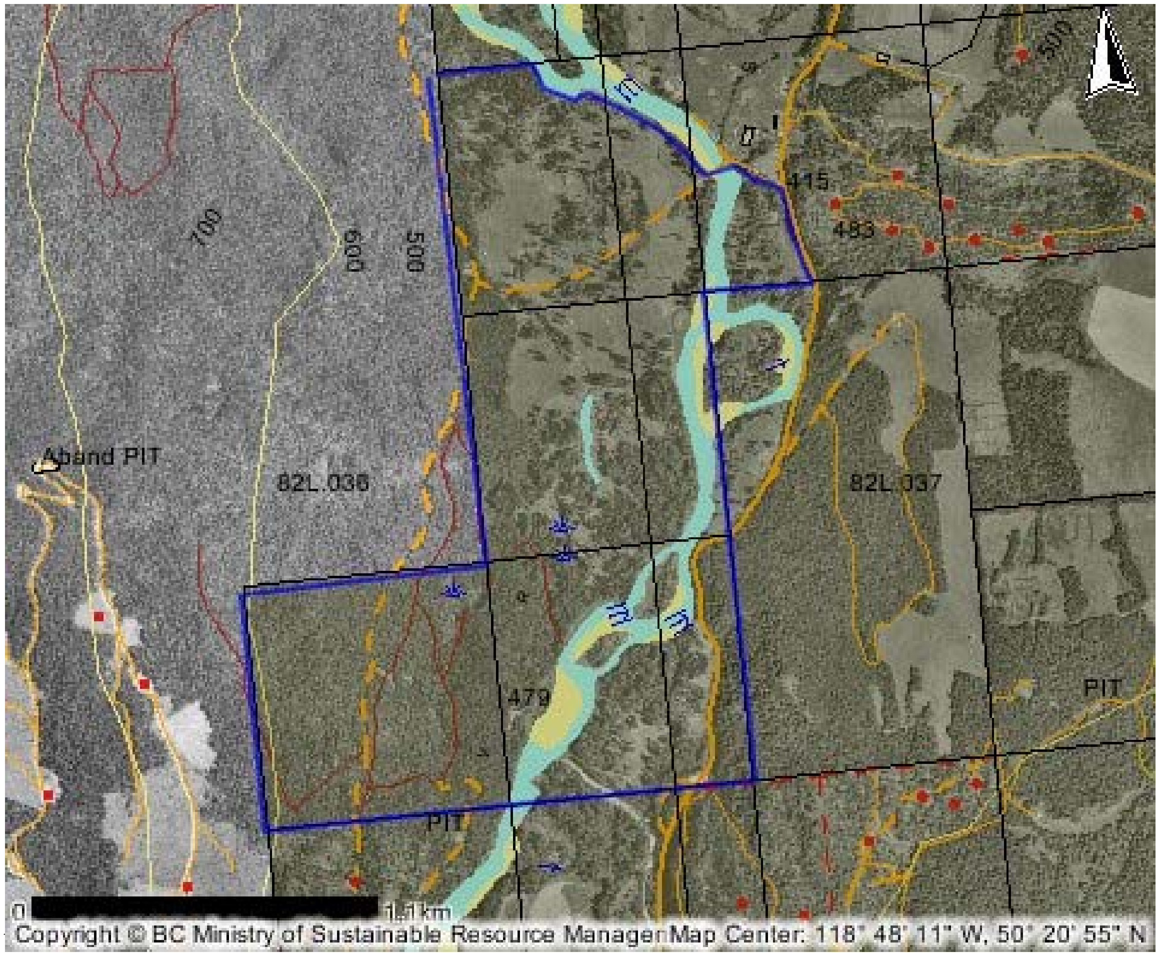
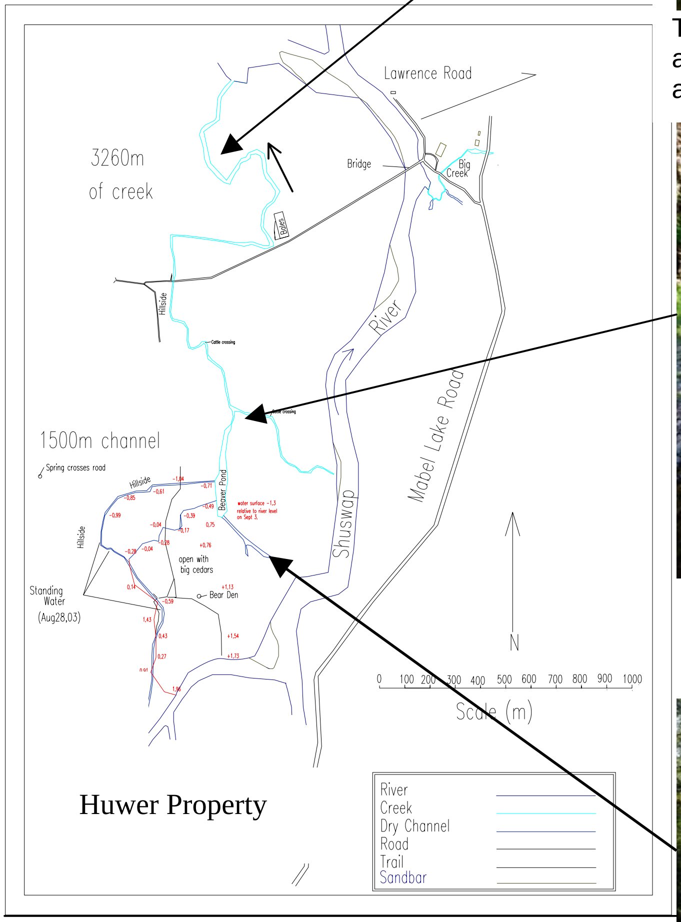


Figure 2: The Huwer property is outlined in blue. Most the property is on the west side of the Shuswap River and is accessed by their Bailey bridge. Approximately 140 acres is cleared for pasture. The remainder is treed. This property has one of the last stands of mature cedar on the Middle Shuswap.

When the Huwers bought the property in the early seventies, there was no access to the property on the west side of the river. Once they established access by placing a Bailey bridge, they were able to use the property for pasturing and over-wintering cattle. The property is unfenced and the cattle have had complete access to both the Shuswap River and the small creek on the property.

The groundwater creek has some riparian cover along approximately 80% of its length even though cows have full access.

The substrate is largely gravel downstream of the beaver pond ranging from 0.5 – 6 cm.



The beaver pond (right) is open and shallow. The intermittent channel upstream of the beaver pond (background) is heavily vegetated with trees and shrubs.

Figure 3: an illustrated map of the creek on the Huwer property showing some of the main features.

The creek is located at the downstream end of the most heavily used spawning grounds on the middle Shuswap River (Arc 2001) and is rearing habitat for juvenile chinook, coho and rainbow trout.

At the head of the creek is an old beaver pond (Figure 3). The substrate of the creek is largely gravel downstream of the beaver pond ranging from 0.5 – 6 cm (Figure 4). The creek has some riparian cover along approximately 80% of its length even though cows have full access.

Currently cows have access to the majority of the creek and cause considerable sedimentation and bank trampling that has resulted in a wider, shallower creek in the areas of heavy congregation (Figure 4).

Figure 4: Cattle trample the banks and cause sedimentation and nutrient loading that has accelerated the eutrification of the pond and the reduction of groundwater flow to the creek.

The landowner has fenced several hundred meters of the most heavily used area along the creek. However, he has given priority to fencing a 15 to 20 m riparian exclusion zone along the Shuswap River.

Method

The engineering staff from the Kamloops office of the Department of Fisheries surveyed the site using a Leica TC800 total station. Eight sites were chosen for the installation of standpipes for monitoring the static groundwater level. The sites were located in or near swales that indicated remnant river channels. The sites were at varying distances between the pond and the river upstream of the pond (Figure 6).

The standpipes were made of 3.05 m lengths of 10.2 cm perforated plastic pipes placed approximately 2.8 m deep. The bottom half was wrapped in filter cloth to prevent sediment from filling the pipes when back filling. The holes were dug during the last week in April with a Hitachi 120 excavator.

After the pipes were placed, a staff gauge was placed at the pond outlet and at the river upstream of the pond. The elevations of the tops of the pipes and the gauges were measured. By inserting a dipstick into the pipes and measuring the distance from the top of the pipe to the water level, the ground water level at each pipe could be compared to the water surface of the river and the pond.

Figure 5: The monitoring wells were made of 3.05 m lengths of 10.2 cm perforated plastic pipe that was wrapped with filter cloth. They were buried about 2.8 m below ground level with 0.2 m of pipe exposed above ground.

The ground water levels at the wells were measured periodically beginning at the end of April through January (Figure 9). The object was to capture the difference in head between the water table at the various monitoring wells and the pond surface, particularly at when at their lowest levels. Once the available head and the soil types were known, it was possible to estimate how much the flow into the pond and stream could be increased.

Water temperature and dissolved oxygen level were also measured at the river and pond outlet using an Oxyguard DO meter (Figure 10).

The stream flow was measured with a Marsh-McBirney FLO-MATE 2000 flowmeter using the method outlined in the RIC standards.

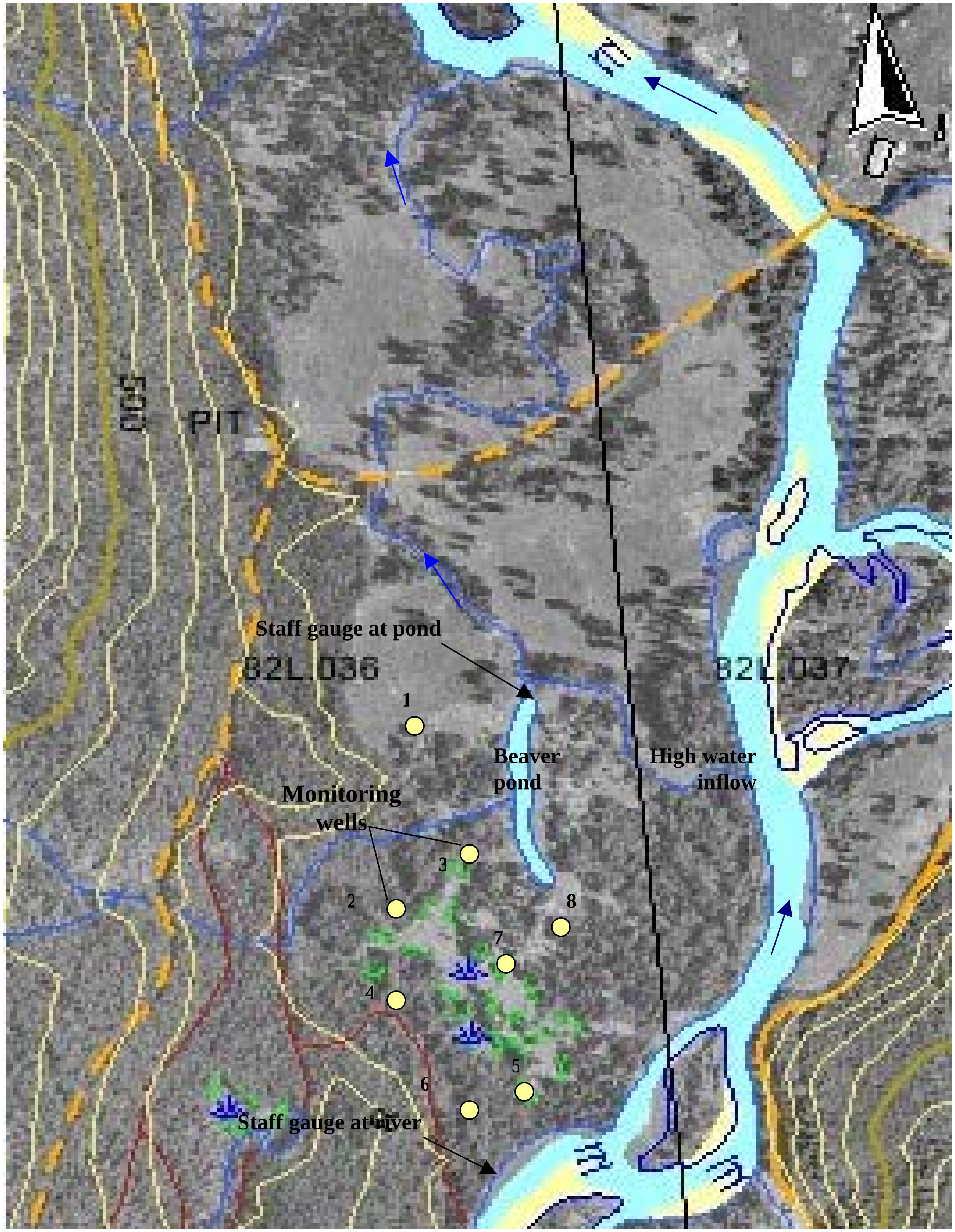


Figure 6: Placement of the eight monitoring wells on the Huwer Property.

Results

The soil was similar at each well site. There was a top layer of organic material 15 – 30 cm deep. Below that were alternating layers of sand and gravel (Figure 7). The gravel was sorted and varied in size from 0.5 to 10 cm in different layers.

Figure 7: The soil at all 8 monitoring wells consisted of about 15 - 30 cm of organic soil covering layers of sorted sand and gravel.

While the groundwater level is influence by the river (Figure 9), fluctuations are dampened considerably. A drop in river flow for a several hours would not influence the groundwater flow into the pond or creek. The pond outflow level shows very little fluctuation despite weekly spikes and drops in the river level. The only time of year that the pond and creek water level is directly affected by the river level is during freshet. At this time, usually from the end of May to mid-June, the river is high enough to flow into a remnant channel and into the creek just below the pond outlet. During this flood period, juvenile chinook and coho enter the complex. The majority of the chinook are ocean type and emigrate in July. The coho remain until the following spring.

The differences in head between the monitoring wells and the pond are shown in Figure 10. The groundwater level in this area is influenced primarily by the river level. Only well #2 showed some influence of subsurface flow from the hillside in April. The difference in ground water elevations at the wells and the pond is a function of both the distance to the river and the hydraulic conductivity (permeability) of the soil.

Table 1 shows the difference in elevation between the eight monitoring wells and the pond surface. The straight-line distance between the wells and the pond is also noted and the slope calculated. These slopes range from 0.11% to 0.33%. The difference in the gradients occurs because of the difference in the porosity of the soil and because the hyporheic flow is not necessarily in a straight line but would follow the meander of the gravel seams of old streambeds.

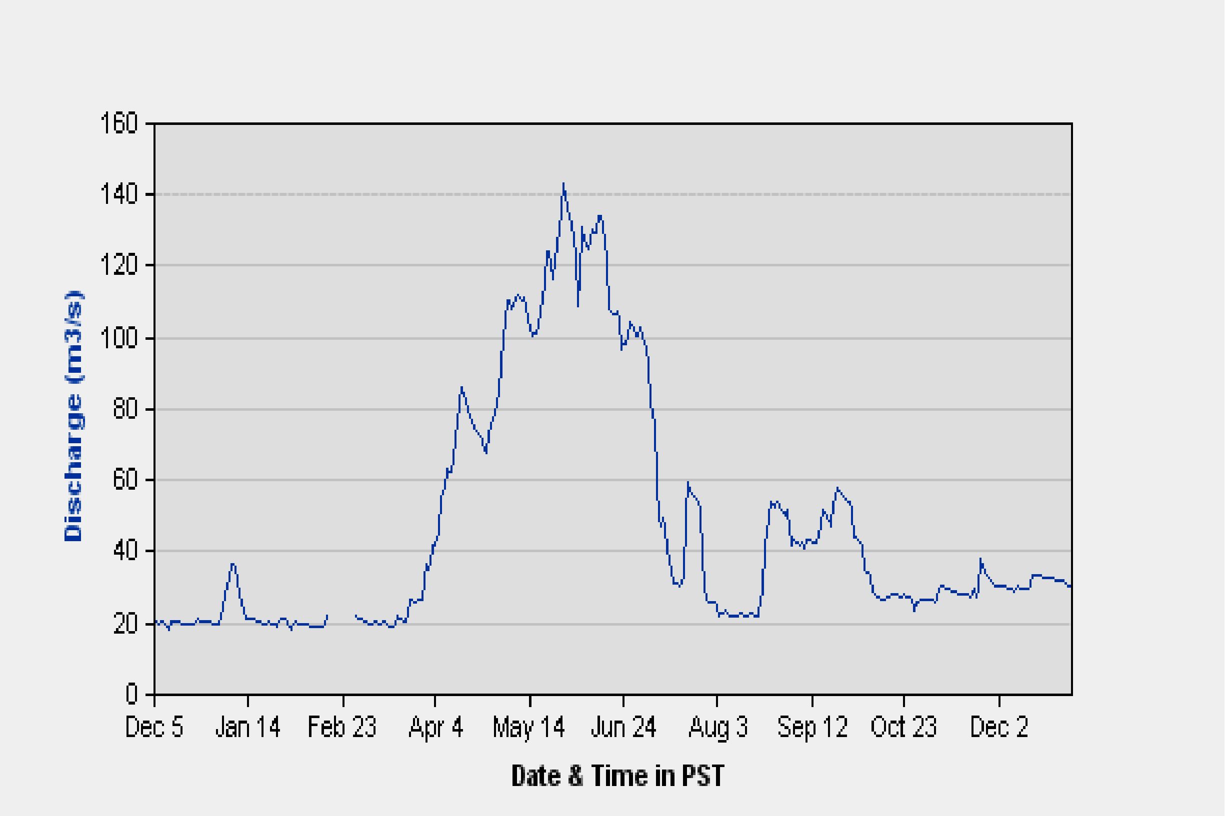


Figure 8: Shuswap River hydrograph measured below the Wilsey Dam from December 2003 to Jan 2005. The lowest river levels during the period of testing were in August.

The temperature and dissolved oxygen levels of the pond and the river taken throughout the year are shown in Figure 11. During the summer the pond stayed cooler than the river except for some very warm weather in June. At the time, the river flow was around 120 m^3/s and influence more by the high rate of snowmelt rather than by the warm air temperatures. In November, the river temperature dropped below the pond temperature. The pond is shallow (< 1m) and open with a slow turnover rate and therefore susceptible to warming by insolation and high air temperatures.

The groundwater temperature was recorded in June when air temperatures were near 30^0C and again in January when nighttime temperatures were –15 ^{0}C. On June 18, the air temperature was 26.9 ^{0}C and the water temperature was 9.9 ^{0}C in well # 4. On January 4, the air temperature was –12 ^{0}C and the water temperature was 8.5 ^{0}C in well #4. The temperature was taken in the standpipes that are open to the air and were therefore influenced slightly by the air temperature.

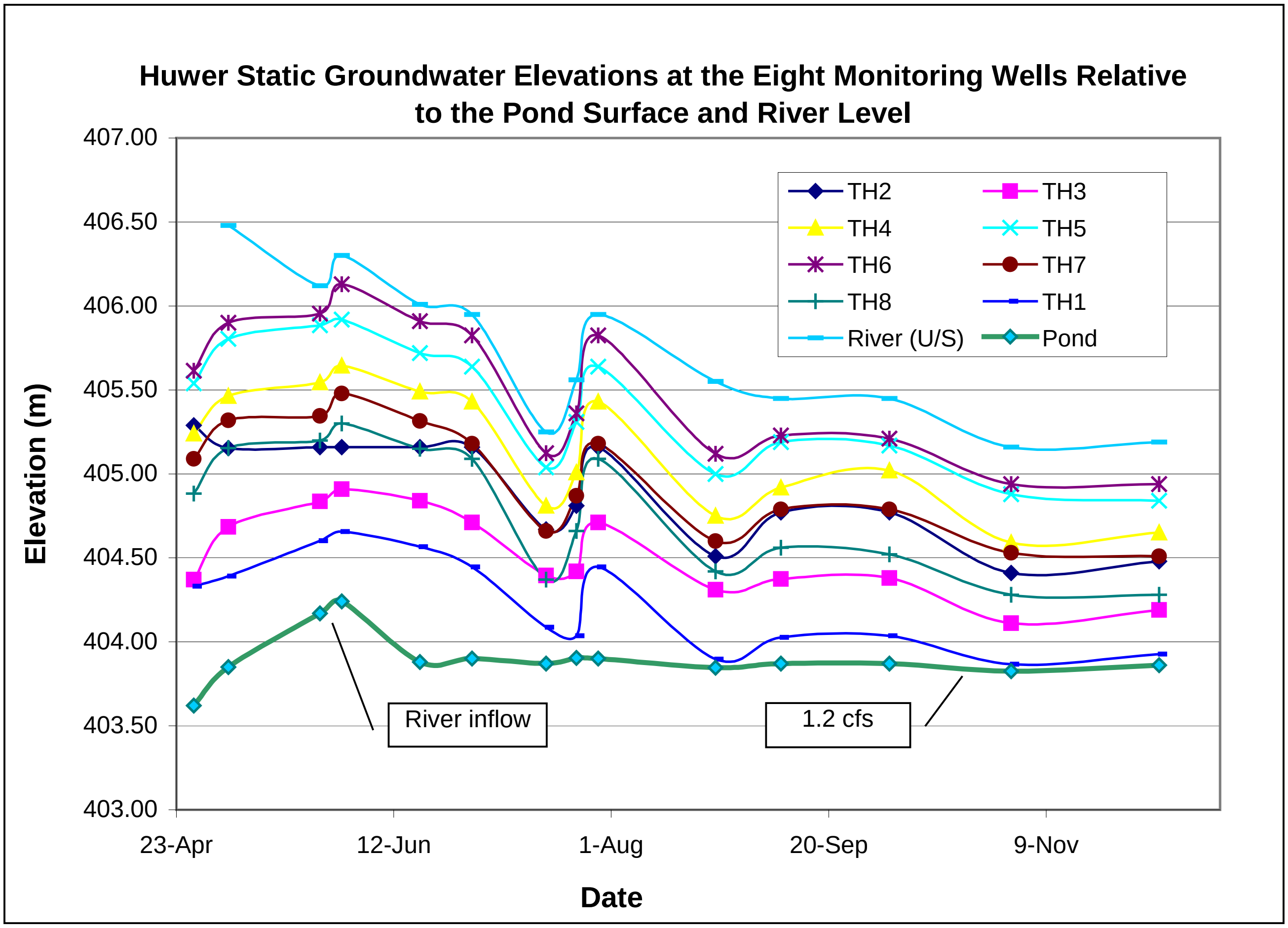


Figure 9: Graph showing the water levels at the eight monitoring wells, the pond and the river. At the time of first measurement taken in April the river level had begun to rise with snowmelt, but the groundwater level had not caught up. Normally, the river is at its lowest in winter. During the period of study, the lowest flows occurred in late fall. The lowest groundwater level was in early spring following an exceptionally dry two years. Test Hole #2 shows some influence of runoff from the hillside in April. The outflow from the pond was measured to be 1.2 cfs in late September when it was at its lowest. During late May and early June, the river is high enough to enter into a remnant channel and back water the pond. There is a noticeable increase in fry at this time.

Table 1: Elevation differences and distance between the monitoring wells and the pond surface.

Lowest Pond Surface Elevation = 403.87 m				(m)
Test Hole	Straight-line Distance to Pond (m)	Lowest Water Table Elevation (m)	Difference in Elevation (m)	Gradient (%)
1	144	404.03	0.16	0.11
2	290	404.51	0.64	0.22
3	82	404.31	0.44	0.54
4	267	404.75	0.88	0.33
5	355	405.00	1.13	0.32
6	420	405.12	1.25	0.30
7	187	404.60	0.73	0.39
8	152	404.37	0.5	0.33

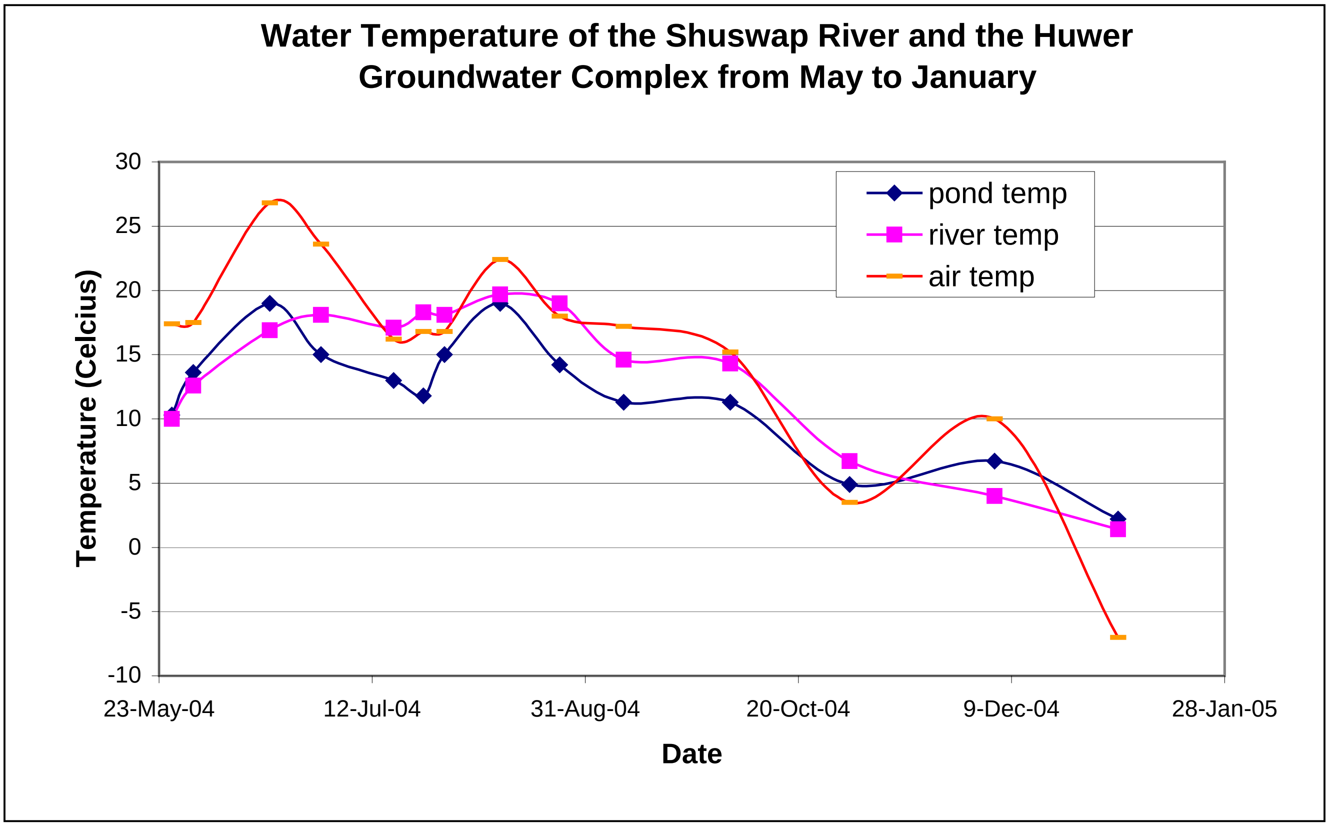


Figure 11: Graph showing the temperature and dissolved oxygen level of the pond compared to the river. Except for the brief hot period in June, the pond was slightly cooler than the river during the summer despite the shallowness and low flow in the pond. During the winter months, the pond is slightly warmer than the river.

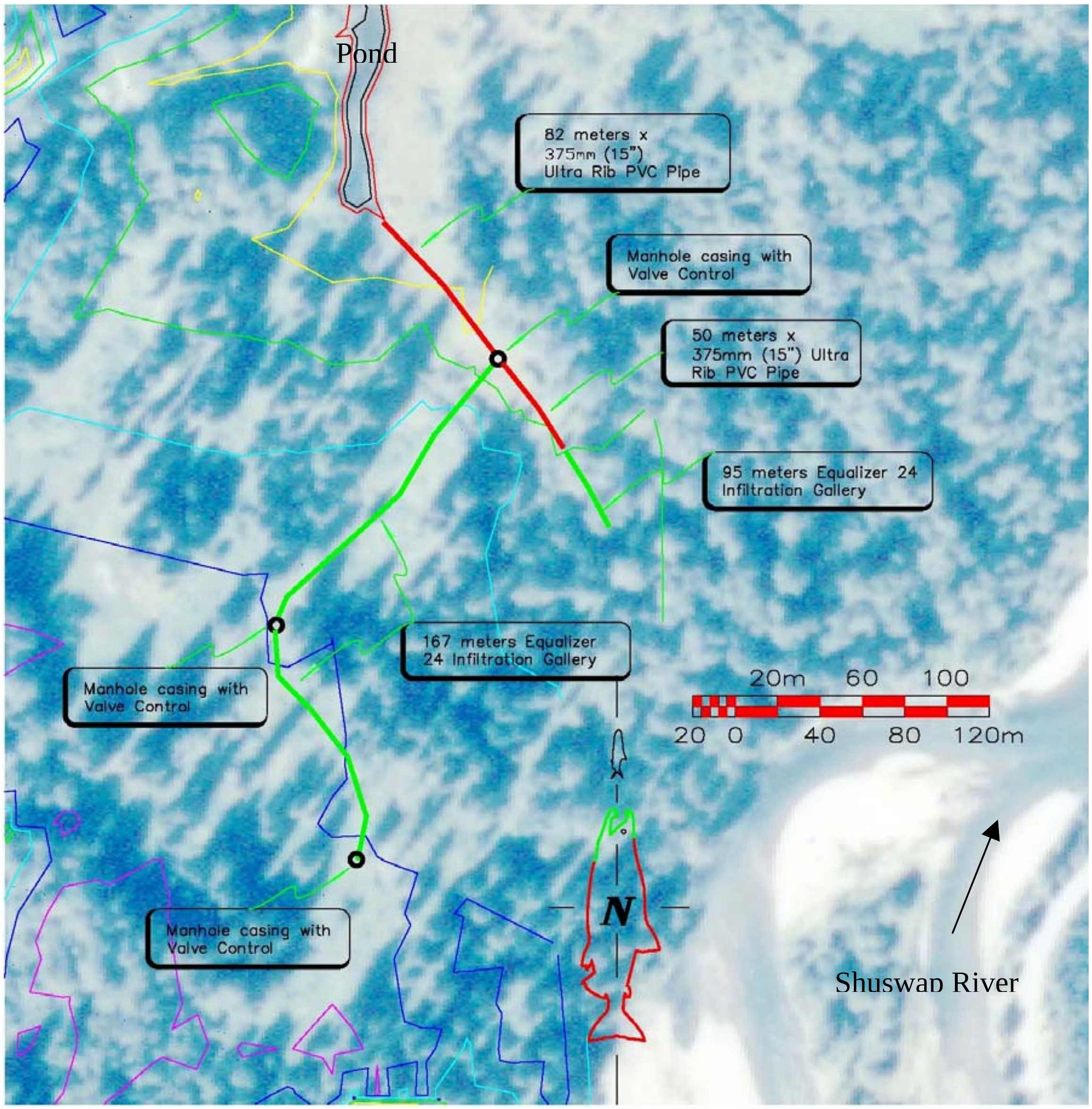


Figure 11: Drawing showing the proposed infiltration galleries and pipe to pick up ground water flow. The infiltration galleries would all be placed in clearings to have the least impact on the standing trees as possible. With the highly permeable soil and a water table within 1.5 m of the surface, there would be no negative impact to the trees.

Discussion

Increased Flow

It is possible to increase the groundwater flow into the Huwer pond and creek complex. There is sufficient difference in elevation between the water levels at the monitoring wells and the pond surface to establish a flow either with an open channel or by installing an infiltration gallery. The soil is well-sorted gravel that is porous enough to ensure a steady, continuous flow.

The data was reviewed in early November by the engineering staff at DFO and a plan was drawn up to capture the groundwater with the greatest head and pipe it to the pond (Appendix A). The plan shows two infiltration galleries feeding into a 375mm pipe that will deliver the groundwater to the pond. The two branches extend towards the area with the greatest head (monitoring wells 5 and 8).

The hydraulic conductivity for well-sorted gravel ranges by several orders of magnitude, from 0.01 to 1.0 cm/s (C.W. Fetter, 1988). The open area of the equalizer 24 infiltration gallery is approximately 0.53 m^2 per linear meter giving in inflow rate of 5.3^{-5} m^3/s to 5.3^{-2} m^3/s or 1.86^{-3} ft^3/s to 1.85 ft^3/s per linear meter of gallery. While this makes predicting the infiltration rate difficult, experience has shown that by following the clean gravel seams while installing the galleries, infiltration rates can be kept at the mid to high end of this range. In the plan designed by DFO, there is 327 m of gallery. This should be more than enough to keep the 375 mm pipe at the lower end of the gallery full. A full, smooth-walled 375 mm pipe at a 0.39% slope will deliver approximately 5.2 ft^3/s (using a Hazen-Williams roughness coefficient of 140). DFO expects a minimum of 5 ft^3/s. This would triple the current low flow of 1.2 ft^3/s.

.

Figure 12: Worker holding a section of infiltration gallery. The infiltration galleries are shaped like an inverted “V” with an open bottom. The sides have fine louvered openings so that they are permeable to water but resist filling with sand (Figure 12). They have been used successfully by DFO and WCRC on several projects.

In addition to the buried galleries, it would be possible to excavate a small section of open channel between the pond and monitoring well #3. There is only a distance of sixty meters and a head of 0.54 m. This open channel could be in the form of a 20 x 40 m bay in the pond that is 3 – 4 m deep. Complexed with woody debris such as large rootwads, the bay would offer excellent deep pool habitat for warm weather and over-wintering. The gravel that was removed during excavation could be used on the access road, especially in two areas where culverts are required to cross the intermittent section of creek. A 20x40 m pool area would provide about 80 loads of gravel. Its use would offset the cost of the excavation of the bay.

There are several benefits of having a buried infiltration gallery over an open channel. The first is that the gallery is unaffected by floods and erosion nor does it exacerbate these conditions. Secondly, with the buried infiltration gallery, there is less disruption of the landowner's current management practices. . Finally, the flow from infiltration gallery is less likely to be reduced over time. With an open channel the inflow of groundwater can be gradually reduced as the channel bed is covered by deposition of fine sediments during flooding and by the accumulation of organic detritus. This accumulated matter gradually seals the streambed reducing the groundwater influx. The fine sediment is further sealed by biofilms created by bacteria and epipelic and epipsammic algae. With a buried line there is no deposition or algal activity and very limited bacterial growth.

The plan includes placing manholes at the main junction and at intervals along the longest run. The manholes would act as sediment collectors and would allow the placement of shutoff valves in the system to be able to control the ground water flow if needed. The flow could be shut off for in-stream work or during flood periods, for example. The flow control would also ease in the installment of the gallery. The galleries could be constructed in sections without sediment being circulated through the entire system. The manholes could also be used to monitor ground water levels.

Temperature

The increased flow to the complex would further modify the water temperature. An additional 5 or 6 ft^3/s of 9 ^{0}C water would keep the pond and creek cooler during the summer and warmer in the winter. The growing season would be lengthened for increased productivity on all trophic levels.

Dissolved Oxygen Levels

The DO levels would have to be monitored during construction. If pond DO levels were too low, a 90^0 elbow and a short section of vertical pipe could be placed on the end on the inflow pipe. The pipe would be slightly higher than the new pond level so that the inflowing ground water flowed first into the air and splashed down on the pond surface like a fountain. Placing large rock around the vertical pipe to increase the splashing action could enhance the aeration of the inflowing groundwater.

Effects of Drawdown on Existing Vegetation

The drawdown of the water table by the infiltration gallery should not have an adverse affect on the existing trees on the property. The proposed infiltration gallery has been located in clearings, generally 10 m from the existing trees. The water table is within a meter of the ground surface during the summer months when evapotranspiration rates are the highest. Even with a local drawdown of up to 1.2 m, the water table would still be within reach of the root systems of the mature cedar and cottonwood present at the site. There may be some change in the more shallow rooted vegetation along the alignment.

Recommendations

Any work done on this site should include exclusion fencing to keep the cattle away from the creek and riparian areas except at armoured crossings and access points. This will prevent bank trampling, sediment and nutrient loading, promote riparian growth and diversity and add stability to the site during high flows.

Increasing the flow to the creek will attract beavers. Any work should include wrapping the existing trees with wire to prevent future damage to riparian trees.

A proposal for partial funding of the construction of the infiltration gallery and riparian fencing has been submitted to BCRP and to the Pacific Salmon Commission

Acknowledgements:

Funding for this project was provided by B.C. Hydro Bridge Coastal Fish and Wildlife Restoration Program.

Technical support was provided by the engineering staff of Fisheries and Oceans Canada.

The Huwer Family has participated in several restoration projects on their properties in the Mabel Lake Valley. They have been exemplary in taking on a stewardship role and working to improve farming and land use practices.

References:

Anonymous, Arc Environmental Ltd., Shuswap River Fish/Aquatic Information Review, February 2, 2001

Chapman, D.W. 1966. Food and space as regulators of salmonid populations in streams. The American Naturalist 100:345-357

Chapman, D.W. and E. Knudsen, 1980. Channelization and livestock impacts on salmonid habitat and biomass in western Washington. Transactions of the American Fisheries Society 109:357-363

Mason, J.E. 1966. The migrant dipper: a trap for downstream-migrating fish. The Progressive Fish-Culturist 28: 96-102

McMahon T.E., 1983. Habitat suitability index models: coho salmon. Report FWS/OBS-82/10.49.u.s.fish and wildlife Service, Western Energy and Land Use Team, Washington,D.C.

Flynn, M., habitat biologist, Fisheries and Oceans Canada in an email relaying data from Chamberlain, M., DFO STAD group

Nickelson, T.E., and J.D. Rodgers, S.L. Johnson, and M.F. Solazzi. 1992. Seasonal changes in habitat use by juvenile coho salmon (*Onchorhynchus kisutch)* in Oregon coastal stream. Canadian Journal of Fisheries and Aquatic Sciences 49: 783-789

Swales, S., and C.D. Levings 1989 Role of off-channel ponds in the life cycle of coho salmon (*Onchorhynchus kisutch)* and other juvenile salmonids in the Coldwater River, Bristish Columbia. Can. J. Fish. Aquat. Sci., 46: 232-242

Fetter, C.W., 1988, Applied Hydrogeology, Prentice-Hall Inc., Upper Saddle River, New Jersey

Appendix I:
Financial Statement

Appendix II:
Public Recognition

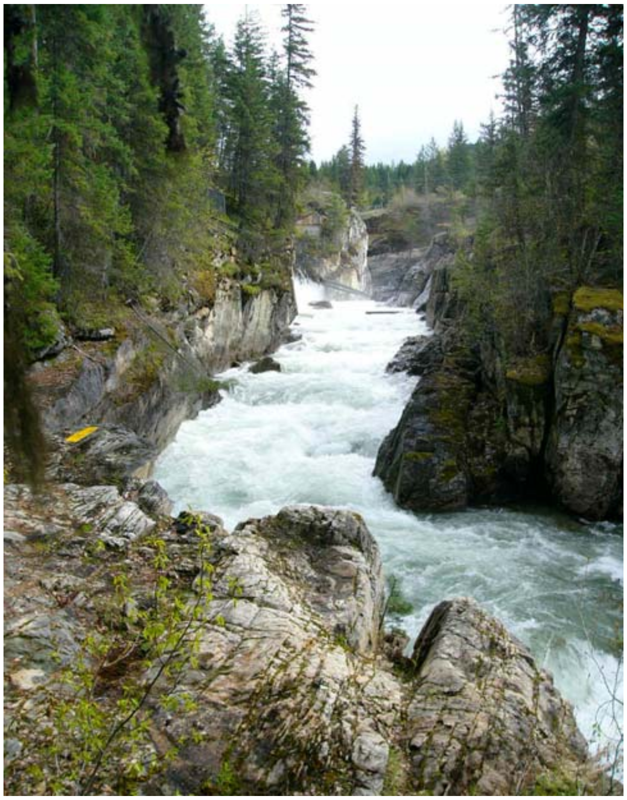
Newspaper Articles

The following article appeared in the *Lumby Valley Times:*

Whitevalley Community Resource Centre Society Watershed Projects 2004-2005

Whitevalley Community Resource Centre Society (WCRC) has three watershed restoration projects for the 2004 – 2005 season.

WCRC has partnered with Fisheries and Oceans Canada (DFO), the Ministry of Water, Land and Air Protection (MWLAP), BC Hydro, the Okanagan Indian Band, the Spallumcheen Indian Band, the Secwepemc Fisheries Commission (SFC) and the Okanagan Nation Fisheries Commission (ONFC) to develop construction drawings for a fish ladder on the Wilsey Dam at Shuswap falls. Northwest Hydraulics has been contracted to build a scale model to determine the best design and placement for the ladder. The ladder will provide passage for salmon, rainbow trout and bull trout to spawning areas in the upper Shuswap River, Cherry Creek and Ferry Creek. B.C. Hydro's Bridge Coastal Fish and Wildlife Restoration Program (BCRP) is providing funding for this project.



View of the spillway at the Wilsey Dam

BCRP has also supplied funding for a feasibility study that is looking at the possibility of increasing the groundwater flow to a small tributary to the middle Shuswap River across from Lawrence Road. Juvenile salmon and rainbow trout currently use this stream for rearing and over-wintering habitat. During the past two years, however, the dry weather has reduced water and the water quality (temperature and dissolved oxygen) has been affected. Observation wells have been placed to monitor the ground water level in relation to the surface water levels to see if the placement of infiltration galleries will increase the stream flow. Because groundwater temperature remains fairly constant year round, these small groundwater-sourced creeks stay ice-free throughout most winters. The juvenile fish can remain active and feed longer and have a better chance of surviving to maturity.

The third project, the Creighton Creek Steam Flow Recovery Project, will be promoting water conservation among the principal water users on Creighton and other Bessette creeks. Dry weather and high irrigation demands have left sections of Creighton Creek dry for the past two years. WCRC will work with the water licensees to encourage them to use the available water to their best advantage while still leaving enough water in the creek for the survival of aquatic life. This project is being funded by the Pacific Salmon Foundation and Fisheries and Oceans Canada's Habitat Stewardship Program.

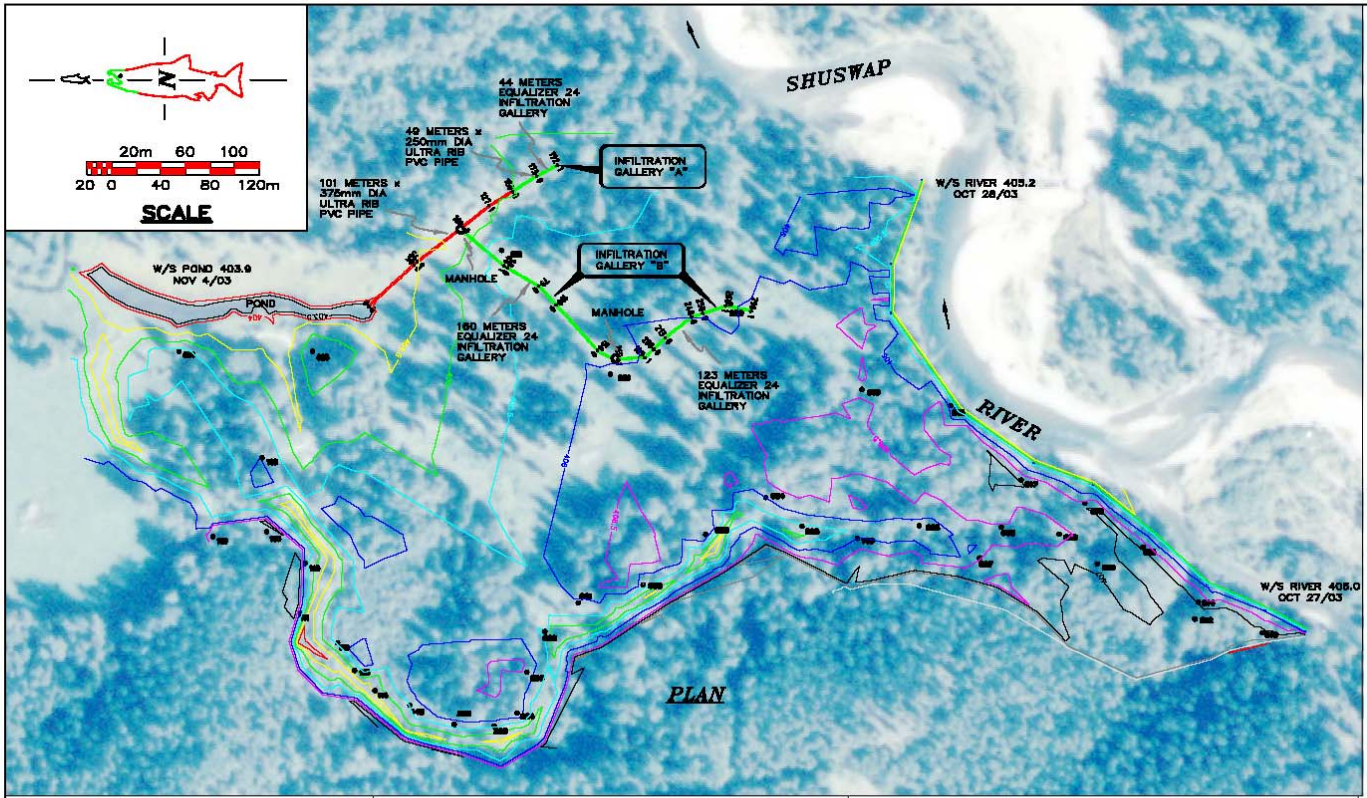
Display Boards

WCRC had display boards that presented current and past projects at Lumby Days, at a public meeting announcing Phase 2 of the Wilsey Fishway Feasibility Study, another BCRP funded project, at a public meeting held in Lumby in which the BCRP board of directors made a call for proposals and at several other public meetings held or participated in by WCRC.

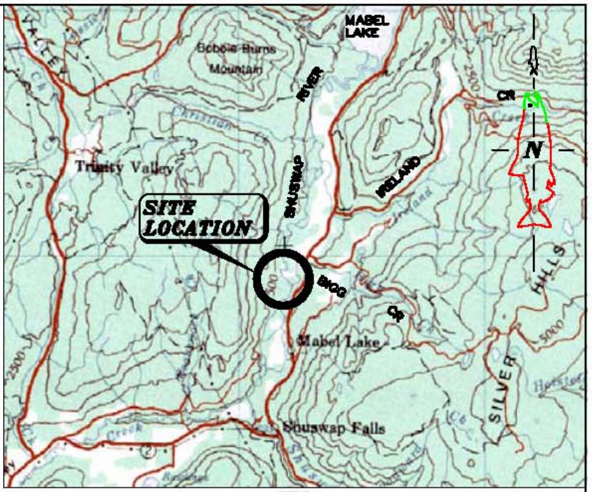
One of the WCRC displays at Lumby days presenting current watershed related projects including 04SH04.

Appendix III:

Site Plan

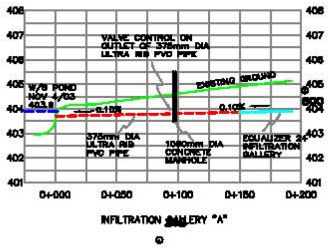


PLAN

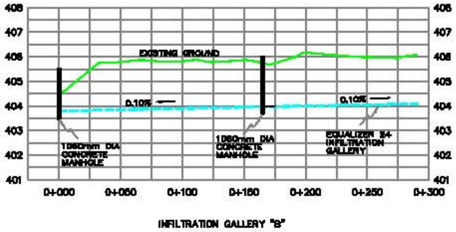


KEY PLAN

● [illegible]				
CONTROL POINT COORDINATES				
PT	NORTH	EAST	ELEV	DESC
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	1711.80	407.19	[illegible]
[illegible]	[illegible]	1772.01	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



PROFILE INFILTRATION GALLERY "A"



PROFILE INFILTRATION GALLERY "B"

FISHERIES AND OCEANS CANADA
HABITAT AND ENHANCEMENT BRANCH

SHUSWAP RIVER
HUWER GROUNDWATER COMPLEX
PLAN, PROFILE, & DETAILS

SCALE
AS SHOWN
DATE
NOV/04
DRAWING NUMBER
[illegible]
REVISION

SURVEYED OCT 21/03, APR 15/04 BY P. COCHRANE
VERTICAL COORDINATES ARE BASED ON GEODETIC TIE IN TO MINISTRY OF ENVIRONMENT FLOOD PLAIN MAPPING CONTROL
CONTOUR INTERVAL 0.5 METERS

DWG. NO.	REFERENCE DRAWINGS	NOTES	NO.	DATE