Atlantic Salmon (*Salmo salar*) Spawning Bed Development on South Feeder River in Response to a Bridge-Induced HADD Determination.

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Abstract

Newfoundland and Labrador is a large province with many of its residents residing in small, isolated communities originally established along the extensive coastline. The Department of Transportation and Works (DTW) undertakes infrastructure initiatives connecting these remote towns to the Trans Canada Highway (TCH) encouraging freedom of travel and economic growth. As part of the extension of the TCH in Labrador, DTW is building the Trans Labrador Highway (TLH). This road will be developed in pristine, wild environments and crosses many brooks, streams, and rivers. In 2005, DTW constructed a 30 meter steel girder bridge across South Feeder River, a tributary of the Paradise River, in Labrador. The project included an infill section. The Department of Fisheries and Oceans (DFO) decided that a Harmful Alteration, Disruption, or Distruction (HADD) occurred which was based upon the loss of 7.3 units (1unit = 100m.sq) of Type II riverine habitat due to this infilling. The DTW was required by DFO to sign a compensation agreement to replace the loss of fish habitat and to undertake a monitoring program.

Subsequent to declaring a HADD, DFO proposed that the 7.3 units of Type II rearing habitat be replaced with like habitats. As Type II habitats are readily accessible and available within the section of river and Type I salmonid spawning habitats were very limited adjacent to the project site, a spawning bed was proposed. It was anticipated that adult Atlantic salmon and Brook Trout would utilize the newly constructed spawning bed and hence increase overall productivity in South Feeder River. Under the approval of DFO, the department built a large spawning bed to create Type I habitats and actually increase the biomass of salmonids in South Feeder River. As of 2007, this project has had three years of salmonid spawning utilization. The monitoring studies undertaken by DTW over three years show evidence of spawning activities on the constructed bed. Young of the Year (YOY) of both species were observed and qualified by Index Fishing on the spawning bed and secondary habitats between 2005 and 2007 indicating continuous utilization by adult salmonids. Invertebrate observations have also shown excellent species representation and colonization.

Monitoring studies have confirmed the development of the spawning bed was deemed a success with an increase in salmonid productivity of the river section adjacent to South Feeder River Bridge.

1.0 Introduction:

The Department of Transportation and Works (DTW) undertakes many infrastructure projects that involve disturbing natural landscapes and environments for the construction of road projects. The building of the Trans Labrador Highway (TLH) is in its final stretch of development and, once completed, will result in the construction of a road across undisturbed, pristine Labrador wilderness, crossing hundreds of watercourses ranging from tiny intermittent brooks to large rivers, including the Churchill River near Goose Bay. This paper will focus on the effects of the construction of a bridge across a tributary of the Paradise River, South Feeder and the resultant HADD determination as outlined in the *DFO Practitioners Guide to Habitat Compensation* (http://www.dfo-mpo.gc.ca/oceans-habitat/habitat/policies-politique/operating-operation/compensation/index_e.asp).

Figure 1. Map of Labrador showing approximate location of South Feeder River Spawning Bed.

Figures 1 through 3 show the project location and engineer drawing of the spawning bed on South Feeder River.

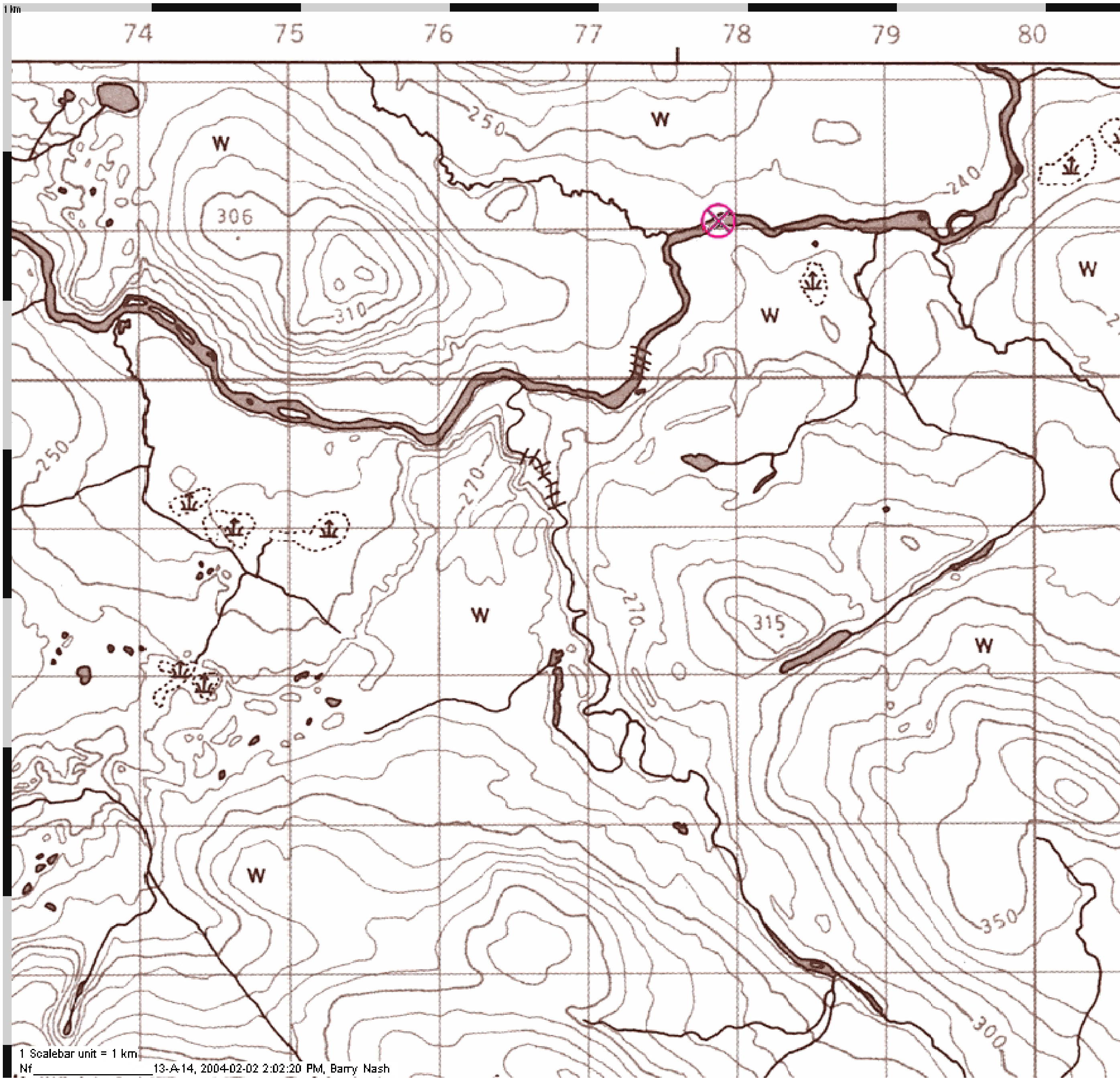

Figure 2. Close up of location of Spawning Bed on South Feeder River

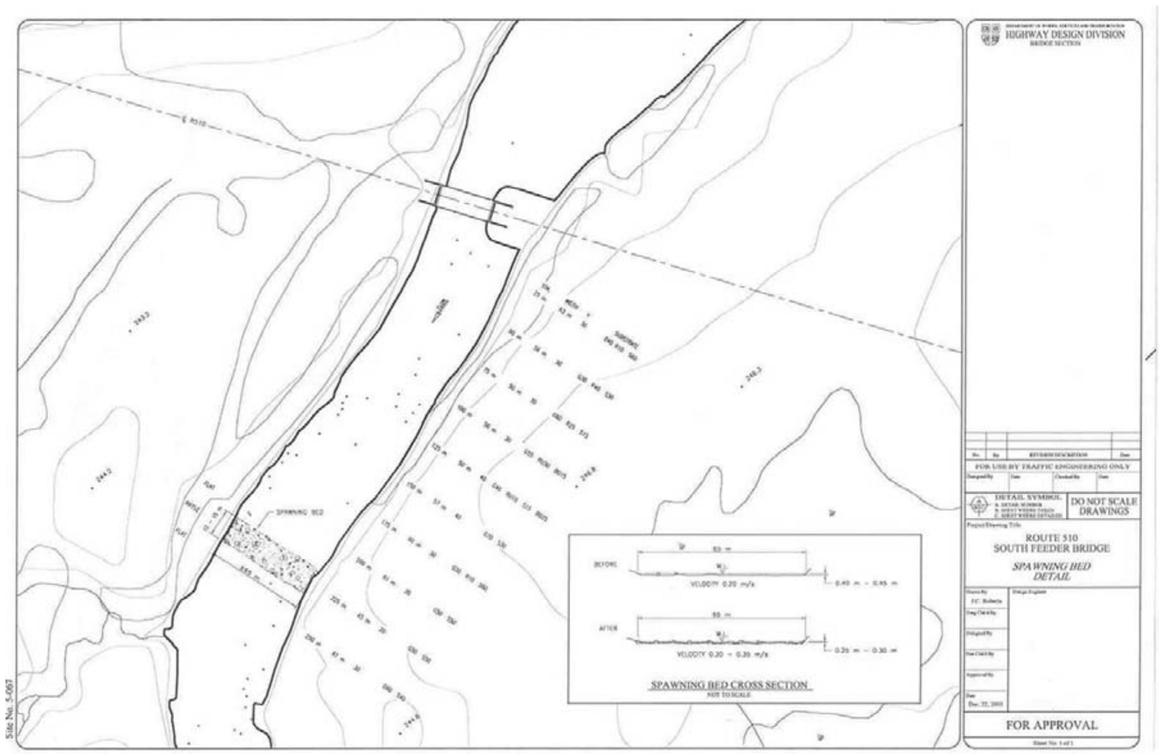

Figure 3. Engineer Drawing of Spawning Bed location in South Feeder River.

To ensure that there is a no net loss of productive riverine fish habitat as a result of the bridge construction, the Fish Habitat Compensation Agreement (herein referred to as the Agreement) set out the responsibilities of DTW to undertake and complete appropriate compensation measures to protect habitat. The Beak units of habitat refer to the various sections of riverine environments and the changing stages of salmonid growth they occupy. The units are indicators of habitat usefulness with spawning (Type I) followed by rearing (Type II), cascades (Type III), and migration/holding (Type IV). As juvenile salmonids need Types I and II for survival, they are deemed the most productive. The DTW proposed to construct/create productive riverine Type II habitat to offset the loss of same habitat associated with bridge construction. After a stream survey which indicated a greater proportion of Type II habitat with portions of Type IV migration habitats existed in the river previously, DTW decided to replace the loss with more valuable Type I spawning habitat of greater area. A site was selected approximately 225-250m downstream where Type IV habitat existed. This was converted to Type I habitat by the placement of spawning gravels, thereby increasing the potential for a greater number of salmonid fry to be produced in this area. It was surmised that the creation of more than 8 units of productive spawning riverine habitat will help address spawning requirements of salmonids as well as increase the overall productivity of the system.

Spawning bed creation was selected for habitat compensation as it appeared to be a limiting factor with production in this particular stretch of the river. In the 250 m surveyed on August 24, 2004 by DTW, approximately 9% of the substrate consisted of gravels potentially capable of supporting spawning fish. The area of the surveyed reach is approximately 15,000 m^2 with an estimate of 1400 m^2 gravels potentially available for spawning. It is important to note that although these gravels are present it is unknown if they are actually used by fish for spawning. Depths and velocities are just under the higher and lower limits respectively for usage due to the geomorphological conditions of the river and the presence of high amounts of naturally occurring sand. The majority of gravels are embedded and unavailable for spawning. Adding a minimum of 800 m^2 of new spawning habitat was proposed to increase the overall percentage by 5% to give a total close to 14%. As the amount of Type II habitat is substantial, at least 5,000 m^2, having an increase in egg-production will increase the colonization of this rearing habitat with young-of-the-year.

During the application for Environmental Approval for the proposed bridge from the Provincial Department of Environment and Conservation, information was gleaned regarding flows and basin hydrology. The watershed area is 327 km^2 with a basin perimeter of 124 km. The length of the main channel is 33 km with a basin slope of 0.403 %. The flood frequency analysis was found using 327 km^2 and equations pertaining to Labrador. The return period was found to be 100 years and the design flow 220 m/s. A stream survey was carried out in the reach to show width, depths, velocities, substrate materials and composition values and vegetation cover. The Manning's number, or roughness coefficient, was found to be 0.04 – typical of salmonid- bearing rivers in Labrador.

Also while preparing the application for the Environmental Approval, the maximum flow was calculated to be 260 m/s with a maximum velocity of 1.80 m/s. Stream surface velocities have also been measured across each station in the survey reach. This was done at low to medium-low flows during August 2003.

3.0 **Methodology**:

All works were carried out with due diligence and care to minimize disturbance and sedimentation in the river and were done during low flow. Boulders were recycled from the temporary bridge crossing site upstream and gravels were obtained from an esker near the project site. The composition of the gravels was identical to natural gravels found within rivers. Heavy machinery placed the material in selected locations and after the bed was constructed, the project site was tidied up and re-vegetated. DTW also prepared an Environmental Protection Plan (EPP) which outlined specific construction and mitigation measures for the project prior to development.

3.1 Pre-Construction:

The first activity was the construction of a “tote” road for access to the site. Care was taken to minimize disturbance and enhance restoration using indigenous plants. Vegetation was removed and placed to the side to be replaced after construction activities were finished. However, there was only 2.5 – 5 cm humus on the sand in which the vegetation was growing. When trees and plants were lifted the sandy soil fell away leaving the roots exposed. As a result, the material was just pushed aside to be returned as a mixture upon completion of the project. The material which consisted of branches, roots, and other portions of vegetation was partially buried by the naturally occurring sand that was present in the surrounding landscape.

Once the underlying sand was exposed, the larger equipment made access. The boulders and gravels that were to be used to construct the spawning bed were stockpiled near the site to be used in a specific order. The material needed for the project was brought to the river with selected heavy equipment. A 6 wheel drive Terex truck with a capacity of 35 tons was used for bringing in the gravels, two front-end loaders were used to strategically place the boulders, and a tracked excavator was used to flatten out the gravels and strategically place the substrate and boulders in key locations.

3.2 Primary Spawning Bed Construction:

Large boulders and rubble were placed across the width of the stream to simulate natural riffles. This worked as the foundation to hold the gravels which would be placed immediately upstream. During the assessment a 50:50 gravel/sand mix was found to make up the substrate with water velocities of 20 cm/s and lower. Some alterations had to be made in the river to bring the velocities up and the depths down. The existing depth, velocity, and composition of the substrate made this site unsuitable for spawning. By decreasing the depth, from 44 cm to 25-30 cm, and increasing velocities to match that found in the riffles nearby, approximately 30-35 m/s, helped keep any gravels already present in the river free of sand and reduce embeddedness of the substrate. This allowed substantial percolation of water through any redds that may be made by spawning adults below the proposed spawning bed in sorted gravels. Some of the coarse substrate, most notably the boulders, was placed to break the surface of the water at low to medium flows creating riffling.

A stone foundation was first laid to ensure gravels were maintained upstream during periods of high flow. It was constructed of blasted angular rock and compacted to give greatest stability. Large stones were used downstream against the foundation as additional support. As the velocity in this area was only 20 cm/sec it was increased to approximately 35-40 cm/sec by using large boulder deflectors on either end of the foundation stones giving an environment similar to that of a pool outlet with increasing water velocities and shallower water depth. Cobbles and boulders were used to form a bar, similar to others found within the reach, which stretches the entire width of the river. This boulder/rubble bar was used to decrease the depth from 44 cm to 25-30 cm, thus causing the flows to riffle over the substrate in the same manner as it does in the natural riffles already present in the surveyed section. The purpose is to maintain relatively consistent water depths ranging from 25-30cm to closely mimic the depths found over natural spawning beds. Boulders and cobble were used to lay out a working platform from which to work from stream bank to stream bank. The large boulders and cobble also act as a foundation to support and stabilize gravel and pebble-sized materials which were added upstream forming the actual spawning material.

As the work involved creating spawning habitat, flows needed to be increased to maintain optimal levels necessary for spawning, egg incubation and riffle habitats (between 30 – 45 cm/s) (Figure 1). It was necessary to decrease the width and depth of the river at the site to bring it closer to that required for spawning salmonids. This was done using coarse substrate such as boulders and cobble. Gravels were obtained from esker material which provided the proper mix of various stone sizes matching those found naturally as substrate in the river. These gravels were placed immediately upstream from the foundation stones at a distance of 20 meters. A heterogeneous mix of gravels (Table 1) was carefully added to the site to ensure percolation of water through the substrate. The gravel depth is a minimum of 40 cm to accompany large salmon. As it was proposed to create spawning beds and riffles, the composition of the substrate was changed to maximize potential spawning frequency and success and to ensure adequate aeration of eggs in any redds created.

Table 1
Heterogeneous Spawning Bed Gravel Composition

Substrate Size	Percent Composition
Fines	3%
2 – 12 mm	7%
12 – 50 mm	40%
50 – 100 mm	40%
100 – 150 mm	10%

Immediately upstream of the spawning bed, a deep area was formed which immediately became valuable Type IV habitat for resting adults. This Type IV habitat is of better quality than that originally converted to Type I due to its proximity to the spawning beds and increased depth. Whereas the river was consistent in depth from bank to bank; it now has a variety of depths ranging from ~25 cm on the beds to ~60 cm upstream of the beds.

3.3 Secondary Spawning Habitat Construction:

Large boulders were placed immediately downstream of the foundation stones to focus the thalweg and form scour patterns with the gravels already present there. It is important to note, there is a considerable amount of natural gravels which, with the assistance of increased velocities, can be made available to fish just by using faster flows to naturally sort the material into various sizes. This will not only make spawning habitat available to salmon but the smaller material, such as the pea-gravels, will be sorted further and create new brook trout spawning beds.

Spawning habitats were created using coarse substrate as a foundation for stabilization of the gravels placed by DTW. As natural substrate migration occurs in this river, it is expected that by matching the depths, coarse substrate, and velocities of the current, riffles gravels will continue to be held up as they make their way downstream. At the same time, these gravels will be cleared of fines and sand due to the slightly higher velocities created. This natural sorting of the substrates is dictated by depths and velocities found through river systems and it is planned to take advantage of this process by matching the riffles currently within the reach. As the width and gradient of this reach is consistent, results should easily be compared with the natural riffles. With the presence of large substrate such as boulders, cobble, and rubble, the proposed altered habitats will act as gravel catchments in that they should hold migrating gravels due to bed load shifting. This will ensure long-term sustainability of the spawning site as new gravels are expected to be held up as they make their way downstream over time due to natural bed load movement. It is expected this bar will retain spawning gravels, even capture gravel migrating down from areas above the site, as well as keeping any retained gravels free of sand and fines due to increased velocities.

3.4 Restoration of Disturbed Areas:

Any disturbance created during construction was restored in accordance with the EPP. This was done by the placement of select large stones at the water’s edge for erosion prevention and the placement of a sand/humus/vegetation mix behind the boulders to facilitate plant regeneration. As Labrador has a very short growing season and limited soil, the best method of stabilization was to take advantage of natural roots and rhizomes that were grubbed. Following construction this material was spread over the site and is showing excellent regeneration.

3.5 Monitoring of Activities:

A three year monitoring program began in the summer of 2005 and was repeated in 2006 and 2007. A consultant firm, AMEC Earth and Environmental Limited, was contracted to carry out qualitative biomass analysis and to observe any changes in riverine geomorphology.

4.0 Results:

4.1 Habitat Utilization Observations - Qualification:

Once the bed was completed in September 2004, it was anticipated it will be used by fall spawning adults of that year. Originally it was intended to record any activities observed on the bed visually once fish began testing the gravels for redd potential. This proved difficult especially when attempting to coordinate field visits with the short window when spawning adults are active.

4.2 Fall Redd Observation:

During October 18, 2004, a walk-through inspection was undertaken for redd observations and fish were seen occupying the shallow water flowing over the bed. Unfortunately the helicopter seemed to have spooked them and wakes were observed as the fish swam to the deeper water immediately upstream thus precluding taking any video of spawning fish. After landing the helicopter the beds were observed from shore. Occasional fish were seen moving about in the shallows created by the spawning bed. Adult salmon were observed swimming from the deep upper section, over the beds, and down through the riffle to the fast flowing water amongst the boulder cluster downstream of the bed. The presence of the observation group may have made them wary as they didn't stay long but only moved either up or downstream. No fish was actually observed spawning. At that time, a video was taken of the gravels, particularly where there appeared to be redds. Care was taken not to step upon any potential redds during recording.

Besides the small patch of gravels observed just below the bridge during the initial survey, which may or may not be of use for spawning, the riffles created at this location are the only other place they can be found along the approximate 500m stretch that included the survey site. When the site was visited again in November 18, the river was completely frozen over except where the artificial riffles created enough surface disturbances to maintain open water. An exceptional run was created in the tailrace below this riffle that adult salmon should find appealing for cover, velocities, and oxygenation. This tailrace is actually the water leaving the spawning beds, where it becomes constricted and the velocity increased. The DTW plans to measure the additional habitat variables in this run over the duration of the monitoring program.

4.3 Spring Fry Observations:

In July of 2005, a visual inspection of the spawning bed was undertaken. Video footage of almost 80 fry was taken and presented to DFO for review. These results show the project to be a success. The original request by DFO required DTW to replace 7 units of Beak's Type II rearing habitat and the department actually created approximately 16 units of Type I spawning habitat therefore increasing the productivity of South Feeder. The results obtained exceed the loss of original habitat. With this spawning bed being utilized for many years to come there has been a positive influence of this project on the overall ecosystem of South Feeder.

4.4 Qualification:

As outlined in the Fish Habitat Compensation Agreement South Feeder River – Bridge Installation, Authorization No. 03-04-002, a three year monitoring and analysis using Electrofishing techniques was carried out on August 30, 2005, on August 11 and 12, 2006, and on August 9 and 10, 2007 by an independent consultant firm AMEC Earth & Environmental Limited. This survey was to observe usage of the artificially created habitats by spawning Atlantic salmon.

A video of fry on the spawning bed was undertaken by DTW on July 21, 2005 showing many YOY over the gravel surface. The conditions were perfect for observation with low water levels and bright conditions. Whereas the video could only be taken during the lowest flows which occur in July the electrofishing over the next three years was conducted in August. Flows had generally increased by that time reducing potential electrofishing results. When the water levels in South Feeder rise, tannic, fumic, and humic acids cause the waters to darken, thereby reducing visibility and sightings of fish.

The electrofishing studies revealed salmon fry and yearlings. The fry were from the previous fall's spawning brood while yearlings seemed to have remained from the spawning the year before. An additional study was conducted immediately downstream where deflector boulders were placed by DTW to sort the sand from the naturally occurring embedded gravels in the river. Electrofishing results show the presence of YOY and 1+ salmon in this area as well as YOY brook trout. As sorting and stabilization have both occurred here, as predicted, spawning was expected to take place by both salmon and brook trout during last year's spawning season. This has also occurred.

As outlined in all three Amec Electrofishing Surveys over the monitoring period, in the discussions and conclusions, the enhanced habitats are functioning as designed. Both the spawning bed and downstream scour-induced geo-fluvial processes initiated by careful boulder placement during the construction of the spawning bed are functioning as productive fish habitats with consistent habitation by young salmonids. Originally, the bottom of the river consisted of gravels embedded in sand. The velocities were much too low to sort the substrate and although there was unlimited supply of gravels, they were of no use to spawning fish. After assembling the spawning bed as agreed to in the compensation agreement, DTW realized the potential to create more spawning habitats immediately downstream with a minimal amount of work or cost. Placing boulder clusters in the thalweg was expected to sort the sand from the gravels, thereby making the gravels available for spawning. These habitats are of greater value to the ecosystem than replacing rearing habitats for pre-existing fish populations. The creation of Type I habitats increase the production of fish biomass whereas the replacement of Type II habitats would only be utilized by fish already present in the river and the vast majority of habitats at this location in South Feeder are rearing habitats.

The middle of the run below the tailrace was difficult to electrofish due to the depths and velocities. This is unfortunate as this section is where the majority of the scoured gravels exist and where most spawning would have occurred in this area.

4.5 Structural Integrity of Fish Habitat Creation

As per Subsections 5.1 and 5.2 of the Fish Habitat Compensation Agreement – South Feeder River, Bridge Installation, a visual assessment of the habitat stability and structural integrity of the South Feeder Spawning Bed compensation works was undertaken during the summer of 2006 and again in 2007. This is to complement the assessment carried out in 2005. After the field-visits, it was determined that the spawning bed is showing excellent stability and remained in the same condition as it was when constructed in 2004. A survey of stream bed morphology involving mapping and substrate retention to assess potential scour was conducted by AMEC for comparison over the monitoring period. The bathymetry of the bottom of the river outlining the position of the bed on the river was developed to quantify the positions of the substrate materials. There has been no sign of wash-out of material or dislodging of foundation stones or boulder clusters. The spawning bed and all peripheral components of the project are virtually exactly as when constructed. Observations were made during the 2005-2007 seasons by Ken Hannaford, Environmental Planner with the Department of Transportation and Works, to determine if the structure of the bed had been impacted by the previous winter's ice formation and/or rafting during spring break-up. As expected, the downstream site underwent a slight anticipated period of adjustment where the thalweg sorted the embedded gravels into a range of sizes.

The disturbance on the bank that occurred during construction to create an access to the river is stable with riprap. Natural regeneration is occurring everywhere on the deflectors with mosses, grasses, forbs, and tree seedlings appearing in crevices between the stones. The access to the site was stabilized with stone and the access road was covered with grubbing immediately after construction. Many Alpine Birch and Alpine Blueberry plants are appearing throughout the disturbed area. Caribou Moss *Cladonia rangiferina* is also showing colonization.

4.6 Assessment of Habitat Utilization by Invertebrates:

Instream biota, in particular invertebrates, were observed colonizing the substrate making up the spawning bed and deflector boulders. Although no quantitative analysis was conducted to determine the extent of colonization or total species composition, visual observations were made over the past three years of the macro invertebrates. Observations consisted of randomly taking stones out of the river and observing any life forms apparent on the wet surface.

Algae and diatoms covered the surface of the substrate material which, in turn, formed a primary tropic level for grazing invertebrates. Within the gravels many Midge larval tubes could be clearly seen as tiny lines composed of detritus upon the stone. Mayfly larvae of different age classes were also found under the larger gravels. Caddisfly larvae occupied the bottom of the river between the gravels. Their cases were constructed of small pieces of river sand. Stonefly and Mayfly larvae were also represented and were found clinging to the underside of the stones. Blackfly larvae were observed attached to boulders where the water flowed quickly over the tailrace of the spawning bed. Blackfly pupae cases were seen indicating full life cycle completion. Many metamorphosed emerging adults of all flying insects will become part of the food chain for the salmonids occupying the area within and adjacent to the bed.

As the spawning bed is now into its fourth year, colonization of the instream substrate is reaching high levels. Invertebrate representatives from many genera and age classes occupy the interstitial spaces and stone surfaces. These invertebrates occupying interstitial spaces in gravel beds provide the greatest numbers and species diversification per unit area in riverine habitats providing vital nourishment for developing salmonid fry.

5.0 Observations/Discussions:

It is the opinion of DTW that the approximately14 units of Type I habitat created by the Department of Transportation and Works has replaced the 7 units of Type II habitats originally lost due to bridge construction and is working as anticipated. The habitat type created is of better quality and greater quantity than that lost and is increasing overall biomass and, therefore productivity, of the salmonid populations in South Feeder. Originally, low flows and depths precluded any spawning activity in this area for salmonids. As Atlantic Salmon (*Salmo salar*) and Brook Trout (*Salvelinus fontinalis*) fry are now emerging from the gravels carefully placed in the river and the gravels being sorted by the boulder clusters below the spawning bed, the DTW is satisfied that its commitment to the replacement of lost Type II habitats during bridge installment has been achieved.

The structural integrity of the spawning bed and secondary spawning sites below the tailrace is sound and remains in exactly the same condition as it was created in 2004 (Figures 4 and 5). Furthermore, the disturbed areas adjacent to the project site are stable and are showing excellent signs of regeneration.

As anticipated, the lower section of the enhanced area, below the deflectors, is used primarily by brook trout due to the presence of naturally sorted gravels promoted by the placement of the boulder clusters. The sorting of the gravels below the deflectors separated pea-sized material from larger substrate. It is this smaller material trout utilize for spawning. More brook trout were observed in this section whereas, the majority of salmon fry and parr were found directly on the spawning bed itself.

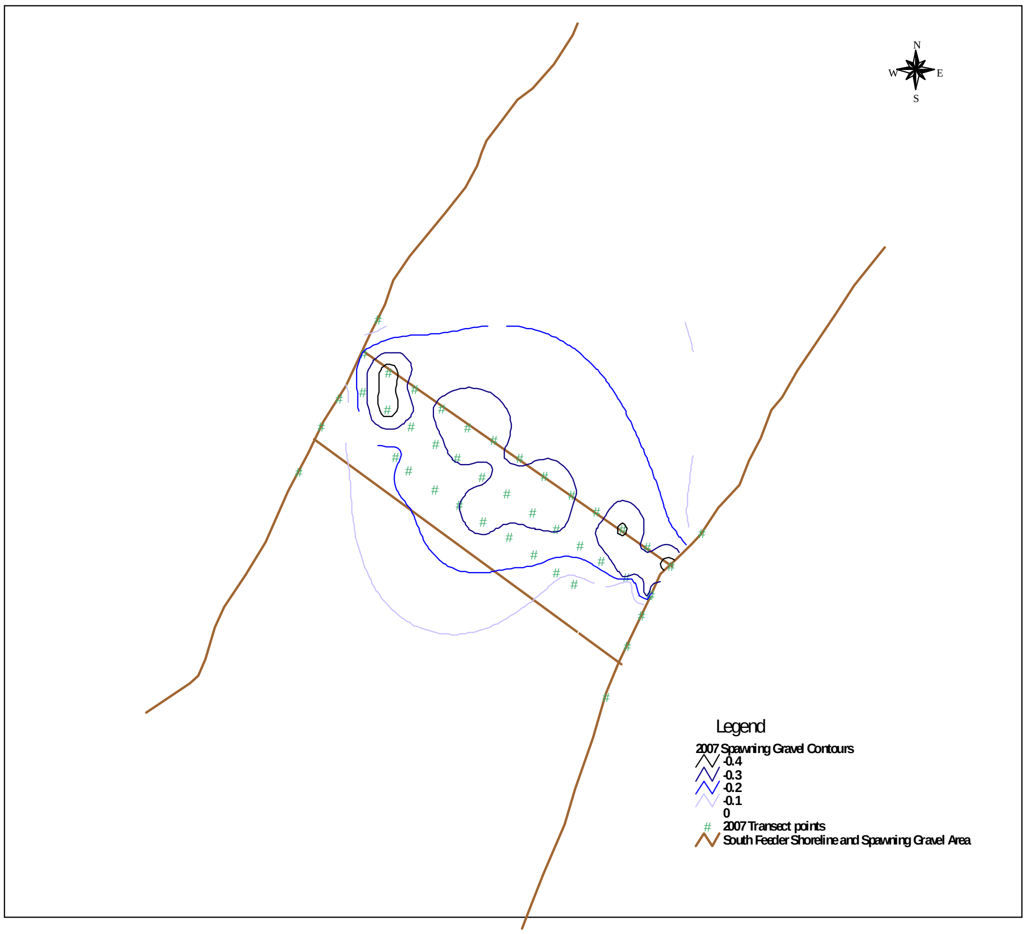

Fig. 4. 2006 Bathymetry contours across the spawning bed.

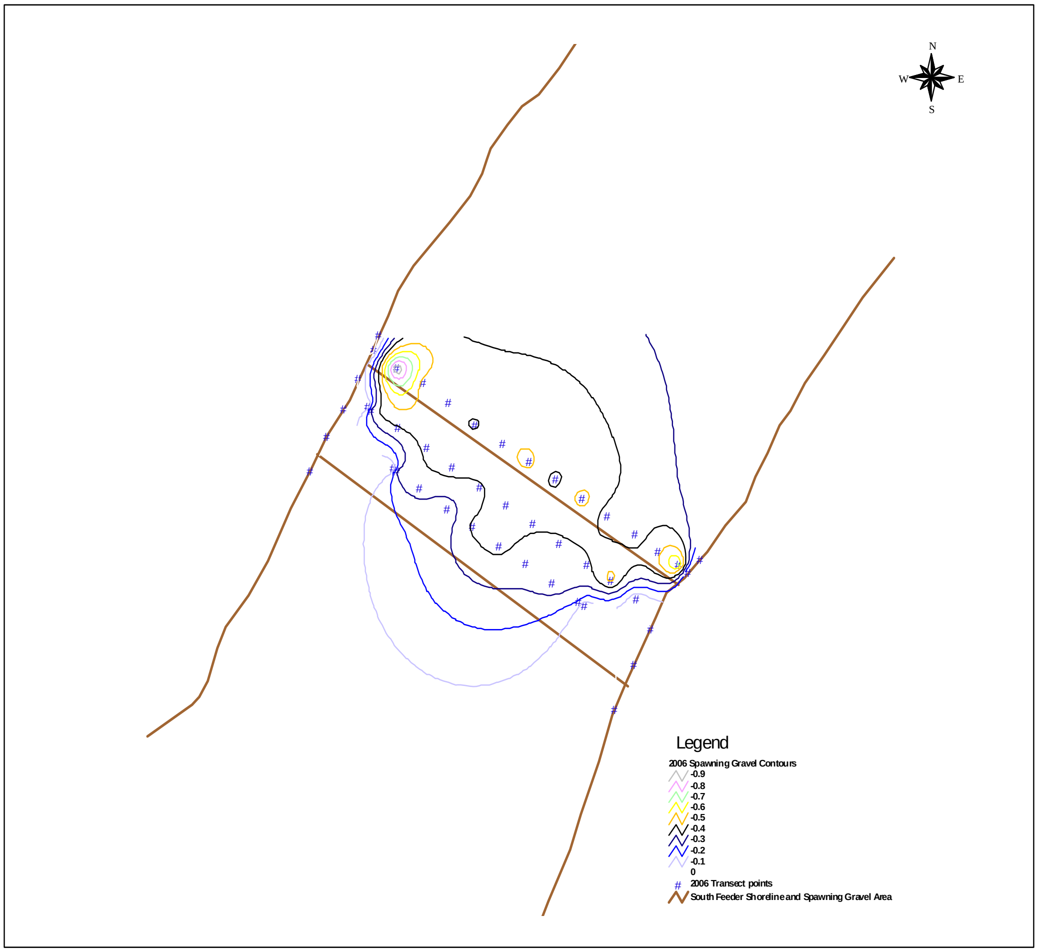

Fig. 5. 2007 Bathymetry contours across the spawning bed.

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