SALMON RIVER NUTRIENT ENRICHMENT
FOR FISH HABITAT RESTORATION
2005

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EXECUTIVE SUMMARY

From June 2 to September 19, 2005, inorganic fertilizer was added to the Salmon River (Kelsey Bay), Grilse Creek, and the Memekay River for the enhancement of winter-run steelhead (*Oncorhynchus mykiss*) and coho (*O. kisutch*). A total of 2,365 L of liquid ammonium phosphate fertilizer (10-34-0), was dispensed through five drip stations: Grilse Creek – 365 L, Salmon River near Rock Creek Main Line – 780 L, Salmon River at the diversion – 500 L, Salmon River at Memekay Main Line bridge crossing – 400 L, and the Memekay River – 320 L. Fertilizer loading rates were adjusted to changing streamflow throughout the treatment period. Water samples were collected June 20, July 12, and August 11, 2005 and analysed for low-level nutrient concentrations. Juvenile fish sampling within treated and control reaches indicated a positive growth response to the inorganic drip fertilizer. Increased algae growth was noted within the treated reaches, although there was an apparent die-off observed between July 20 and August 11.

A new organic nutrient product was tested in the upper Salmon River below Jessie Creek, in 2005. The product was made from fish meal (Alaskan pollock), heat-treated to remove pathogens, and then dried. This product was developed under the guidance of Dr. Ken Ashley of the Ministry of Environment, Fisheries Research Section, Vancouver and experimentally produced by David Murphy of Welcome Harvest Farm Ltd., Saltspring Island. Water samples from the upper Salmon River were collected on July 7, July 22, August 4 and August 11, 2005. Periphyton samples collected from treated and control sites indicated a positive algae growth response downstream of the pollock bone meal application.
ACKNOWLEDGEMENTS

Funding in part was provided by the BC Hydro Bridge Coastal Fish and Wildlife Restoration Program for treatment and field assessments upstream of the Salmon River diversion dam including Grilse Creek. Sites below the dam and in the Memekay River were funded by Weyerhæuser (now Cascadia) through their Forest Investment Account. Craig Wightman, Ministry of Environment (MOE), Nanaimo, supervised the project work. Ken Ashley and Pat Slaney, Fisheries Research Section, MOE, produced the spreadsheet for fertilizer addition rates. The design and planning for the pollock was provided by Ken Ashley and the pollock meal was processed by Dave Murphy at Welcome Harvest Farm Ltd. The barrels of liquid fertilizer were received and stored in the compound at the Ministry of Forests, Campbell River and the pollock was stored temporarily in the freezer at Quinsam Hatchery, Campbell River. The B.C. Conservation Foundation (BCCF) in Nanaimo administered this project under the supervision of Pat Stephenson. Loreta Hansen initiated and completed the majority of the field work for this season. She also provided training and guidance to ensure completion of the field work and report preparation in her absence. Leian Carswell, Kai Taylor, Angeline Donaldson and Sam Wilson (Cape Mudge Band) assisted with fieldwork. Juvenile fish sampling within the control and treatment areas was conducted by Harlan Wright and Dori Manley. Harlan reported all juvenile fish sampling data and information. Harlan also created the map in Figure 1. MoE, Miracle Beach, under the direction of Dan Dwyer, provided storage space for tanks and equipment. Lynne Campo of Water Survey of Canada, Vancouver, supplied the stream discharge data. This report was edited by Loreta Hansen, Harlan Wright and James Craig.
TABLE OF CONTENTS

1.0 INTRODUCTION ...................................................................................................................... 1
2.0 GOALS AND OBJECTIVES ..................................................................................................... 2
3.0 STUDY AREA .......................................................................................................................... 2
  3.1 Site Locations ....................................................................................................................... 2
4.0 MATERIALS AND METHODS .................................................................................................. 4
  4.1 Installation of Tanks .............................................................................................................. 4
  4.2 Liquid Fertilizer Acquisition and Tank Loading ................................................................. 5
  4.3 Calibration of Liquid Fertilizer Additions ........................................................................... 5
  4.4 Water Temperatures and Flow Monitoring ........................................................................ 5
  4.5 Organic Fertilizer Experiment (Pollock Meal) ................................................................. 5
  4.6 Water Sampling .................................................................................................................... 6
  4.7 Periphyton Sampling (Pollock Test) ................................................................................... 7
  4.8 Juvenile Fish Sampling ....................................................................................................... 8
5.0 RESULTS ................................................................................................................................. 8
  5.1 Water Temperatures and Stream Discharge ................................................................. 8
  5.2 Liquid Fertilizer Output ................................................................................................... 9
  5.3 Organic Fertilizer Experiment (Pollock Meal) ................................................................. 9
  5.4 Juvenile fish sampling ..................................................................................................... 11
6.0 DISCUSSION and RECOMMENDATIONS ............................................................................ 13
  6.1 Liquid Nutrient Application .......................................................................................... 13
  6.2 Organic Fertilizer Experiment ....................................................................................... 14
7.0 REFERENCES ....................................................................................................................... 15

LIST OF FIGURES

Figure 1. Location of the fertilization area showing liquid fertilizer tank sites and sampling sites on the mainstem Salmon River, Grilse Creek and the Memekay River in 2005. ............... 3
Figure 2. Information sign posted at each tank location in 2005. ........................................ 4
Figure 3. The valve system installed on all tanks. ............................................................... 4
Figure 4. A burlap bags filled with Pollock placed in the upper Salmon River. ............... 6
Figure 5. Pollock meal distributed in the stream after bags were disturbed, probably by bears. Photo was taken on August 11, 2005. ................................................................. 10
Figure 6. Chlorophyll a and phaeophytin b concentrations sampled from periphyton blocks on the Salmon River, 2005. ......................................................................................... 11
Figure 7. Mean weights and condition factors of steelhead/rainbow fry captured in the upper two sites in Grilse Creek, September 6 and 7, 2005. ................................................................. 12
Figure 8. Mean weights of steelhead/rainbow fry captured in the upper two sites in Grilse Creek from 1999 to 2005. ................................................................................................. 12
Figure 9. Mean depth/velocity adjusted steelhead/rainbow fry abundance sampled at 10 sites in the Salmon River and tributaries, 1998-2005. ................................................................. 13
LIST OF TABLES

Table 1. Pollock bone meal loading rate calculation................................................................. 6
Table 2. Water temperature data collected from Grilse Creek at the upper bridge crossing, the mainstem Salmon River near the diversion and the Memekay River at the tank site from June to September, 2005. ................................................................................................. 8
Table 3. Streamflow measurements (m$^3$/s) from Grilse Creek, the Memekay River, the Salmon River above Memekay River and above the diversion in 2005......................................................... 9
Table 4. Chlorophyll $a$ and phaeophytin $a$ measured from periphyton samples of the upper Salmon River below Jessie Creek, July 7, July 22 and August 4, 2005. ....................... 11

LIST OF APPENDICES

2. Calibrated drip-rate of liquid 10-34-0, given in ml/min, based on streamflow (L/s) to achieve a target addition of 5 $\mu$g/L of soluble reactive phosphorus (SRP).
3. Map showing the location of the upper Salmon River pollock test in 2005.
4. Daily mean, minimum and maximum temperatures ($^\circ$C) for Grilse Creek, Memekay River and the Salmon River from June to August, 2005, using StowAway® Tidbit® Loggers (Onset Computer Corp.).
5. Spot temperatures (and time) recorded at the sample sites in Grilse Creek, Salmon River and Memekay River in 2005. A hand-held alcohol thermometer was used.
6. Water Survey of Canada, discharge data (preliminary) for the Salmon River from June 1 to September 21, 2005.
7. Fertilizer drip-rates of liquid 10-34-0 at stations on Grilse Creek, mainstem Salmon River and the Memekay River from June 2 to September 19, 2005. The output rates (ml/min) and re-calibration rates (ml/min) are shown.
8. Water chemistry results from samples of the mainstem Salmon River, Grilse Creek and the Memekay River: June 20, July 12 and August 11, 2005.
9. Water chemistry results from samples of upper Salmon River below Jessie Creek: July 7, July 22, August 4 and August 11, 2005.
10. Results of juvenile fish sampling in the mainstem Salmon River, Grilse Creek and Memekay River in September, 2005.
1.0 INTRODUCTION

The spring and summer of 2005 marked the seventeenth consecutive year of inorganic nutrient addition in the upper Salmon River watershed (Kelsey Bay). Past years have been reported by Perrin, 1989-91; Carswell, 1992-3; Hansen, 1994-5, 1999a-d, and 2001-04; and Hansen & Wright, 2003. This stream enrichment project was designed to improve the growth and survival of juvenile salmonids through the addition of liquid fertilizer and pollock bone meal. Studies suggest that 6-7% of the historical input of marine-derived nutrients from spawning salmon is currently available in Pacific Northwest streams (Gresh et al. 2000). In combination with other stream habitat restoration techniques, nutrient addition is recommended as a strategy to replace losses in marine-derived nutrients during periods of poor salmon returns (Larkin and Slaney 1996).

The Salmon River diversion, located 58 km from tidewater, diverts part of the upper Salmon River watershed via flume to the Campbell River watershed. This diversion contributes to hydroelectric generation at the Ladore and John Hart power stations. When the dam was constructed in 1958, anadromous fish were blocked by a 5 m obstruction located about 12 km downstream. This obstruction was made passable by the BC Fish and Wildlife Branch in 1975 and 1976. Hatchery-reared steelhead fry, progeny of wild Salmon River broodstock, were released into the upper Salmon River and Grilse Creek from 1986 to 1998. In addition, numbers of wild steelhead in the upper watershed increased following the construction and operation of the fishway at the BC Hydro diversion dam in 1992. The first year of operation of the fishway (winter 1992/93) allowed adult steelhead to migrate upstream of the dam. Counts of downstreaming kelts at the fish screen and trap in 1998 and 1999, supported by snorkel surveys, indicated that steelhead escapement to the upper Salmon River above the diversion dam was well established. No wild steelhead broodstock was taken after 1998. Enumeration of downstream migrating juveniles has been conducted at the Salmon River fish screen (located in the diversion canal) since 1987, and summarized in contract reports beginning in 1989 (Perrin 1989; Carswell 1990 to 1993 inclusive; Hansen 1994; Hansen & Rimmer 1995; and Hansen 1997 to 2003, inclusive).

Annual snorkel surveys have indicated a decline in steelhead abundance in the Salmon River in the past three years. In 2002, the winter run stock was determined to be in the routine management zone, or within 30% of capacity (Lill 2002). The mean peak fish per kilometre observed from 1998 to 2002 was 12.4, declining to 3.5 in the past three years (MoE and BCCF files). Well documented at the nearby Keogh River research station, declines in steelhead abundance are largely due to poor survival during the marine stage, therefore habitat restoration is recommended to improve production in freshwater.

Development of a slow-release fertilizer has been undertaken by the Fisheries Research and Development Section, Ministry of Environment (MoE), Vancouver, B.C. and supervised by Dr. Ken Ashley. Field trials to study the instream application of solid inorganic fertilizer in Salmon River tributaries were initiated in 1995 and continued each season to 1997 inclusive (Moulday Ewing et al. 1996-8). In 2002, another experimental product, a struvite-coated urea granule, was applied to the upper Salmon River just below the Jessie Creek confluence (Hansen 2003). An organic product made from Alaskan pollock bone meal was developed for initial testing in 2003 and field tested in 2004 in the upper Salmon River. In 2003 and 2004 the bone meal was compressed into ‘presto-logs’ and in 2005 it was packaged loose in burlap bags. Pollock bone meal underwent extensive testing at the MoE Fish Health Lab in Nanaimo and is confirmed pathogen free.

A chronology of stream fertilization treatment in the Salmon River watershed, including Grilse Creek from 1988 to 2005, is detailed in Appendix 1. This was also the ninth year of stream nutrient addition to the Memekay River.

Funding for 2005 was provided by the BC Hydro, Bridge Coastal Restoration Program (year 2 of 3) and Weyerhaeuser’s (now Cascadia) Forest Investment Account. All costs pertaining to sites
upstream of the Salmon River diversion dam were covered by BC Hydro and all costs for sites below the dam were covered by Weyerhaeuser.

2.0 GOALS AND OBJECTIVES

This stream enrichment project is designed to enhance the growth and survival of juvenile steelhead (*Oncorhynchus mykiss*) and coho (*O. kisutch*) through increased periphyton accrual and subsequent increases in the invertebrate food supply. Stream flow, water chemistry, periphyton accrual, and fish growth monitoring is intended to ensure fertilizer loading rates are not excessive and to assess the effectiveness of fertilizer additions.

3.0 STUDY AREA

The Salmon River is located on the east coast of Vancouver Island and flows into Johnston Strait at Sayward, located 65 km north of Campbell River. Total mainstem length is 87.4 km. BC Hydro’s diversion dam on the mainstem is located approximately 58 km from the mouth. Water is diverted via a 14 km flume to the Campbell River watershed, and contributes to power generation at the Ladore and John Hart power stations. The three largest tributaries to the Salmon River are Grilse Creek, Memekay River, and White River. Stream enrichment has yet to occur in the latter.

3.1 Site Locations

Five drip-sites adding liquid 10-34-0 were operated in the Salmon River watershed in 2005 (Figure 1). Two of the five drip-sites were located upstream of the BC Hydro diversion dam. The first site provided nutrient addition to Grilse Creek at the upper bridge crossing on Grilse Creek Main Line (ML) just below the old Reliable logging camp. The second site provided nutrient addition to the mainstem Salmon River, and was located 1 km upstream of the deactivated Rock Creek ML bridge crossing. Drip-sites below the diversion dam included two sites on the mainstem Salmon, one at the bridge-crossing adjacent to the diversion fish screen and another at the Memekay ML (MML) bridge crossing. The fifth site was located on the Memekay River at the Memekay ML bridge crossing and was accessed from a short spur road on the west side of the bridge. These locations were accessible by logging roads of Weyerhaeuser Canada Ltd., North Island Timberlands (Figure 1).

Pollock bone meal was added to one site in the upper Salmon River mainstem (right fork), just below the confluence with Jessie Creek (Appendix 3).
Figure 1. Enrichment area showing liquid fertilizer tank locations and sampling sites on the mainstem Salmon River, Grilse Creek and the Memekay River in 2005.
4.0 MATERIALS AND METHODS

4.1 Installation of Tanks

Polyethylene tanks were placed at streambank locations accessible by vehicle, but placed out of view of road traffic. Information signs were posted beside each tank describing the enhancement goal and listing the project partners (Figure 2). Each tank was set fully supported on smooth ground and slightly angled toward the outlet valve (Figure 3). A 1-inch or 3/4 inch PVC ball-valve was installed at the outlet of each tank with Teflon tape to ensure a complete seal. The seal was tested before filling the tank with fertilizer. Each valve outlet was fitted with a fine-mesh in-line filter to remove solid and colloidal material. A stainless steel low-volume output valve was installed on each tank (for fine control of the drip-rate) (Figure 3). A length of 12 mm (I.D.) polyethylene hose was attached to apply fertilizer directly to the wetted stream channel and, where possible, into the thalweg. At suitable locations, the output end of the hose was attached to a steel tripod to dispense the drip at the surface of the water to allow for immediate mixing into the streamflow.

Figure 2. Information sign posted at each tank location in 2005.

Figure 3. The valve system installed on all tanks.
4.2 Liquid Fertilizer Acquisition and Tank Loading

The fertilizer, liquid ammonium polyphosphate, was purchased from TerraLink Horticulture Inc. in Abbotsford. Each barrel contained 208 L of fertilizer, with a density of 1.40 kg/L. Fertilizer specifications (by weight) were 10% N, and 34% P₂O₅ (10-34-0). The mix contained 14.85% P.

The fertilizer was pumped from barrels in storage into empty barrels in the transport vehicle and driven to the sites. A small gas-operated pump was used to download the fertilizer into the drip tanks. Once filled, the tank load needed to settle (24 hours) before a reliable drip-rate could be maintained. The in-line filters were checked periodically and cleaned if necessary. Tanks and equipment were removed, cleaned, and returned to storage at the end of the season.

4.3 Calibration of Liquid Fertilizer Additions

Fertilizer additions were calculated to increase the instantaneous stream soluble reactive phosphorus (SRP) concentration to approximately 5 µg/L. Target drip-rates were determined from tables provided by K. Ashley and P. Slaney (Fisheries Research Section, MoE) shown in Appendix 2. Stream discharge for the Salmon River was estimated using information from the gauge stations at the BC Hydro diversion dam and above the Memekay River confluence. Stream discharge was also measured in Grilse Creek and the Memekay River on three occasions through the summer. Tanks were calibrated to achieve target drip-rates using measured and estimated streamflow. Head reduction in the tank, variations in humidity, and air temperature affect drip-rates. Therefore, tanks output was adjusted every few days. The output of each tank was measured in mL/min and recorded and tanks were re-calibrated to achieve the target SRP concentration.

4.4 Water Temperatures and Flow Monitoring

Spot water temperatures were noted each day the drip stations were calibrated or samples were collected. Continuous water temperature data were recorded using StowAway® Tidbit® Loggers (Onset Computer Corp.) measuring every 10 minutes +/- 0.1 °C (Onset, 1996-1998). Data loggers were operated at the Grilse Creek site, the Memekay River site and in the mainstem Salmon River at the bridgecrossing site near the BC Hydro diversion.

Daily discharge for the upper Salmon River was obtained from the BC Hydro DCP (data collection platform) website, (http://www.bchydro.bc.ca/info/res_hydromet/data/sam.txt). Discharge was read telemetrically from the gauge at the Water Survey of Canada (WSC) site #08HD015, above the diversion dam. To calibrate the downstream tank on the Salmon River (at the Memekay ML Bridge), daily discharge at the gauging station, #08HD007, was read from the website (http://www.bchydro.bc.ca/info/res_hydromet/data/mky.txt). The preliminary mean daily discharges were provided by WSC, Vancouver. Streamflow was measured in Grilse Creek, the Memekay River and the upper Salmon River below Jessie Creek using a Marsh-McBirney streamflow meter, model 201.

4.5 Organic Fertilizer Experiment (Pollock Meal)

Loading rates for pollock bone meal were calculated to achieve a target concentration of 5.0 µg/L of ortho-phosphorus. Pollock meal is 7.69% P (17.6% P₂O₅) and is estimated to release most of the nutrients over a 90 day period. The following example calculation shows a loading rate calculation using an average summer flow of 0.8 m³/s (Table 1).
### Table 1. Pollock bone meal loading rate calculation.

<table>
<thead>
<tr>
<th>Streamflow during treatment period=</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average flow (m³·sec⁻¹)</td>
</tr>
<tr>
<td>Sec·day⁻¹</td>
</tr>
<tr>
<td>0.8 x</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Kilograms of fertilizer needed=</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target concentration. (µg·L⁻¹ P)</td>
</tr>
<tr>
<td>5.0 x</td>
</tr>
</tbody>
</table>

On June 22, 2005, 500 kg of pollock meal (divided equally into 50 burlap bags) were placed in the upper Salmon River (right fork) below Jessie Creek. The loading rate was increased since flows were much higher than 0.8 m³/s at the start of the treatment and the bone meal has a fairly gradual phosphorus release. Burlap bags were anchored on the streambed with rocks (Figure 4 and 5). Two periphyton plates were placed above the pollock placement (control), two plates were placed 100 m downstream of the pollock bags (Full Mix) and two additional plates were placed 3.4 km downstream of the pollock placement at the bridge washout on South Fork A (Downstream Dilution). A map showing the sites can be found in Appendix 3.

![Figure 4. Burlap bags filled with Pollock placed in the upper Salmon River.](image)

#### 4.6 Water Sampling

Water samples were collected three times in reaches treated with liquid fertilizer during the treatment period. Four water samples were collected for the Pollock treatment in the upper Salmon River.

Water chemistry samples were collected in two 250 mL plastic bottles supplied by Maxxam Analytical Services. The bottles were rinsed three times with stream water in the field before being filled with sample water. The samples were packed with ice in a cooler and shipped by courier to the lab within 24 hours. Water samples collected from between July 7 and August 4 were analyzed by Maxxam Analytics. Pacific Environmental Science Centre analyzed samples collected on August 11, 2005. Water samples were analyzed for:
• total alkalinity;
• low-level ortho-phosphorus (soluble reactive phosphorus);
• low-level nitrate + nitrite;
• ammonia;
• total dissolved phosphorus; and
• total phosphorus.

**Water Sample Sites - Liquid Fertilizer Application**
The sample sites for liquid fertilizer applications are shown in Figure 1 and described as follows:

• **Grilse Creek:**
  Grilse Creek control – 0.8 km upstream of the Grilse Creek ML bridge crossing, accessed along a small ephemeral tributary.
  Grilse Creek bridge – just above the lower bridge on South Fork (SF) ML, accessed from the south side approximately 100 m west along SF-B.

• **Salmon River mainstem:**
  Salmon River control – 10 m below the Jessie Creek confluence.
  Salmon River-WSC – at the WSC site at the end of the Big Tree-2 (BT-2) spur. This site was only sampled once on June 20, 2005 and then the site was moved due to access problems to Big Tree Mainline.
  Big Tree Mainline – east side of Big Tree Mainline bridge crossing of the Salmon River.
  Salmon River Pallans – the old Pallans bridge site, opposite bank from Spur DY-R.

• **Memekay River:**
  Memekay River control – just upstream of the drip station at the Memekay ML bridge.
  Memekay River bridge – just downstream of the bridge crossing on Airstrip Road.

**Water Sample Sites - Pollock Test**
Three sites were included for water samples and periphyton samples for the pollock test:

• Salmon River control - just below Jessie Creek (served as the control for this test also),
• Full Mix – 100 m downstream from the closest pollock application,
• Washout – 3.4 km downstream of the treatment at the Washout on South Fork Main Line.

**4.7 Periphyton Sampling (Pollock Test)**
Two periphyton blocks were placed at three sample sites in the upper Salmon River below the Jessie Creek confluence on June 22, 2005 (Appendix 3). Blocks consist of a sheet of white florist’s foam, 1.25 cm thick, attached to Plexiglas plates with electrical ties. The plates were bolted to concrete blocks and placed in the stream, tipped slightly into the direction of flow. Rocks were placed around the block edges for extra stability. Each block was submerged under at least 12 cm of water to allow for decreasing streamflow. Sites were selected so as to have similar solar exposure, water depth, and water velocity.

Using a 7 dram plastic vial, two cores of foam (each 2.7 cm in diameter, 5.73 cm² in surface area) were punched, one out of each of the two periphyton blocks (Mouldy Ewing et al. 1998). Each sample was drained and placed in the vial. The vial was vented with holes through the cap to allow the sample to dry. Vials were placed in a sealed, light-proof container, kept cool with ice, and frozen as soon as possible. Samples were taken on July 7, July 22 and August 4, 2005. At the end of the sampling period, all samples were shipped frozen, in a cooler with dry ice, to Maxxam Analytics. The samples were measured for chlorophyll a and phaeophytin a in µg cm⁻².
4.8 Juvenile Fish Sampling

Juvenile sampling was conducted by BCCF fisheries technicians in September, 2005. Ten sites, located in treatment and control areas, were sampled on the Salmon River mainstem, Grilse Creek and the Memekay River.

Sampling was conducted using closed-site electrofishing techniques. At each electrofishing site, approximately 100 m² of suitable steelhead fry habitat (typically cobble/gravel riffles, <30 cm in depth, and <25 cm/sec in velocity) was enclosed with small mesh stopnets, and all fish were removed using the standard, 2-pass removal method (deLeeuw 1981). Lengths were recorded for all fish captured, and 30+ juveniles per species and age class were weighed using Ohaus top loading scales (model CS 200) accurate to 0.1 g. Habitat parameters were documented consistent with current Fisheries Branch techniques (methodology by R. Ptolemy, Rivers Biologist, MoE, Victoria), and each site was photographed. Upon removal of the stopnets, a depth/velocity profile across a representative transect within the site was recorded using a Swoffer current velocity meter, model 2100. Population estimates were derived and depth/velocity profile adjusted using Fisheries Branch habitat suitability index curves. Sites on the Salmon River were chosen to monitor stock abundance in general and also to assess effectiveness of fertilizer additions.

5.0 RESULTS

5.1 Water Temperatures and Stream Discharge

Data loggers were placed in the Salmon River at the bridge crossing near the diversion, and in Grilse Creek and the Memekay River at the respective tank sites. Recorded water temperature measurements for the Salmon River, Grilse Creek and the Memekay River are summarized by month in Table 2. Daily mean, minimum and maximum temperatures are shown in Appendix 4. Spot temperatures were recorded using a hand-held thermometer each day of field work (Appendix 5).

Table 2. Water temperature data collected from Grilse Creek at the upper bridge crossing, the mainstem Salmon River near the diversion and the Memekay River at the tank site from June to September, 2005.

<table>
<thead>
<tr>
<th>Stream</th>
<th>Month (2005)</th>
<th>Monthly Mean (°C)</th>
<th>Range of Daily Mean (°C)</th>
<th>Minimum Temp (°C)</th>
<th>Maximum Temp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grilse Ck.</td>
<td>June</td>
<td>10.5</td>
<td>9.2-12.7</td>
<td>7.5</td>
<td>15.5</td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>12.2</td>
<td>10.2-14.6</td>
<td>9.7</td>
<td>16.9</td>
</tr>
<tr>
<td></td>
<td>August</td>
<td>13.7</td>
<td>12.2-15.6</td>
<td>10.3</td>
<td>18.3</td>
</tr>
<tr>
<td>Memekay R.</td>
<td>June</td>
<td>10.6</td>
<td>8.8-12.4</td>
<td>7.8</td>
<td>15.4</td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>12.3</td>
<td>10.9-15.0</td>
<td>10.0</td>
<td>17.5</td>
</tr>
<tr>
<td></td>
<td>August</td>
<td>14.2</td>
<td>12.0-16.3</td>
<td>9.8</td>
<td>18.6</td>
</tr>
<tr>
<td>Salmon R – near Diversion</td>
<td>June</td>
<td>12.1</td>
<td>9.6-14.8</td>
<td>8.6</td>
<td>16.9</td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>14.4</td>
<td>11.3-17.7</td>
<td>10.5</td>
<td>19.1</td>
</tr>
<tr>
<td></td>
<td>August</td>
<td>16.4</td>
<td>14.2-18.6</td>
<td>12.6</td>
<td>20.1</td>
</tr>
</tbody>
</table>

Streamflow measurements for Grilse Creek, the Memekay River and the upper Salmon River (Washout- South Fork ML) are shown in Table 3. The mean daily discharge (preliminary data) for the Salmon River above Memekay River and above the diversion are shown as a comparison. Mean daily discharge data (preliminary) provided by WSC are shown in Appendix 6.
### Table 3. Streamflow measurements (m³/s) from Grilse Creek, the Memekay River, the Salmon River above Memekay River and above the diversion in 2005.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun 16</td>
<td>1.00</td>
<td>2.63</td>
<td>5.88</td>
<td>5.55</td>
<td></td>
</tr>
<tr>
<td>Jun 28</td>
<td>1.89</td>
<td>2.13</td>
<td>5.97</td>
<td>6.30</td>
<td></td>
</tr>
<tr>
<td>Jul 7</td>
<td>2.95</td>
<td>7.02</td>
<td>8.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul 22</td>
<td>1.30</td>
<td>4.08</td>
<td>3.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul 25</td>
<td>0.51</td>
<td>0.70</td>
<td>3.25</td>
<td>2.63</td>
<td></td>
</tr>
<tr>
<td>Aug 4</td>
<td>0.90</td>
<td>3.04</td>
<td>2.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug 8</td>
<td>0.31</td>
<td>0.39</td>
<td>2.20</td>
<td>1.52</td>
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</tr>
</tbody>
</table>

* Measured with a Marsh-McBirney streamflow meter, model 201.

#### 5.2 Liquid Fertilizer Output

The total load of 10-34-0 applied at each site over approximately 110 days was as follows: Grilse Creek- 365 L; Salmon River near Rock Creek ML – 780 L; Salmon River at the diversion – 500 L; Salmon River at the Memekay ML bridge – 400 L; and the Memekay River – 320 L. The total load for the Salmon River watershed was 2,365 L. The calibrated and output rates of each tank are shown in Appendix 7. The tanks were calibrated 30 times from June 2 to September 19 (110 days). The period of low growth in the river was first noted around July 20 and lasted until approximately August 11, 2005.

Complete water chemistry results are listed in Appendix 8. Poor nitrogen concentrations (<0.02 mg/L Nitrate+Nitrite) were measured in 10 out of 21 samples. In the third set of samples collected on August 11, all of the samples had relatively high concentrations of nitrogen (0.03 to 0.11 mg/L Nitrate+Nitrite). Phosphorus concentrations did not appear to be limiting (>0.01 mg/L ortho-phosphorus) in any of the samples.

#### 5.3 Organic Fertilizer Experiment (Pollock Meal)

On June 22, 2005, 500 kg of pollock contained within burlap bags were placed in the upper Salmon River (right fork) just below Jessie Creek. Water temperature at the application site was 14 °C at 1345h. Following the placement of pollock in the upper Salmon, water samples were collected on July 7, July 22, August 4 and August 11, 2005. Periphyton samples were collected on July 7, July 22 and August 4, 2005.
Complete water chemistry results for the pollock treatment are provided in Appendix 9. Results indicate a gradual increase in available nitrogen over the summer. Samples in early July had low concentrations of nitrate+nitrate and the late season August samples had relatively high concentrations in control and treated sites. Phosphorus concentrations were fair in treatment and control sites on all dates during the treatment period.

Agal results indicated a very positive growth response to the pollock bone meal, particularly in the full mix site. The first samples, which were collected 16 days after the plates were installed, showed very little difference between treated and control. After 31 days the full mix and washout site (3.5 km downstream) had chlorophyll and phaeophytin concentrations approximately 8 times greater than that of the control. After 44 days, algal growth persisted in the full mix site, but decreased dramatically in the washout site (Table 3, Figure 7).
Table 4. Chlorophyll a and phaeophytin a measured from periphyton samples of the upper Salmon River below Jessie Creek, July 7, July 22 and August 4, 2005.

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample</th>
<th>Control</th>
<th>Full Mix</th>
<th>Washout</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 7</td>
<td>Chlorophyll a</td>
<td>0.57</td>
<td>1.13</td>
<td>1.09</td>
</tr>
<tr>
<td>(16 days)</td>
<td>Phaeophytin a</td>
<td>1.09</td>
<td>1.03</td>
<td>1.23</td>
</tr>
<tr>
<td>July 22</td>
<td>Chlorophyll a</td>
<td>0.51</td>
<td>3.57</td>
<td>3.81</td>
</tr>
<tr>
<td>(31 days)</td>
<td>Phaeophytin a</td>
<td>0.39</td>
<td>4.31</td>
<td>4.62</td>
</tr>
<tr>
<td>August 4</td>
<td>Chlorophyll a</td>
<td>0.89</td>
<td>4.74</td>
<td>0.86</td>
</tr>
<tr>
<td>(44 days)</td>
<td>Phaeophytin a</td>
<td>&lt;0.03</td>
<td>4.91</td>
<td>0.90</td>
</tr>
</tbody>
</table>

Figure 6. Chlorophyll a and phaeophytin b concentrations sampled from periphyton blocks on the Salmon River, 2005.

5.4 Juvenile fish sampling

Steelhead fry sampling in treated and control reaches of Grilse Creek confirmed there was a positive growth response to the inorganic drip fertilizer. The mean weight of steelhead fry sampled in the treated site was more than double the mean weight of those captured in the control, located approximately 1.5 km upstream. While differences in mean weight were obvious, condition factors were roughly equal (Figure 7). Improved growth in treated versus control sites has been observed in the upper two sites in Grilse Creek since 1999. The 1999 sample does not show a significant difference in mean weight between treated and control, but the drip tanks were started two months later than normal due to abnormally high spring run-off (Figure 8).
The mean steelhead fry density from the 10 sites typically sampled in the Salmon River, Memekay River and Grilse Creek indicates that 2005 was average compared with previous year’s results. The geometric mean density of 36 fry per 100 m$^2$ (FPU) represents a significant improvement over the 2004 value of 17 FPU, but is still well below the conservation concern level, or target density of 60 FPU set for Salmon River by provincial biologists (Figure 9).
Figure 9. Mean depth/velocity adjusted steelhead/rainbow fry abundance sampled at 10 sites in the Salmon River and tributaries, 1998-2005.

6.0 DISCUSSION and RECOMMENDATIONS

6.1 Liquid Nutrient Application
Throughout the 17 years of nutrient addition to the Salmon River watershed, there is commonly a period of very little growth, and die-off of existing growth observed over a period of 10 days to two weeks. In 2005, this phenomenon occurred between July 20 and August 11. An investigation of these circumstances is recommended to determine if this change is results of seasonal weather differences, changing weather patterns or result of nutrient addition.

Data from the 2004 and 2005 treatments have recently identified nitrogen as a limiting nutrient (i.e., less than 0.02 mg/L nitrate+nitrite) throughout July. Liquid ammonium polyphosphate (10-34-0) has a relatively low nitrogen concentration, therefore a small addition of liquid urea (23-0-0) is recommended for future treatments. These products must be applied in separate tanks, because once they are mixed a precipitate forms in the bottom of the tank, and the valves become clogged (K. Ashley, pers. comm.). Currently, there are no high nitrogen/high phosphate liquid fertilizers available for stream applications.

Ortho-phosphorus concentrations in the 2005 water samples were suspiciously high. Background concentrations are typically undetectable (<0.001 mg/L), but samples collected from the control sites in 2005 had concentrations ranging from 0.001 to 0.005 mg/L. Furthermore, ortho-phosphorus concentrations were higher than total phosphorus concentrations in 20 of 33 samples. There is often error associated with low-level nutrient analysis, particularly when expected results are close to the detection limits. These results were brought to the attention of MoE Environmental Protection staff and will be considered when next year’s terms of reference for laboratory contracting are developed.
6.2 Organic Fertilizer Experiment

There was evidence of bear activity at the pollock application site. Some of the filled bags had been pulled to the stream edge. Appropriate caution during fieldwork must be observed by all field personnel.

Pollock bone meal applied in burlap bags proved to be a better application method than placing meal compressed into logs. The bags remained intact for approximately five weeks and had an effective distance of approximately 3.5 km. The downstream treated site had good algae growth during the first 31 days, and then suffered a die-off after 44 days (Figure 6). During the first 31 days there was likely a greater nutrient release from the bone meal, and by day 44, a relatively small amount of phosphate was still being released from the larger bone pieces. The available phosphate was likely being consumed within a short distance of the application site as good algae growth was maintained at the full mix site (Figure 6). More consistent nutrient release could be maintained with a second application of bone meal in mid-July, or with a greater number of application sites if access permitted.
7.0 REFERENCES


Reports of operation of the Salmon River fish screen 1989 - 2003

Carswell, L. 1990. Results of fish enumeration at the Salmon River smolt screen, April-June 1990. BCCF report for MELP, Fisheries Section, Nanaimo, B.C.


Carswell, L. 1993. Results of fish enumeration at the Salmon River smolt screen, April-June 1993. BCCF report for BCH and MELP, Fisheries Section, Nanaimo, B.C.


Hansen, L. 1999. Results of fish enumeration at the Salmon River smolt screen, April 24 – June 30, and October 14 to November 12, 1998. BCCF report for BCH and MELP, Fisheries Section, Nanaimo, B.C.


Hansen, L. 2001. Results of fish enumeration at the Salmon River smolt screen, April 4 to July 5 and October 22 to November 3, 2000. BCCF report for BCH, Burnaby, B.C. and MELP, Fisheries Section, Nanaimo, B.C.


Salmon River Fertilization Project 1988 – 2005: Chronology of Treatments

The Salmon River fertilization project has been initiated and supervised by the Ministry of Environment, Lands and Parks (MELP), Fisheries Section, in Nanaimo (now Ministry of Environment (MOE)). Other agencies and contractors involved are listed below, along with specific details of each year of application. Juvenile sampling by electrofishing was carried out every year in the late summer. MWLAP records are computer filed at the Nanaimo office and the B.C. Conservation Foundation office in Nanaimo.

Water chemistry analysis included low-level measurement of nitrogen-ammonia, nitrogen-nitrate, total nitrogen, dissolved ortho-phosphate, total dissolved phosphorus, and total phosphorus. In some years, additional tests were conducted. Periphyton samples were collected on artificial substrate and analysed for chlorophyll a and phaeophytin a. Sample sets were collected at intervals throughout the fertilizer application period.

Pre-fertilization sampling

1988 Agencies: MELP, NANAIMO. Contractor: Limnotek Research and Development Inc.
Water chemistry samples: □ Five sample sets from 2 sites.
Periphyton samples: □ Two series of 3 sample sets over 21 days- from 2 sites.
Taxonomy samples: Algae. □

Fertilization and Sampling

1989 Agencies: MELP, NANAIMO. Contractor: Limnotek Research and Development Inc.
Funding from the B.C. Habitat Conservation Fund.
Fertilizer Applied: prill (solid) form – 34-0-0 and 12-51-0 blend.
Period of Application: June 2 – August 26, 1989.
Sites: Norris Creek, Grilse Creek (upper bridge site).
Water chemistry samples: 10 sample sets from 3 sample sites.
Periphyton samples: □ Two series of 35 and 40 days- from 3 sites.
Taxonomy samples: Algae □ Three sample sites.

1990 Agencies: MELP, NANAIMO. Contractor: Limnotek Research and Development Inc.
Funding from the B.C. Habitat Conservation Fund.
Fertilizer Applied: Liquid- 32-0-0 (Norris Creek only) and 10-34-0.
Sites: Norris Creek, Grilse Creek (upper), Grilse Creek (lower bridge site).
Water chemistry samples: Yes sample sets from 5 sites.
Periphyton samples: Yes One series (7 samples over 51 days) from 4 sites.
Taxonomy samples: One set from 4 sites; one replicate from 2 sites.

1991 Agencies: MELP, NANAIMO. Contractor: Limnotek Research and Development Inc.
Funding from the B.C. Habitat Conservation Fund.
Fertilizer Applied: Liquid- 32-0-0 (Norris Creek only) and 10-34-0.
Sites: Norris Creek, Grilse Creek (upper) and Grilse Creek (lower bridge site).
APPENDIX 1 (cont’d)

Water chemistry samples: Four sample sets from six sites.
Periphyton samples: Eight sample sets from five sites (one series over 57 days).
Taxonomy samples: Algae One sample set from 5 sites.

Fertilizer Applied: Liquid- 32-0-0 (Norris Creek only) and 10-34-0.
Sites: Norris Creek, Grilse Creek (upper bridge), Grilse Creek (lower bridge).
Water chemistry samples: Three sample sets from six sites.
Periphyton samples: No.
Taxonomy samples: No.

1993 Agencies: MELP, NANAIMO. (Admin. by BCCF. Funding from the B.C. Habitat Conservation Fund and fertilizer purchased by the Campbell River Chapter of the Steelhead Society of B.C.).
Fertilizer Applied: Liquid- 32-0-0 (Norris Ck. only) and 10-34-0.
Period of Application: May 25 – August 8, 1993.
Sites: Norris Creek, Grilse Creek (upper bridge), Salmon River- Rock Creek ML bridge crossing, Memekay ML bridge crossing.
Water chemistry samples: Three sample sets from six sites.
Periphyton samples: No.
Taxonomy samples: No.

Comments: Water, periphyton and insect sampling were conducted by Daiva Zaldokas, MELP, Vancouver, Fisheries Research and Development Section.

1994 Agencies: MELP, NANAIMO. (Admin. by BCCF. Funding from the B.C. Habitat Conservation Fund, liquid fertilizer purchased by the Campbell R. Chapter of the Steelhead Society of B.C.).
Fertilizer Applied: Liquid- 32-0-0 (Norris Creek only) and 10-34-0.
Sites: Norris Creek, Grilse Creek (upper bridge), Salmon River- Rock Creek ML bridge crossing, Memekay ML bridge crossing.
Water chemistry samples: Two sample sets from ten sites.
Periphyton samples: No.
Taxonomy samples: No.

1995 Agencies: MELP, NANAIMO. (Admin. by BCCF. Funding from Habitat Conservation Fund, liquid fertilizer purchased by the Campbell R. Chapter of the Steelhead Society of B.C.).
MELP, Vancouver, Fisheries Research and Development Section monitored slow-release briquettes (pucks) in Norris Creek and Grilse Creek.
APPENDIX 1 (cont’d)

**Fertilizer Applied:** Briquettes in Norris Creek and Grilse Creek and liquid 10-34-0 in the mainstem Salmon River.


**Sites:** Norris Creek, Grilse Creek (upper bridge), Salmon River- Rock Creek ML bridge crossing, Memekay ML bridge crossing.

**Water chemistry samples:** Two sample sets from five sites on the mainstem Salmon River. Seven sample sets from five sample sites on Norris Creek and Grilse Creek (MELP, Vancouver).

**Periphyton samples:** (MELP, Vancouver).

**Taxonomy samples:** (MELP, Vancouver).


**Comments:** An in-depth study of the slow-release fertilizer was conducted by the MELP Fisheries Research and Development Section, Vancouver, from 1995 to 1997 inclusive. Three reports are cited in REFERENCES (Mouldey Ewing, et al. 1996, 1998, 1998).

1996 **Agencies:** MELP, NANAIMO. (Admin. by BCCF. Funding from the B.C. Habitat Conservation Fund, liquid fertilizer paid for by the Campbell River Chapter of the Steelhead Society of B.C.)

MELP, Vancouver, Fisheries Research and Development Section, monitored slow-release briquettes in Norris Creek and Grilse Creek.

**Fertilizer Applied:** Briquettes- Norris Creek and Grilse Creek. Liquid 10-34-0- Salmon River mainstem.

**Period of Application:** June 1 – September 5.

**Sites:** Briquettes- Norris Creek, Grilse Creek (upper bridge). Liquid- (Salmon River)- Rock Creek ML bridge crossing, fish screen, and Memekay ML bridge crossing.

**Water chemistry samples:** Two sample sets from six sites on the mainstem Salmon River. Nine sample sets of five sites on Norris Creek (2 sites) and Grilse Creek (3 sites).

**Periphyton samples:** Nine sample sets from five sites on Norris Creek (2 sites) and Grilse Creek (3 sites).

**Taxonomy samples:** algae.

**Benthic invertebrate biomass measured:**


**Comments:** Fertilizer toxicology testing was conducted by EVS Environmental Consultants (1997) for rainbow trout, chironomids, amphipods and daphnids.

1997 **Agencies:** MELP, NANAIMO. (Admin. by BCCF. Funding by BC Hydro and the Campbell River Chapter of the Steelhead Society of B.C.).

MELP, Vancouver. Fisheries Research and Development Section.

**Fertilizer Applied:** Briquettes (7-40-0) (Norris Creek and Grilse Creek) and 10-34-0 (mainstem Salmon River).

**Period of Application:** June 12 – October 6.

**Sites:** Norris Creek (briquettes), Grilse Creek (upper bridge) (briquettes), Salmon River-Rock Creek ML bridge crossing (liquid), fish screen (liquid), and Memekay ML bridge crossing (liquid).

**Water chemistry samples:** Every two weeks (eight sample sets) from nine sample sites throughout 40 km of the river treatment area.

**Periphyton samples:** Eight sample sets from nine sample sites.
APPENDIX 1 (cont’d)

**Taxonomy samples:** algae.

**Benthic invertebrate biomass measured:**


**Comments:** In addition to treatment of the upper Salmon River and tributaries, the Memekay River and Cooper Creek were treated with briquettes (7-40-0): 60 kg to Cooper Creek and 599 kg to each of two sites on the Memekay River (total – 1,198 kg).

**Water chemistry samples:** Two sample sets. **Periphyton:** none. **Taxonomy:** none.

---

1998

**Agencies:** MELP, NANAIMO. (Admin. by BCCF. Funding - BC Hydro).

**Fertilizer Applied:** Briquettes - 7-40-0 (Norris Creek) and liquid 10-34-0.

**Period of Application:** June 10 – August 19.

**Sites:** Norris Creek, Grilse Creek (upper bridge), Salmon River- above Rock Creek ML bridge crossing, fish screen and Memekay ML bridge crossing.

**Water chemistry samples:** No.

**Periphyton samples:** No.

**Taxonomy samples:** No.

**References:** Hansen (1999c).

**Comments:** In addition to the mainstem Salmon River and upper Salmon tributaries, the Memekay River and Cooper Creek were also treated. Sixty kilograms of briquettes were added to the upper end of Cooper Creek and liquid 10-34-0 was applied by drip station to the Memekay River just below the ML bridge.

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1999

**Agencies:** MELP, NANAIMO. (Admin. by BCCF. Funding BC Hydro).

**Fertilizer Applied:** 10-34-0.

**Period of Application:** August 9 – September 28.

**Sites:** Grilse Creek (upper bridge), Salmon River- above Rock Creek ML bridge crossing, fish screen and Memekay ML bridge crossing.

**Water chemistry samples:** No.

**Periphyton samples:** No.

**Taxonomy samples:** No.

**References:** Hansen (1999d).

**Comments:** In addition, a liquid drip station (10-34-0) was maintained on the Memekay River just below the Memekay ML bridge. Due to extremely high flows from a record high snow-pack, discharge in the Salmon River and tributaries was too high in June and July for practical delivery of a fertilizer drip-rate. Fertilization did not start until early August when flows had moderated, and was continued later than in previous years.

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2000

**Agencies:** MELP, NANAIMO. (Admin. by BCCF. Funding BC Hydro)

**Fertilizer Applied:** 10-34-0 and briquettes (new formula).

**Period of Application:** June 19 – September 12.

**Sites:** Briquettes- Grilse Creek just upstream of the falls, Liquid- Grilse Creek (upper bridge), Salmon River- above Rock Creek ML bridge crossing, fish screen and Memekay ML bridge crossing.

**Water chemistry samples:** No.

**Periphyton samples:** No.

**Taxonomy samples:** No.
APPENDIX 1 (cont’d)


Comments: Briquettes were placed in Cooper Creek, 7 km upstream of the confluence with the Memekay River. A liquid drip station (10-34-0) was maintained on the Memekay River just below the Memekay ML bridge.

2001 Agencies: MWLAP, NANAIMO. (Admin. by BCCF. Funding by Weyerhaeuser (FRBC) & BC Hydro, Bridge Coastal Restoration Program).
Fertilizer Applied: 10-34-0.
Period of Application: July 5 – August 24.
Sites: Memekay River at the ML bridge crossing, Grilse Creek (upper bridge), Salmon River- upstream of Rock Creek ML bridge crossing (deactivated), fish screen and Memekay ML bridge crossing.
Water chemistry samples: Yes.
Periphyton samples: Yes.
Taxonomy samples: No.

2002 Agencies: MWLAP, NANAIMO. (Admin. by BCCF. Funding by BC Hydro, Bridge Coastal Restoration Program).
Fertilizer Applied: 10-34-0.
Period of Application: June 18 – August 19.
Sites: Memekay River at the ML bridge crossing, Grilse Creek (upper bridge), Salmon River upstream of Rock Creek ML bridge crossing (deactivated), fish screen and Memekay ML bridge crossing.
Water chemistry samples: Yes.
Periphyton samples: Yes.
Taxonomy samples: No.

Comments: An experimental, slow-release fertilizer product was applied to the upper Salmon River just below the Jessie Creek confluence on July 29, 2002. The fertilizer was a struvite-coated urea granule (18-6-0) produced by PSP Enterprises of Urbana, Ohio.
Water chemistry samples: Yes. Periphyton samples: Yes.

2003 Agencies: MWLAP, NANAIMO. (Admin. by BCCF. Funding by BC Hydro, Bridge Coastal Restoration Program and Weyerhaeuser Canada Ltd., Renewal Investment Corp.).
Fertilizer Applied: 10-34-0.
Period of Application: June 17 – Sept 6.
Sites: Memekay River at the ML bridge crossing, Grilse Creek (upper bridge), Salmon River upstream of Rock Creek ML bridge crossing (deactivated), Salmon River bridge near the diversion and Memekay ML bridge crossing.
Water chemistry samples: Yes.
Periphyton samples: No.
Taxonomy samples: No.

Salmon River Nutrient Enrichment for Fish Habitat Restoration 2005.
APPENDIX 1 (cont’d)

Comments: A new product providing organic instream nutrients was tested in Paterson Creek in 2003. The product was made from organic fish meal (Alaskan pollock) pressed into 4 kg logs.  
Water chemistry samples: Yes.  Periphyton samples: Yes.

2004  Agencies: MWLAP, NANAIMO. (Admin. by BCCF. Funding by BC Hydro, Bridge Coastal Restoration Program and Weyerhaeuser Canada Ltd.  
Fertilizer Applied: 10-34-0.  
Period of Application: June 8 – September 17.  
Sites: Memekay River at the ML bridge crossing, Grilse Creek (upper bridge), Salmon River upstream of Rock Creek ML bridge crossing (deactivated), fish screen and Memekay ML bridge crossing.  
Water chemistry samples: Yes.  
Periphyton samples: No.  
Taxonomy samples: No.  

Comments: An experimental, organic fishmeal product (Pollock) was applied to the upper Salmon River just below the Jessie Creek confluence on June 17 and July 22, 2004.  
Water chemistry samples: Yes.  Periphyton samples: Yes.

2005  Agencies: MWLAP, NANAIMO. (Admin. by BCCF. Funding by BC Hydro, Bridge Coastal Restoration Program) and Weyerhaeuser Canada Ltd.  
Fertilizer Applied: 10-34-0.  
Period of Application: June 18 – August 19.  
Sites: Memekay River at the ML bridge crossing, Grilse Creek (upper bridge), Salmon River upstream of Rock Creek ML bridge crossing (deactivated), fish screen and Memekay ML bridge crossing.  
Water chemistry samples: Yes.  
Periphyton samples: No.  
Taxonomy samples: No.  
References: Hansen, (200 )

Comments: An experimental, organic fishmeal product (Pollock) was applied to the upper Salmon River just below the Jessie Creek confluence on June , 2005.  
Water chemistry samples: Yes.  Periphyton samples: Yes.

References (for APPENDIX 1)


**APPENDIX 1 (cont’d)**


**Hansen, L. 1999a.** Stream enrichment of the upper Salmon River watershed (Kelsey Bay) below Grilse Creek, June 1 – September 5, 1996. BCCF report for MELP, Fisheries Section, Nanaimo, B.C. 10 p. + app.

**Hansen, L. 1999b.** Stream enrichment of the upper Salmon River watershed (Kelsey Bay) below Grilse Creek, and Salmon River tributaries- the Memekay River and Cooper Creek – 1997. BCCF report for MELP, Fisheries Section, Nanaimo, B.C. 10 p. + app.

**Hansen, L. 1999c.** Stream enrichment of Vancouver Island’s upper Salmon River including Norris Creek, Grilse Creek, Cooper Creek, and the Memekay River, June 10 – August 19, 1998. Report for MELP, Fisheries Section, Nanaimo, B.C. and BC Hydro, Burnaby, B.C. 8 p. + app.


**Hansen, L. 2001.** Stream enrichment of Vancouver Island’s upper Salmon River including Grilse Creek, Memekay River and Cooper Creek, June 19 – September 12, 2000. Report for MELP, Nanaimo, B.C. and BC Hydro, Burnaby. 8 p. + app.

**Hansen, L. 2002.** Stream enrichment of Vancouver Island’s upper Salmon River including Grilse Creek, and Memekay River, July 5 to August 24, 2001. Report for MWLAP, Nanaimo, B.C., Weyerhaeuser (FRBC) and BC Hydro, Burnaby, B.C. 13 p. + app.


Salmon River Nutrient Enrichment for Fish Habitat Restoration 2005.
**APPENDIX 1 (cont’d)**


**Other reports that provide supportive information:**


Appendix 1 (cont’d)

Reports of operation of the Salmon River fish screen 1989 - 2000

Carswell, L. 1990. Results of fish enumeration at the Salmon River smolt screen, April-June 1990. BCCF report for MELP, Fisheries Section, Nanaimo, B.C.


Carswell, L. 1993. Results of fish enumeration at the Salmon River smolt screen, April-June 1993. BCCF report for BCH and MELP, Fisheries Section, Nanaimo, B.C.


Hansen, L. 1999. Results of fish enumeration at the Salmon River smolt screen, April 24 – June 30, and October 14 to November 12, 1998. BCCF report for BCH and MELP, Fisheries Section, Nanaimo, B.C.


Hansen, L. 2001. Results of Fish Enumeration at the Salmon River smolt screen, April 4 to July 5 and October 22 to November 3, 2000. BCCF report for BCH, Burnaby, B.C. and MELP, Fisheries Section, Nanaimo, B.C.


Salmon River Nutrient Enrichment for Fish Habitat Restoration 2005.
APPENDIX 2.

Calibrated drip-rate of liquid 10-34-0, given in ml/min, based on streamflow (L/s) to achieve a target addition of 5 µg/L of soluble reactive phosphorus (SRP).

<table>
<thead>
<tr>
<th>Applied SRP (µg/L)</th>
<th>Flow L/s</th>
<th>weight/min grams P</th>
<th>weight/min gr 10-34-0</th>
<th>mL/min 10-34-0</th>
<th>L/day 10-34-0</th>
<th>weight/day kg P</th>
<th>weight/day kg N</th>
</tr>
</thead>
</table>
APPENDIX 3. Map showing the location of the upper Salmon River pollock test in 2005.
**APPENDIX 4.**

Daily mean, minimum and maximum temperatures (°C) for Grilse Creek, Memekay River and the Salmon River from June to August, 2005, using StowAway® Tidbit® Loggers (Onset Computer Corp.).

<table>
<thead>
<tr>
<th>DATE</th>
<th>AVG</th>
<th>MIN</th>
<th>MAX</th>
<th>DATE</th>
<th>AVG</th>
<th>MIN</th>
<th>MAX</th>
<th>DATE</th>
<th>AVG</th>
<th>MIN</th>
<th>MAX</th>
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<tbody>
<tr>
<td>2-Jun-05</td>
<td>9.9</td>
<td>8.9</td>
<td>10.9</td>
<td>1-Jul-05</td>
<td>12.2</td>
<td>11.1</td>
<td>13.3</td>
<td>1-Aug-05</td>
<td>12.8</td>
<td>11.4</td>
<td>14.4</td>
</tr>
<tr>
<td>3-Jun-05</td>
<td>10.5</td>
<td>8.9</td>
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<td>2-Jul-05</td>
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<td>10.9</td>
<td>10.3</td>
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<td>10.9</td>
<td>10.5</td>
<td>11.4</td>
<td>4-Aug-05</td>
<td>13.3</td>
<td>11.1</td>
<td>15.8</td>
</tr>
<tr>
<td>6-Jun-05</td>
<td>9.4</td>
<td>8.4</td>
<td>11.2</td>
<td>5-Jul-05</td>
<td>11.2</td>
<td>10.6</td>
<td>11.9</td>
<td>5-Aug-05</td>
<td>14.3</td>
<td>11.7</td>
<td>17.2</td>
</tr>
<tr>
<td>7-Jun-05</td>
<td>9.7</td>
<td>7.7</td>
<td>11.7</td>
<td>6-Jul-05</td>
<td>11.6</td>
<td>11.1</td>
<td>12.5</td>
<td>6-Aug-05</td>
<td>14.5</td>
<td>12.3</td>
<td>17.4</td>
</tr>
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June-September, 2005

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APPENDIX 4 (cont’d)

Memekay River Water Temperature (° C)
June-September, 2005
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**Monthly Average**

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APPENDIX 4 (cont’d)

Salmon River Water Temperature (° C)
June-September, 2005

Salmon River Nutrient Enrichment for Fish Habitat Restoration 2005.
APPENDIX 5.

Spot temperatures (and time) recorded at the sample sites in Grilse Creek, Salmon River and Memekay River in 2005. A hand-held alcohol thermometer was used.

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APPENDIX 6.

Water Survey of Canada, discharge data (preliminary) for the Salmon River from June 1 to September 21, 2005.

Salmon River - Above the diversion dam (#08HD015)

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| Average | 6.65 | 5.83 | 1.51 |
| Min     | 4.42 | 1.83 | 0.74 |
| Max     | 10.9 | 15.9 | 4.96 |

Note: The diversion was closed on July 14, 2005.
Water Survey of Canada, discharge data (preliminary) for the Salmon River from June 1 to September 21, 2005.

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| Average | 6.85 | 6.34 | 2.18 |
| Min     | 5.41 | 2.61 | 1.34 |
| Max     | 9.95 | 21.3 | 5.27 |
**APPENDIX 7.**

Fertilizer drip-rates of liquid 10-34-0 at stations on Grilse Creek, mainstem Salmon River and the Memekay River from June 2 to September 19, 2005. The output rates (ml/min) and re-calibration rates (ml/min) are shown.

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The total load for the Salmon River watershed was 2,365 L of 10-34-0.

* Hose was not re-attached to tank after calibration on June 7, 2005.

** Re-cal is estimated as the timer was broken.
APPENDIX 8.

Water chemistry results from samples of the mainstem Salmon River, Grilse Creek and the Memekay River: June 20, July 12 (from MAXXAM lab) and August 11, 2005 (from PESC lab).

### C.O.C. #140124

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<tr>
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<td>&lt;0.005</td>
<td>0.008</td>
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<td>0.005</td>
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Sampled on: 05/06/20 05/06/20 05/06/20 05/06/20 05/06/20 05/06/20 05/06/20

### C.O.C. #140126

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<td>MEMEKAY R.</td>
<td>MEMEKAY R.</td>
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<tr>
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<td>WSC</td>
<td>MAINLINE</td>
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<td>CONTROL</td>
<td>BRIDGE</td>
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<td>&lt;0.005</td>
<td>&lt;0.005</td>
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Salmon River Nutrient Enrichment for Fish Habitat Restoration 2005.
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<th>&lt;0.002</th>
<th>&lt;0.002</th>
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<td>05/07/12</td>
<td>05/07/12</td>
<td>05/07/12</td>
<td>05/07/12</td>
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<th>Lab ID</th>
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<td>MDL</td>
</tr>
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<td>Alkalinity Total as CaCO3</td>
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<td></td>
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<td>&lt;0.005</td>
</tr>
<tr>
<td>Nitrate+Nitrite (N)</td>
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<td>Phosphorus Total (P)</td>
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<td>&lt;0.002</td>
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<td>Sampled on:</td>
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APPENDIX 9.

Water chemistry results from samples of upper Salmon River below Jessie Creek: July 7, July 22, August 4 (MAXXAM lab) and August 11 (PESC lab), 2005.

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<td>850927</td>
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<td>Full Mix</td>
<td>Washout (South Fork)</td>
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<td></td>
<td></td>
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<td>Alkalinity Total as CaCO3</td>
<td>18.0</td>
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<td>0.008 mg/L</td>
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<td>0.005</td>
<td>0.003 mg/L</td>
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</tr>
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<td></td>
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</tr>
<tr>
<td>Alkalinity Total as CaCO3</td>
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<td>22.7</td>
<td>21.2 mg/L</td>
</tr>
<tr>
<td>Unit</td>
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<td>0.5</td>
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<td>0.027</td>
<td>0.024 mg/L</td>
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<td>0.003 mg/L</td>
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<tr>
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<td>&lt;0.002 mg/L</td>
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<td>Washout (South Fork)</td>
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<td></td>
<td>Unit MDL</td>
</tr>
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<td>Alkalinity Total as CaCO3</td>
<td>23.4</td>
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<td>20.8</td>
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<tr>
<td>Ortho-Phosphorus (P)</td>
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<td>0.006</td>
<td>0.004</td>
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<tr>
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<td>&lt;0.002</td>
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<td>12:55</td>
<td>13:37</td>
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| PESC ID     | 126762  | 126763  | 126764  |
| Client ID   | Salmon R. Control | Full Mix | Washout (South Fork) |
| GENERAL INORGANICS | | | Unit MDL |
| Alkalinity Total as CaCO3 | 24.6 | 24.2 | 23.2 | mg/L | 0.5 |
| NITROGEN    | | | | |
| Ammonia Nitrogen (N) | <0.005 | <0.005 | <0.005 | mg/L | 0.005 |
| Nitrate+Nitrite | 0.048 | 0.048 | 0.050 | mg/L | 0.002 |
| PHOSPHORUS  | | | |
| Ortho-Phosphorus (P) | 0.001 | 0.021* | 0.003 | mg/L | 0.001 |
| Phosphorus Total Diss (P) | <0.002 | 0.020 | <0.002 | mg/L | 0.002 |
| Phosphorus Total (P) | <0.002 | 0.024 | <0.002 | mg/L | 0.002 |
| Sampled on: | 05/08/11 | 05/08/11 | 05/08/11 |
| Sampled at: | 12:36 | 12:50 | 13:17 |

* Probable contamination from bonemeal.
### APPENDIX 10. Results of juvenile fish sampling in the mainstem Salmon River, Grilse Creek, and Memekay River in September, 2005.

**Watershed:** Salmon  
**Stream Code:** 925-725300

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<th>Site #</th>
<th>Site Description</th>
<th>Site Reference (km)</th>
<th>Date</th>
<th>UTM Code</th>
<th>Length</th>
<th>Width</th>
<th>Area</th>
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<td>Pallan's</td>
<td>12.24</td>
<td>13-Sep-05</td>
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<td>Memekay ML Bridge</td>
<td>52.6</td>
<td>09-Sep-05</td>
<td>309222,5556664</td>
<td>17.7</td>
<td>4.8</td>
<td>72.39</td>
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<td>Smolt Screen</td>
<td>58.02</td>
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<td>Washout</td>
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<td>302790,5548002</td>
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<td>5.8</td>
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<td>Salmon</td>
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<td>Washout 500 m u/s of Grilse confluence</td>
<td>69.25</td>
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<td>301495,5547162</td>
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<td>27.93</td>
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<td>Grilse Ck (300 m d/s of upper bridge)</td>
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<td>297264,554698</td>
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Salmon River Nutrient Enrichment for Fish Habitat Restoration 2005.
Salmon Alkalinity: 16.5
Salmon Biomass: 147.5

## Juvenile Steelhead Electrofishing Results

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<th>DV Adj'd FPU</th>
<th>Predicted FPU</th>
<th>% of Predicted</th>
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<tr>
<td>1</td>
<td>2.25</td>
<td>189.8</td>
<td>201.90</td>
<td>65.5</td>
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<tr>
<td>2</td>
<td>4.01</td>
<td>31.76</td>
<td>52.10</td>
<td>36.8</td>
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<tr>
<td>3</td>
<td>3.79</td>
<td>63.45</td>
<td>64.10</td>
<td>38.9</td>
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<tr>
<td>4</td>
<td>3.48</td>
<td>60.42</td>
<td>67.10</td>
<td>42.4</td>
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<tr>
<td>5</td>
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<td>75.06</td>
<td>97.50</td>
<td>47.1</td>
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</tr>
<tr>
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<td>2.33</td>
<td>27.87</td>
<td>37.20</td>
<td>63.3</td>
<td>59%</td>
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<tr>
<td>7</td>
<td>4.03</td>
<td>25.9</td>
<td>41.10</td>
<td>36.6</td>
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<td>54.70</td>
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<tr>
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<td>10</td>
<td>3.56</td>
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<td>51.10</td>
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<td><strong>MEAN</strong></td>
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<table>
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<th>DV Adj'd FPU</th>
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<th>% of Predicted</th>
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### 2002

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<th>% of Predicted</th>
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* NOTE: These are geometric means.

### 2003

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### 2004

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### 2005

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