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Upper Fraser River Environmental Effects Monitoring (EEM) Cycle Five Interpretive Report

March 2010

Prepared for:

Canfor Pulp Limited Partnership
Prince George, British Columbia

Quesnel River Pulp Company
Quesnel, British Columbia

Cariboo Pulp And Paper Company
Quesnel, British Columbia

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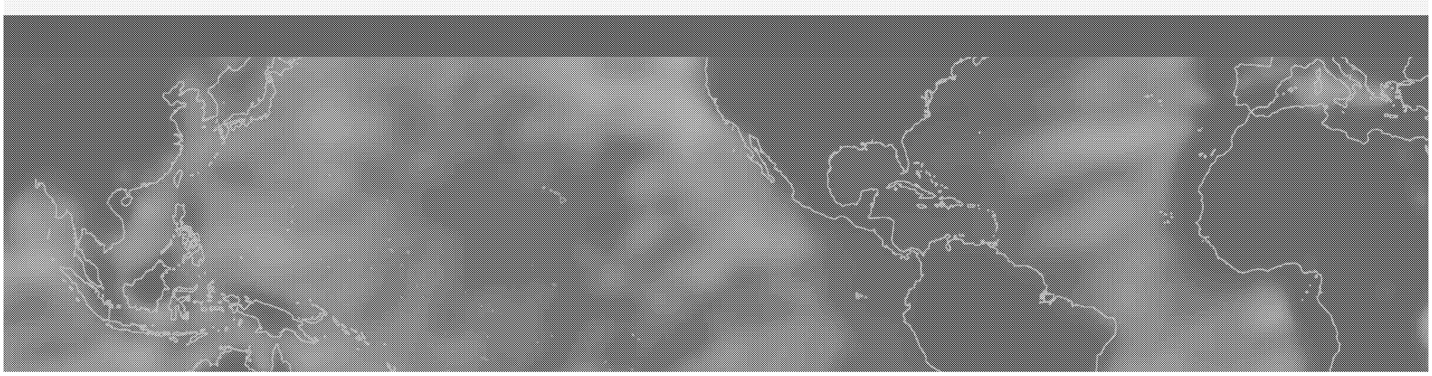

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UPPER FRASER RIVER

ENVIRONMENTAL EFFECTS MONITORING (EEM) CYCLE FIVE INTERPRETIVE REPORT

Prepared for:

CANFOR PULP LIMITED PARTNERSHIP
PRINCE GEORGE, BC

QUESNEL RIVER PULP COMPANY
QUESNEL, BC

CARIBOO PULP AND PAPER COMPANY
QUESNEL, BC

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MARCH 2010

FR1333.2

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ACKNOWLEDGEMENTS

Primary field investigators for the Upper Fraser River EEM Cycle Five program from Hatfield Consultants (Hatfield) included Mr. Daniel Moats and Dr. Wade Gibbons. Project management was provided by Mr. Moats; Dr. Wade Gibbons provided EEM program overview. Report production was provided by Mr. Moats, Ms. Leslie Uhlig and Mr. Tim Arciszewski, and graphics production was provided by Ms. Susan Stanley. Hatfield would like to acknowledge Drs. Kelly Munkittrick and Mark McMaster (EEM Science Advisory scientists), Environment Canada, for their assistance with the fish study design. Hatfield would also like to acknowledge ALS Environmental and North/South consulting for their assistance with the program.

The Local Monitoring Committee (LMC) for the Upper Fraser River EEM program consists of representatives from the federal and provincial governments, environmental managers from Canfor Pulp Limited Partnership, Quesnel River Pulp Company, and Cariboo Pulp and Paper Company, and Hatfield. LMC meetings and discussions provided a valuable forum for reviewing results from previous surveys, the Technical Guidance Document, and the Cycle Five design document. Hatfield would like to acknowledge members of the LMC for their assistance:

- Ms. Janice Boyd, Environment Canada;
- Ms. Melissa Winfield-Lesk, Mr. James Jacklin, and Ms. Kym Keogh, BC Ministry of Environment;
- Mr. James Spankie, Canfor Pulp Limited Partnership, Northwood Division;
- Mr. Kim Lentz, Canfor Pulp Limited Partnership, Prince George and Intercontinental Division;
- Ms. Anna Rankin and Mr. Brian McLean, Quesnel River Pulp Company; and
- Mr. Wayne Strang and Ms. Judy Kowalski, Cariboo Pulp and Paper Company.

EXECUTIVE SUMMARY

This report interprets data and findings of the environmental effects monitoring (EEM) Cycle Five program for upper Fraser River mills in the vicinity of Prince George and Quesnel, British Columbia, consisting of Canfor Pulp Limited Partnership (Northwood and Prince George/Intercontinental Divisions), Quesnel River Pulp Company (QRP), and Cariboo Pulp and Paper Company (CPP). The program included sublethal toxicological testing of each mill's final effluent (two terms per year), a juvenile fish survey, and measurement of supporting environmental variables. Field surveys were conducted in September 2009; results of field surveys and laboratory tests are summarized herein.

MILL, STUDY AREA AND CYCLE FIVE DESIGN UPDATE

Northwood produces bleached Kraft softwood pulp from primarily pine and spruce wood chips at an approximate rate of 1,600 ADt/d. No significant process or effluent treatment changes were made during Cycle Five. Final effluent is discharged into the Fraser River approximately 10 km upstream of the Nechako River confluence through a three-port submerged outfall.

PG/IC mills produce Kraft pulp at a combined capacity of 1,600 ADt/d. No significant process or effluent treatment changes were made during Cycle Five; however, PG installed new chip screens in fall 2008, and Intercon added aerators to the biobasin. Effluent from these mills is discharged through one diffuser with three submerged downcomer ports, located 7.8 km downstream of the Northwood outfall and 2 km upstream of the Nechako River confluence.

QRP uses a chemo-thermomechanical pulping process to produce approximately 900 ADt/d. As reported in the Cycle Four report, QRP commissioned a new effluent treatment system in March, 2005. In July 2007, QRP completed the mill upgrade, installing high consistency pumps and reducing water usage by 20%. Effluent is discharged into the Fraser River through a two-port bottom diffuser located approximately 4 km upstream of the Quesnel River confluence.

Cariboo currently produces bleached Kraft pulp at a production rate of approximately 890 ADt/d. No significant process or effluent treatment changes were made during Cycle Five. Effluent is discharged from a two-port bottom diffuser approximately 1 km upstream of the confluence of the Quesnel River.

SUBLETHAL TOXICITY TESTING OF MILL EFFLUENT

Sublethal toxicological testing of process effluent was conducted six times from winter 2007 to summer 2009, in accordance with the winter/summer testing schedule for Cycle Five. A grab sample of effluent was collected by mill personnel for each test event. Summaries for each mill effluent follow.

Canfor Northwood

In general, Cycle Five sublethal toxicity results improved from Cycle Four, with toxicities of effluent slightly below those reported in previous cycles. Based on invertebrate reproduction and low flow conditions, the maximum potential zone of sublethal effect was estimated to be 235 m downstream of the Northwood diffuser.

Canfor PG/IC

Cycle Five sublethal toxicity results were variable, although a trend of lower toxicity was observed for the rainbow trout early life stage test up to its removal from the EEM program in 2008. There was a slight decreasing trend in toxicity observed for invertebrate reproduction tests in Cycle Five, with the lowest IC25 observed in winter 2007 and the highest value observed in summer 2009. The algal growth tests were relatively consistent except for summer 2008, which resulted in an IC25 of 0.13%. This result, and the calculation of the IC25 endpoint, was under review by Environment Canada during completion of this report. The maximum potential zone of sublethal effect was estimated to be 214 m downstream of the diffuser for invertebrate reproduction, and 237 m for algal growth.

Quesnel River Pulp Company

Sublethal toxicity tests conducted during Cycle Five exhibited similar results to previous cycles for all organisms. Sublethal toxicity results exhibited some variability; however, no temporal trend was observed over Cycle Five. Unlike other mills, an enhancement of algal growth at low concentrations of effluent (hormesis) was not noted in any of the tested samples. Based on algal growth results and low flow conditions, QRP's effluent may impact the receiving environment up to 78 m downstream of the diffuser.

Cariboo Pulp and Paper Company

Sublethal endpoints were more variable throughout Cycle Five than during Cycle Four. In comparison to previous cycles, invertebrate reproduction continued to show an increased toxicity response. Similarly, rainbow trout early life stage and invertebrate survival tests indicated toxicity of effluent was higher than previous cycles, although toxicity was observed at concentrations well above what occurs in the receiving environment. Based on invertebrate reproduction results and low flow conditions, Cariboo's effluent may impact the receiving environment up to 152 m downstream of the diffuser.

EFFECTS ON FISH AND FISHERIES RESOURCES: FISH SURVEY, TISSUE ANALYSES AND TAINTING EVALUATION

A fish survey of juvenile chinook populations was conducted for the upper Fraser River mills during September 2009. The survey was conducted in four study areas, including Shelley (reference) and Prince George (near-field) in the Prince George region, and Cottonwood (reference) and Quesnel (near-field) in the Quesnel region. A summary of results are provided below below:

- Fish collection was completed by shoreline seining in each study area; the target number of 100 juvenile chinook was achieved at each of the four sampling locations;

- Catch-per-unit-effort (CPUE) for juvenile chinook was highest at Cottonwood (33.3 fish per seine), with CPU in the other areas measuring between 12.5 and 14.3 fish/seine;
- Juvenile chinook length-frequency distributions from the Prince George near-field area differed significantly from the Shelley reference area; no difference was observed between the Quesnel near-field and reference areas;
- Length and weight measurements for Prince George juvenile chinook were significantly smaller than Shelley reference fish. Fish from Cottonwood and Quesnel were not significantly different;
- Condition was significantly lower in Quesnel juvenile chinook relative to Cottonwood fish; there was no difference among Prince George and Shelley fish;
- Liver weight (20 fish per area) was significantly higher in Prince George juvenile chinook relative to Shelley fish; no difference was observed among Quesnel near-field and reference fish;
- Liver weight of Prince George near-field juvenile chinook indicated a potential increase in energy storage. Quesnel juvenile chinook reflected a response of lower energy storage (condition) relative to the Cottonwood reference area;
- Responses of effect endpoints during Cycle Five for both the Prince George and Quesnel regions were variable compared to previous cycles using largescale suckers. There was no clear evidence of enrichment from pulpmill effluent in either the Prince George or Quesnel regions; and
- Statistical differences observed during the juvenile chinook survey are most likely the result of very large sample sizes (100 fish per area), which results in very small differences being assessed as significant.

Dioxin/furan tissue analyses and fish tainting studies were not required for Cycle Five.

CONCLUSIONS

A review of previous historical data suggested a mild enrichment response may have been present during previous cycles, in both the Quesnel and Prince George regions. In Cycle Three, liver size showed significant increases in both sexes in the near-field areas of both Prince George and Quesnel. Condition factor also showed an infrequent but suggestive pattern of enrichment downstream of the Quesnel mills.

In Cycle Five, there was no evidence of enrichment observed in the Quesnel Region. Results were mixed in the Prince George area. Exposure fish were smaller, but had larger liver sizes, relative to reference fish; these results are not indicative of a clear enrichment response.

Toxicity results suggest that the potential zones of sublethal toxicity were small during Cycle Five, ranging from 78 m at Quesnel River Pulp Company to 235 m at Canfor Northwood.

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The following individuals/firms have received this document:

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1.0 INTRODUCTION

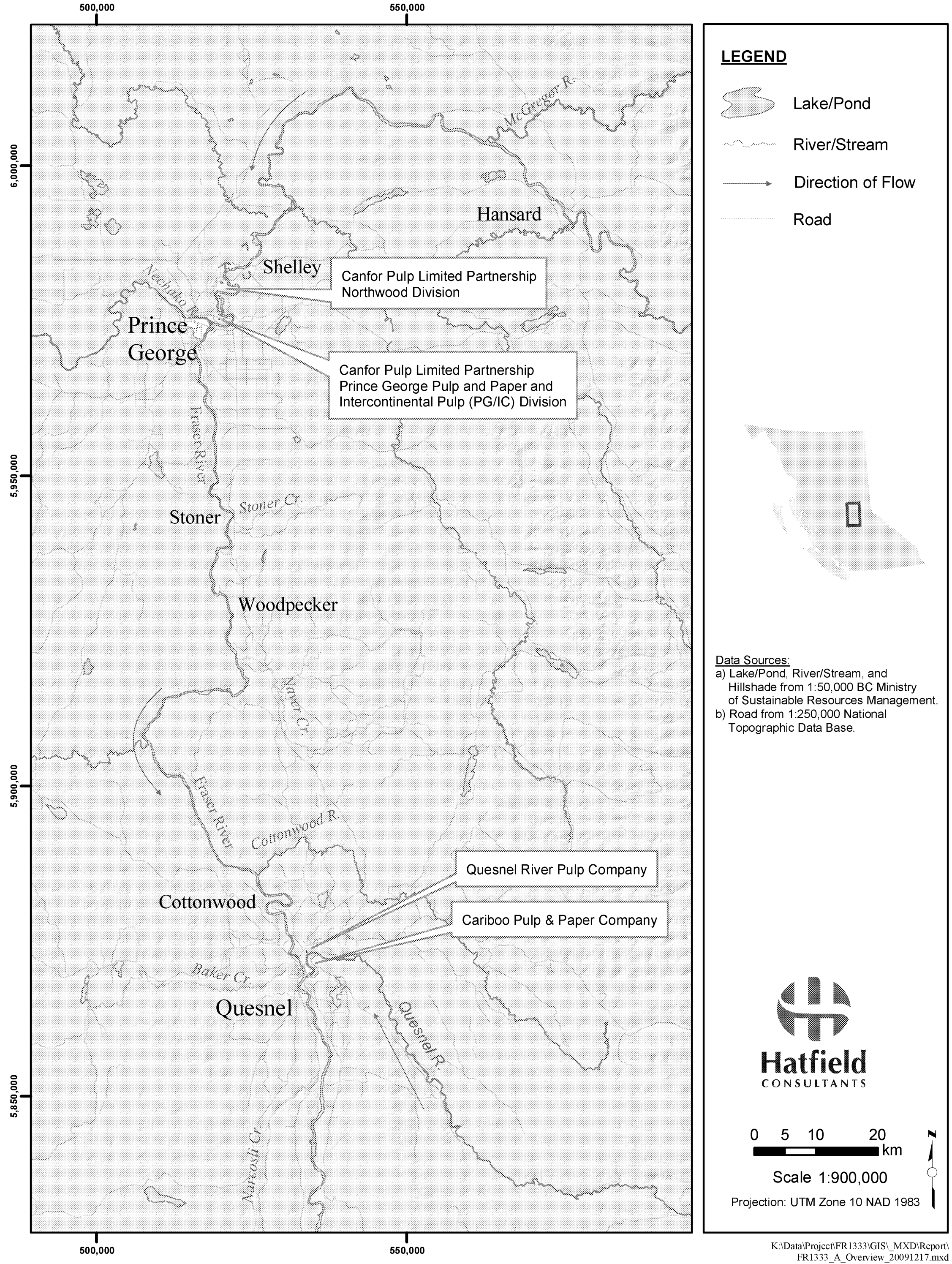
Under the federal *Pulp and Paper Effluent Regulations*, which were originally released in 1992 and revised in August 2008 (Government of Canada 2008), pulpmills are required to monitor the chemistry and toxicity of mill effluent and its potential effects on the receiving environment. Effluent chemistry (limited to total suspended solids and biological oxygen demand) and lethal toxicity are measured to evaluate effluent quality and its potential to affect aquatic biota. However, because there are many factors that can alter the chemistry and toxicity of effluent in the receiving environment, Environmental Effects Monitoring (EEM) studies are also required to directly assess the effects of mill effluent on fish, fish habitat, and use of fisheries resources in the vicinity of the effluent discharge (Environment Canada 2005a). Although not all components are necessarily required for a particular program, a standard EEM study includes:

- A fish population survey to assess the health of fish downstream of effluent discharges;
- A fish tissue survey to assess concentrations of dioxins and furans (only required for mills where dioxins and furans are present in mill effluent) and/or palatability of edible portions of fish;
- A benthic invertebrate community survey to assess the condition of fish habitat; and
- Sublethal toxicity testing to assess effects of effluent on growth and reproduction of representative aquatic organisms.

EEM programs typically are conducted in three-year cycles, which begin with the development of a study design, followed by study implementation, data analysis, and reporting. All components of an EEM program are conducted in accordance with the *Pulp and Paper EEM Guidance Document*, which was last updated in July 2005 (Environment Canada 2005a). The first cycle of EEM monitoring, initiated following the release of the original PPER, was completed between 1993 and 1996. Cycles Two, Three and Four were completed between 1997 and 2000, 2001 and 2004, and 2005 and 2007, respectively. Amendments to the PPER occurred in August 2008 that resulted in discontinuation of the rainbow trout early life stage sublethal toxicity test, evaluation of fish and benthic invertebrate community survey results as independent components, and guidance for investigations of cause and solutions for a specific mill-related effect (Government of Canada 2008).

This report presents results from the EEM Cycle Five program for five mills along the upper Fraser River between Prince George and Quesnel (Figure 1.1). Due to the proximity of the mills, a combined Upper Fraser River EEM program has been implemented to satisfy PPER requirements for each facility.

Figure 1.1 Location of pulp and paper mills along the upper Fraser River in the vicinity of Prince George and Quesnel, BC.



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The three pulpmills in the Prince George region include Northwood Pulp Mill (Northwood), Prince George Pulp and Paper Mill, and Intercontinental Pulp Mill (PG/IC), owned by Canfor Pulp Limited Partnership. The two pulpmills in the Quesnel region include the Quesnel River Pulp Company (QRP) and Cariboo Pulp and Paper Company (Cariboo), both owned by West Fraser Timber Company Ltd. Prince George Pulp and Paper and Intercontinental Pulp combine effluents and discharge through a common diffuser; hence, four discharges are monitored within this EEM program.

The Cycle Five program, previously described in the study design (Hatfield Consultants 2010), included sublethal toxicity testing of mill effluent, a juvenile chinook population survey, and collection of supporting water quality variables. The objective of the Cycle Five program was to further investigate possible enrichment effects on fish observed in previous cycles. Information on changes in mill processes, effluent treatment, and/or the receiving environment that occurred during Cycle Five are also presented. The sections in this report include:

- Section 2.0 — Mill, Study Area and Cycle Five Design Update;
- Section 3.0 — Sublethal Toxicity Testing of Mill Effluent;
- Section 4.0 — Fish Population Survey;
- Section 5.0 — Fish Tissue Analysis;
- Section 6.0 — Benthic Invertebrate Survey;
- Section 7.0 — Conclusions;
- Section 8.0 — Closure;
- Section 9.0 — References;
- Section 10.0 — Glossary; and
- Appendices.

2.0 MILL, STUDY AREA AND CYCLE FIVE DESIGN UPDATE

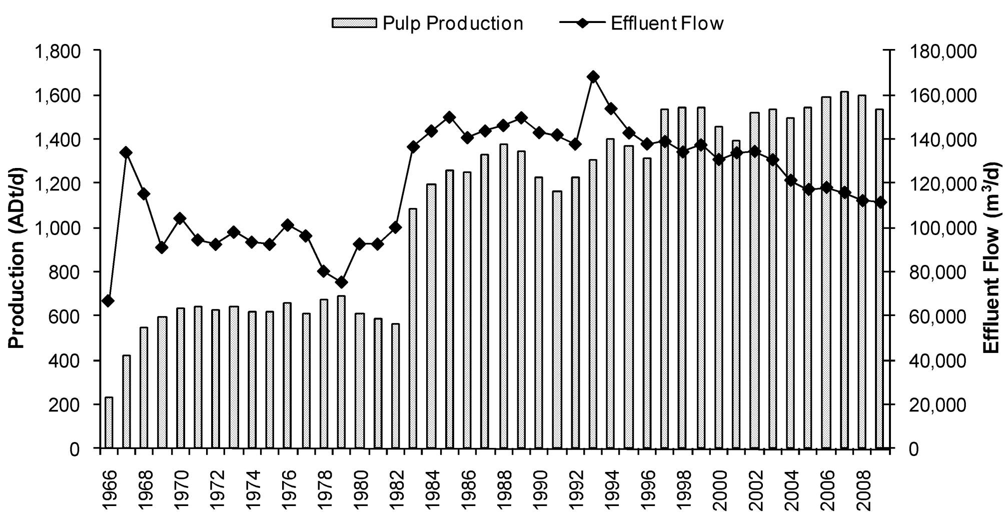
Five pulp and paper mills are located along the upper Fraser River. The five mills discharge to the river via four outfalls: two at Prince George and two at Quesnel. The following sections present updates for each mill relating to each outfall and its effluent quality. Changes to the study area and/or Cycle Five design are also discussed in this section.

2.1 CANFOR PULP LIMITED PARTNERSHIP, NORTHWOOD MILL

2.1.1 Process Description and Update

Canadian Forest Products Ltd. (now Canfor Pulp Limited Partnership - Canfor) purchased Northwood Pulp and Timber Ltd. (Northwood) in late 1999. The Canfor Northwood mill is located on the upper Fraser River north of Prince George, British Columbia. A premium grade of bleached Kraft softwood pulp is produced using two ('A' and 'B') operation lines. The pulp mill came online in 1966 at a production capacity of 625 ADt/d; however, expansion over the years has increased this rate to approximately 1,600 ADt/d (Figure 2.1). Effluent flow has decreased slightly with increased pulp production since 1983; current effluent flow levels are approximately 112,000 m^3/d.

Figure 2.1 Annual mean pulp production and effluent flow, Canfor Northwood mill, 1966 to 2009.



Major species used for wood furnish are pine (80%) and spruce (20%). The bleaching sequence used at the mill is $DE_{op}DE_{P}D$ (D = chlorine dioxide, E = caustic extraction, O = oxygen, P = peroxide). All bleaching is carried out at 100% chlorine dioxide substitution. Total usage of chlorine dioxide has been reduced in recent years at the mill (starting in the early 1990s) resulting in a decrease in absorbable organic halides (AOX) (Figure 2.2). In 1990, changes were made to the plant to accommodate high substitution chlorine dioxide bleaching. Effluent treatment at the mill currently consists of a clarifier and two aerated stabilization basins (ASBs).

Since 2001, a silicone-based defoamer has been used in the effluent treatment process. In 2004, two 75-horsepower floating aerators were added to the "A" ASB and eight 75-horsepower floating aerators were added to the "B" ASB, to improve effluent treatment.

Final effluent is discharged into the Fraser River approximately 10 km upstream of the Nechako River confluence through a three-port submerged outfall, which was installed in 1966. The zone of 1% effluent concentration for Northwood during low flows (January to March) extends downstream to the Prince George Pulp and Paper /Intercontinental Pulp Company (PG/IC) outfall (approximately 7.8 km downstream) and possibly beyond (Hatfield Consultants Ltd. 1994).

2.1.2 Effluent Chemistry

Most effluent quality monitoring data have not changed significantly since 1993 (Figure 2.2). Concentrations of total suspended solids (TSS) have varied in recent years, increasing from a low reported for 1998 (6,078 kg/d), and decreasing since 2007. Biochemical oxygen demand (BOD) has remained relatively constant since 1996. Both TSS and BOD levels are well within government permit requirements. AOX concentrations have decreased considerably since the early 1990s, reflecting the implementation of chlorine dioxide substitution in the bleaching process. In addition, dioxins (as 2,3,7,8-T_4CDD) and furans (as 2,3,7,8-T_4CDF) levels in final effluent have either been non-detectable or well below permit levels since chlorine dioxide was substituted for elemental chlorine.

Results from acute toxicity testing of effluent on rainbow trout and *Daphnia magna* have met government requirements regarding effluent toxicity (i.e., all LC50s greater than 100% v/v effluent). No acute toxicity of effluent to rainbow trout has been observed since 2003; there was some variability in *Daphnia* LC50s, although the annual means were approximately 99%.

Figure 2.2 Annual mean TSS, BOD and AOX concentrations in effluent, Canfor Northwood mill, 1966 to 2009.

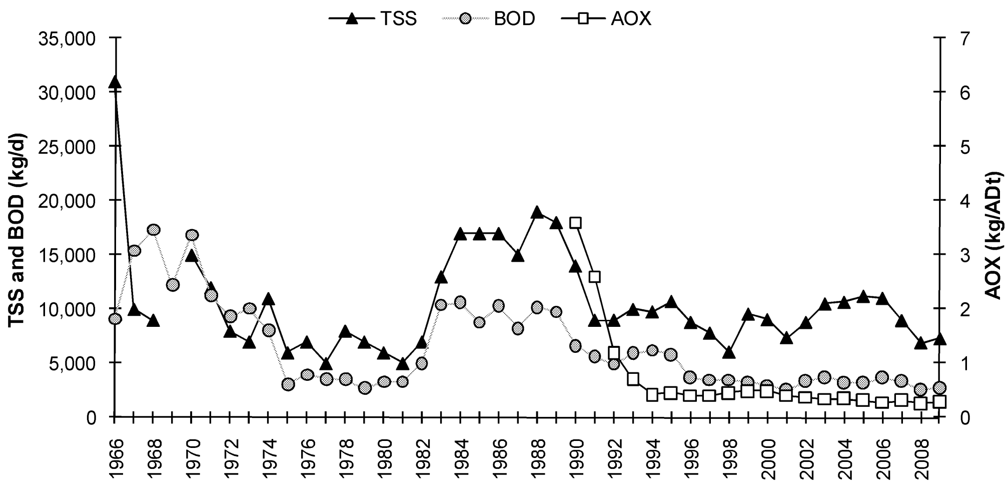


Table 2.1 Annual mean values for process effluent quality variables, Canfor Northwood mill, 2003 to 2009.

Variable	2003	2004	2005	2006	2007	2008	2009
Total production (ADt/d)	1,538	1,495	1,554	1,588	1,618	1,595	1,538
Effluent flow (m^3/d)	130,810	121,551	117,458	118,274	115,960	112,310	111,561
pH	7.9	8.0	8.0	7.9	7.8	7.7	7.6
Temperature (°C)	25.6	25.3	24.8	26	25.8	24.6	25.8
TSS (kg/d)	10,513	10,652	11,219	11,029	8,963	6,929	7,292
BOD (kg/d)	3,762	3,239	3,225	3,677	3,372	2,578	2,775
AOX (kg/ADt)	0.34	0.35	0.32	0.27	0.32	0.26	0.28
2,3,7,8-T_4CDD (pg/L)	1.96	2.3	ND (<2.0)	ND (<2.0)	ND (<1.0)	ND (<2.0)	ND (<2.0)
2,3,7,8-T_4CDF (pg/L)	31.6	34	4.1	4.9	5.6	5.7	ND (<2.0)
Rainbow trout 96-hr LC50 (% effluent)	>100	>100	>100	>100	>100	>100	>100
Daphnia magna 48-hr LC50 (% effluent)	>100	>100	99.2	>100	>100	99.4	>100

2.1.3 Spills to the Receiving Environment

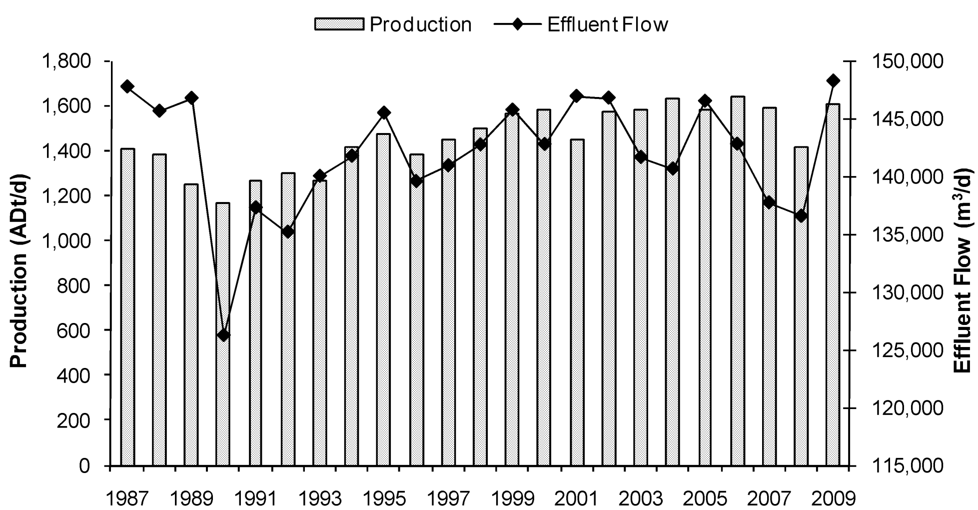
No spills have occurred since 2001.

2.2 CANFOR PULP LIMITED PARTNERSHIP, PG/IC MILLS

2.2.1 Process Description and Update

Prince George Pulp and Paper (PG) and Intercontinental Pulp Company (IC) are bleached Kraft pulp mills owned and operated by Canfor; both are located on the Fraser River at Prince George, British Columbia. The PG mill began operation in May 1966, and the IC mill started two years later in May 1968. Combined production capacity in 2009 was 1,600 ADmt/d of Kraft pulp with a combined effluent flow of approximately 148,000 m^3/day (Figure 2.3).

Figure 2.3 Annual mean pulp production and effluent flow, Canfor PG/IC mills, 1987 to 2009.



Major species used for wood furnish are pine (80%), spruce (15%) and fir (5%). A chloride dioxide generator began operation in early 1991 and between July 1991 and 1994 virtually all bleached pulp produced was bleached with a minimum of 70% chloride dioxide substitution. Further process changes occurred between spring 1994 and spring 1995 at these mills. In May 1994, oxygen delignification came on-line at the IC mill. In September 1994, the PG mill reached 100% chlorine dioxide substitution. No elemental chlorine has been used at either mill since 1994. In fall 2008, new chip screens were installed at PG, and the Intercon pulp machine was 'double felted'.

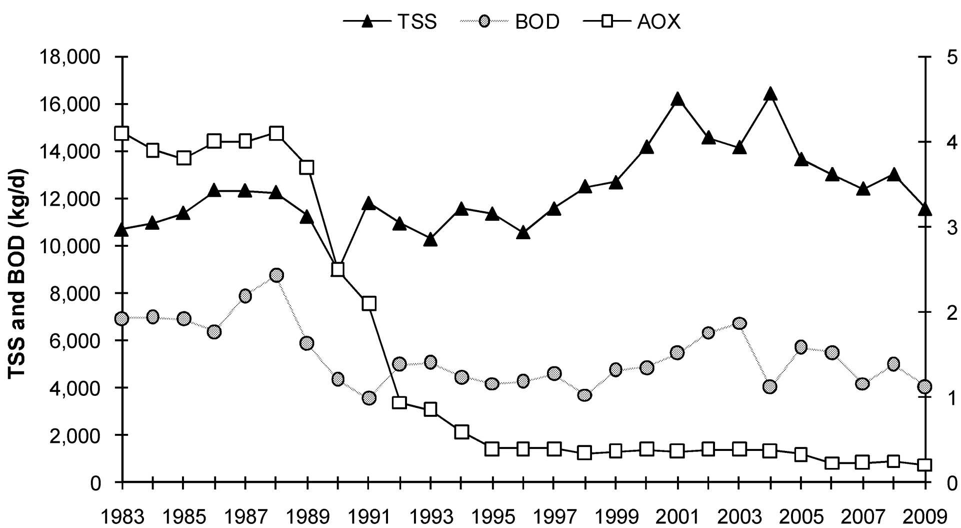
In July 2007, two 30-horsepower aerators were added to the Intercon biobasin to improve effluent treatment. In 2009, an existing 60 hp aerator was replaced with a new 30 hp unit, and three more 30 hp units were added.

The PG/IC combined effluent diffuser is located 7.8 km downstream of the Northwood outfall and 2 km upstream of the Nechako River confluence. Effluent is discharged into the river through three submerged downcomer ports along the west shore. The estimated 1% zone of effluent concentration extends 7 km downstream of the diffuser during low flow.

2.2.2 Effluent Chemistry

TSS concentrations during Cycle Five were lower relative to those recorded between 2000 and 2006 (Figure 2.4 and Table 2.2); levels for Cycle Five were approaching TSS concentrations reported between 1983 and 2000. BOD concentrations have decreased from pre-1990 levels and were similar to levels between 2003 and 2006. The decline in AOX since 1991 is indicative of the implementation of chlorine dioxide substitution, which has reduced the potential for these compounds to form. AOX concentrations during Cycle Five were the lowest observed since 1983.

Figure 2.4 Annual mean TSS, BOD and AOX concentrations in effluent, Canfor PG/IC mills, 1983 to 2009.



The PG/IC effluent was in compliance with *Pulp and Paper Effluent Regulations* throughout Cycle Five. Results from acute toxicity testing of effluent on rainbow trout and *Daphnia magna* have also met government requirements; most results were >100% v/v effluent. The acute test results that were <100% likely were a result of fish and invertebrate viability from the laboratory rather than effluent quality (K. Lentz, *pers. comm.*, Canfor PG/IC, February 2010).

Table 2.2 Annual mean values for process effluent quality variables, Canfor PG/IC, 2003 to 2009.

Variable	2003	2004	2005	2006	2007	2008	2009
Total production (ADt/d)	1,580	1,629	1,578	1,636	1,591	1,412	1,609
Effluent flow (m3/d)	141,600	140,609	146,462	142,751	137,671	136,522	148,195
pH	7.5	7.5	7.3	7.3	7.4	7.3	7.5
Temperature (°C)	29.6	29.0	28.8	28.7	28.4	28.0	29.8
TSS (kg/d)	14,145	16,394	13,646	13,014	12,412	13,004	11,559
BOD (kg/d)	6,730	4,031	5,723	5,511	4,165	5,012	4,060
AOX (kg/ADt)	0.39	0.38	0.33	0.23	0.24	0.25	0.21
2,3,7,8-T4CDD (pg/L)	ND (<2.0)	ND (<2.0)	ND (<2.0)	ND (<2.0)	ND (<2.0)	ND (<2.0)	ND (<2.0)
2,3,7,8-T4CDF (pg/L)	2.8	ND (<2.0)	ND (<2.0)	ND (<2.0)	ND (<2.0)	ND (<2.0)	ND (<2.0)
Rainbow trout 96-hr LC50 (% effluent)	>100	>100	>100	>100	>100	99.2	98.3
Daphnia magna 48-hr LC50 (% effluent)	>100	91.7	>100	>100	>100	99.8	98.7

2.2.3 Spills to the Receiving Environment

One spill incident was reported in November 2008 when a dark coloured pool was observed along the edge of the Nechako River where it enters the Fraser River during a flyover inspection by Fisheries and Oceans personnel. Subsequent investigation determined that a spring-like stream of dark coloured liquid was percolating out of the ground halfway up the bank to the Intercon landfill area. Analyses of the liquid indicated that it was non-toxic based on a microtox bioluminescence test result of 70.86%. Corrective actions involved closing the old storm sewer lines and creating a proper drainage system in the Intercon Landfill areas; these actions were completed in December 2009.

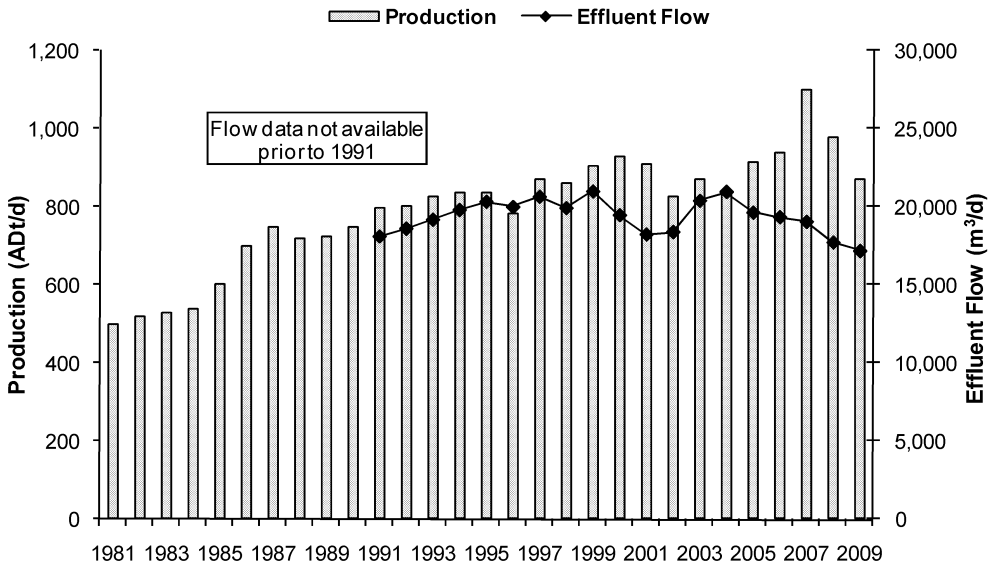
No other spills to the receiving environment were reported during Cycle Five.

2.3 QUESNEL RIVER PULP COMPANY

2.3.1 Process Description and Update

The Quesnel River Pulp Company (QRP) began operation in 1981 in Quesnel, British Columbia, using a thermomechanical pulping process. Shortly after opening, chemi-thermomechanical production was added to operations. Current pulp production rates are approximately 1,000 ADmt/d (Figure 2.5). Effluent flow and production have remained relatively steady over recent years; flow volumes during Cycle Five were approximately 18,000 m^3/d.

Figure 2.5 Annual mean pulp production and effluent flow, QRP, 1981 to 2009.



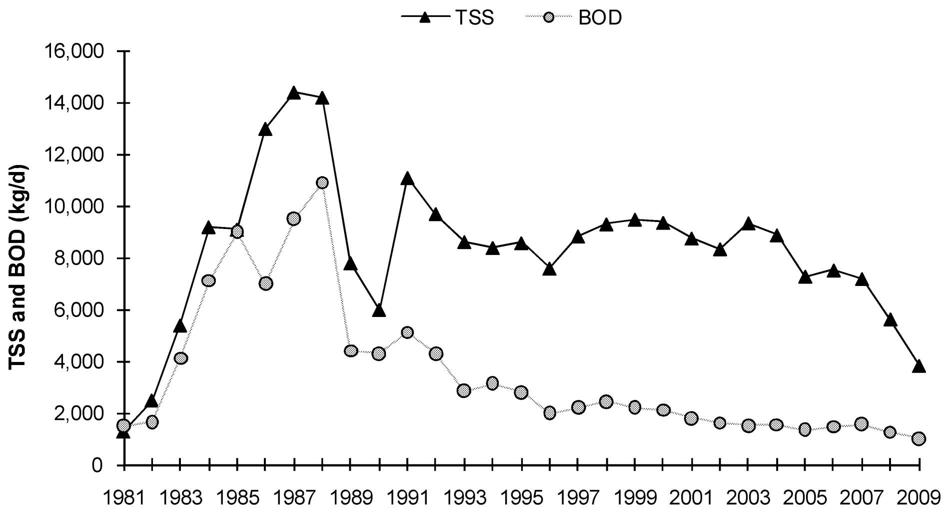
Wood furnish is supplied from by-products of local sawmills. Furnish consists primarily of pine (80%), spruce (15%), and balsam fir (5%). Pulping, bleaching, and effluent treatment processes carried out by the mill were described in detail in the pre-design document (Hatfield Consultants Ltd. 1994). Pulp bleaching is achieved using hydrogen peroxide. Effluent treatment consists of a clarifier (to remove fibre), followed by bio-film activated sludge (BAS) effluent treatment system, consisting of two moving bed bio-film reactors in series followed by activated sludge and final clarification. A new treatment system was commissioned in March 2005. In addition to pulpmill effluent, the company receives effluent from a medium density fibreboard plant for processing. In July 2007, QRP completed a mill upgrade, installing high consistency pumps and reducing water usage by 20%.

Effluent is discharged into the Fraser River through a mid-channel, two-port bottom diffuser. The zone of 1% effluent concentration is very small due to the low volume of effluent and high dilution capacity of the Fraser River. Sodium dispersion modeling undertaken in Cycle Four documented a maximum effluent concentration of 0.56% at 100 m downstream of the diffuser. At 125 m downstream the concentration dropped to 0.20%. Concentrations at sampling sites located 25, 50 and 75 m downstream of the diffuser were 0.17, 0.25 and 0%, respectively.

2.3.2 Effluent Chemistry

Annual averages for QRP's effluent chemistry variables from 2003 to 2009 are presented in Table 2.3. TSS and BOD concentrations are presented in Figure 2.6, which illustrates decreasing trends in both variables since 1988. These decreases are likely attributable to activated sludge treatment upgrades in the aeration basin completed in 1988, as well as new high consistency pumps that reduce water usage that were installed in July 2007.

Figure 2.6 Annual mean TSS and BOD concentrations in effluent, QRP, 1981 to 2009.



Results from acute toxicity testing of effluent on rainbow trout and *Daphnia magna* met government requirements throughout Cycle Five. QRP effluent was in compliance with *Pulp and Paper Effluent Regulations* for the duration of Cycle Five, except for one event. Acute toxicity tests failed one time when a valve was opened allowing untreated process water to mix with treated discharge water. The final LC50 for this test was 96% (A. Rankin, *pers. comm.*, Quesnel River Pulp Company, 2010).

Table 2.3 Annual mean values for process effluent quality variables, QRP, 2003 to 2009.

Variable	2003	2004	2005	2006	2007	2008	2009
Total production (ADt/d)	869	840	917	941	1,100	979	873
Effluent flow (m3/d)	20,401	20,973	19,644	19,361	19,064	17,739	17,196
pH	7.7	7.7	7.8	7.7	7.9	7.7	7.7
Temperature (°C)	35.6	35.4	35.1	34.3	35.2	34.8	33.3
Conductivity (µs/cm)	3,618	3,146	3,244	3,546	3,793	3,685	3,665
TSS (kg/d)	9,347	8,883	7,284	7,526	7,193	5,632	3,837
BOD (kg/d)	1,506	1,543	1,344	1,471	1,550	1,259	1,021
Rainbow trout 96-hr LC50 (% effluent)	>100	>100	>100	>100	99.8	>100	>100
Daphnia magna 48-hr LC50 (% effluent)	99.9	>100	>100	99.7	98.3	>100	>100

2.3.3 Spills to the Receiving Environment

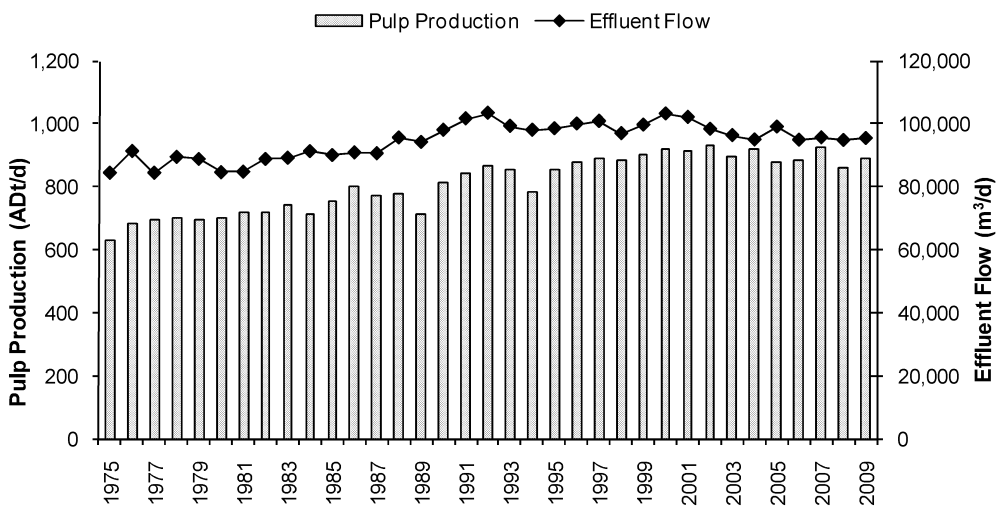
No spills to the Fraser River receiving environment have occurred from Quesnel River Pulp Company since 1993.

2.4 CARIBOO PULP AND PAPER COMPANY

2.4.1 Process Description and Update

Cariboo Pulp and Paper Company (Cariboo), Quesnel, British Columbia began operation in 1972. The mill currently produces bleached Kraft pulp at a production rate of approximately 890 ADt/d (Figure 2.7). The effluent discharge rate in 2009 was approximately 95,000 m^3/d.

Figure 2.7 Annual mean pulp production and effluent flow, Cariboo, 1975 to 2009.



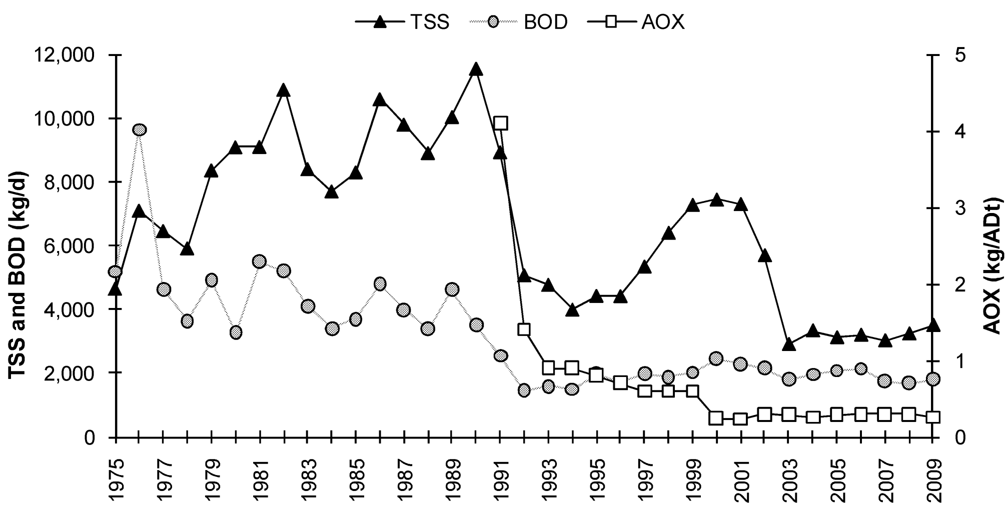
No major process changes in pulping have occurred since elemental chlorine free (ECF) production at the mill was fully implemented in 2000. The composition of the wood furnish is pine (70%), spruce (25%) and fir (5%). The current bleaching sequence is ODcE/ODED (Dc = chlorine dioxide, E = caustic extraction, O = oxygen). Mill effluent is segregated into general and bleach sewers. General sewer effluent undergoes primary clarification before joining the bleach sewer and sanitary sewage (from the City of Quesnel and the Cariboo Regional District) in a settling basin at one end of the pretreatment lagoon. The remainder of the pretreatment lagoon has surface aeration. Effluent then flows to a second lagoon with subsurface aeration, then on to a final lagoon for additional surface aeration. Effluent from the final lagoon is discharged to the Fraser River. A new final lagoon was added to the effluent treatment process in September 2002; the old final lagoon currently receives less than 10% of the total effluent flow. The new lagoon has considerably reduced TSS concentrations in the final effluent (Figure 2.8).

Effluent is discharged from a mid-channel two-port bottom diffuser to the Fraser River, approximately 1 km upstream of the confluence of the Quesnel River. The zone of 1% effluent concentration extends approximately 4.5 km downstream of the diffuser during low flow conditions.

2.4.2 Effluent Chemistry

Effluent chemistry variables are routinely measured to satisfy provincial and federal permits; annual average values for 2003 to 2009 are presented in Table 2.4 for Cariboo. TSS levels continued to be low following the construction of a new lagoon in September 2002 (Figure 2.8), while BOD have levels remained relatively consistent since 1995. AOX levels in effluent decreased dramatically in 1992, and again in 2000, following the substitution of elemental chlorine with chlorine dioxide. During Cycle Five, no detectable measurements (i.e., <2.0 pg/L) of dioxins or furans were recorded in Cariboo effluent (Table 2.4).

Figure 2.8 Annual mean TSS, BOD and AOX concentrations in effluent, Cariboo, 1975 to 2009.



Cariboo undertakes regularly scheduled acute toxicity testing using rainbow trout and the cladoceran *Daphnia magna*. All LC50 values were >100% during Cycle Five (Table 2.4). The effluent from Cariboo was compliant with the federal Pulp and Paper Effluent Regulation by sustaining no acute toxicity of effluent to trout.

Table 2.4 Annual mean values for process effluent quality variables, Cariboo, 2003 to 2009.

Variable	2003	2004	2005	2006	2007	2008	2009
Total production (ADt/d)	895	920	880	886	925	862	889
Effluent flow (m^3/d)	96,271	94,917	98,931	94,816	95,552	94,732	95,350
pH	7.9	7.8	8.0	8.0	7.8	7.8	7.8
Temperature (°C)	26	27	26	27	28	26	28
TSS (kg/d)	2,901	3,328	3,110	3,191	3,016	3,231	3,501
BOD (kg/d)	1,802	1,958	2,087	2,146	1,747	1,684	1,814
AOX (kg/ADt)	0.29	0.26	0.30	0.30	0.30	0.30	0.26
2,3,7,8-TCDD (pg/L)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
2,3,7,8-TCDF (pg/L)	<2.0	<2.0	<2.0	3.0	<2.0	<2.0	<2.0
Rainbow trout 96-hr LC50 (% effluent)	>100	>100	>100	>100	>100	>100	>100
Daphnia magna 48-hr LC50 (% effluent)	>100	>100	>100	>100	>100	>100	>100

2.4.3 Spills to the Receiving Environment

No spills resulting from Cariboo's operations occurred to the Fraser River during Cycle Five (2007 through 2009).

2.5 STUDY AREA UPDATE

No natural or anthropogenic changes of significant size occurred in the study area during Cycle Five.

2.6 CYCLE FIVE STUDY DESIGN UPDATE

No major changes were made to the Upper Fraser River Cycle Five study design.

3.0 SUBLETHAL TOXICITY TESTING OF MILL EFFLUENT

Summary of Cycle Five Sublethal Toxicity Testing for Canfor Northwood Mill:

- No effect on rainbow trout (*Oncorhynchus mykiss*) embryo viability (EC25 >100%);
- No effect on survival of the invertebrate *Ceriodaphnia dubia* (LC50 >100%), while effects on reproduction were observed at a mean effluent concentration of 30% (IC25);
- Growth of the alga *Pseudokirchneriella subcapitata* was affected at a mean effluent concentration of 88% (IC25); and
- Environment Canada's predictive model suggests maximum potential zones of sublethal effect from the effluent discharge were <70 m for embryo viability, <70 m for invertebrate survival, 235 m for invertebrate reproduction, and 79 m for algal growth. This is based on an estimated 1% effluent concentration zone of 7,000 m.

Summary of Cycle Five Sublethal Toxicity Testing for Canfor PG/IC Mill:

- Rainbow trout (*Oncorhynchus mykiss*) embryo viability was affected at a mean effluent concentration of 95% (EC25);
- No effect on survival of the invertebrate *Ceriodaphnia dubia* (LC50 >100%), while effects on reproduction were observed at a mean effluent concentration of 33% (IC25);
- Growth of the alga *Pseudokirchneriella subcapitata* was affected at a mean effluent concentration of 30% (IC25). One IC25 calculation of 0.13% is being reviewed by Environment Canada. When excluded, the IC25 geometric mean is 88%; and
- Environment Canada's predictive model suggests maximum potential zones of sublethal effect from the effluent discharge were 74 m for embryo viability, <70 m for invertebrate survival, 214 m for invertebrate reproduction, and 80 m for algal growth. This is based on an estimated 1% effluent concentration zone of 7,000 m.

Summary of Cycle Five Sublethal Toxicity Testing for Quesnel River Pulp Company:

- Rainbow trout (*Oncorhynchus mykiss*) embryo viability was affected at a mean effluent concentration of 31% (EC25);
- Invertebrate survival of *Ceriodaphnia dubia* was affected at a mean effluent concentration of 76% (LC50), and reproduction was affected at a mean effluent concentration of 17% (IC25);
- Growth of the alga *Pseudokirchneriella subcapitata* was affected at a mean effluent concentration of 2.6% (IC25); and
- Environment Canada's predictive model suggests maximum potential zones of sublethal effect from the effluent discharge were 6.5 m for embryo viability, 2.6 m for invertebrate survival, 11.6 m for invertebrate reproduction, and 78 m for algal growth. This is based on an estimated 1% effluent concentration zone of 200 m.

Summary of Cycle Five Sublethal Toxicity Testing for Cariboo Pulp and Paper Company:

- Rainbow trout (*Oncorhynchus mykiss*) embryo viability was affected at a mean effluent concentration of 91% (EC25);
- A slight effect on invertebrate survival of *Ceriodaphnia dubia* was observed (LC50 85%), while effects on reproduction were observed at a mean effluent concentration of 30% (IC25);
- Growth of the alga *Pseudokirchneriella subcapitata* was not affected (IC25 >90.91%); and
- Environment Canada's predictive model suggests maximum potential zones of sublethal effect from the effluent discharge were 49 m for embryo viability, 53 m for invertebrate survival, 152 m for invertebrate reproduction, and <50 m for algal growth. This is based on an estimated 1% effluent concentration zone of 4,500 m.

3.1 INTRODUCTION

Federal and provincial government regulations require pulp and paper mills to undertake toxicity testing as part of their EEM programs to determine potential lethality or inhibitory effects of their effluent on fish populations and fish habitat. Current EEM regulations require the use of sublethal toxicity tests to help meet the following objectives (Environment Canada 2005a):

- Contribute to the field program as part of a weight-of-evidence approach;
- Compare process effluent quality between mill types and measure changes in effluent quality as a result of effluent treatment and process changes; and
- Contribute to the understanding of a mill's relative contribution to downstream water quality in multiple discharge situations.

Sublethal toxicity testing for the Upper Fraser River EEM Cycle Five included the following tests, as stipulated in Annex 1 for freshwater mills west of the Rocky Mountains (Environment Canada 2005a):

- Fish early life stage development test, using rainbow trout (*Oncorhynchus mykiss*). This test was excluded from EEM testing requirements in August 2008 as stated in the amended *Pulp and Paper Effluent Regulations* (Government of Canada 2008);
- Invertebrate reproduction and survival tests, using the cladoceran *Ceriodaphnia dubia*; and
- Algal growth test, using the alga *Pseudokirchneriella subcapitata* (formerly named *Selenastrum capricornutum*).

Sublethal toxicity testing was undertaken by Cantest Ltd. (formerly Vizon SciTec Ltd.) at their Vancouver, British Columbia testing facility. Complete reports from each set of tests were submitted to Environment Canada within 90 days of test completion. A summary of reported endpoints is included with this report; reported results are presented in Appendix A1.

3.2 METHODS

3.2.1 General Methods and Definitions

During Cycle One, quarterly tests were required for the year field studies were completed. Since Cycle Two, the *Pulp and Paper EEM Guidance Document* (Environment Canada 2005a) stipulates that sublethal toxicity testing of process effluent is undertaken during winter and summer test terms each year. Testing for Cycle Five was initiated in winter 2007 (May 2007) and continued until summer 2009 (December 2009). The apparent discrepancy between the test period name (i.e., "summer" and "winter") and the actual date of sample collection/testing is a result of delays caused by test failures and requisite re-tests dating back to 2000. For the purposes of this report "winter" refers to the first test term of a given year and "summer" refers to the second test term; these terms should occur approximately six months apart.

On each test date, a grab sample of effluent is collected by mill personnel according to the methodology described in the *Pulp and Paper EEM Guidance Document* (Environment Canada 2005a) and shipped to CanTest Ltd. Sublethal toxicity testing involves exposure of organisms to a series of effluent dilutions. All sublethal toxicity tests were conducted with controls in order to assess the "background response" of test organisms and determine the acceptability of the test using predefined criteria. In addition, in-house cultures were tested with a reference toxicant to monitor the health and sensitivity of the culture. For test endpoints reported in EEM Cycle Five, all controls met or exceeded protocol requirements.

These sublethal toxicity tests report LC50, EC25 or IC25 endpoints. The EC25 endpoint reported for the fish early life stage development test is an estimate of the effective concentration of effluent that causes 25% of embryos to be non-viable. Both algal and invertebrate tests provide IC25 endpoints, which are estimates of the concentration of effluent that causes 25% inhibition of a quantitative biological function, such as reproduction or growth. The invertebrate test also yields an LC50 endpoint, which is the effluent concentration that is lethal to 50% or more of the test species.

A geometric mean of all results for a given species and sublethal toxicity test is calculated for each cycle. These results are used to track changes in effluent quality between cycles and may be useful in understanding the relative contribution of each mill effluent in multiple discharge situations.

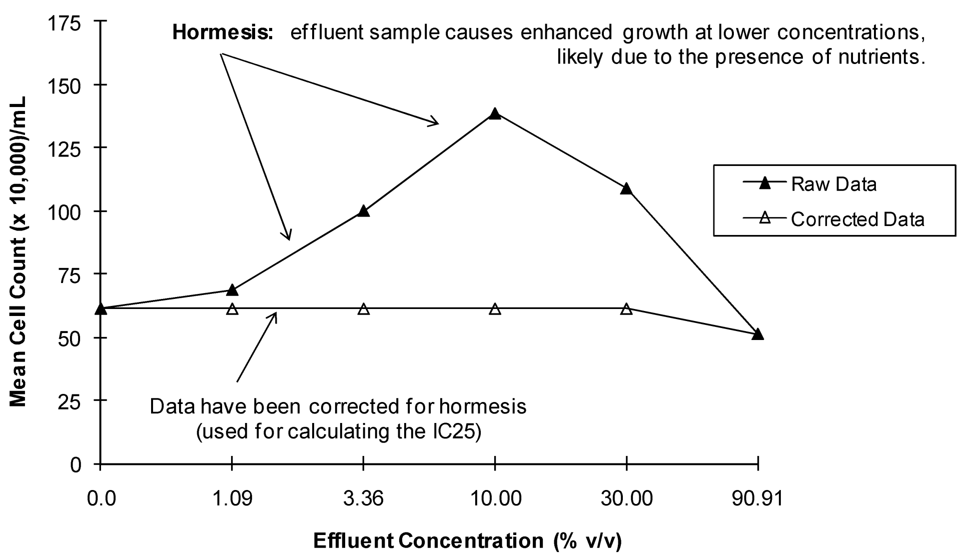
3.2.2 Sublethal Toxicity Test Methods

General procedures for conducting the rainbow trout (*Oncorhynchus mykiss*) tests were based on Environment Canada's *Biological Test Method: Toxicity Tests Using Early Life Stages of Salmonid Fish (Rainbow Trout)* (EPS 1/RM/28 Second Edition) (Environment Canada 1998b). The fish early life stage test was conducted as a static-renewal 7-day embryo test using newly fertilized rainbow trout eggs exposed to a series of effluent concentrations. The resulting endpoint was the effluent concentration for a 25% effect measured as percent viable embryos (EC25) relative to controls.

The invertebrate reproduction tests were conducted as three brood (7±1 day) static renewal tests using the cladoceran *Ceriodaphnia dubia*. Procedures for culturing *C. dubia* and conducting tests were based on Environment Canada's *Biological Test Method: Test of Reproduction and Survival Using the Cladoceran Ceriodaphnia dubia* (EPS 1/RM/21 Second Edition) (Environment Canada 2007a). Daphnids were exposed to a series of different effluent concentrations to assess the survival of the first generation (survival LC50) and to compare the reproductive success (reproduction IC25) in a sample to a control, which must produce three broods of neonates during a 7±1 day term. The LC50 endpoint is the percent effluent concentration at which 50% of the daphnids survive while the IC25 endpoint is the percent effluent concentration whereby reproduction is reduced by 25% from control reproduction rates.

Algal growth tests were conducted as 72-hour inhibition tests using the freshwater alga *Pseudokirchneriella subcapitata* (formerly named *Selenastrum capricornutum*). The procedures used for conducting tests and culturing *P. subcapitata* were based on Environment Canada's *Biological Test Method: Growth Inhibition Using a Freshwater Alga* (EPS 1/RM/25 Second Edition) (Environment Canada 2007b). Algal cells were grown in various concentrations of effluent for 72 hours, after which cell populations of each replicate were calculated. The test result for growth (IC25) represents the algal cell growth at the experimental concentrations compared to the growth of a control. *P. subcapitata* test effluent concentrations that indicate hormesis (an enhancement of growth which often occurs at lower effluent concentrations due to the presence of nutrients in the sample) are excluded from the statistical calculation of the IC25 endpoint as per Environment Canada's *Guidance Document on Statistical Methods for Environmental Toxicity Tests* (Report EPS 1/RM/46 (Environment Canada 2005a, including June 2007 amendments). To calculate the IC25 corrected for hormesis, the control value was assigned to all test concentrations yielding greater growth than the control (Figure 3.1).

Figure 3.1 Example of an algal growth dose-response curve showing data with and without hormesis correction.



3.2.3 Zone of Effluent Concentration

The zone of effluent mixing was determined for each mill by plume delineation surveys (Hatfield Consultants 1994, Colodey et al. 1999). These surveys estimated the maximum extent of 1% effluent concentration (i.e., 100:1 dilution) or greater in receiving waters (i.e., the Fraser River). The 1% effluent concentration zone originally was used to define near-field and far-field areas to aid in selecting sampling sites for EEM field studies.

The 1% effluent zone represents conditions of minimum dilution, maximum extent, and long-term average conditions (i.e., long-term effect of effluent discharge) (Environment Canada 1998a), and therefore represents worst-case effluent dilution conditions. In riverine systems, such conditions usually occur in late winter, when annual river flows are lowest.

A maximum potential zone of sublethal effect was calculated for each test species from the geometric mean of IC25, EC25, or LC50 results and the extent of the 1% effluent concentration zone, as per Environment Canada (2005a) for each mill. This potential zone of sublethal effect describes the downstream area where effluent concentrations may exceed the geometric mean of the IC25, EC25, or LC50 results, and is the maximum distance from the effluent discharge where a specified effect may be expressed for a test species. This maximum potential zone of sublethal effect was calculated as follows:

$$\text{Zone (m)} = \frac{\text{Extent of 1\% effluent zone (m)}}{\text{Geometric mean of IC25, EC25 or LC50 results}}$$

This model assumes simple linear dilution of effluent downstream of the diffuser, which may not be realistic for the upper Fraser mills, given that these effluents are discharged through multi-port diffusers that rapidly dilute effluent into the river flow upon release.

3.3 CANFOR PULP LIMITED PARTNERSHIP, NORTHWOOD MILL: TOXICITY TEST RESULTS

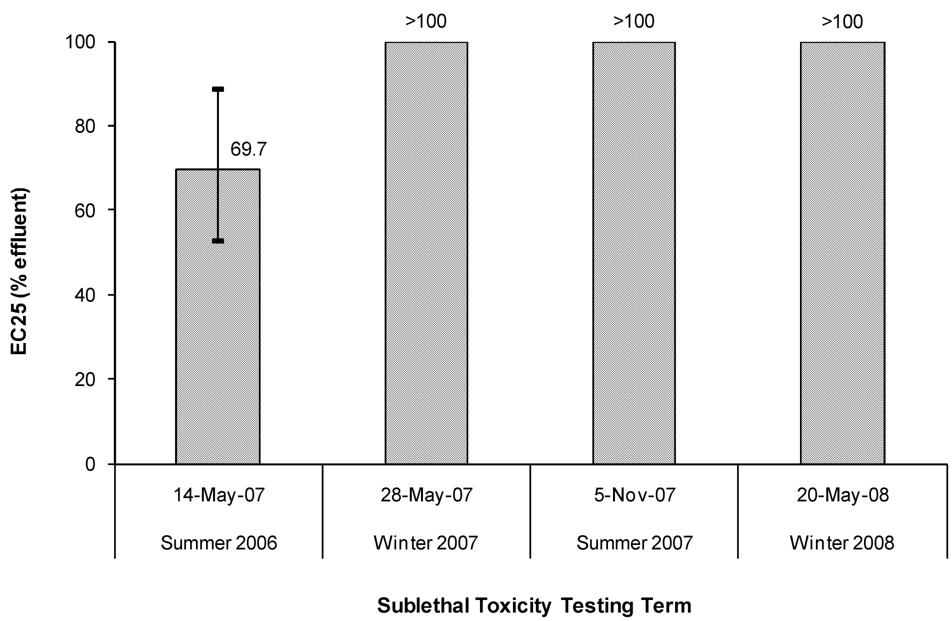
Northwood conducted six sublethal toxicity tests between winter 2007 and summer 2009. Results of these six tests are presented herein. Appendix A1 provides a summary of Northwood Cycle Five sublethal toxicity test results, including dose-response plots for all tests conducted.

3.3.1 Rainbow Trout Early Life Stage Development Test

During summer 2006 (test date of November 2006), a power outage at the laboratory resulted in test temperatures below test requirements and the absence of aeration for portions of the rainbow trout early life stage development test. The test control survival did not meet QA/QC requirements (>70%, Environment Canada 2005a) and, consequently, test results were considered invalid. The rainbow trout test was redone in May 2007 when rainbow trout eggs were again available. The result of the summer 2006 re-test (EC25 of 69.7%) has been incorporated into results previously reported for Cycle Four and is included in the summary calculations in this report.

Figure 3.2 presents a summary of Cycle Four summer 2006 and Cycle Five EC25 results and confidence limits for the rainbow trout embryo viability tests conducted on Northwood effluent samples. The rainbow trout test was dropped from the EEM program after winter 2008 (Government of Canada 2008).

Figure 3.2 Effect of exposure to Canfor Northwood effluent on early life stages of rainbow trout (*Oncorhynchus mykiss*), expressed as EC25 ± 95% confidence limits, EEM Cycle Five (and summer 2006).



EC25 results for embryo viability for Cycle Five were >100% v/v effluent, for a geometric mean of >100% (using 100% to represent >100% in the geomean calculations). Results indicated lower toxicity relative to Cycle Four, where EC25s of 69.7 to >100% v/v effluent were observed. No substantial temporal changes in relative toxicity were observed between winter 2007 and winter 2008.

3.3.2 Invertebrate Reproduction and Survival Tests

Invertebrate reproduction (IC25) and survival (LC50) results for *Ceriodaphnia dubia* are summarized in Figure 3.3 and Figure 3.4.

Reproduction IC25 results ranged from 10.3 to 59.3% v/v effluent for a geometric mean of 29.8%. Results were similar to Cycles Three and Four, where the geometric means of IC25s were 22.3 and 21.8% v/v effluent, respectively. Invertebrate reproduction IC25 results were relatively consistent for Cycle Five and no temporal trend in toxicity was observed.

Consistent with all previous cycles, no effect of effluent was noted on invertebrate survival (i.e., LC50 >100% v/v effluent).

Figure 3.3 Effect of exposure to Canfor Northwood effluent on invertebrate reproduction using *Ceriodaphnia dubia*, expressed as IC25 ± 95% confidence limits, EEM Cycle Five.

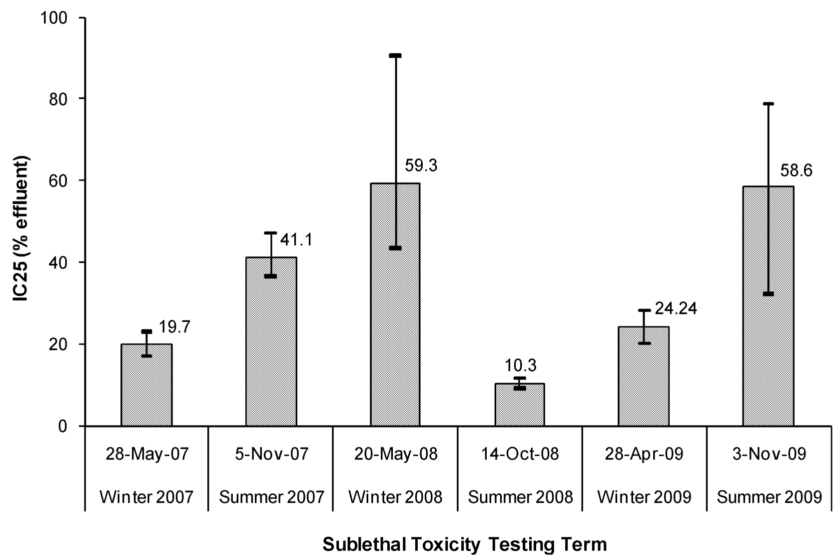
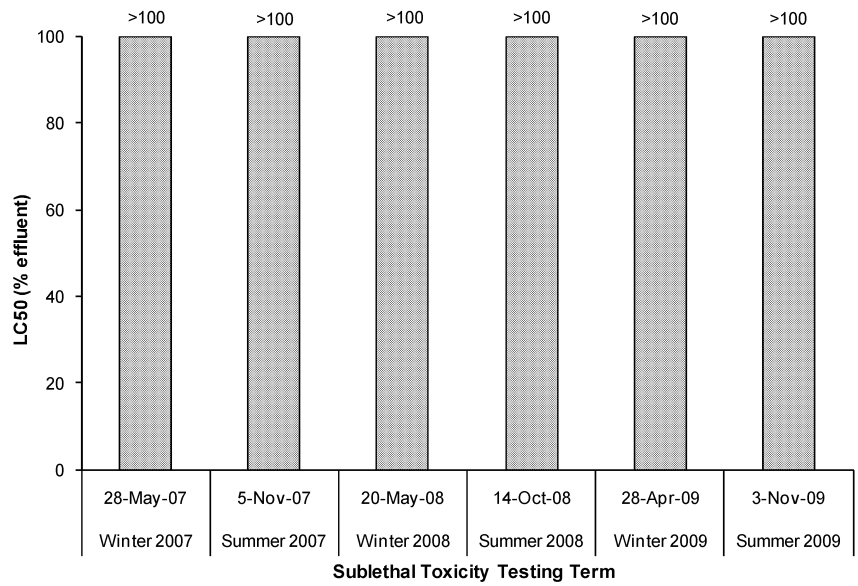


Figure 3.4 Effect of exposure to Canfor Northwood effluent on invertebrate survival using *Ceriodaphnia dubia*, expressed as LC50 ± 95% confidence limits, EEM Cycle Five.

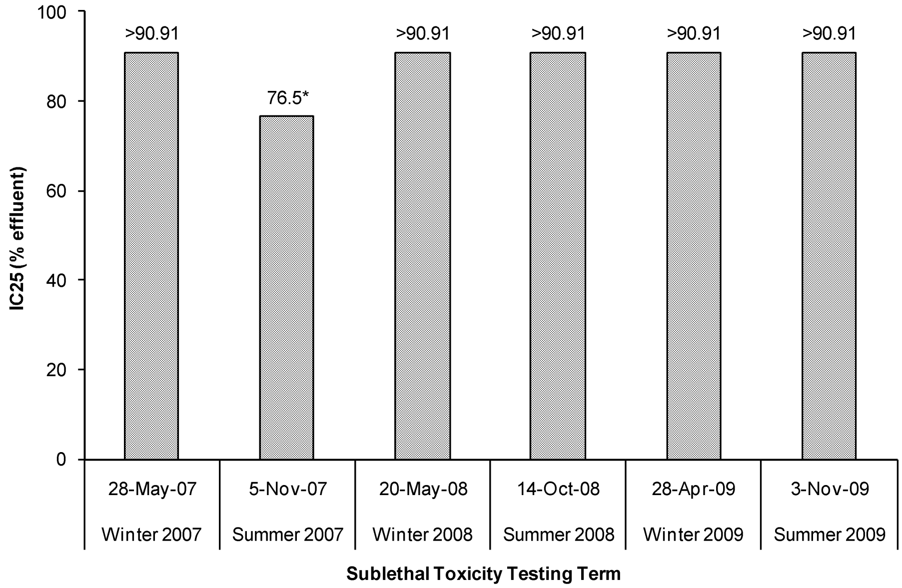


3.3.3 Algal Growth InhibitionTest

The IC25 results and confidence limits for the algal growth tests are summarized in Figure 3.5.

Growth IC25s ranged from 76.5 to >90.9% v/v effluent for a geometric mean of 88.3% (using 90.9% to represent >90.9% in the calculation). The original dose response curves show that hormesis was present in each test during Cycle Five (Appendix A1). A comparison among EEM cycles indicated less toxicity in Cycle Five compared to the previous four cycles. Five of the six testing terms for algal growth did not indicate any effluent toxicity.

Figure 3.5 Effect of exposure to Canfor Northwood effluent on algal growth using *Pseudokirchneriella subcapitata*, expressed as IC25 ± 95% confidence limits, EEM Cycle Five.



* 95% confidence limits could not be calculated by ToxCalc© Software (upper confidence limit exceeded 90.91%).

3.3.4 Maximum Potential Zone of Sublethal Effect

The 1% zone of effluent concentration for the Northwood mill has been estimated to extend 7,000 m downstream of the effluent diffuser during the lowest water discharge (i.e., worst-case dilution conditions) of the Fraser River (Hatfield Consultants 1994, Colodey *et al.* 1999), extending from the Northwood mill diffuser in the Fraser River to immediately upstream of the Prince George/ Intercontinental mills. Table 3.1 and Figure 3.6 present the geometric means of endpoint results for each test species for all cycles. Table 3.1 also presents the maximum potential zone of sublethal effect. Calculations of geometric means and maximum potential zones of sublethal effects can be found in Appendix A1.

The maximum zone of sublethal effect for rainbow trout survival decreased from 78 m in Cycle Four to <70 m in Cycle Five. The zone decreased for invertebrate reproduction from 320 m in Cycle Four to 235 m in Cycle Five. A maximum potential zone of sublethal effect could not be calculated for invertebrate survival since no sublethal toxicity has been observed in any cycle. The algal growth test results showed a decrease in the zone of sublethal effect from 86 m to 79 m between Cycles Four and Five; this zone has decreased consistently since the EEM program began.

Effluent concentrations equal to the geometric mean of the IC25, EC25, or LC50 results have not been observed downstream of the Northwood diffuser (Hatfield Consultants 1994). The highest concentration of effluent observed immediately downstream of the diffuser was 2.86%, using sodium concentrations as an effluent tracer (Hatfield Consultants 1994). These concentrations are well below the lowest geometric mean (IC25 of 29.8%) calculated for the invertebrate reproduction tests.

Table 3.1 Maximum potential zones of sublethal effect, Canfor Northwood mill, EEM Cycles One to Five.

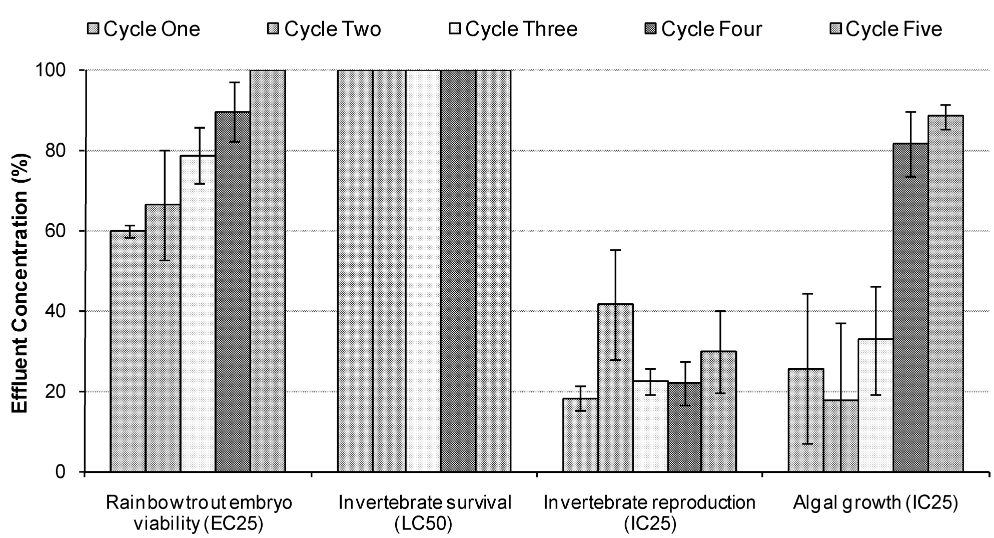
Sublethal Toxicity Test Species	IC25 / EC25 / LC50 Geometric Mean (% v/v)					Maximum Potential Zone of Sublethal Effect[1] (m)				
	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
Rainbow Trout Viability EC25	59.8%	70.0%	78.6%	89.5%[2]	>100%[3]	117 m	100 m	89 m	78 m[2]	<70 m[3]
Invertebrate Reproduction IC25	18.2%	41.6%	22.3%	21.9%	29.8%	385 m	168 m	314 m	320 m	235 m
Invertebrate Survival LC50	>100%	>100%	>100%	>100%	>100%	<70 m	<70 m	<70 m	<70 m	<70 m
Algal Growth IC25	25.5%	17.5%	32.6%	81.6%	88.3%	274 m	401 m	215 m	86 m	79 m

[1] Based on a 1% effluent zone of 7,000 m.

[2] Revised with updated summer 2006 results.

[3] Rainbow trout geometric means and potential zones are based on three tests given this toxicity test was not required after winter 2008.

Figure 3.6 Geometric means of IC25, EC25, and LC50 results from sublethal toxicity tests of Canfor Northwood effluent, EEM Cycle One through Cycle Five.



3.4 CANFOR PULP LIMITED PARTNERSHIP, PG/IC MILLS: TOXICITY TEST RESULTS

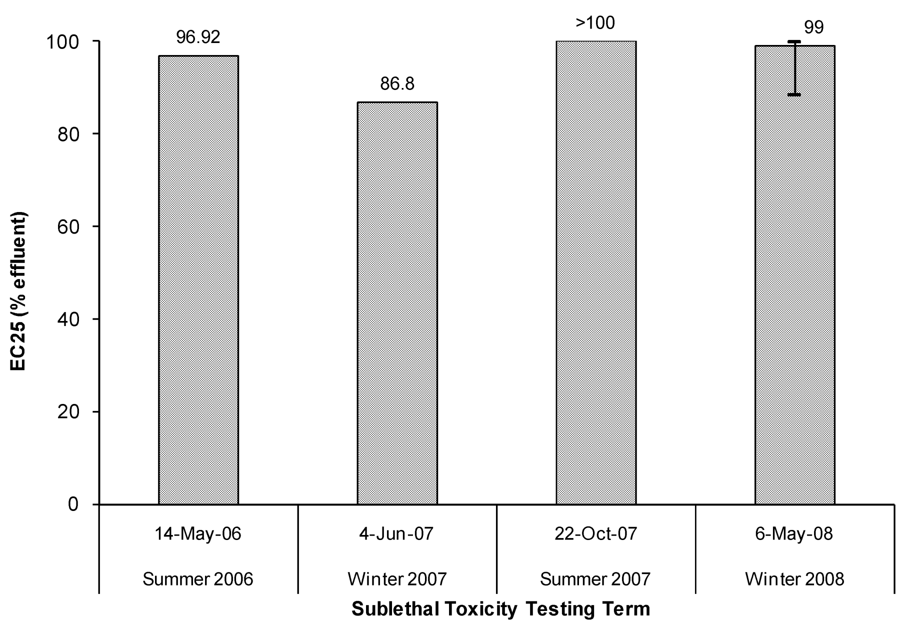
The Prince George and Intercontinental (PG/IC) mills conducted six sublethal toxicity tests between winter 2007 and summer 2009. Results of these tests are presented herein. Appendix A1 provides a summary of PG/IC Cycle Five sublethal toxicity test results, including dose-response plots for all tests conducted.

3.4.1 Rainbow Trout Early Life Stage Development Test

As discussed for the Northwood mill, a power outage resulted in the need to repeat the November 2006 rainbow trout test for the PG/IC mill in May 2007. The result of the summer 2006 re-test (EC25 of 96.9%) has been incorporated into results previously reported for Cycle Four and is included in the summary calculations in this report.

Figure 3.7 presents a summary of Cycle Four summer 2006 and Cycle Five EC25 results and confidence limits for the rainbow trout early life stage development test conducted on PG/IC effluent samples. The rainbow trout test was dropped from the EEM program after winter 2008 (Government of Canada 2008).

Figure 3.7 Effect of exposure to Canfor PG/IC effluent on early life stages of rainbow trout (*Oncorhynchus mykiss*), expressed as EC25 ± 95% confidence limits, EEM Cycle Five (and summer 2006).



EC25 results for embryo viability ranged from 86.8 to >100% v/v effluent during Cycle Five with a geometric mean of 95.1% (using 100% to represent >100% in the calculation). Cycle Five results indicated reduced toxicity relative to Cycle Four (geometric mean 83.6% v/v effluent). The winter 2007 testing term represented the lowest EC25 in Cycle Five; there were no process changes that would account for the lower survival. No temporal trend in toxicity was observed in Cycle Five.

3.4.2 Invertebrate Reproduction and Survival Tests

Invertebrate reproduction (IC25) and survival (LC50) results and confidence limits from Cycle Five tests using *Ceriodaphnia dubia* are summarized in Figure 3.8 and Figure 3.9.

Reproduction IC25 results ranged from 19.6 to 56.1% v/v effluent for a geometric mean of 32.7%, indicating slightly higher toxicity compared to Cycles Two through Four (geometric means ranged from 49.5 to 51.1% v/v effluent). There was a slight decreasing trend in toxicity observed for invertebrate reproduction tests in Cycle Five, with the lowest IC25 observed in winter 2007 and the highest value observed in summer 2009. There were no process changes over the same term; the cause of the increase in toxicity over Cycle Five is unknown.

Figure 3.8 Effect of exposure to Canfor PG/IC effluent on invertebrate reproduction using *Ceriodaphnia dubia*, expressed as IC25 ± 95% confidence limits, EEM Cycle Five.

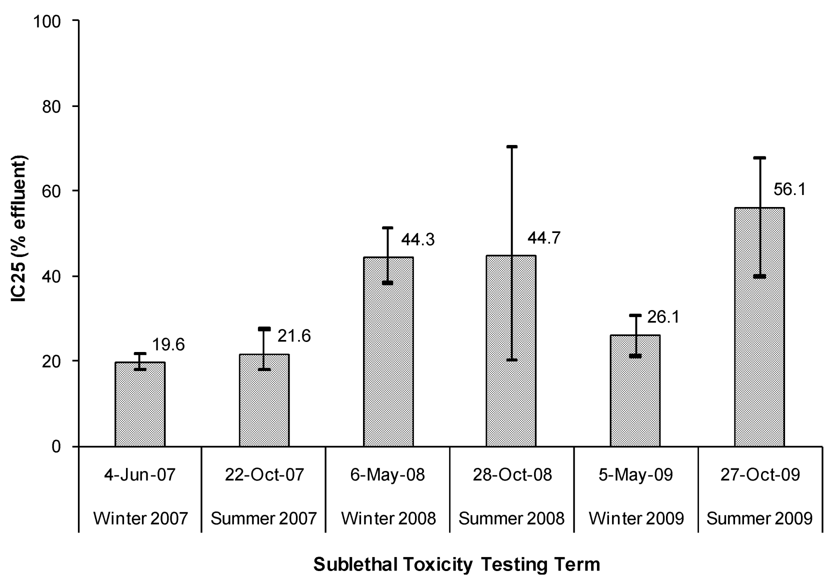
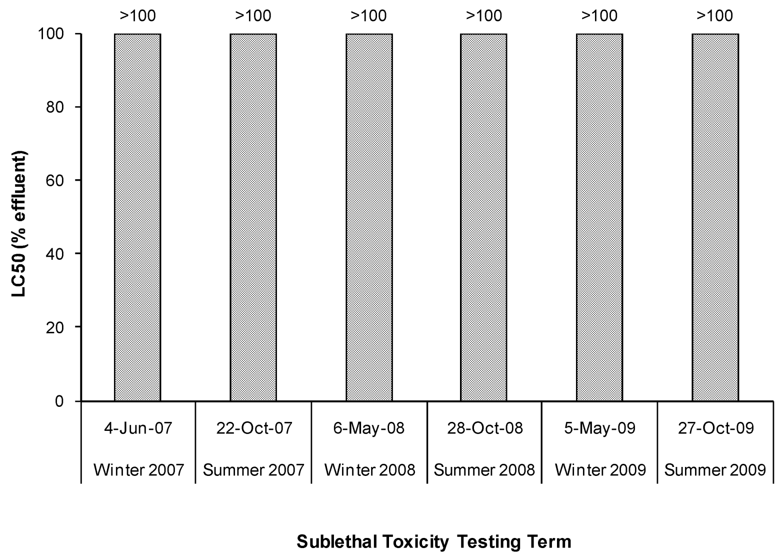


Figure 3.9 Effect of exposure to Canfor Northwood effluent on invertebrate survival using *Ceriodaphnia dubia*, expressed as LC50 ± 95% confidence limits, EEM Cycle Five.



Invertebrate survival was not affected by effluent; LC50 results were >100% v/v effluent for all tests. Results were similar to those observed in all previous cycles.

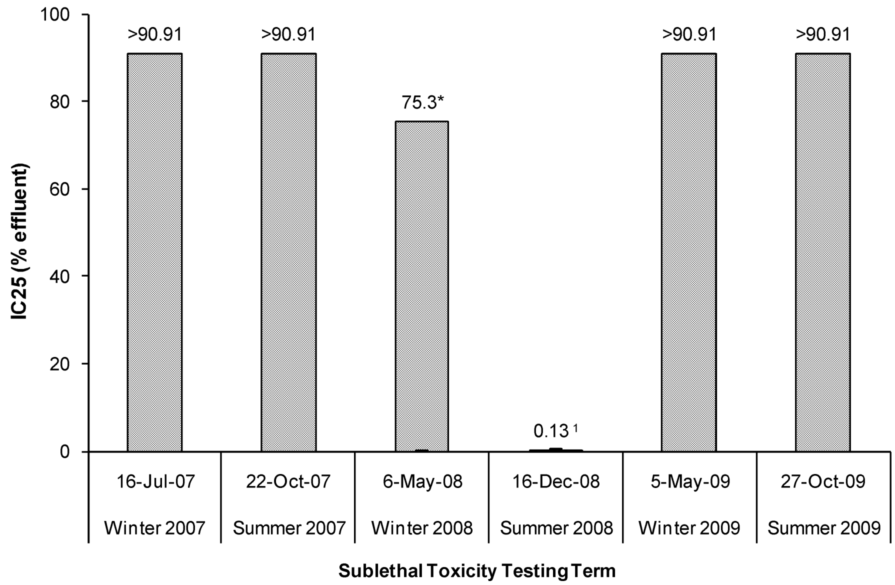
3.4.3 Algal Growth Inhibition Test

The IC25 results and confidence limits for Cycle Five algal growth tests are summarized in Figure 3.10.

Growth IC25 results ranged from 0.13 to >90.9% with a geometric mean of 29.6% v/v effluent for Cycle Five. Four tests demonstrated no toxicity to PG/IC effluent, one effluent sample exhibited slight toxicity (IC25 of 75.3%), and the summer 2008[1] test result is being reviewed by Environment Canada. When the summer 2008 IC25 is excluded, the Cycle Five geometric mean is 87.5% v/v effluent, which indicates reduced toxicity relative to Cycle Four (geometric mean of 83.6%).

[1] The reported IC25 result for the summer 2008 test period is currently under review by Environment Canada and may be revisited in the Cycle Six Interpretive Report. This test displayed an unusual dose-response curve (Appendix A1) which showed algal growth inhibition at very low effluent concentrations, inconsistent with results obtained for all other test periods in Cycle Five. A modified regression model was unavailable to accurately interpret these results; therefore, the IC25 calculated is exceedingly low, and resulted in a probable overestimate of effluent toxicity for Cycle Five. Excluding this value from geomean calculations produces a result of 87.5% v/v effluent and a potential zone of sublethal effect of 80 m.

Figure 3.10 Effect of exposure to Canfor PG/IC effluent on algal growth using *Pseudokirchneriella subcapitata*, expressed as IC25 ± 95% confidence limits, EEM Cycle Five.



* 95% confidence limits could not be calculated by ToxCalc © Software (upper confidence limit exceeds 90.91%).

[1] Summer 2008 IC25 calculation is being reviewed. See footnote on the next page.

3.4.4 Maximum Potential Zone of Sublethal Effect

The 1% zone of effluent concentration for PG/IC mills has been estimated to extend 7,000 m downstream from the effluent diffuser during the lowest water discharge of the Fraser River (i.e., worst-case dilution conditions) (Hatfield Consultants 1994, Colodey *et al.* 1999), extending downstream from the effluent diffuser in the Fraser River past the city of Prince George. Table 3.2 and Figure 3.11 present geometric means of IC25, EC25, and LC50 results for each test species for all EEM cycles. Table 3.2 also presents the associated maximum potential zones of sublethal effect calculated for the 1% effluent concentration zone.

The maximum potential zones of sublethal effects are small for PG/IC relative to the estimated 1% effluent zone of 7,000 m. The zone for rainbow trout embryo viability decreased for Cycle Five to 74 m. The zones increased for invertebrate reproduction and algal growth tests to 214 m and 237 m, respectively. No zone of sublethal effect could be calculated for invertebrate survival as no mortality was observed.

Table 3.2 Maximum potential zones of sublethal effect, Canfor PG/IC mills, EEM Cycles One to Five.

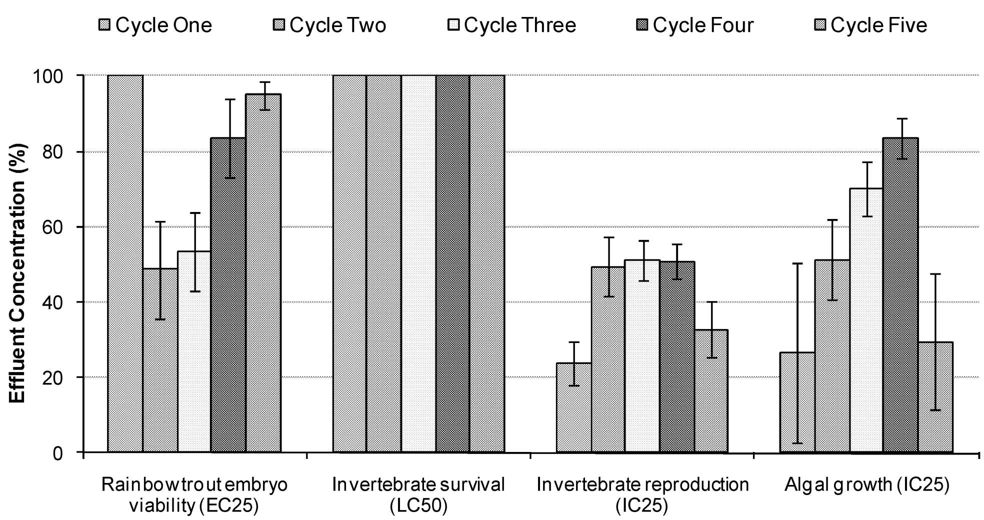
Sublethal Toxicity Test Species	IC25 / EC25 / LC50 Geometric Mean (% v/v)					Maximum Potential Zone of Sublethal Effect[1] (m)				
	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
Rainbow Trout Viability EC25	>100%	48.6%	53.5%	81.2%	95.1%[2]	<70 m	144 m	131 m	86 m	74 m[2]
Invertebrate Reproduction IC25	23.9%	49.5%	51.2%	50.8%	32.7%	293 m	141 m	137 m	138 m	214 m
Invertebrate Survival LC50	>100%	>100%	>100%	>100%	>100%	<70 m	<70 m	<70 m	<70 m	<70 m
Algal Growth IC25	26.6%	51.4%	70.2%	83.6%	29.6%[3]	263 m	136 m	100 m	84 m	237 m[3]

1 Based on a 1% effluent zone of 7,000 m.

2 Cycle Five geomeans and Potential Zones of Sublethal Effect for rainbow trout viability are based on three test periods. Testing for this species was no longer required after winter 2008.

3 See Footnote 1 for more information regarding the summer 2008 algal growth IC25 and alternate calculations.

Figure 3.11 Geometric means of IC25, EC25, and LC50 results from sublethal toxicity tests of Canfor PG/IC effluent, EEM Cycle One through Cycle Five.



Effluent concentrations equal to geometric means for IC25, EC25, or LC50 results have not been observed in the Fraser River downstream of the PG/IC diffuser (Hatfield Consultants 1994). The highest concentration of effluent observed immediately downstream of the diffuser was 3.35%, based on sodium concentrations (Hatfield Consultants 1994); this concentration is well below the lowest geometric mean (IC25 of 29.6%) calculated for the algal growth test for Cycle Five.

3.5 QUESNEL RIVER PULP COMPANY: TOXICITY TEST RESULTS

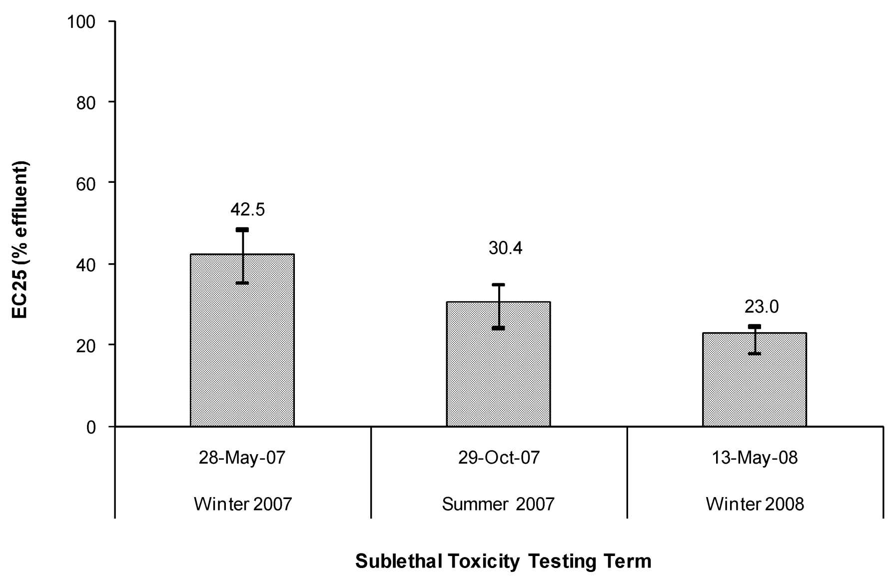
Quesnel River Pulp Company (QRP) conducted six sublethal toxicity tests between winter 2007 and summer 2009. Results of these six tests are presented herein. Appendix A1 provides a summary of Quesnel Cycle Five sublethal toxicity test results, including dose-response plots for all tests conducted.

3.5.1 Rainbow Trout Early Life Stage Development Test

Figure 3.12 presents a summary of Cycle Five EC25 results and confidence limits for the rainbow trout embryo viability test conducted on QRP effluent samples. The rainbow trout test was dropped from the EEM program after winter 2008 (Government of Canada 2008).

EC25 results for embryo viability ranged from 23.0 to 42.5% v/v effluent for a geometric mean of 31.0% for Cycle Five. These results were slightly higher (i.e., less toxic) than those observed in Cycles Two to Four (geometric means of 20.2 to 27.6% v/v effluent). Effluent quality was relatively consistent among sampling dates and no process upsets were reported. Results in Cycle Five were variable and appeared to be decreasing (Figure 3.12).

Figure 3.12 Effect of exposure to QRP effluent on early life stages of rainbow trout (*Oncorhynchus mykiss*), expressed as EC25 ± 95% confidence limits, EEM Cycle Five.

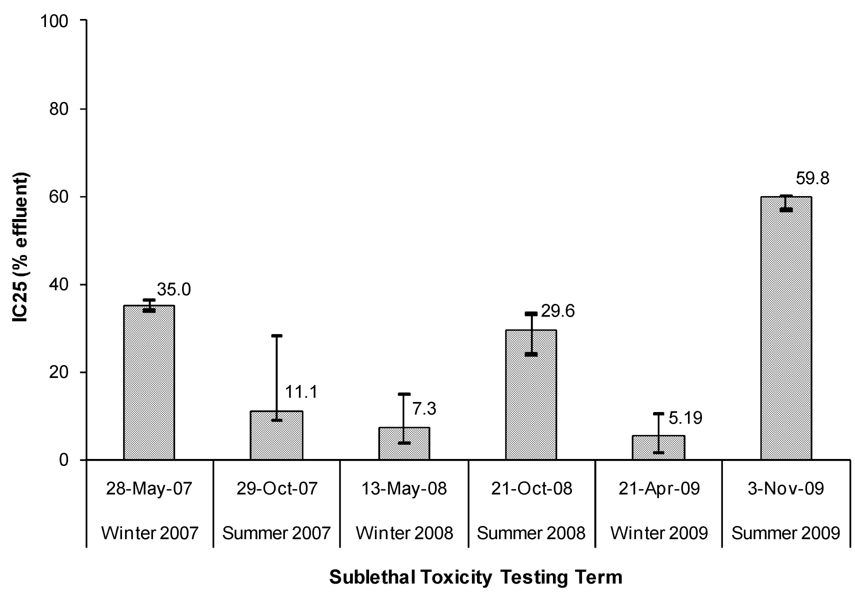


3.5.2 Invertebrate Reproduction and Survival Tests

Invertebrate reproduction (IC25) and survival (LC50) results and confidence limits from Cycle Five for *Ceriodaphnia dubia* are summarized in Figure 3.13 and Figure 3.14.

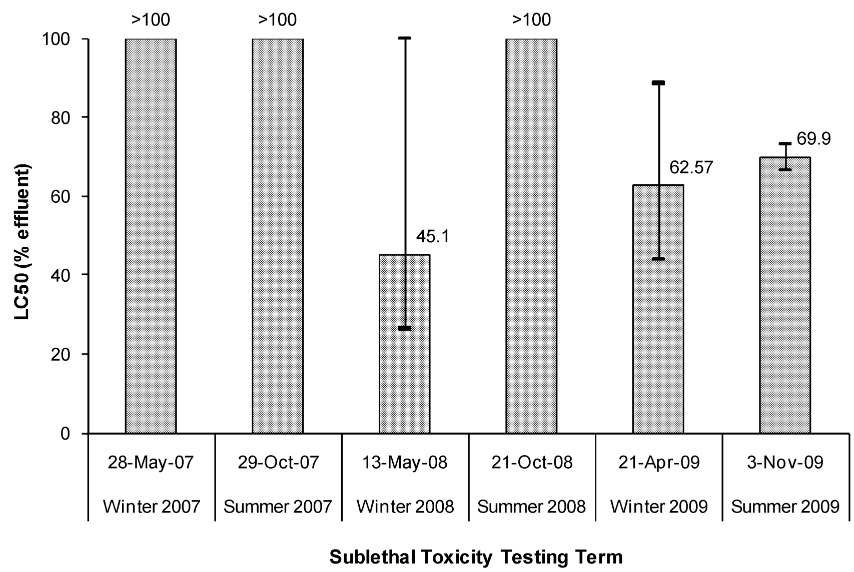
Reproduction IC25 results were variable and ranged from 5.2 to 59.8% with a geometric mean of 17.2%. Results are similar to mean values from Cycles One and Two (15 to 17% v/v effluent), but lower than observed during Cycles Three and Four (geometric means of 21.7 and 22.7%, respectively). There was no temporal trend observed during Cycle Five.

Figure 3.13 Effect of exposure to QRP effluent on invertebrate reproduction using *Ceriodaphnia dubia*, expressed as IC25 ± 95% confidence limits, EEM Cycle Five.



Invertebrate survival LC50 results ranged from 45.1 to >100% with a geometric mean of 76.3% v/v effluent. Results from Cycle Five indicated average toxicity relative to previous cycles (geometric means ranged from 69.6 to 89.8% v/v effluent). Three of the six tests indicated no toxicity of QRP effluent to invertebrate survival during Cycle Five (Figure 3.14).

Figure 3.14 Effect of exposure to QRP effluent on invertebrate survival using *Ceriodaphnia dubia*, expressed as LC50 ± 95% confidence limits, EEM Cycle Five.

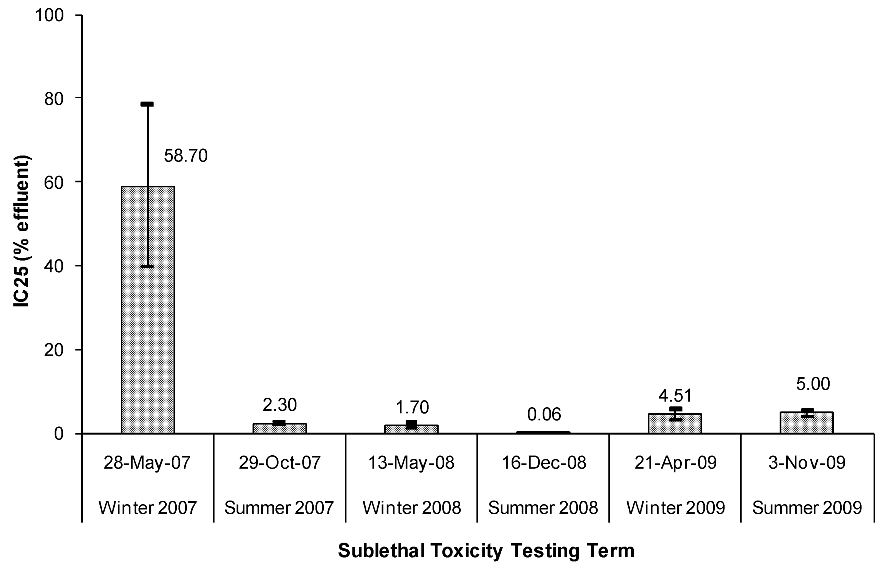


3.5.3 Algae Growth Inhibition Test

The IC25 results and confidence limits for the growth tests using *Pseudokirchneriella subcapitata* are summarized in Figure 3.15.

Growth IC25s ranged from 0.06 to 58.7% v/v effluent, for a geometric mean of 2.6%. These results indicate a lower toxicity in Cycle Five relative to Cycles Two to Four (geometric means ranged from 0.12% to 1.8% v/v effluent). The winter 2007 test yielded the greatest growth (least toxicity; IC25 = 58.7% v/v) during Cycle Five, which is the highest IC25 reported for the algal growth test at QRP. All other IC25s were similar to those reported for previous cycles.

Figure 3.15 Effect of exposure to QRP effluent on algal growth using *Pseudokirchneriella subcapitata*, expressed as IC25 ± 95% confidence limits, EEM Cycle Five.



3.5.4 Maximum Potential Zone of Sublethal Effect

The 1% zone of effluent concentration for Quesnel River Pulp extends a distance of 200 m from the effluent discharge during the lowest water discharge of the Fraser River (i.e., worst-case dilution conditions) (Hatfield Consultants 1994, Colodey *et al.* 1999). Table 3.3 and Figure 3.16 present geometric means for endpoint results for each test species for all EEM cycles. Table 3.3 also provides the associated calculated maximum potential zones of sublethal effect for the 1% effluent concentration zone. Calculations of geometric means and maximum potential zones of sublethal effects appear in Appendix A1.

The maximum potential zones of sublethal effect were very small for three of the four sublethal toxicity tests: rainbow trout embryo viability (6.5 m), invertebrate reproduction (11.8 m), and invertebrate survival (2.6 m). The calculated zones are also comparable to those calculated in previous cycles. In Cycle Five, the algal growth IC25 indicated a much smaller zone relative to Cycle Four (78 m, reduced from 1,640 m). The Cycle Five zone is similar in size to the Cycle One zone (69 m).

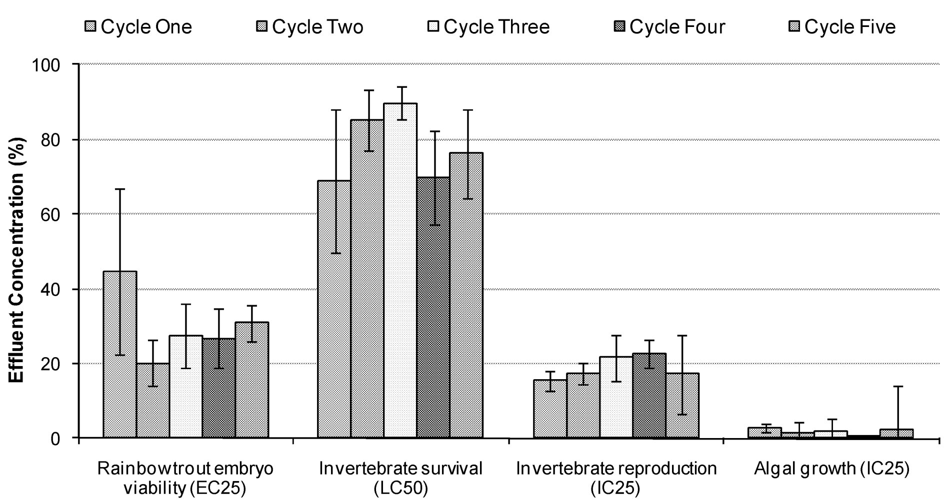
Table 3.3 Maximum potential zones of sublethal effect, Quesnel River Pulp Company, EEM Cycles One to Five.

Sublethal Toxicity Test Species	IC25 / EC25 / LC50 Geometric Mean (% v/v)					Maximum Potential Zone of Sublethal Effect[1] (m)				
	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
Rainbow Trout Viability EC25	44.7%	20.2%	27.7%	26.7%	31.0%[2]	4 m	10 m	7.2 m	7.5 m	6.5 m[2]
Invertebrate Reproduction IC25	15. 5%	17.5%	21.7%	22.7%	17.2%	13 m	11 m	9.2 m	8.8 m	11.6 m
Invertebrate Survival LC50	69.0%	85.3%	89.8%	69.7%	76.3%	3 m	2 m	2.2 m	2.9 m	2.6 m
Algal Growth IC25	2.89%	1.57%	1.85%	0.12%	2.56%	69 m	127 m	108 m	1640 m	78 m

[1] Based on a 1% effluent zone of 200 m.

[2] Rainbow trout geometric means and potential zones are based on three tests given this toxicity test was not required after winter 2008.

Figure 3.16 Geometric means of IC25, EC25, and LC50 results from sublethal toxicity tests of QRP effluent, EEM Cycle One through Cycle Five.



Prior to Cycle Two, a 50 m 1% dilution zone was used. This value was considered a conservative estimate of the 1% dilution zone and was based on plume dispersion studies of sodium and chloride concentrations downstream of the QRP diffuser. These studies documented a maximum effluent concentration downstream of the mill of 0.19% (v/v); therefore, the delineation of a 1% effluent isopleth was somewhat arbitrary, although it was clear that the true area was small (Hatfield Consultants 1994).

In the fall of 2006, river water samples were collected by QRP and analyzed for sodium concentrations to reassess effluent concentrations downstream of the mill. Within 125 m of the mill, the maximum estimated effluent concentration was 0.56%, with four out of the five samples measuring less than 0.25% v/v effluent. These results indicate that the 200 m 1% plume dilution zone is an overestimate; however, it is used as a conservative measure of sublethal toxicity effect from the Quesnel River Pulp diffuser.

Effluent concentrations equal to the geometric means calculated for QRP have not been observed in the Fraser River downstream of the diffuser (Hatfield Consultants 1994). Considering that the highest geometric mean for Cycle Five was 2.56% v/v effluent (IC25 for algal growth), sublethal toxicity impacts of QRP effluent to algae or other organisms are unlikely.

3.6 CARIBOO PULP AND PAPER COMPANY: TOXICITY TEST RESULTS

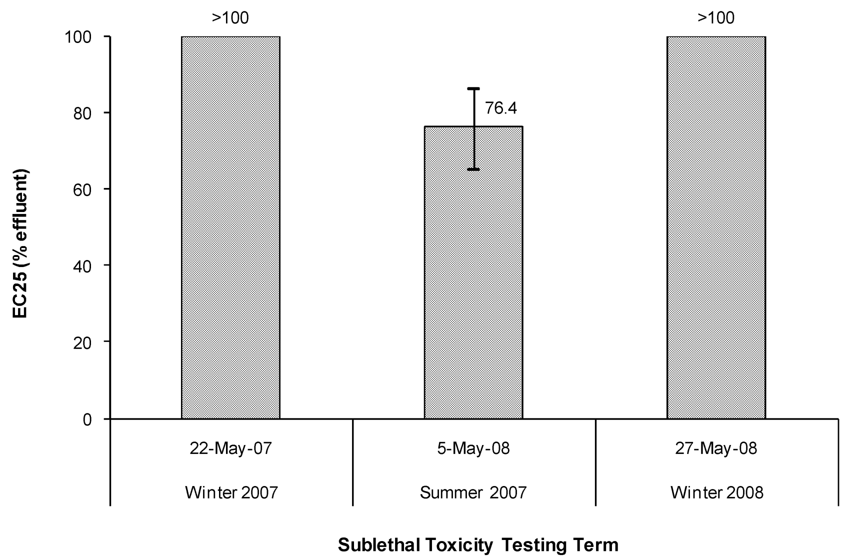
Cariboo Pulp and Paper Company (Cariboo) conducted six sublethal toxicity tests between winter 2007 and summer 2009. Results of these six tests are presented herein. Appendix A1 provides a summary of Cariboo Cycle Five sublethal toxicity test results, including dose-response plots for all tests.

3.6.1 Rainbow Trout Early Life Stage Development Test

Figure 3.17 presents a summary of Cycle Five EC25 results and confidence limits for the rainbow trout embryo viability test for Cariboo. The summer 2007 test did not meet minimum acceptability criteria; therefore, a retest was conducted in May 2008.

EC25 results for embryo viability ranged from 76.4 to >100% v/v effluent for a geometric mean of 91.4%. Results from Cycle Five indicated very low effluent toxicity to rainbow trout, similar to all previous cycles. There were no known process changes during Cycle Five that may have influenced the test on May 5, 2008 (a retest for summer 2007).

Figure 3.17 Effect of exposure to Cariboo effluent on early life stages of rainbow trout (*Oncorhynchus mykiss*), expressed as EC25 endpoints ± 95% confidence limits, EEM Cycle Five.



3.6.2 Invertebrate Reproduction and Survival Tests

Invertebrate reproduction (IC25) and survival (LC50) results and confidence limits from Cycle Five tests for *Ceriodaphnia dubia* are summarized in Figure 3.18 and Figure 3.19.

Reproduction IC25 results were highly variable among testing terms, ranging from 7.6 to >100% v/v effluent with a geometric mean of 29.6%; results were similar those observed in Cycle Four (geometric mean 31.8% v/v effluent). The winter 2007 and 2008 testing results represented the lowest IC25s recorded during the EEM program at Cariboo to date. Invertebrate reproduction IC25 results were variable throughout Cycle Five.

Invertebrate survival LC50 results ranged from 57.3 to >100% v/v effluent (Figure 3.19), with a geometric mean of 85.1%. These results were lower than observed in previous cycles (all IC25 endpoints were >100% v/v effluent). The LC50 for winter 2008 was the lowest reported in Cycle Five (57.3%), and corresponded to the low IC25 value for reproduction. However, that correspondence was not observed during winter 2007 when the LC50 was >100% and reproduction IC25 was 12.9% v/v effluent.

Figure 3.18 Effect of exposure to Cariboo effluent on invertebrate reproduction using *Ceriodaphnia dubia,* expressed as IC25 ± 95% confidence limits, EEM Cycle Five.

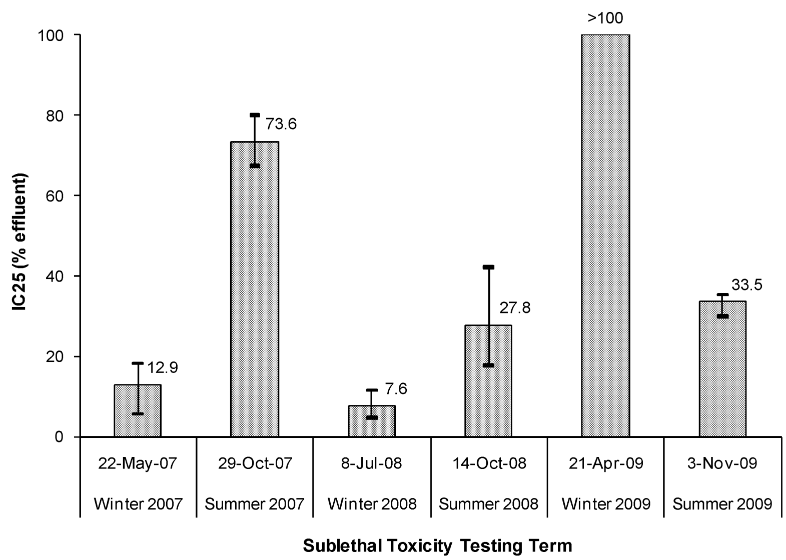
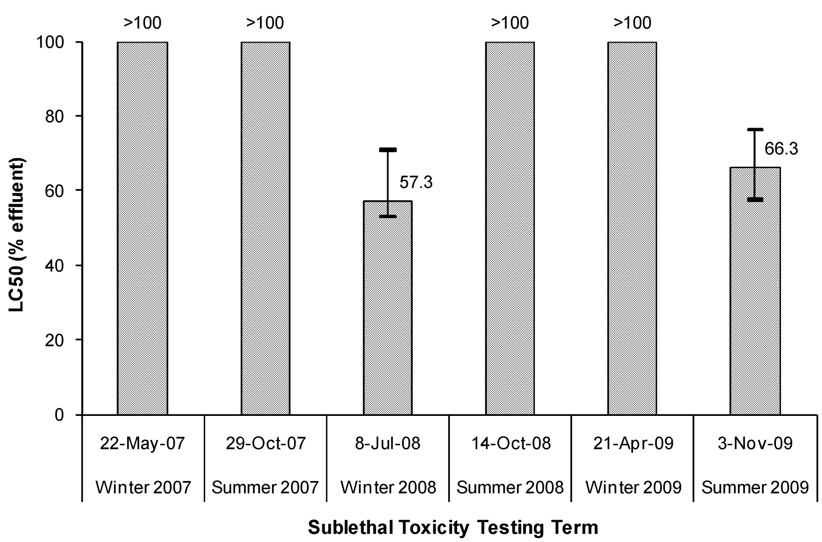


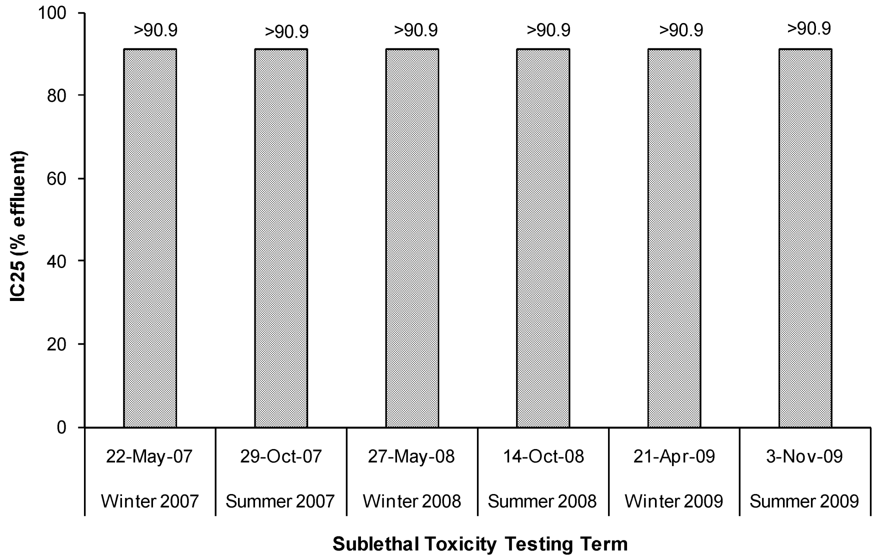
Figure 3.19 Effect of exposure to Cariboo effluent on invertebrate survival using *Ceriodaphnia dubia,* expressed as LC50 ± 95% confidence limits, EEM Cycle Five.



3.6.3 Algal Growth Inhibition Test

The IC25 results and confidence limits for the algal growth tests using *Pseudokirchneriella subcapitata* are summarized in Figure 3.20.

Figure 3.20 Effect of exposure to Carboo effluent on algal growth using *Pseudokirchneriella subcapitata*, expressed as IC25 endpoints ± 95% confidence limits, EEM Cycle Five.



No toxicity to algal growth was observed during Cycle Five for effluent from Cariboo. Growth IC25 results were consistently >90.9% v/v effluent, for a geometric mean of >90.9%. The results of Cycles Four and Five indicate a decrease in effluent toxicity relative to Cycles One to Three (geometric means ranging from 40.8 to 69.1% v/v effluent) for the algal growth test.

3.6.4 Maximum Potential Zone of Sublethal Effect

The 1% zone of effluent concentration for Cariboo extends between 4,000 m (Colodey *et al.* 1999) and 4,500 m (Hatfield Consultants 1994) downstream of the effluent discharge during the lowest annual river flow (i.e., worst-case dilution conditions). Table 3.4 and Figure 3.21 present geometric means of IC25, EC25, and LC50 results for each test species for all EEM cycles. Table 3.4 also presents associated maximum potential zones of sublethal effect calculated using the 4,500 m extent for the 1% effluent concentration zone. Calculations of geometric means and maximum potential zones of sublethal effects appear in Appendix A1.

The maximum potential zones of sublethal effect for Cycle Five are slightly larger for rainbow trout and invertebrate reproduction and survival relative to Cycle Four. An accurate maximum zone of sublethal effect could not be calculated for the algal growth test as no toxicity was observed this cycle.

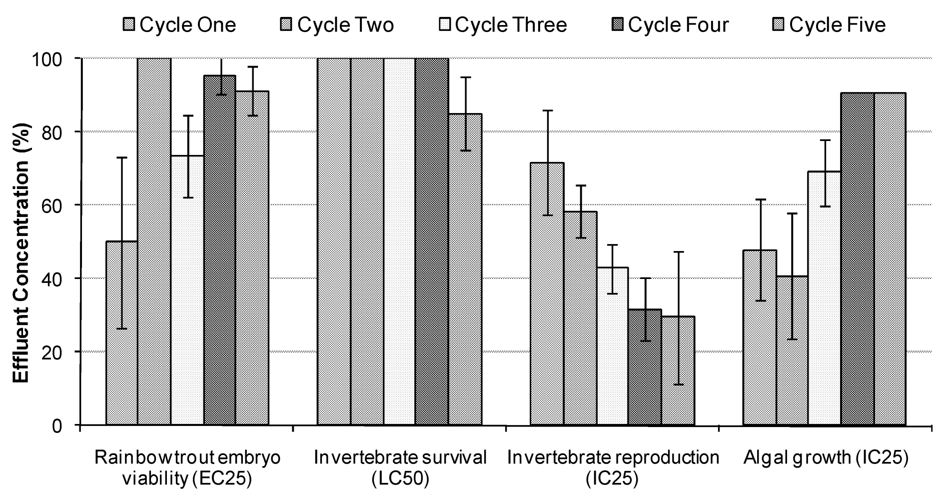
Table 3.4 Maximum potential zones of sublethal effect, Cariboo Pulp and Paper Company, EEM Cycles One to Five.

Sublethal Toxicity Test Species	IC25 / EC25 / LC50 Geometric Mean (% v/v)					Maximum Potential Zone of Sublethal Effect[1] (m)				
	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
Rainbow Trout Viability EC25	50.0%	>100%	73.5%	95.5%	91.4%[2]	90 m	<45 m	61 m	47 m	49 m[2]
Invertebrate Reproduction IC25	71.9%	58.5%	43.0%	31.8%	29.6%	63 m	77 m	105 m	141 m	152 m
Invertebrate Survival LC50	>100%	>100%	>100%	>100%	85.1%	<45 m	<45 m	<45 m	<45 m	53 m
Algal Growth IC25	48.0%	40.8%	69.1%	>90.9 %	>90.9 %	94 m	110 m	65 m	<50 m	<50 m

[1] Based on a 1% effluent zone of 4,500 m.

[2] Rainbow trout geometric means and potential zones are based on three tests given this toxicity test was not required after winter 2008.

Figure 3.21 Geometric means of IC25, EC25, and LC50 results from sublethal toxicity tests of Cariboo effluent, EEM Cycle One through Cycle Five.



Effluent concentrations equal to geometric means of IC25, EC25, or LC50 results have not been observed downstream of the Cariboo diffuser (Hatfield Consultants 1994). The highest concentration of effluent documented immediately downstream of the diffusers was 1.24% using sodium concentrations as a tracer for effluent (Hatfield Consultants 1994). This concentration is well below the lowest geometric mean calculated for Cycle Five (IC25 of 29.6% for invertebrate reproduction).

3.7 CONCLUSIONS

Toxicity testing results contribute to the overall weight-of-evidence used to assess potential environmental effects of effluent discharges. However, laboratory toxicity test results must be interpreted with some caution, as they may not accurately predict toxicity in natural receiving environments. Toxicity tests utilize single species that may or may not be found in the study area, and they do not incorporate factors such as characteristics of the receiving environment.

Northwood Mill

In general, Cycle Five sublethal toxicity results improved from Cycle Four, with the toxicity of effluent slightly below what was reported in previous cycles. An enhancement of algal growth at lower concentrations of effluent was noted in all samples. Based on invertebrate reproduction and low river flow conditions, the maximum potential zone of sublethal effect was estimated to be 235 m downstream of the Northwood diffuser.

PG/IC Mills

Cycle Five sublethal toxicity results were variable, although a trend of lower toxicity was observed for the rainbow trout early life stage test up to its removal from the EEM program in 2008. Invertebrate reproduction results indicated slightly higher effluent toxicity during Cycle Five compared to previous cycles. The algal growth tests were relatively consistent, with the exception of the summer 2008 test, which exhibited a low IC25 of 0.13%. This test, and the calculation of the IC25 endpoint, is being reviewed by Environment Canada. In four algal growth tests, enhancement of growth was observed at lower concentrations of effluent. The maximum potential zone of sublethal effect was estimated to be 214 m downstream of the diffuser for invertebrate reproduction, and 237 m for algal growth.

Quesnel River Pulp Company

Sublethal toxicity tests conducted during Cycle Five exhibited similar results to previous cycles for all test organisms. Sublethal toxicity results exhibited some variability; however, no temporal trend was observed over Cycle Five. Unlike other mills, an enhancement of algal growth at low concentrations of effluent was not noted in any of the tested samples. Based on algal growth results and low river flow conditions, the maximum potential zone of sublethal effect of QRP's effluent was estimated to be 78 m downstream of the diffuser.

Cariboo Pulp and Paper Company

Sublethal endpoints were more variable throughout Cycle Five than during Cycle Four. In comparison to previous cycles, invertebrate reproduction continued to show an increased toxicity response. Similarly, rainbow trout early life stage and invertebrate survival tests indicated toxicity of effluent was higher than previous cycles, although toxicity was observed at concentrations well above what occurs in the receiving environment. An enhancement of algal growth at lower concentrations of effluent was noted in most samples. Based on invertebrate reproduction results and low river flow conditions, the maximum potential zone of sublethal effect of Cariboo's effluent was estimated to be 152 m downstream of the diffuser.

4.0 FISH POPULATION SURVEY

Summary of Fish and Fish Resources for the upper Fraser River mills, September 2009:

- A non-lethal survey, with a lethal sub-component, of juvenile chinook populations was conducted in four study areas, including Shelley (reference) and Prince George (near-field) in the Prince George region, and Cottonwood (reference) and Quesnel (near-field) in the Quesnel region;
- Fish collection was completed by shoreline seining in each area; the target number of 100 juvenile chinook was achieved in each of the four study areas;
- Catch-per-unit-effort (CPUE) for juvenile chinook was highest at Cottonwood (33.3 fish per seine), with CPU ranging from 12.5 to 14.3 fish/seine at the other three sampling locations;
- Juvenile chinook length-frequency distributions from the Prince George near-field area differed significantly from the Shelley reference area; no difference was observed between the Quesnel near-field and reference areas;
- Length and weight measurements for Prince George juvenile chinook were significantly smaller than Shelley reference fish; there was no significant difference between fish from Cottonwood and Quesnel;
- Condition was significantly lower in Quesnel juvenile chinook relative to Cottonwood fish; there was no difference among Prince George and Shelley fish;
- Liver weight (20 fish per area) was significantly higher in Prince George juvenile chinook relative to Shelley fish; no difference was observed among Quesnel reference and exposure area fish;
- Liver weight of Prince George near-field juvenile chinook indicated a potential increase in energy storage. Quesnel juvenile chinook reflected a response of lower energy storage (condition) relative to the Cottonwood reference area;
- Responses of effect endpoints during Cycle Five both the Prince George and Quesnel regions were variable compared to previous cycles using largescale suckers. There was no clear evidence of enrichment from pulpmill effluent in either the Quesnel or Prince George regions; and
- Statistical differences observed during the juvenile chinook survey are most likely the result of very large sample sizes (100 fish per area), which results in very small differences being assessed as significant.

4.1 INTRODUCTION

The EEM fish survey incorporates a sentinel species monitoring approach to assess the effects of pulpmill effluent on wild fish populations. The performance (e.g., growth, reproduction, survival, or condition) of one or two selected fish species inhabiting the effluent receiving environment are characterized relative to unexposed or reference fish. The underlying premise of the monitoring approach is that the status of the sentinel species is a reflection of the overall condition of the aquatic environment in which the fish resides.

In EEM Cycle One, largescale sucker (*Catostomus machrocheilus*) and peamouth chub (*Mylocheilus caurinus*) were chosen as sentinel species; however, only largescale sucker were collected in sufficient numbers in all areas (Hatfield Consultants 1997). In EEM Cycle Two, largescale sucker (the only sentinel species examined) were captured in sufficient numbers (Hatfield Consultants 2000a). In EEM Cycle Three, a small-bodied fish reconnaissance survey was unsuccessful in identifying an alternate sentinel fish species. Accordingly, a fish survey using largescale sucker as the sentinel species was completed for EEM Cycle Three (Hatfield Consultants 2004), which observed that the proportion of largescale sucker that was likely to spawn in spring ranged from 37 to 49% of females and 31 to 88% of males. In response to the difficulty of capturing adequate numbers of sexually mature adult largescale sucker, a non-lethal survey of largescale sucker condition and growth was conducted for EEM Cycle Four (Hatfield Consultants 2007). Characteristics of near-field largescale sucker in both the Prince George and Quesnel regions generally reflected a response to an increase in the availability of food resources, with largescale sucker length-frequency distributions from both near-field areas differing significantly from their respective reference areas. However, challenges using largescale sucker still occur, such as difficulties catching male fish, and identifying fish <76 mm long.

A conference call was held in January 2009 with scientists on the EEM Science Advisory Committee, Drs. Kelly Munkittrick, (University of New Brunswick, St. John, NB) and Mark McMaster (National Water Research Institute, Burlington, ON), to discuss the results of previous cycles and identify possible approaches for the Cycle Five fish survey. Two options were proposed: (1) repeat the Cycle Four non-lethal study of largescale sucker, or (2) conduct a non-lethal study with juvenile chinook (with a lethal sub-component) and pool and analyze the largescale sucker data collected during previous cycles. The two options were initially presented to Drs. Munkittrick and McMaster, and later to the LMC for discussion. An agreement was reached that the juvenile chinook study option, as described in the Upper Fraser River Cycle Five Design Document (Hatfield 2009a), be undertaken. The advantages of this study design included:

- Consistency with methods described by Gray *et al*. (2002) and recognized as an approved approach for EEM;
- Selection of a fish species that is abundant throughout the study area;
- Ability to assess traditional effects endpoints, such as body size, condition, and growth, using non-lethal length and weight data;
- Targeting a sedentary life-stage of chinook; and
- Limiting sampling impact on wild fish populations by incorporating a less destructive methodology for collecting fish data.

A subset of juvenile chinook were to be lethally sampled for liver size estimates. An attempt would also be made to collect bile for analysis of resin acid metabolites as a tracer for effluent exposure. In addition, existing largescale sucker data from previous cycles would be synthesized and reported to further discuss the hypothesis of a nutrient enrichment response.

4.2 METHODS

4.2.1 Sampling Areas

The juvenile chinook survey for the EEM Cycle Five program focused on reference and exposed fish populations from two regions:

Prince George Region

- Reference area at Shelley - upstream reference area for both Prince George mills (Northwood and PG/IC); and
- Near-field area in Prince George - 1% effluent zones downstream of the Northwood and PG/IC mills.

Quesnel Region

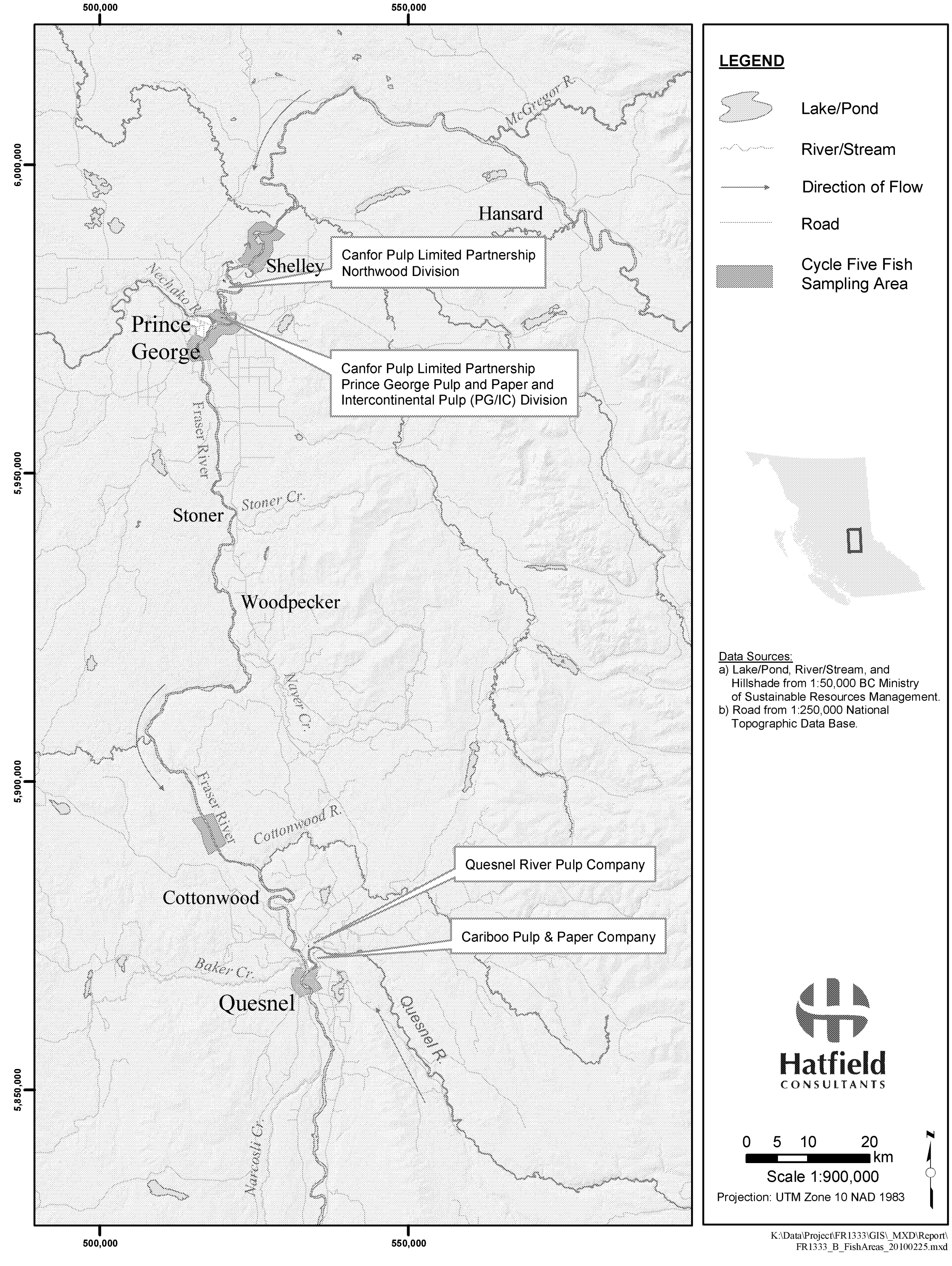
- Reference area near the Cottonwood River – upstream reference area for the Cariboo mill in Quesnel; and
- Near-field area in Quesnel – 1% effluent zone downstream of the Cariboo Pulp and Paper mill.

Table 4.1 and Figure 4.1 provide details on the locations of each sampling area. The Prince George reference area was moved from Hansard to Shelley for Cycle Five because the habitat was more similar to the Prince George exposure area and fish mobility among the two areas was not a concern. Use of the reference area near the Cottonwood River was continued due to the proximity to Quesnel and the similarity in habitat characteristics relative to the Quesnel near-field area.

Table 4.1 Location of fish and water quality sampling areas, Upper Fraser River EEM Cycle Five, September 2009.

Station	Latitude (ddmmss.s)	Longitude (dddmmss.s)	Sampling Date
Shelley (Reference)			
Start Location	540013.7	1223744.2	24 Sep 2009
End Location	540008.1	1223751.8	
Prince George Near-field			
Location	535504.2	1224201.3	25 Sep 2009
Cottonwood (Reference)			
Location	530721.6	1223716.0	26 Sep 2009
Quesnel Near-field			
Location	525730.6	1223052.2	27 Sep 2009

Figure 4.1 Fish and water quality collection areas for the upper Fraser River EEM Cycle Five, September 2009.



K:\Data\Project\FR1333\GIS_MXD\Report\FR1333_B_FishAreas_20100225.mxd

4.2.2 Fish Survey

4.2.2.1 Fish Collections

For fish population surveys, sample sizes must be large enough to allow for sufficient statistical power to detect differences between areas. For non-lethal approaches, sample sizes must also be adequate to provide an accurate representation of each juvenile chinook population as defined by length and weight distributions.

Guidance provided by Gray *et al.* (2002) and the *Pulp and Paper EEM Guidance Document* (Environment Canada 2005a) recommends that at least 100 individual fish be collected from each study area. Fall was selected for the Cycle Five fish survey as it would provide an additional measure of certainty that sampled fish are sedentary, as juvenile chinook begin to exhibit overwintering behaviour at this time of year (Healey 1991). It also ensures that all fish sampled are of the "stream-type" life history, limiting the introduction of confounding data related to physiological differences associated with "ocean-type" chinook. The ocean-type chinook migrate to sea within three months of their emergence in the spring, while stream-type overwinter in freshwater systems prior to their sea migration the following spring (McPhail 2007). By late summer, the predominant 1+ age-class remaining in the upper Fraser River is the stream-type young-of-the-year (YOY) chinook (Bradford and Taylor 1997). Further, the timing also takes advantage of low discharge conditions that may reduce the potential for downstream migration of chinook fry (Kjelson *et al.* 1981). This survey was conducted from September 24 to 27, 2009.

All areas sampled during the fish survey were accessed by road and a 6-m aluminum jetboat. Fish were collected by beach seining, using a 30 m long by 2 m deep juvenile seine net with a 5 mm mesh size. Seines were set by pulling the net perpendicular to the shoreline using the jetboat. The net was then pursed in a downstream direction, with two people on shore responsible for retrieving each end of the net. Care was taken to ensure the leadline remained in contact with the river bottom during net retrieval. All seining took place on shallow gravel bars or mid-channel shoals in moderate river flows. All fishing was conducted during morning hours at each site. Live juvenile chinook were placed into a large holding tank filled with ambient river water where they were held until 100 fish were collected (approximately 2 hours holding time). Oxygen levels in the tank were maintained with battery-operated aquarium bubblers and water was refreshed regularly. All non-target fish species were immediately released. Records were not kept of the by-catch as it was felt that released fish were likely being recaptured in subsequent seines.

4.2.2.2 Fish Measurements

All biological data collected from fish specimens were recorded on fish collection data sheets. Individual fish were removed from the tank, measured for fork length (± 1 mm) and total body weight using an Ohaus Scout Pro digital balance (±0.1 g). An external pathology examination (e.g., eyes, skin, fins, gills, and opercles) was conducted on each fish.

Liver weights were measured with an UWE NJW-3000 jewelers balance (±0.001 g) after anesthetizing fish with alka-seltzer (one tablet per four litres of water), sacrificing, and dissecting a subset of 20 specimens randomly selected for lethal sampling. Whole gall bladders from these fish were placed into a vial for one composite sample per area; the vial was immediately placed on dry ice for storage.

4.2.2.3 Whole-organism Metrics

Various metrics were used to assess and compare fish size and growth between exposure areas.

Growth

- Size – mean fork length and body weight comparisons between areas; and
- Condition – relationship between body weight and fork length (i.e., describes how "fat" fish are); analyzed by ANCOVA (length as the covariate), as well as the descriptive index of K, defined as:

$$K = [\text{body weight (g)} / (\text{fork length (cm)})^3] \times 100$$

Liver Size

- Liver-Somatic Index – a expression of the relative weight of liver versus body weight; analyzed by ANCOVA (body weight as the covariate), as well as the descriptive index of LSI, defined as:

$$LSI = (\text{Liver Weight} / \text{Body Weight}) \times 100$$

4.2.3 Statistical Analyses

Statistical analyses of fish survey data were conducted separately for the Prince George and Quesnel regions. Fish data analyses were completed using SYSTAT v.10/v.11 statistical software (SPSS Inc. 2000). Comparisons of fork length, body weight and condition by area were conducted on all data; analyses using liver weights were conducted on sacrificed fish.

Table 4.2 Definition of whole-organism metrics assessed for the juvenile fish survey, Upper Fraser River EEM Cycle Five.

Type of Response	Parameter	Dependent Variable (Y)	Covariate (X)	Statistical Procedure
Size Distribution	Frequency	Length	None	K-S[1]
Energy Expenditure	Size	Fork Length	None	ANOVA
		Body Weight	None	ANOVA
Energy Storage	Condition	Body Weight	Fork Length	ANCOVA
	LSI	Liver Weight	Body Weight	ANCOVA

Table modified from Environment Canada (2005a).
[1] K-S is the Kolmogorov-Smirnov test.

Whole-Organism Metrics

An analysis of variance was used to compare mean fork length and mean total body weight among reference and near-field areas in each study region. Assumptions of ANOVAs were tested using residual plots. Data were log_{10}-transformed if data did not meet assumptions of ANOVA. If, after log_{10}-transformation, the data still did not meet the assumptions of ANOVA, the non-parametric counterpart to an ANOVA was performed on ranked data.

Analysis of covariance (ANCOVA) was used to compare relationships between exposure areas and their respective reference areas for condition and liver size. An assumption of the ANCOVA model is that the slopes of the regression lines are equal between areas. Generally, ANCOVA is fairly robust even when slopes are not equal, so slopes were only considered different when $p<0.01$ (Paine 1998). If slopes were considered statistically different, scatterplots were used to qualitatively assess differences between areas.

Statistical results in this survey were assessed at a significance level of $\alpha=0.10$ and $P=0.90$ (i.e., $\alpha=\beta=0.10$).

Outliers

Data were initially screened for potential outliers through visual examination of scatter plots. ANOVAs and ANCOVAs that generated Studentized Residuals (SRs) greater than four standard deviations (i.e., SR>4) from the cell mean were removed and the analysis repeated (Grubbs 1971). If any new outliers (SR>4) occurred, they were removed and the analysis was again repeated. No further outliers were deleted after this point.

Determination of Effects

Results from ANOVAs and ANCOVAs were used to determine whether there were effects on fish in the exposure area. An effect is defined as a statistically significant difference ($p<0.10$) in metrics including age, size-at-age, and condition between reference and exposure areas (Environment Canada, 2005a). If a statistically significant difference was observed, the direction and magnitude of the effect was calculated.

To calculate the magnitude and direction of the effect, the percent difference between near-field and reference areas was determined as follows:

% difference = 100 * ([Exposed Area LSM / Reference Area LSM] – 1);

Where LSM = least-square means from the ANOVA or ANCOVA.

The percent difference was then compared to critical effect sizes defined by EEM to determine if magnitude and extent monitoring had been triggered. Magnitude and extent monitoring is triggered when a statistically significant difference which exceeds the critical effect sizes is observed for at least one of the effects metrics (e.g., effect size for condition is ±10% the reference area mean) for two consecutive cycles (Environment Canada 2005a).

Power Analysis

Power analysis was used to evaluate the possibility of falsely negative results (i.e., concluding that no difference in fish response exists when in fact a difference does exist). *A posteriori* power analysis was conducted for condition and liver weight to evaluate the adequacy of the study design. *A posteriori* power analyses were used to evaluate the ability to detect a 10% difference in condition factor, or 25% difference in liver weight, between areas (e.g., reference vs. near-field). Statistical comparisons were considered to have sufficient power when $P \geq 0.90$ ($P = 1-\beta$, probability of detecting an effect size). The power of a test was calculated using the mean squared error (MSE) term from the ANCOVA, which provides an estimate of between-area variance in relative condition, using methods described in Cohen (1998). Power analysis was not conducted in cases where the ANCOVA was significant because sufficient power existed to allow a statistically significant outcome. *A priori* analysis also was conducted to determine the number of fish that would be required in future programs to provide the recommended level of power. All analyses were conducted using G*Power software (Faul and Erdfelder 1992), using methods described in Cohen (1998).

4.3 CHEMICAL TRACERS

Mills are required, where practical, to provide confirmation at the time of field sampling that the sampling conditions are representative of typical effluent exposure. The selection of a tracer depends on the type of mill involved and the complexity of the receiving environment. Resin acids have been identified as a useful tracer in fish for mills that use at least 50% softwood furnish and for effluents that have concentrations of resin acids equal or greater than 50 µg/L. In receiving waters, sodium has been used as an effluent tracer chemical.

Bile was collected from 20 juvenile chinook per area that had been sacrificed to obtain liver size measurements (see section 4.2.2.2). Quantities of bile were limited given the small size of fish. All 20 bladders were combined to create one composite sample per area. Vials containing bile were immediately frozen on dry ice and shipped to ALS in Edmonton for analysis.

In addition, water quality samples were collected in triplicate from the near-field and reference areas in conjunction with the fish survey; a single effluent sample was collected from each pulp mill during the field survey for sodium analyses. See Section 4.4.1 for information on water and effluent quality sampling and analyses.

4.4 SUPPORTING ENVIRONMENTAL VARIABLES

4.4.1 Water and Effluent Quality

EEM Cycle Five guidelines required that a number of supporting variables be measured in the receiving environment and effluent to aid in the interpretation of the fish and benthic invertebrate surveys (Environment Canada 2005a).

Standard *in situ* water quality variables that were measured include:

- Water temperature;
- Dissolved oxygen;
- pH;
- Conductivity; and
- Secchi depth.

Water and effluent samples were also collected for laboratory analysis of:

- Hardness;
- Sodium (effluent tracer);
- Total phosphorus;
- Total nitrogen; and
- Total organic carbon.

As part of the EEM Cycle Five program, Environment Canada also recommended that certain nutrients be analyzed in water and effluent at all freshwater mills. Consequently, the following variables were also measured during the fish survey:

- Dissolved phosphorus;
- Soluble reactive phosphorus;
- Nitrate-nitrite;
- Ammonia; and
- Dissolved organic carbon.

4.4.1.1 Sample Collection Methods

Water and effluent samples were collected for nutrient, sodium, and hardness analyses. Water samples were collected by hand in glass or plastic containers (Table 4.3). All water samples were collected by hand (0.1 m depth) in the area where fish sampling was conducted. All containers were labeled with station and individual sample identification numbers. Given that three samples were collected at each fish study area, no further duplicate samples were collected. One trip blank was used for QA/QC purposes. Mill personnel collected a grab effluent sample near the time that fish collections were undertaken in each mill near-field area. The Northwood mill effluent sample, however, was not properly preserved. Instead, existing data from the analysis of effluent collected on August 2009 were used for the Northwood effluent characterization.

Table 4.3 Sample bottle size, chemical preservative, and variables analyzed for mill effluents and water collected at fish sampling areas, Upper Fraser River EEM Cycle Five, September 2009.

Bottle Size (mL) / Type	Preservative Added	Variables Tested
125 (plastic)	HNO_3	Total Sodium
125 (plastic)	HNO_3	Hardness
500 (glass)	None	TP, TDP, NO_2-NO_3, NH_4
250 (glass)	H_2SO_4	Ammonia, TN
250 (glass)	None	DOC
125 (glass)	HCl	TOC

All water quality collections at each fish sampling area were completed on the final day of the program to ensure laboratory holding times were met. Samples were stored in a cooler on ice, and shipped to ALS Environmental (Vancouver, British Columbia) for analysis following the field program.

In each study area, field measurements of dissolved oxygen (±0.1 mg/L) were made by LaMotte™ micro-titration. A YSI 85 meter was used to record temperature (±0.1 °C) and conductivity (±0.1 µS/cm). pH was measured using a Hanna Combo multi-meter (±0.05 units). A Secchi disk was also used to determine water clarity.

4.5 QA/QC

A variety of QA/QC procedures were used in the field, office, and laboratory to ensure the quality of the data collected and analyzed for the fish survey were in accordance with requirements detailed in the draft version of the *Pulp and Paper EEM Guidance Document* (Environment Canada 2005a). These procedures are outlined in the following sections.

4.5.1 General

Data collection and analyses were conducted in accordance with Hatfield Consultants Standard Operating Procedures (Hatfield Consultants 2009b).

All Hatfield personnel working on the project possessed extensive experience in monitoring pulp and paper mill effluents, including environmental effects monitoring.

Field crew responsibilities were clearly established prior to the commencement of the sampling program through the use of Field Work Instructions (FWIs), which contain detailed information regarding sampling locations, an inventory of the samples to be collected, an inventory of equipment and methods to be used, and a field safety plan. The FWI was prepared and discussed prior to beginning field sampling to ensure that field crewmembers were familiar with the work plan, and to address any foreseeable issues that may affect data quality or program implementation.

Sampling gear and equipment used for the field program are regularly inspected and maintained according to manufacturer's instructions to ensure equipment is operating properly and safely. Water quality meters were calibrated according to manufacturer's protocols prior to collection of *in situ* measurements.

Collected data were recorded on customized datasheets, which were developed to increase efficiency in the field and reduce the likelihood of potential errors or omissions.

Water samples collected for laboratory analysis were preserved and stored in accordance with current standard technical guidance and QA/QC practices.

The following procedures were used in the field to prevent sample contamination:

- During water sample collections, crew members wore powder-free latex gloves;
- Samples collected from the boat were acquired on the upstream side to limit possible introduction of contaminants from the hull;
- Samples were collected upstream of the sampler to avoid introduction of river substrate; and
- Pre-cleaned laboratory bottles were used for all sample collections.

To assess potential contamination during the field program, two QA/QC samples, a trip blank and a trip blank, were analyzed. Field duplication exceeded QA/QC requirements given three samples were analyzed from each study area. The acceptable range of QA/QC sampling recommended by EEM is 5% to 10% of the total number of samples collected (Environment Canada 2005a).

4.6 RESULTS

4.6.1 General Fish Collections

Fish survey data, including individual fish data, are presented in Appendix A2. Initially, information on species and sizes of fish were collected for all fish captured during seining; however, it was determined that the repeated seining in the area could result in the recapture of the same individuals. Therefore, the recording of by-catch was discontinued.

Over 400 juvenile chinook were captured via beach seining during the Upper Fraser River Cycle Five fish program; however, 100 from each sampling area were retained for analysis (Table 4.4). Seven to eight seine sets were required to collect the 100 target fish at Shelley, Prince George and Quesnel. Only three seines were needed at Cottonwood.

Table 4.4 **Relative abundance (CPUE) of juvenile chinook captured via beach seining in each study area, Upper Fraser River EEM Cycle Five, September 2009.**

Sampling Area	# of Juvenile Chinook Retained	Number of Seine Sets	Total CPUE (# of fish per unit effort)
Shelley	100	8	12.5
Prince George	100	7	14.3
Cottonwood	100	3	33.3
Quesnel	100	8	12.5

4.6.2 Whole-Organism Metrics: Weight and Length

Whole-organism metrics of juvenile chinook are presented separately for the Prince George and Quesnel study regions. Whole-organism analyses were conducted on all fish captured. Table 4.5 provides descriptive statistics for fish collected from each area for the Cycle Five fish survey.

Table 4.5 **Descriptive statistics for juvenile chinook collected from the reference and near-field areas, Upper Fraser River EEM Cycle Five, September 2009.**

Variable	n	Mean	Median	SD	SE	Min	Max
Shelley Reference Area							
Fork Length (mm)	100	66	65.5	6.4	0.64	53	83
Weight (g)	100	3.81	3.64	1.06	0.11	1.81	7.55
Liver Weight (g)	20	0.035	0.033	0.010	0.002	0.017	0.065
Liver Somatic Index	20	1.00	0.92	0.26	0.06	0.66	1.57
Condition (K)	100	1.29	1.30	0.09	0.01	0.85	1.49
Prince George Near-Field Area							
Fork Length (mm)	100	64	63	6.8	0.7	49	84
Weight (g)	100	3.49	3.27	1.11	0.11	1.49	7.23
Liver Weight (g)	20	0.042	0.038	0.012	0.003	0.028	0.069
Liver Somatic Index	20	1.17	1.11	0.30	0.07	0.78	2.02
Condition (K)	100	1.31	1.30	0.10	0.01	1.02	1.61
Cottonwood Reference Area							
Fork Length (mm)	100	73	73	7.7	0.77	52	94
Weight (g)	100	4.79	4.57	1.42	0.14	1.87	9.23
Liver Weight (g)	20	0.053	0.052	0.015	0.003	0.029	0.080
Liver Somatic Index	20	0.87	0.89	0.19	0.04	0.55	1.21
Condition (K)	100	1.19	1.19	0.10	0.01	0.99	1.40
Quesnel Near-Field-Area							
Fork Length (mm)	100	73	72	6.5	0.65	62	92
Weight (g)	100	4.57	4.29	1.37	0.14	2.64	9.33
Liver Weight (g)	20	0.049	0.050	0.011	0.003	0.029	0.068
Liver Somatic Index	20	0.95	0.86	0.23	0.05	0.72	1.46
Condition (K)	100	1.14	1.14	0.09	0.01	0.84	1.56

[1] 100 fish were used for non-lethal measurements; 20 fish were sacrificed for liver size measurements from each area.

Results of ANOVA and ANCOVA comparisons of whole-organism characteristics are provided in Table 4.6.

Juvenile chinook length differed significantly between the Prince George near-field area and the Shelley reference area (Table 4.6). A length-frequency K-S test confirmed that fish from the Prince George near-field were significantly shorter than the Shelley reference area. Although the near-field fish were shorter and lighter, condition was very similar and the relative liver weight was greater, compared with the reference area. The percent difference in liver weight, when calculated using the ANCOVA least-squared means (untransformed) was large (23.0%), and was very close to the ±25% critical effects size for this endpoint.

No statistical differences in length or weight (ANOVA: p=0.10) were observed between reference and exposure juvenile chinook populations in the Quesnel region (Table 4.6). Length-frequency was also not significantly different between the exposure and reference areas (ANOVA: p=0.10). There was no difference observed for relative liver weights in the Quesnel reference and exposure areas (ANOVA: p=0.10).

The slopes of the weight-length (i.e., condition) regression lines for the Cottonwood reference and Quesnel near-field areas were significantly different (Table 4.6). This was also observed when the analysis was repeated following the removal of potential outliers. The individual lines were plotted for each area in Figure 4.2, illustrating that the condition of Quesnel near-field area chinook was lower at shorter fork lengths relative to Cottonwood reference area fish until a length of approximately 79 mm, after which the condition of Quesnel fish was greater than Cottonwood fish. It is important to note that the greatest difference of condition observed between fish from the reference and exposed area was 4.5%, suggesting that any difference in condition between these areas is well below the critical effect size of ±10%.

Figure 4.2 Fork-length versus body-weight (log-transformed) for Quesnel near-field and reference area juvenile chinook, Upper Fraser River EEM Cycle Five, September 2009.

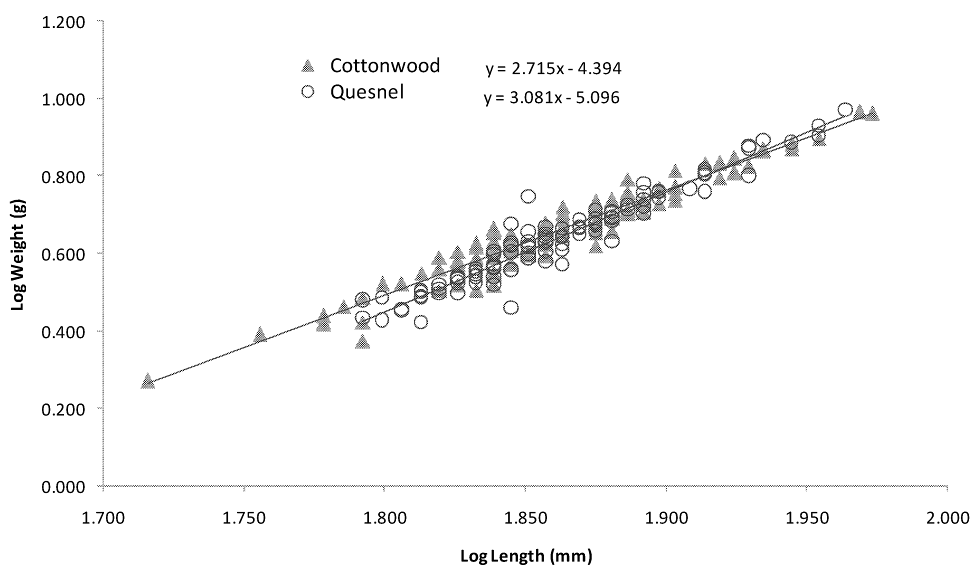


Table 4.6 **Results of ANOVA and ANCOVA tests comparing whole-organism characteristics of juvenile chinook captured from exposure and reference study areas, Upper Fraser River EEM Cycle Five, September 2009.**

Region	Type of Response	Parameter	Covariate	n	ANOVA[1]	ANCOVA[2]		% Difference[3]	Power
					Mean	Slope	Intercept		
Prince George	Size Distrivution	Length Frequency	-	200	**0.0063**	-	-	-	
	Energy Use	Length	-	200	**0.012**	-	-	-3.03	
		Body weight	-	200	**0.02**	-	-	-8.40	
	Energy Storage	Condition	Length	199[4]	-	0.975	0.835	0.23	>0.99
		Liver Weight	Weight	40	-	0.883	**0.002**	23.0	
Quesnel	Size Distribution	Length Frequency	-	200	0.967	-	-	-	>0.99
	Energy Use	Length	-	200	0.962	-	-	0.0	>0.99
		Body weight	-	200	0.283	-	-	-4.59	>0.99
	Energy Storage	Condition	Length	198[4]	-	**0.007[4]**	**-**	-4.50	
		Liver Weight	Weight	40	-	0.135	0.716	2.33	>0.99

Bold values indicate a significant difference between areas.

1 A difference between means was considered significant when p<0.10.

2 A difference between slopes was considered significant when p<0.01; a difference between intercepts was considered significant when p<0.10.

3 % Difference is for exposed (near-field) relative to reference sites calculated using ANCOVA adjusted least squared means. Actual means were used for ANOVA analyses.

4 Outliers were removed from analyses. Guidance of Barrett *et al.* 2009 followed for highly influential points; high leverage points retained because removal didn't change result of significant slopes.

4.6.3 Statistical Power

All tests for the juvenile chinook survey had sufficient power to meet the P>0.9 objective to detect effect sizes of ±10% for condition and size comparisons. Relative liver weight, based on 20 fish per area, also had sufficient power to provide a significant finding using an effects size of ±25%. Power values were P>0.99 for condition and liver weight measurement endpoints, when exposure area fish were compared with their corresponding reference area at α=0.1.

4.6.4 Supporting Environmental Variables

Supporting environmental variables were collected during the fish survey and are reported in Table 4.7 and Appendix A3. Dissolved oxygen (DO) levels ranged from 9.8 to 11 mg/L among the four fish collection areas. Mean river temperature was similar among areas, spanning a range from 11.2°C in the Prince George near-field area to 12.3°C at the Quesnel near-field area. Conductivity was highest in the Quesnel near-field area (231 µS/cm) relative to all other areas (138 to 154 µS/cm). Average pH was similar among areas, ranging from 8.06 to 8.41. Secchi depth ranged from 0.23 m to 0.40 m; the Cottonwood reference area exhibited the highest water clarity.

Table 4.7 ***In situ* water quality measurements for the fish survey, Upper Fraser River EEM Cycle Five, September 2009.**

Station	Dissolved Oxygen (mg/L)	Temperature (°C)	Conductivity (μS/cm)	pH	Secchi Depth (m)
Shelley (Reference)	9.8	12.0	142	8.30	0.23
Prince George (Near-Field)	9.8	11.2	154	8.06	0.30
Cottonwood (Reference)	11	12.3	138	8.41	0.40
Quesnel (Near-Field)	9.9	11.8	231	8.12	0.25

Mean hardness was 71.9 and 71.7 mg/L in reference areas (Shelley and Cottonwood, respectively) compared to 76.7 and 77.2 mg/L in the near-field areas (Prince George and Quesnel, respectively) (Table 4.8).

Ammonia and nitrite were not detected in the upper Fraser River. Nitrate was highest at the Shelley reference area (0.0392 mg/L) and lowest at Cottonwood reference area (0.0250 mg/L). Total nitrogen concentrations increased gradually from Shelley to Quesnel (from <0.050 to 0.090 mg/L), while total Kjeldahl nitrogen was highest at the Prince George exposure area (triplicate mean of 0.76 mg/L). Canadian Water Quality Guidelines stipulate a nitrate threshold of ≤ 13mg/L to ensure protection of freshwater aquatic organisms (Environment Canada 2005b); levels observed at all four study areas of the Fraser River were well below this guideline and, with the exception of the Cariboo mill (0.18 mg/L), were not detected in mill effluent samples.

Ortho-phosphate was not detected at Shelley, but did show a small increase from the Prince George near-field area to the Quesnel near-field area (0.0019 to 0.0036 mg/L). Total dissolved phosphate was only detected at Quesnel (0.0027 mg/L). Total phosphate concentrations were low; ranging from 0.0155 mg/L at Shelley to 0.0279 mg/L at Quesnel (Table 4.8).

Dissolved organic carbon and total organic carbon also increased gradually in a downstream direction, with the largest increase observed between the Prince George near-field and Cottonwood reference areas.

Mean sodium concentrations in the Prince George and Quesnel near-field areas were higher than their respective reference areas, and similar between Prince George and Cottonwood (Table 4.8). Using sodium concentration as a tracer, the average effluent concentrations observed during the 2009 fish survey were 0.26% in the Prince George near-field area, and 0.08% in the Quesnel near-field area (Table 4.9). The Cariboo and QRP mills combined contribution to the total effluent concentration in the Quesnel near-field was estimated at 0.03% (Table 4.9).

Table 4.8 Analytical results (mg/L) of water and effluent samples collected for the Upper Fraser River Cycle Five fish program, September 2009.

Sample ID	Matrix	Hardness (as CaCO3)	Sodium[1] (Na)	Ammonia (as N)	Nitrate (as N)	Nitrite (as N)	Total Kjeldahl Nitrogen	Total Nitrogen	Ortho Phosphate (as P)	Total Dissolved Phosphate (as P)	Total Phosphate (as P)	Dissolved Organic Carbon	Total Organic Carbon
SHE-1	Water	72.6	0.650	<0.020	0.0371	<0.0010	0.064	<0.050	<0.0010	<0.0020	0.0109	0.95	1.20
SHE-2	Water	72.6	0.647	<0.020	0.0372	<0.0010	0.062	<0.050	<0.0010	<0.0020	0.0151	0.95	1.16
SHE-3	Water	70.4	0.679	<0.020	0.0434	<0.0010	<0.050	<0.050	<0.0010	<0.0020	0.0204	0.92	1.20
Shelley Average		***71.9***	***0.66***	***<0.020***	***0.0392***	***<0.0010***	***0.063***	***<0.050***	***<0.0010***	***<0.0020***	***0.0155***	***0.94***	***1.19***
PRG-1	Water	77.5	2.32	<0.020	0.0353	<0.0010	1.04	<0.050	0.0018	<0.0020	0.0206	1.27	1.66
PRG-2	Water	76.1	2.39	<0.020	0.0386	<0.0010	0.067	0.060	0.0020	<0.0020	0.0217	1.22	1.67
PRG-3	Water	76.6	2.45	<0.020	0.0348	<0.0010	1.18	0.050	0.0019	<0.0020	0.0211	1.29	1.58
Prince George Average		***76.7***	***2.39***	***<0.020***	***0.0362***	***<0.0010***	***0.762***	***0.055***	***0.0019***	***<0.0020***	***0.0211***	***1.26***	***1.64***
COT-1	Water	71.9	2.32	<0.020	0.0260	<0.0010	0.111	0.080	0.0020	<0.0020	0.0217	2.48	2.75
COT-2	Water	70.3	2.37	<0.020	0.0249	<0.0010	0.122	0.070	0.0021	<0.0020	0.0221	2.38	2.78
COT-3	Water	72.9	2.36	<0.020	0.0242	<0.0010	0.132	0.060	0.0029	<0.0020	0.0219	2.56	2.68
Cottonwood Average		***71.7***	***2.35***	***<0.020***	***0.0250***	***<0.0010***	***0.122***	***0.070***	***0.0023***	***<0.0020***	***0.0219***	***2.47***	***2.74***
QUE-1	Water	77.5	2.76	<0.020	0.0282	<0.0010	0.135	0.110	0.0031	0.0026	0.0299	2.77	2.93
QUE-2	Water	76.1	2.67	<0.020	0.0264	<0.0010	0.103	0.080	0.0034	0.0028	0.0267	2.57	3.11
QUE-3	Water	78.0	2.64	<0.020	0.0269	<0.0010	0.116	0.080	0.0043	0.0027	0.0271	2.78	2.89
Quesnel Average		***77.2***	***2.69***	***<0.020***	***0.0272***	***<0.0010***	***0.118***	***0.090***	***0.0036***	***0.0027***	***0.0279***	***2.71***	***2.98***
Mill Effluent													
NOR-1	Effluent[2]	156	377	1.16	<0.25	0.055	7.8	na	0.38	0.44	0.85	164	141
PGIC-1	Effluent	93.7	285	0.381	<0.10	<0.020	11.7	10.1	0.0106	0.069	2.03	91	166
QRP-1	Effluent	162	903	0.086	<0.25	<0.050	37.9	26.0	1.15	1.56	4.04	212	404
CAR-1	Effluent	305	298	1.98	0.18	0.354	4.00	3.84	0.579	0.643	0.870	72.7	80.2
QA/QC													
TES-1[3]	Water	<1.0	<0.050	<0.020	<0.0050	<0.0010	<0.050	<0.050	<0.0010	<0.0020	<0.0020	<0.50	<0.50
TRIP BLANK	Water	<1.0	<0.050	<0.0050	<0.0050	<0.0010	<0.050	<0.050	<0.0010	<0.0020	<0.0020	<0.50	<0.50

[1] Dissolved sodium concentrations reported for river water; total sodium used for effluents given the high concentrations.

[2] NOR-1 was not analyzed for nutrients; these variables were taken from the September 1, 2009 effluent sample (total nitrogen not available).

[3] TES-1 is a field blank.

4.6.5 Chemical Tracers of Effluent Exposure

Bile was composited from the 20 juvenile chinook sacrificed at each area, to analyze for resin acid metabolites. The small volume of material available to analyze (approximately 50 mL was collected from each area) resulted in relatively high detection limits (5 mg/kg). The recommended minimum volume for analysis of resin acid metabolites is 200 mL. No resin acids were detected in bile from any of the four fish collection areas.

Table 4.9 Sodium and estimated percent effluent concentrations at the four fish collection areas, Upper Fraser River EEM Cycle Five, September 2009.

Area	Sodium Observed (mg/L)	By Region		Cumulative	
		Adjusted Sodium[1] (mg/L)	Effluent Concentration[2] (%)	Adjusted Sodium[1] (mg/L)	Effluent Concentration[2] (%)
Shelley	0.65	na	na	na	na
(reference)	0.65				
	0.68				
Average	**0.66**				
Prince George	2.32	1.66	0.25	1.66	0.25
(near-field)[3]	2.39	1.73	0.26	1.73	0.26
	2.45	1.77	0.27	1.77	0.27
Average	**2.39**	**1.72**	**0.26**	**1.72**	**0.26**
Cottonwood	2.32	na	na	1.66	0.25
(reference)	2.37			1.71	0.26
	2.36			1.70	0.26
Average	**2.35**			**1.69**	**0.26**
Quesnel	2.76	0.41	0.03	2.10	0.11
(near-field)	2.67	0.32	0.03	2.01	0.11
	2.64	0.28	0.02	1.98	0.01
Average	**2.69**	**0.34**	**0.03**	**2.03**	**0.08**

1 Adjusted sodium level is the observed downstream sodium level minus the mean reference sodium level.

2 Effluent concentration calculated by dividing adjusted sodium by sum of total sodium measured in mill effluents.

3 Total sodium concentrations at the time of sampling: PG/IC 285 mg/L, QRP 903 mg/L, Cariboo 298mg/L. Sodium concentration in Northwood effluent from September 1, 2009 was 377 mg/L.

na: not applicable. Effluent contributions assumed to be '0'

4.6.6 Quality Assurance/Quality Control (QA/QC)

No water quality QA/QC issues were identified in the September 2009 analytical data. Field blank results did not identify any issues of concern related to sample contamination during field surveys, and trip blank results did not identify any laboratory contamination issues. All QA/QC sample analytes were below method detection limits, and variability among the three triplicates collected from each of the four study areas was low, with most replicate measurements within 10% of the area mean (Table 4.8).

The Northwood effluent sample was preserved using on-site acids from the mill, which did not lower the nutrients sample pH to the necessary acidity for preservation; therefore, nutrient results from an effluent sample collected 1 September, 2009 were used in this report. These nutrient results are considered representative of summer effluent quality at Northwood, and the data are suitable for inclusion in this report given the juvenile chinook survey was designed to assess potential effects related to chronic (i.e., May to September) exposure to mill effluents.

The standard QA/QC analysis for resin acids in fish bile was not applicable in this study given the small amount of bile present in juvenile chinook gall bladders. The recommended minimum volume of bile requested by ALS for analysis of resin acid metabolites is 200 mg; composite volumes from each of the four study areas were less than 50 mg.

4.7 DISCUSSION

4.7.1 Review of Largescale Sucker Data from Previous Cycles

Largescale sucker (*Catostomus macrocheilus*) have been used in the past four EEM cycles as the sentinel species for the upper Fraser River pulp mills (Hatfield Consultants 1997, 2000a, 2004, 2007). Although largescale sucker have been caught in high numbers at all sampling areas, there has been a consistent challenge in collecting sufficient numbers of sexually mature adults to quantify reproductive variables, such as gonad size or fecundity. Several large and small-bodied fish reconnaissance surveys proved unsuccessful in identifying an alternate sentinel fish species (Dwernychuk 1990, Hatfield Consultants 2007).

During cycles One and Two, largescale sucker surveys were conducted in fall as per the EEM Technical Guidelines. However, in Cycle Three, sampling was conducted in spring immediately prior to spawning in an attempt to capture more individuals with ripe gonads (i.e., gonad weights exceeding 1.5% of total body weight). Although spring sampling did improve the capture of mature individuals, the proportion of largescale sucker in pre-spawning condition ranged from only 37 to 49% for females and 31 to 88% for males. These data suggest that a substantial proportion of largescale sucker populations in the upper Fraser River do not spawn every year and that sampling season has little impact on the capture success of spawning adults. Largescale sucker data collected from the upper Fraser River are comparable to EEM fish survey results from the Thompson River (13 to 18% spawners; Hatfield Consultants 2000b) and Kootenay River (40 to 50% spawners; Hatfield Consultants 2000c), indicating skipped spawning may be a consistent life history characteristic of largescale sucker in the interior of British Columbia.

Accordingly, the challenge remained in Cycle Four to design a fish survey that provided information on reproduction and/or recruitment of largescale sucker. Following a conference with Environment Canada scientists (Mark McMaster, National Water Research Institute, Burlington; Janice Boyd, Pacific and Yukon Region) a non-lethal fish survey using largescale sucker was selected with the objective of quantifying the proportion of young-of-the-year fish at each site, as an estimator of recruitment and reproductive performance of adults. Data from this survey observed a high proportion of adults in the Quesnel near-field area relative to smaller size classes, indicating a possible reproductive impairment. The high number of adults, however, may have been influenced by the close proximity to Baker Creek, a known spawning tributary for largescale sucker. The spatial overlap with the other sucker species such as white sucker (*Catostomus commersoni*) and bridgelip sucker (*Catostomus columbianus*) limited positive field identification of largescale sucker to a minimum size of 76 mm; identification of sucker species less than 100 mm is difficult because the mouth parts of young suckers are inadequately distinct in this early life-stage. Sucker species generally attain sizes of 75 mm or greater in their second year of growth and therefore the smallest fish positively identified to species were likely ≥1 y old. As a result, the Cycle Four study focused on inter-annual variability (e.g., condition, growth) rather than young-of-year specific measures of recruitment and reproduction.

To date, the upper Fraser River mills have collected a substantial volume of data on largescale sucker. As such, in an April 2008 discussion with Drs. Kelly Munkittrick and Mark McMaster (EEM Science Advisory scientists), it was recommended that the fall data from cycles One and Two be combined to provide adequate sample sizes for evaluating reproductive variables. This analysis identified a significant increase in the Prince George near-field area male GSI (25.2%), in comparison the reference area at Hansard ($p=0.042$; Figure 4.3). No differences were found for female GSI ($p\geq0.31$) or for either gender in the Quesnel near-field area ($p\geq0.45$). These data suggest, at most, a possible enrichment response in the Prince George near-field area.

Analyses of data collected in support of upper Fraser River EEM Cycle Two, Cycle Three and Cycle Four also suggest a mild eutrophication/enrichment response (Table 4.10). In Cycle Three, liver size showed significant increases in both sexes in the near-field areas of both Prince George and Quesnel (Table 4.10). Condition factor also showed an infrequent but suggestive pattern of enrichment downstream of the Quesnel mills, although the magnitude of change was within the ±10% effect size defined by EEM (Environment Canada 2005a). Based on a weight-of-evidence approach, a mild enrichment effect was the most probable response pattern in the Prince George and Quesnel near-field areas of the upper Fraser River.

Figure 4.3 Gonadosomatic index (GSI) of largescale sucker; data pooled from Upper Fraser River EEM Cycle One and Cycle Two (both cycles used fall collections).

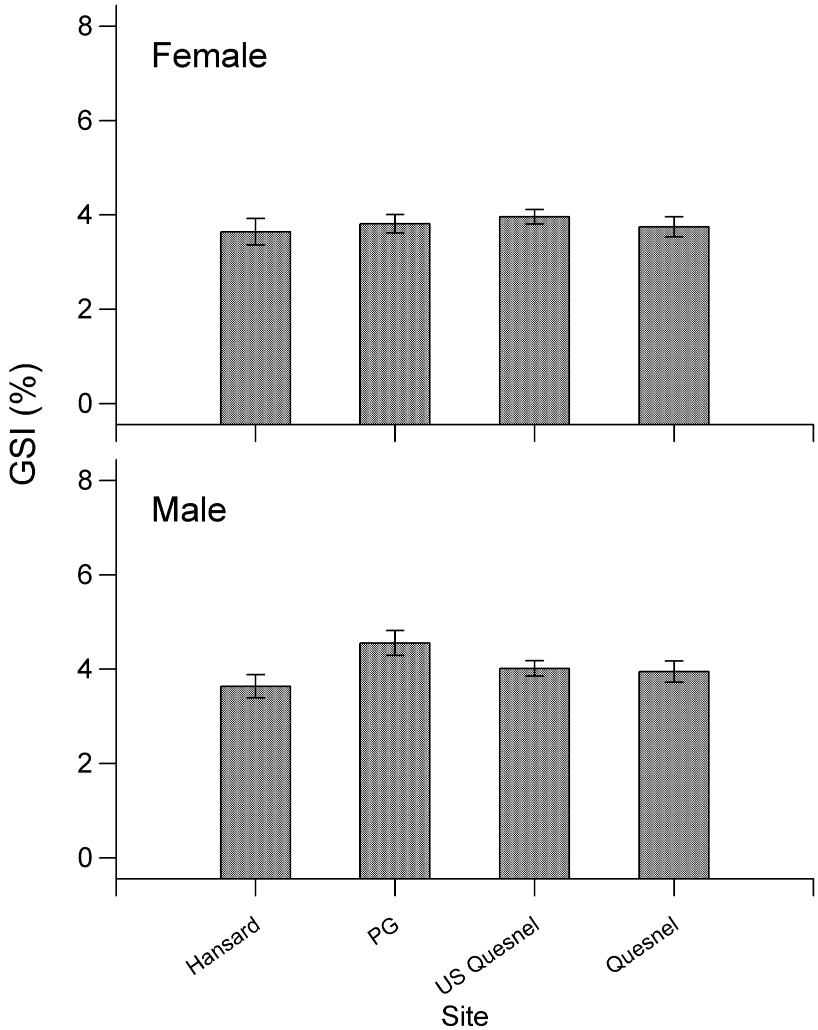


Table 4.10 Summary of magnitude of change data between exposed and respective reference sites using Upper Fraser River EEM Cycle Two to Cycle Four largescale sucker data.

Area	Sex	Cycle	Condition (%)	Liver Wt. (%)	Age (%)
Prince George	Male	2	-3.0	8.0	20
		3	5.0	59	26
		4	-0.9	n/a	10
	Female	2	1.0	8.0	0
		3	-0.2	32	1.4
		4	-0.2	n/a	0.9
Quesnel	Male	2	0	6.0	-7.0
		3	5.2	19	-4.9
		4	6.9	n/a	-5.2
	Female	2	0	-3.0	-8.0
		3	5.4	32	18
		4	7.6	n/a	-0.2

N/A: data not available; 0: no change.

4.7.2 Cycle Five Response of Juvenile Chinook

The Cycle Five fish survey was designed to investigate the potential enrichment of juvenile chinook residing downstream of mill effluent discharges. Based on the Cycle Five results there is little consistent evidence of a strong enrichment response.

In Prince George, near-field fish did exhibit greater liver weight relative to juvenile chinook from Shelley; however, there was no concomitant increase in condition, and mean length and weight were moderately lower than reference area fish. This is in contrast to a typical enrichment response of increased energy expenditure (e.g., growth measures of length and weight) and energy storage (e.g., condition, liver size) (Gibbons and Munkittrick 1994). The increase in liver size is significant and the magnitude of difference between near-field and reference fish approaches the critical effects size of ±25%; however, there is little other evidence to support a general response of juvenile chinook to increasing nutrients or food resources related to effluent exposure.

Table 4.11 Summary of magnitude of change between near-field and respective reference site data for Upper Fraser River EEM Cycle Five juvenile chinook, September 2009.

Near-Field Study Area	Length (%)	Weight (%)	Condition (%)	Liver Wt. (%)
Prince George	**-0.30**	**-8.40**	0.23	**23.0**
Quesnel	0.0	-4.59	**-4.50**	2.33

Bold indicates a significant difference between the exposure area and the corresponding reference area data.

In the Quesnel near-field area, juvenile chinook weighed less than Cottonwood reference fish, liver weight was slightly higher in Quesnel fish (but not significantly different), and length was the same. Condition was significantly lower in Quesnel near-field area fish relative to Cottonwood, but this difference did not exceed the ±10% critical effect size. These results do not indicate an enrichment response in juvenile chinook as a result of Quesnel pulpmill effluents.

A summary of endpoint responses for fish surveys conducted from Cycle Two through Cycle Five is presented in Table 4.12; Cycle One results were not included in this overview, as the data were not considered to be detailed enough to conduct valid magnitude of effect assessments. Cycle One data were combined with Cycle Two to increase sample replication; the results of this assessment are presented in Section 4.7.1 Measures of energy storage and energy use (liver weight and/or condition) are available for comparison among all four (Cycle Two through Five) fish surveys. As shown in Table 4.12, some endpoint responses were significant but the magnitude of difference was ≤5% (shaded boxes on the table). Endpoints assigned a '+' or '-' demonstrated significant increases or decreases, respectively, between the near-field and corresponding reference area.

Condition in the Prince George near-field area was higher in male largescale suckers in Cycle Three, although the difference was ≤5%. All other condition parameters, including that for juvenile chinook in Cycle Five, indicate no change from reference condition. Liver size indicated an increase in energy storage in exposure area suckers for Cycle Three, and for juvenile chinook in the Prince George exposure area in Cycle Five. Based on these endpoints, the fish data from previous cycles using largescale suckers and juvenile chinook in Cycle Five indicate, at most, a possible mild enrichment effect in the Prince George near-field area, resulting from Prince George pulpmill effluent discharges.

In the Quesnel region, condition endpoint responses have been mixed. In Cycle Two, condition was the same between exposure and reference areas; in Cycle Three and Four, largescale suckers exhibited increased condition relative to reference fish. A decrease in condition was observed in near-field area juvenile chinook in Cycle Five, although the magnitude was less than 5% (below the critical effect size of 10%). Liver size endpoints for exposure area fish increased for Cycle Three; however, no change was observed for juvenile chinook in Cycle Five. Based on these endpoints, the fish data from previous cycles using largescale suckers and juvenile chinook in Cycle Five indicate that Quesnel pulpmill effluents are not affecting fish populations in the near-field area of the Fraser River.

Table 4.12 Summary of largescale sucker (Cycles Two through Four) and juvenile chinook (Cycle Five) effects endpoint responses from the Prince George and Quesnel near-field areas relative to its reference area, Upper Fraser River EEM.

Near-Field Area	Effects Endpoint	Parameter	Largescale Sucker									Chinook Cycle Five Juveniles
			Cycle Two		Cycle Three		Cycle Four			Cycle Five Re-analysis		
			Females	Males	Females	Males	All	Females	Males	Females	Males	
Prince George[1]	Survival/Size Distribution	Age	0	+	0	+	0	0	0	na	na	na
	Energy Use	Weight-at-age	0	0	+	+	+	+	0	na	na	na
		Gonad size	0	+	0	+	na	na	na	0	+	na
	Energy Storage	Condition	0	0	0	+	0	0	0	na	na	0
		Liver Size	0	0	+	+	na	na	na	na	na	+
Quesnel[3]	Survival/Size Distribution	Age	0	0	+	0	+	0	0	na	na	na
	Energy Use	Weight-at-age	0	0	+	0	+	+	0	na	na	na
		Gonad size	0	0	?	0	na	na	na	0	0	na
	Energy Storage	Condition	0	0	+	+	+	+	?	na	na	-
		Liver Size	0	0	+	+	na	na	na	na	na	0

A shaded cell indicates the comparison was significant, but the magnitude of difference was ≤5%.

'+' indicates a significant increase; '-' indicates a significant decrease; '0' indicates no change; '?' indicates difficult to classify as power was insufficient.

na = data not available (i.e., not measured during survey).

[1] Hansard was the Prince George reference area for Cycles Two, Three, Four; Shelley was the reference area for Cycle Five.

[2] Slopes of regression lines were significantly different in mature adults.

[3] Reference areas for Quesnel include Stoner/Woodpecker (Cycle Two), and Cottonwood (Cycles Three through Five).

4.8 SUMMARY AND CONCLUSIONS

The Cycle Five fish survey consisted of a juvenile chinook study that included the collection of 100 young-of-the-year fish from each of four study areas (reference and near-field areas for Prince George and Quesnel). Twenty fish from each area were sacrificed for liver measurements; the remaining 80 fish were measured, weighed and returned to the Fraser River near their original point of capture. Gall bladders were collected from the sacrificed fish and submitted to ALS Laboratories for resin acid metabolites analyses. The total available volumes of bile from the 20 fish lethally sampled at each study area was approximately 50ml, which was considerably less than the 200ml minimum recommended sample volume for resin acid metabolite testing in bile (D. Birkholz, ALS Director of Research and Toxicology, *pers. comm.*). As a result of the small sample volumes, detection limits were high and no resin acid metabolites were detected in any sample.

The Cycle Five juvenile chinook survey produced varying results. Given the large number of fish collected from each area (n=100), small differences in fork length and body weight were found to be significant in the Prince George region. Liver size of 20 fish sacrificed in the Prince George region indicated increased energy storage (23%) in the near-field area, which was near the EEM critical effect size (25%) for this endpoint (Environment Canada 2005a). Comparison of Prince George reference and near-field fish condition found no significant difference between the two areas. The only difference observed between near-field and reference fish in the Prince George area was larger liver weight in near-field juvenile chinook. Larger liver size is often related to increased energy storage associated with increased food resources; however, the response is likely mild given there were no concomitant increases in condition or body size.

Historical EEM fish survey results from the Quesnel region have often shown increased condition and liver size in the near-field area, indicating a possible enrichment effect (Table 4.12). In contrast, the Cycle Five survey data observed no significant difference in liver size or condition when Quesnel near-field juvenile chinook were compared with fish from the reference area. The results of Cycle Five indicate no enrichment effects related to Quesnel pulpmill effluent are occurring in juvenile chinook.

Near-field areas in both the Prince George and Quesnel regions exhibited greater sodium concentrations than their respective reference areas. The mean concentration of sodium observed in the Shelley reference area was 0.66 mg/L, and 2.4 mg/L in the Prince George near-field. The mean concentration of sodium observed in the Cottonwood reference area was 2.4 mg/L, and 2.7 mg/L in the Quesnel near-field area. These data indicate that effluent concentrations in the Fraser and Quesnel near-field areas were 0.26% and 0.08%, respectively, with 0.03% of the Quesnel near-field effluent contributed from the Cariboo and QRP mills.

5.0 FISH TISSUE ANALYSIS

Tissue analyses for chlorinated dioxins and furans are required if:

- Effluent contained measurable concentrations of 2,3,7,8–TCDD or TCDF since the submission of the most recent EEM report; or
- Dioxin and furan concentrations exceeded 15 pg/g in muscle or 30 pg/g in liver in fish from the exposure area in the previous EEM survey.

No health advisories or consumption guidelines are present for the upper Fraser River in the vicinity of Prince George and Quesnel. All four Kraft mills have remained in compliance with CEPA regulations for dioxin and furan levels in final effluent. Therefore, a survey for dioxin and furan in fish tissues was not required for the Upper Fraser River EEM Cycle Five.

6.0 BENTHIC INVERTEBRATE SURVEY

Based on past results, no definitive effects have been observed for three consecutive cycles on near-field benthos monitoring stations. The revised *Regulations Amending the Pulp and Paper Effluent Regulations* (Government of Canada 2008) have decoupled the benthos and fish surveys, meaning that effects observed in the fish survey no longer trigger a benthic invertebrate study in the subsequent cycle. It was determined during the Cycle Five design for the upper Fraser River that no benthic invertebrate survey was needed for this cycle (Hatfield 2009a).

7.0 CONCLUSIONS

The following conclusions are a summation of the Cycle Five programs for Canfor Pulp Limited Partnership, Quesnel River Pulp Company, and Cariboo Pulp and Paper Company (upper Fraser River) based on the study design, collection of field samples and observations, and results gained from laboratory analysis.

No major process changes were carried out at any of the mills during Cycle Five. In fall 2008, new chip screens were installed at PG, and additional aerators were installed at the Intercon biobasin in 2007 and 2009. Intercon also replaced storm sewer lines in the landfill areas in December 2009. In July 2007, QRP completed a mill upgrade, installing high consistency pumps and reducing water usage by 20%.

Sublethal toxicity testing of effluent indicated that zones of potential sublethal effect for each mill were relatively small. Maximum zones for each mill were: 235 m at Northwood (for invertebrate reproduction), 214 m at PG/IC (for invertebrate reproduction), 78 m at QRP (for algal growth), and 152 m at Cariboo (for invertebrate reproduction).

The Cycle Five juvenile chinook survey produced varying results. Given the large number of fish collected from each area (n=100), small differences in lengths and weights were found to be significant in Prince George. Liver weight of the 20 fish sacrificed in the Prince George region for the survey indicated increased energy storage (23%), similar to the critical effect size (25%); however, this was not reflected in condition. Overall, there is little evidence to support a general response of juvenile chinook to increasing nutrients or food resources related to effluent exposure.

Fish surveys in the Quesnel region generally have shown increased condition and LSI, indicating an enrichment effect. However, for the Cycle Five juvenile chinook survey, size and LSI were not different, and condition was lower in the near-field relative to reference fish. Based on Cycle Five data, no enrichment was observed in juvenile chinook characteristics that may be related to pulpmill effluent.

8.0 CLOSURE

We trust the above information meets your requirements. If you have any questions or comments, please contact the undersigned.

HATFIELD CONSULTANTS:

Approved by: ______________________ 29-MAR-2010

Daniel Moats
Project Manager

Date

Approved by: ______________________ for 29 March 2010

Dr. Wade N. Gibbons
Project Director

Date

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10.0 GLOSSARY

Acute	With reference to toxicity tests with fish, usually means an effect that happens within four to seven days, or an exposure of that duration. An acute effect could be mild or sublethal, if it were rapid.
ANCOVA	Analysis of covariance. ANCOVA compares regression lines, testing for differences in either slopes or intercepts (adjusted means).
ANOVA	Analysis of variance. An ANOVA tests for differences among levels of one or more factors. For example, individual sites are levels of the factor site. Two or more factors can be included in an ANOVA (e.g., site and year).
Benthos	Organisms that inhabit the bottom substrates (sediments, debris, logs, macrophytes) of aquatic habitats for at least part of their life cycle. The term benthic is used as an adjective, as in benthic invertebrates.
BOD	Biochemical oxygen demand. The test measures the oxygen utilized during a specified incubation period for the biochemical degradation of organic material and the oxygen used to oxidize inorganic material such as sulfides and ferrous iron. Usually conducted as a 5-day test (i.e., BOD_5).
Chronic	Long-lasting or continued. Can refer to the effect or the duration of exposure. In mammalian toxicology, it usually signifies exposures lasting at least one-tenth of a lifetime. In aquatic toxicology, it sometimes is used to mean a full life-cycle test.
CL	Confidence limits. A set of possible values within which the true value will lie with a specified level of probability.
Community	A set of taxa coexisting at a specified spatial or temporal scale.
Concentration Units	See table:

Concentration Units	Abbreviation	Units
Parts per million	ppm	mg/kg or µg/g or mg/L
Parts per billion	ppb	µg/kg or ng/g or µg/L
Parts per trillion	ppt	ng/kg or pg/g or ng/L
Parts per quadrillion	ppq	pg/kg or fg/g or pg/L

Condition Factor	A measure of the plumpness or fatness of aquatic organisms. For oysters and mussels, values are based on the ratio of the soft tissue dry weight to the volume of the shell cavity. For fish, the condition factor is based on length-weight relationships.
Conductivity	A numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions, their total concentration, mobility, valence and relative concentrations, and on the temperature of measurement.
Covariate	An independent variable; a measurement taken on each experimental unit that predicts to some degree the final response to the treatment, but which is unrelated to the treatment (e.g., body size [covariate] included in the analysis to compare gonad weights of fish collected from reference and exposed areas).
DO	Dissolved oxygen, the gaseous oxygen in solution with water. At low concentrations it may become a limiting factor for the maintenance of aquatic life. It is normally measured in milligrams/litre, and is widely used as a criterion of receiving water quality. The level of dissolved oxygen which can exist in water before the saturation point is reached is primarily controlled by temperature, with lower temperatures allowing for more oxygen to exist in solution. Photosynthetic activity may cause the dissolved oxygen to exist at a level that is higher than this saturation point, whereas respiration may cause it to exist at a level that is lower than this saturation point. At high saturation, fish may contract gas bubble disease, which produces lesions in blood vessels and other tissues and subsequent physiological dysfunctions.
ECp	A point estimate of the concentration of test material that causes a specified percentage effective toxicity (sublethal or lethal). In most instances, the ECp is statistically derived by analysis of an observed biological response (e.g., incidence of nonviable embryos or reduced hatching success) for various test concentrations after a fixed period of exposure. EC25 is used for the rainbow trout sublethal toxicity test.
Fecundity	The number of eggs or offspring produced by a female.
Hardness	Total hardness is defined as the sum of the calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per litre.

ICp	A point estimate of the concentration of test material that causes a specified percentage inhibition in a quantitative biological test that measures a change in rate, such as reproduction, growth, or respiration.
LC50	Median lethal concentration. The concentration of a substance that is estimated to kill half of a group of organisms. The duration of exposure must be specified (e.g., 96-hour LC50).
Macroinvertebrates	Those invertebrate (without backbone) animals that are visible to the eye and retained by a sieve with 500 µm mesh openings for freshwater, or 1,000 µm mesh openings for marine surveys (EEM methods).
Negative Control	Material (e.g., water) that is essentially free of contaminants and of any other characteristics that could adversely affect the test organism. It is used to assess the "background response" of the test organism to determine the acceptability of the test using predefined criteria.
Organochlorine	Chlorine that is attached to an organic molecule. The amount present is expressed as the weight of the chlorine. There are thousands of such substances, including some that are manufactured specifically as pesticides because of their toxicity.
pH	A measure of the acid or alkaline nature of water or some other medium. Specifically, pH is the negative logarithm of the hydronium ion (H30+) concentration (or more precisely, activity). Practically, pH 7 represents a neutral condition in which the acid hydrogen ions balance the alkaline hydroxide ions. The pH of the water can have an important influence on the toxicity and mobility of chemicals in pulpmill effluents.
Plume	The main pathway for dispersal of effluent within the receiving waters, prior to its complete mixing.
Population	A group of organisms belonging to a particular species or taxon, found within a particular region, territory or sampling unit. A collection of organisms that interbreed and share a bounded segment of space.

Quality Assurance (QA)	Refers to the externally imposed technical and management practices which ensure the generation of quality and defensible data commensurate with the intended use of the data; a set of operating principles that, if strictly followed, will produce data of known defensible quality.
Quality Control (QC)	Specific aspect of quality assurance which refers to the internal techniques used to measure and assess data quality and the remedial actions to be taken when data quality objectives are not realized.
Salinity	A measure of the quantity of dissolved salts in seawater - in parts per thousand by weight.
SD	Standard deviation.
SE	Standard error.
Secondary Treatment	A stage of purification of a liquid waste in which micro-organisms decompose organic substances in the waste. In the process, the micro-organisms use oxygen. Oxygen usually is supplied by mechanical aeration and/or large surface area of treatment ponds (lagoons). Most secondary treatment also reduces toxicity.
Sentinel Species	A monitoring species selected to be representative of the local receiving environment.
Stressor	An environmental factor or group of factors eliciting a response by a community.
Sublethal	A concentration or level that would not cause death. An effect that is not directly lethal.
TN	Total nitrogen.
TOC	Total organic carbon.
TS	Total sulphides.
TSS	Total suspended solids (TSS) is a measurement of the oven dry weight of particles of matter suspended in the water which can be filtered through a standard filter paper with pore size of 0.45 µm.
Turbidity	Turbidity in water is caused by the presence of matter such as clay, silt, organic matter, plankton, and other microscopic organisms that are held in suspension.

APPENDICES

Appendix A1

Sublethal Toxicity Data and Calculations

Table A1.1 Canfor Pulp Limited Partnership, Northwood Division, Effluent Sublethal Toxicity Test Results, Cycle Five.

Testing Period	Project Number	Effluent Description	Collection Date	Laboratory	Species Tested	Test type	Flag LC50%	LC50 %	LC50 Lower 95% cl	LC50 Upper 95% cl	Flag EC25 or IC25%	EC25 or IC25 %	EC25 or IC25 Lower 95% cl	EC25 or IC25 Upper 95% cl	Comments
		(final, cooling, etc.)	yyyymmdd				> for greater than 100%				> for greater than 100%				
Summer 2006[1]	pp1149	final	20061120	Vizon SciTec Inc.	Oncorhynchus mykiss	Survival						69.7	52.7	88.7	Re-test
Winter 2007	pp1149	final	20070528	Vizon SciTec Inc.	Oncorhynchus mykiss	Survival					>	100			
Winter 2007	pp1149	final	20070528	Vizon SciTec Inc.	Ceriodaphnia dubia	Survival	>	100							
Winter 2007	pp1149	final	20070528	Vizon SciTec Inc.	Ceriodaphnia dubia	Reproduction						19.7	16.9	23.00	
Winter 2007	pp1149	final	20070528	Vizon SciTec Inc.	Pseudokirchneriella subcapitata	Growth					>	90.91			Hormesis present
Summer 2007	pp1149	final	20071105	Cantest Ltd.	Oncorhynchus mykiss	Survival					>	100			
Summer 2007	pp1149	final	20071105	Cantest Ltd.	Ceriodaphnia dubia	Survival	>	100							
Summer 2007	pp1149	final	20071105	Cantest Ltd.	Ceriodaphnia dubia	Reproduction						41.1	36.5	47.00	
Summer 2007	pp1149	final	20071105	Cantest Ltd.	Pseudokirchneriella subcapitata	Growth						76.5			Corrected for hormesis
Winter 2008	pp1149	final	20080520	Cantest Ltd.	Oncorhynchus mykiss	Survival					>	100			
Winter 2008	pp1149	final	20080520	Cantest Ltd.	Ceriodaphnia dubia	Survival	>	100							One replicate in 3.13% and 50% concentration was lost during transfer and was not used in statistical calculations.
Winter 2008	pp1149	final	20080520	Cantest Ltd.	Ceriodaphnia dubia	Reproduction						59.3	43.4	90.60	Same as above.
Winter 2008	pp1149	final	20080520	Cantest Ltd.	Pseudokirchneriella subcapitata	Growth					>	90.91			Hormesis present
Summer 2008	pp1149	final	20081014	Cantest Ltd.	Ceriodaphnia dubia	Survival	>	100							
Summer 2008	pp1149	final	20081014	Cantest Ltd.	Ceriodaphnia dubia	Reproduction						10.3	9.1	11.50	
Summer 2008	pp1149	final	20081014	Cantest Ltd.	Pseudokirchneriella subcapitata	Growth					>	90.91			Hormesis present
Winter 2009	pp1149	final	20090428	Cantest Ltd.	Ceriodaphnia dubia	Survival	>	100							
Winter 2009	pp1149	final	20090428	Cantest Ltd.	Ceriodaphnia dubia	Reproduction						24.24	20.14	28.15	
Winter 2009	pp1149	final	20090428	Cantest Ltd.	Pseudokirchneriella subcapitata	Growth					>	90.91			Hormesis present
Summer 2009	pp1149	final	20091103	Cantest Ltd.	Ceriodaphnia dubia	Survival	>	100							One test organism missing (100% concentration) and excluded from statistical calculations
Summer 2009	pp1149	final	20091103	Cantest Ltd.	Ceriodaphnia dubia	Reproduction						58.6	32.2	78.80	One test organism missing (100% concentration) and excluded from statistical calculations
Summer 2009	pp1149	final	20091103	Cantest Ltd.	Pseudokirchneriella subcapitata	Growth					>	90.91			Hormesis present

[1] Summer 2006 trout embryo re-test was completed during Cycle 5.

Table A1.2 Canfor Pulp Limited Partnership, Northwood Division - Calculation of geomeans and potential zones of sublethal effect.

	Fish					Invertebrate										Algae				
	Early Life Stage (EC25)					*Survival (LC50)*					*Reproduction (IC25)*					*Growth (IC25)*				
	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
	61.2	100	100	73.84	100	100	100	100	100	100	26.2	100	28.96	37.99	19.7	7.8	90.91	5.76	90.91	90.91
	59.1	71.98	100	100	100	100	100	100	100.00	100.00	11	38.72	11.10	17.71	41.10	10.2	90.91	57.12	90.91	76.5
	56.2	100	100	100	100	100	100	100	100.00	100.00	18.3	44.66	23.68	11.40	59.30	79.2	39.66	20.33	90.91	90.91
	62.9	24.92	63.04	100		100	100	100	100.00	100.00	20.6	31.97	23.88	36.16	10.30	67.4	0.72	20.90	50.7	90.91
		71.97	60.23	100			100	100	100.00	100.00		22.4	38.38	16.20	24.24		6.85	12.21	90.91	90.91
			71.74	69.7				100	100.00	100.00			25.08	24.20	58.60			90.91	85.5	90.91
			56.79					100					12.06					90.91		
			93.78					100					29.21					90.91		
Geomean	**59.8**	**66.4**	**78.6**	**89.5**	**100**	**100**	**100**	**100**	**100**	**100**	**18.2**	**41.5**	**22.3**	**21.8**	**29.8**	**25.5**	**17.4**	**32.6**	**81.6**	**88.3**
SE	1.4	13.7	6.9	7.3	0.0	0.0	0.0	0.0	0.0	0.0	3.1	13.6	3.2	5.5	10.4	18.7	19.6	13.5	8.1	2.9
1% effluent zone (m)																				
7000	117	105	89	78	70	70	70	70	70	70	386	168	314	320	235	274	401	215	86	79

Table A1.3 Canfor Pulp Limited Partnership, Prince George/Intercontinental Division, Sublethal Effluent Toxicity Test Results, Cycle Five.

Testing Period	Project Number	Effluent Description	Collection Date	Laboratory	Species Tested	Test type	Flag LC50%	LC50 %	LC50 Lower 95% cl	LC50 Upper 95% cl	Flag EC25 or IC25%	EC25 or IC25 %	EC25 or IC25 Lower 95% cl	EC25 or IC25 Upper 95% cl	Comments
		(final, cooling, etc.)	yyyymmdd				> for greater than 100%				> for greater than 100%				
Summer 2006[1]	pp1054	final	20070514	Cantest	Oncorhynchus mykiss	Survival						96.92	-	-	Retest
Winter 2007	pp1054	final	20070604	Cantest	Oncorhynchus mykiss	Survival						86.8	-	-	Mean control survival was 63.3%; below the 70% pass level.
Winter 2007	pp1054	final	20070604	Cantest	Ceriodaphnia dubia	Survival	>	100							Three adults were lost during the test; these replicates were removed from the statistical calculations.
Winter 2007	pp1054	final	20070604	Cantest	Ceriodaphnia dubia	Reproduction						19.6	17.9	21.8	
Winter 2007	pp1054	final	20070716	Cantest	Pseudokirchneriella subcapitata	Growth					>	90.91			Retest; not corrected for Hormesis
Summer 2007	pp1054	final	20071022	Cantest	Oncorhynchus mykiss	Survival					>	100			
Summer 2007	pp1054	final	20071022	Cantest	Ceriodaphnia dubia	Survival	>	100							One adult was lost during the test; this replicate was removed from the statistical calculations. Some of the final temperatures were as low as 23°C, below the recommended range of 24-26°C.
Summer 2007	pp1054	final	20071022	Cantest	Ceriodaphnia dubia	Reproduction						21.6	18	27.5	same as above.
Summer 2007	pp1054	final	20071022	Cantest	Pseudokirchneriella subcapitata	Growth					>	90.91			Hormesis observed
Winter 2008	pp1054	final	20080506	Cantest	Oncorhynchus mykiss	Survival						99	88.5	100	
Winter 2008	pp1054	final	20071022	Cantest	Ceriodaphnia dubia	Survival	>	100							Replicate 3 was not used for statistical calculations due to the lack of neonates in most concentrations.
Winter 2008	pp1054	final	20071022	Cantest	Ceriodaphnia dubia	Reproduction						44.3	38.4	51.3	same as above.
Winter 2008	pp1054	final	20071022	Cantest	Pseudokirchneriella subcapitata	Growth						75.3	n/a	n/a	Corrected for Hormesis
Summer 2008	pp1054	final	20081028	Cantest	Ceriodaphnia dubia	Survival	>	100							
Summer 2008	pp1054	final	20081028	Cantest	Ceriodaphnia dubia	Reproduction						44.7	20.3	70.3	
Summer 2008	pp1054	final	20081216	Cantest	Pseudokirchneriella subcapitata	Growth						0.13	0.12	0.14	IC25 calculation under review by Environment Canada
Winter 2009	pp1054	final	20090505	Cantest	Ceriodaphnia dubia	Survival	>	100							
Winter 2009	pp1054	final	20090505	Cantest	Ceriodaphnia dubia	Reproduction						26.1	21.1	30.8	
Winter 2009	pp1054	final	20090505	Cantest	Pseudokirchneriella subcapitata	Growth					>	90.91			Hormesis observed
Summer 2009	pp1054	final	20091027	Cantest	Ceriodaphnia dubia	Survival	>	100							Three test organisms were missing (one each from 3.13, 6.25 and 12.5% concentrations) and were excluded from statistical calculations
Summer 2009	pp1054	final	20091027	Cantest	Ceriodaphnia dubia	Reproduction						56.1	39.9	67.8	Three test organisms were missing (one each from 3.13, 6.25 and 12.5% concentrations) and were excluded from statistical calculations
Summer 2009	pp1054	final	20091027	Cantest	Pseudokirchneriella subcapitata	Growth					>	90.91			Hormesis observed

[1] Trout re-test result (new result).

Table A1.4 **Canfor Pulp Limited Partnership, Prince George/Intercontinental Division - Calculation of geomeans and potential zones of sublethal effect.**

	Fish					Invertebrate										Algae				
	Growth (EC25)					*Survival (LC50)*					*Reproduction (IC25)*					*Growth IC25)*				
	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
	100	20.71	11.10	57.58	86.8	100	100	100	100	100	21.6	32.76	61.08	63.76	19.6	7.7	72.24	57.63	75.22	90.91
	100	44.01	65.94	100.00	100	100	100	100	100	100.00	17.7	37.34	38.46	56.13	21.60	8.4	73.22	90.91	90.91	90.91
	100	100	64.75	100.00	99	100	100	100	100	100.00	20.1	75.28	70.65	56.20	44.30	77.3	70.86	62.60	90.91	75.3
	100	50.47	100.00	100.00		100	100	100	100	100.00	42.2	57.14	40.09	43.75	44.70	100	17.61	42.25	90.91	0.13
		59.17	58.90	61.10			100	100	100	100.00		56.62	62.83	50.60	26.10		54.2	56.67	90.91	90.91
			100.00	96.92				100	100	100.00			61.79	38.60	56.10			90.91	66.4	90.91
			60.74					100					61.86					90.91		
			39.50					100					29.17					90.91		
Geomean	**100**	**48.6**	**53.5**	**83.6**	**95.1**	**100**	**100**	**100**	**100**	**100**	**23.9**	**49.5**	**51.1**	**50.8**	**32.7**	**26.6**	**51.4**	**70.2**	**83.6**	**29.6**
SE	0.0	13.0	10.4	10.3	3.7	0.0	0.0	0.0	0.0	0.0	5.7	7.7	5.3	4.6	7.5	23.7	10.6	7.1	5.4	18.2
1% effluent zone (m)																				
7000	70	144	131	84	74	70	70	70	70	70	293	141	137	138	214	263	136	100	84	237

This IC25 value and calculation is under review by Environment Canada given an effect in growth observed at extremely low concentrations and higher concentrations were not tested.

The geomean for algal growth IC25 without the low value is 87.5%, SE is 3.5%, 1% effluent zone is 80 m.

Table A1.5 Quesnel River Pulp Company Effluent Sublethal Toxicity Test Results, Cycle Five.

Testing Period	Project Number	Effluent Description	Collection Date	Laboratory	Species Tested	Test type	Flag LC50%				Flag EC25 or IC25%				Comments
		(final, cooling, etc.)	yyyymmdd				> for greater than 100%	LC50 %	LC50 Lower 95% cl	LC50 Upper 95% cl	> for greater than 100%	EC25 or IC25 %	EC25 or IC25 Lower 95% cl	EC25 or IC25 Upper 95% cl	
Winter 2007	pp1057	final	20070528	Cantest Ltd.	Oncorhynchus mykiss	Survival						42.5	35.3	48.4	
Winter 2007	pp1057	final	20070528	Cantest Ltd.	Ceriodaphnia dubia	Survival	>	100							One organism in the control and one in the 100% concentration were missing, possibly lost during transfer and were not used for statistical calculations.
Winter 2007	pp1057	final	20070528	Cantest Ltd.	Ceriodaphnia dubia	Reproduction						35	33.9	36.2	Same as above
Winter 2007	pp1057	final	20070528	Cantest Ltd.	Pseudokirchneriella subcapitata	Growth						58.7	39.7	78.5	Corrected for Hormesis
Summer 2007	pp1057	final	20071029	Cantest Ltd.	Oncorhynchus mykiss	Survival						30.4	24.1	34.8	
Summer 2007	pp1057	final	20071029	Cantest Ltd.	Ceriodaphnia dubia	Survival	>	100							
Summer 2007	pp1057	final	20071029	Cantest Ltd.	Ceriodaphnia dubia	Reproduction						11.1	8.9	28.1	
Summer 2007	pp1057	final	20071029	Cantest Ltd.	Pseudokirchneriella subcapitata	Growth						2.3	1.9	2.7	
Winter 2008	pp1057	final	20080513	Cantest Ltd.	Oncorhynchus mykiss	Survival						23	17.8	24.5	
Winter 2008	pp1057	final	20080513	Cantest Ltd.	Ceriodaphnia dubia	Survival		45.1	26.6	100					
Winter 2008	pp1057	final	20080513	Cantest Ltd.	Ceriodaphnia dubia	Reproduction						7.3	3.6	14.8	
Winter 2008	pp1057	final	20080513	Cantest Ltd.	Pseudokirchneriella subcapitata	Growth						1.7	1.1	2.5	
Summer 2008	pp1057	final	20081021	Cantest Ltd.	Ceriodaphnia dubia	Survival	>	100							
Summer 2008	pp1057	final	20081021	Cantest Ltd.	Ceriodaphnia dubia	Reproduction						29.6	23.9	33.1	
Summer 2008	pp1057	final	20081216	Cantest Ltd.	Pseudokirchneriella subcapitata	Growth						0.0551	0.0006	0.0765	Corrected for Hormesis
Winter 2009	pp1057	final	20090421	Cantest Ltd.	Ceriodaphnia dubia	Survival		62.57	44.13	88.73					
Winter 2009	pp1057	final	20090421	Cantest Ltd.	Ceriodaphnia dubia	Reproduction						5.19	1.58	10.33	
Winter 2009	pp1057	final	20090421	Cantest Ltd.	Pseudokirchneriella subcapitata	Growth						4.51	3.06	5.74	
Summer 2009	pp1057	final	20091103	Cantest Ltd.	Ceriodaphnia dubia	Survival		69.9	66.6	73.2					Two test organisms missing (50% concentration) and were excluded from statistical calculations
Summer 2009	pp1057	final	20091103	Cantest Ltd.	Ceriodaphnia dubia	Reproduction						59.8	56.9	60.1	Two test organisms missing (50% concentration) and were excluded from statistical calculations
Summer 2009	pp1057	final	20091103	Cantest Ltd.	Pseudokirchneriella subcapitata	Growth						5	3.9	5.4	Corrected for Hormesis

Table A1.6 **Quesnel River Pulp Company - Calculation of geomeans and potential zones of sublethal effect.**

	Fish					Invertebrate										Algae				
	Early Life Stage (EC25)					*Survival (LC50)*					*Reproduction (IC25)*					Growth (IC25)				
	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
	6.25	29.24	14.47	18.79	42.5	100	100	70.72	98.96	100	21.2	13.06	20.58	26.66	35	4.3	5.61	0.08	3.15	58.7
	100	16.12	32.42	56.66	30.4	100	100	95.58	100	100	12.2	14.59	13.86	13.21	11.1	6	5	1.81	0.08	2.3
	63.8	43.5	43.54	11.5	23	22.6	61.61	100	78.36	45.1	10.6	26.63	30.62	27.27	7.3	2.7	16.05	2.08	0.0379	1.7
	100	21.97	38.85	37.8		100	73.49	77.11	76	100	20.8	13.56	12.37	30.8	29.6	1	0.55	0.33	0.025	0.0551
		7.4	27.23	26.6			100	100	52.5	62.57		23.67	23.3	15.2	5.19		0.039	1.40	0.69	4.51
			10.31	29.5				100	36.9	69.9			63.25	30.6	59.8			30.90	0.02	5
			91.24					100					31.45					4.99		
			12.83					81					9.82					6.46		
			36.18																	
Geomean	**44.7**	**20.2**	**27.6**	**26.7**	**31.0**	**68.9**	**85.3**	**89.8**	**69.7**	**76.3**	**15.5**	**17.5**	**21.7**	**22.7**	**17.2**	**2.89**	**1.57**	**1.85**	**0.12**	**2.57**
SE	22.1	6.1	8.7	7.9	4.9	19.4	8.2	4.3	12.6	11.9	2.8	2.8	6.1	3.9	10.6	1.07	2.88	3.64	0.62	11.46
1% effluent zone (m)																				
200	4	10	7	7	6	3	2	2	3	3	13	11	9	9	12	69	127	108	1640	78

Table A1.7 Cariboo Pulp and Paper Company Effluent Sublethal Toxicity Test Results, Cycle Five.

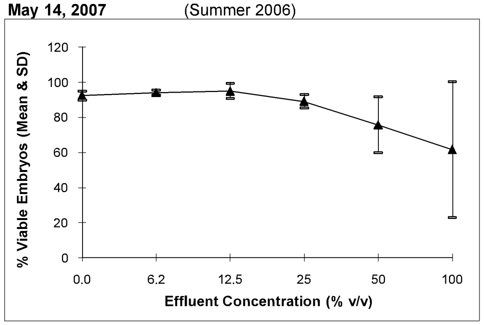
Testing Period	Project Number	Effluent Description	Collection Date	Laboratory	Species Tested	Test type	Flag LC50%	LC50 %	LC50 Lower 95% cl	LC50 Upper 95% cl	Flag EC25 or IC25%	EC25 or IC25 %	EC25 or IC25 Lower 95% cl	EC25 or IC25 Upper 95% cl	Comments
		(final, cooling, etc.)	yyyymmdd				> for greater than 100%				> for greater than 100%				
Winter 2007	pp1068	final	20070522	Cantest Ltd	Oncorhynchus mykiss	Survival					>	100			
Winter 2007	pp1068	final	20070522	Cantest Ltd	Ceriodaphnia dubia	Survival	>	100							
Winter 2007	pp1068	final	20070522	Cantest Ltd	Ceriodaphnia dubia	Reproduction						12.9	5.5	18.1	
Winter 2007	pp1068	final	20070522	Cantest Ltd	Pseudokirchneriella subcapitata	Growth					>	90.91			Hormesis present
Summer 2007	pp1068	final	20080506	Cantest Ltd	Oncorhynchus mykiss	Survival						76.4	65.1	86.3	Test repeated because original test failed minimum acceptability criteria
Summer 2007	pp1068	final	20071029	Cantest Ltd	Ceriodaphnia dubia	Survival	>	100							
Summer 2007	pp1068	final	20071029	Cantest Ltd	Ceriodaphnia dubia	Reproduction						73.6	67.5	80.1	
Summer 2007	pp1068	final	20071029	Cantest Ltd	Pseudokirchneriella subcapitata	Growth					>	90.91			Hormesis present
Winter 2008	pp1068	final	20080527	Cantest Ltd	Oncorhynchus mykiss	Survival					>	100			
Winter 2008	pp1068	final	20080708	Cantest Ltd	Ceriodaphnia dubia	Survival		57.3	53	70.8					
Winter 2008	pp1068	final	20080708	Cantest Ltd	Ceriodaphnia dubia	Reproduction						7.6	4.7	11.6	
Winter 2008	pp1068	final	20080527	Cantest Ltd	Pseudokirchneriella subcapitata	Growth					>	90.91			
Summer 2008	pp1068	final	20081014	Cantest Ltd	Ceriodaphnia dubia	Survival	>	100							
Summer 2008	pp1068	final	20081014	Cantest Ltd	Ceriodaphnia dubia	Reproduction						27.8	17.7	42.2	
Summer 2008	pp1068	final	20081014	Cantest Ltd	Pseudokirchneriella subcapitata	Growth					>	90.91			
Winter 2009	pp1068	final	20090421	Cantest Ltd	Ceriodaphnia dubia	Survival	>	100							
Winter 2009	pp1068	final	20090421	Cantest Ltd	Ceriodaphnia dubia	Reproduction					>	100			
Winter 2009	pp1068	final	20090421	Cantest Ltd	Pseudokirchneriella subcapitata	Growth					>	90.91			Hormesis present
Summer 2009	pp1068	final	20091103	Cantest Ltd	Ceriodaphnia dubia	Survival		66.3	57.6	76.3					
Summer 2009	pp1068	final	20091103	Cantest Ltd	Ceriodaphnia dubia	Reproduction						33.5	29.9	35.3	
Summer 2009	pp1068	final	20091103	Cantest Ltd	Pseudokirchneriella subcapitata	Growth					>	90.91			Hormesis present

Table A1.8 Cariboo Pulp and Paper Company - Calculation of geomeans and potential zones of sublethal effect

	Fish					Invertebrate										Algae				
	Early Life Stage (EC25)					*Survival (LC50)*					*Reproduction (IC25)*					*Growth (IC25)*				
	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
	6.25	100	52.69	100	100	100	100	100	100	100	71.6	56.39	43.36	26.13	12.9	18.4	67.14	90.91	90.91	90.91
	100	100	100	100	76.4	100	100	100	100	100	96.7	67.14	19.37	35.78	73.6	51.3	90.91	90.91	90.91	90.91
	100	100	100	100	100	100	100	100	100	57.3	38.6	36.09	19.36	49.2	7.6	67.8	90.91	26.01	90.91	90.91
	100	100	16.23	75.74		100	100	100	100	100	100	78.74	51.07	20.16	27.8	83	2.23	42.10	90.91	90.91
		100	100	100			100	100	100	100		63.76	66.95	61.9	100		90.91	90.91	90.91	90.91
			100	100				100	100	66.3			59.98	18	33.5			76.29	90.91	90.91
			100					100					58.82					90.91		
			100					100					59.54					90.91		
Geomean	**50**	**100**	**73.5**	**95.5**	**91.4**	**100**	**100**	**100**	**100**	**85.1**	**71.9**	**58.5**	**43.0**	**31.8**	**29.6**	**48.0**	**40.8**	**69.1**	**90.9**	**90.9**
SE	23.4	0.0	11.3	6.1	6.8	0.0	0.0	0.0	0.0	10.7	14.2	7.1	6.6	6.3	15.0	13.8	17.2	9.2	0.0	0.0
1% effluent zone (m)																				
6000	120	60	82	63	66	60	60	60	60	71	83	103	140	189	203	125	147	87	66	66

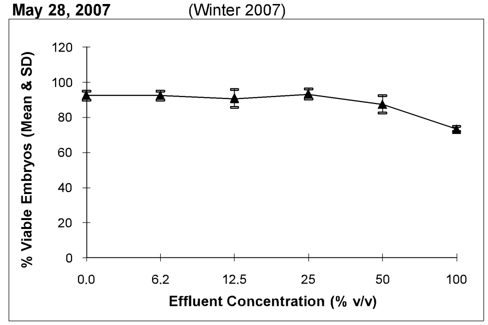
Figure A1.1 **Mean percent viable rainbow trout embryos (± 1 standard deviation) in test concentrations and controls for effluent sublethal toxicity tests, Canfor Pulp Limited Partnership, Northwood Division, EEM Cycle Five.**

May 14, 2007 (Summer 2006)

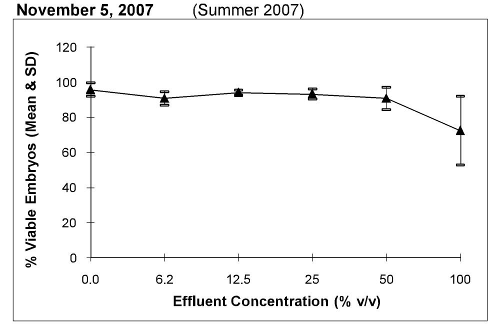


(retest from Cycle 4, not reported in Cycle 4 interpretive report)

May 28, 2007 (Winter 2007)



November 5, 2007 (Summer 2007)



May 20, 2008 (Winter 2008)

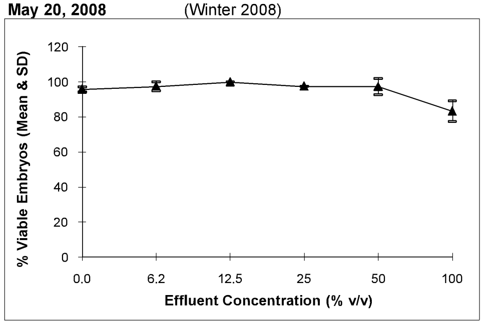
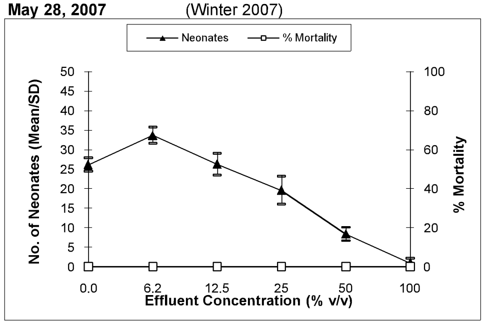
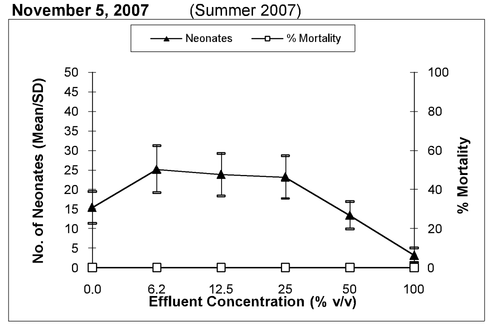


Figure A1.2 **Mean mortality and number of *Ceriodaphnia dubia* neonates (± 1 standard deviation) in test concentrations anc controls for effluent sublethal toxicity tests, Canfor Pulp Limited Partnership, Northwood Division, EEM Cycle Five.**

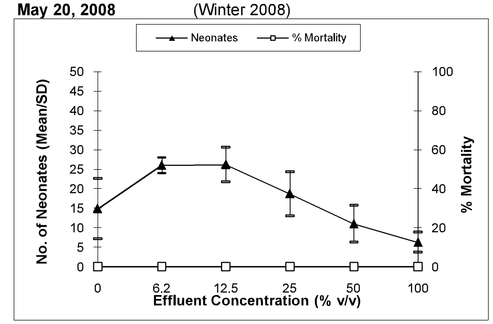
May 28, 2007 (Winter 2007)



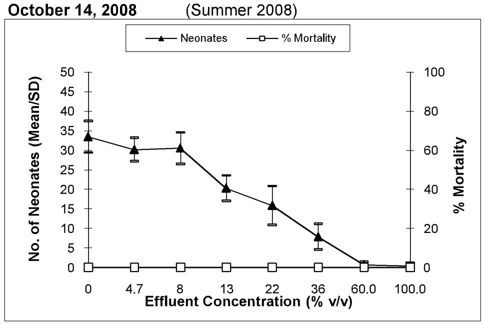
November 5, 2007 (Summer 2007)



May 20, 2008 (Winter 2008)

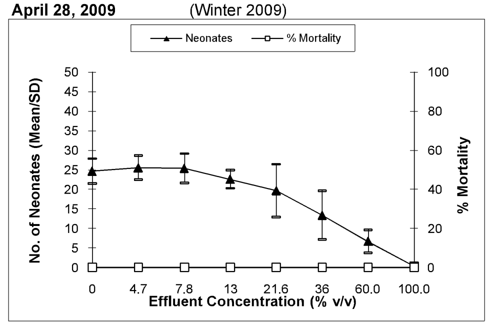


October 14, 2008 (Summer 2008)



SD = Standard deviation, noted as one SD above and below the mean.

April 28, 2009 (Winter 2009)



SD = Standard deviation, noted as one SD above and below the mean.

November 3, 2009 (Summer 2009)

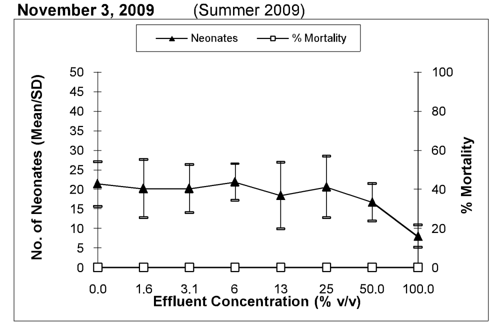
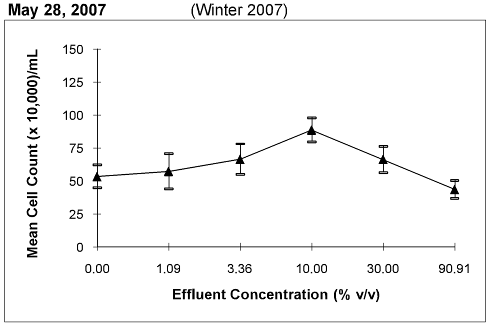
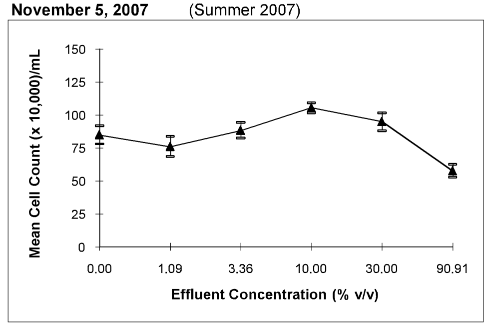


Figure A1.3 **Mean cell counts (± 1 standard deviation) of *Pseudokirchneriella subcapitata* in test concentrations and controls for effluent subletha toxicity tests, Canfor Pulp Limited Partnership, Northwood Division, EEM Cycle Five.**

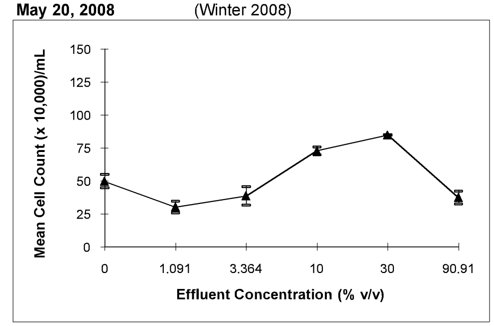
May 28, 2007 (Winter 2007)



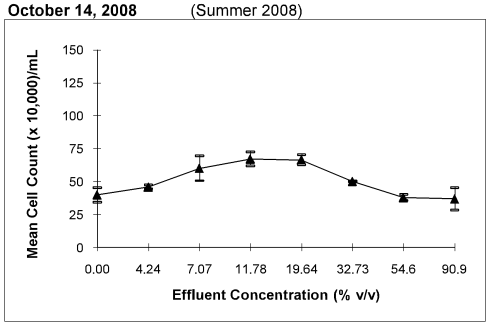
November 5, 2007 (Summer 2007)



May 20, 2008 (Winter 2008)

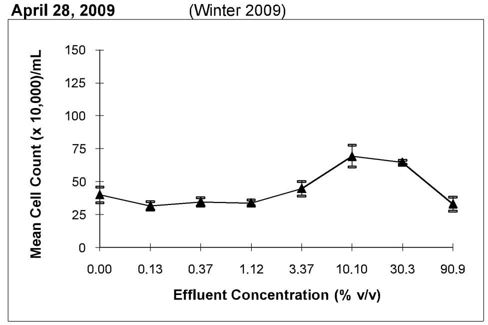


October 14, 2008 (Summer 2008)



SD = Standard deviation, noted as one SD above and below the mean.

April 28, 2009 (Winter 2009)



SD = Standard deviation, noted as one SD above and below the mean.

November 3, 2009 (Summer 2009)

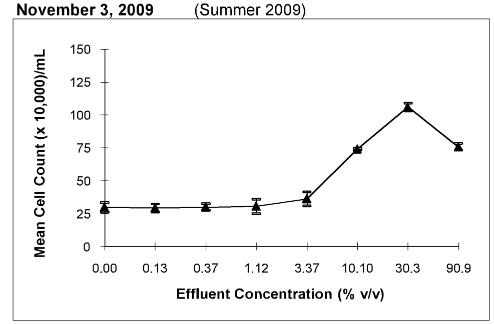


Figure A1.4 **Mean percent viable rainbow trout embryos (± standard deviation) following exposure to effluent, Canfor Pulp Limited Partnership, PG/IC Division, Upper Fraser River EEM Cycle Five.**

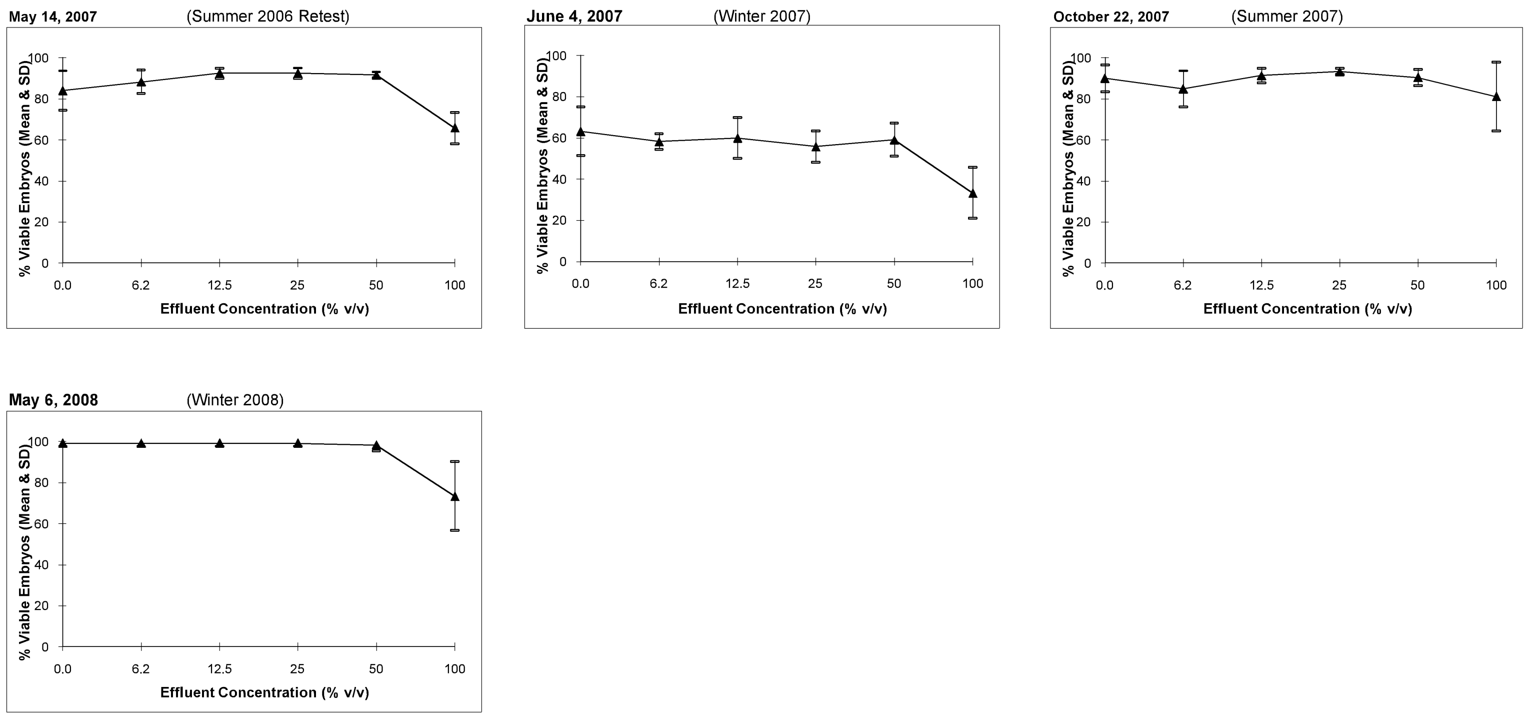


Figure A1.5 **Mean mortality and number of neonates (± standard deviation) produced by Ceriodaphnia dubia following exposure to effluent, Canfor Pu Limited Partnership, PG/IC Division, Upper Fraser River EEM Cycle Five**

June 4, 2007 (Winter 2007) — **October 22, 2007** (Summer 2007) — **May 6, 2008** (Winter 2008)

October 28, 2008 (Summer 2008) — **May 5, 2009** (Winter 2009) — **October 27, 2009** (Summer 2009)

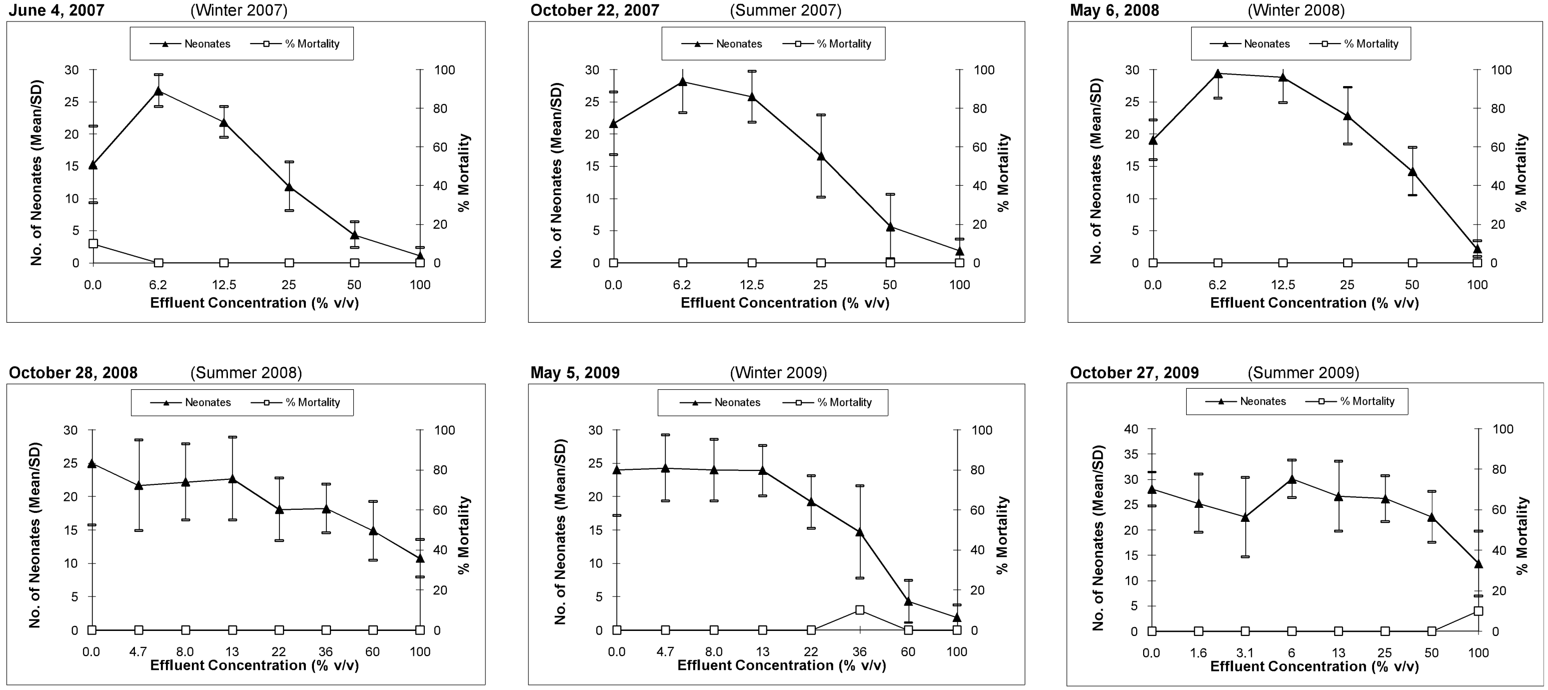
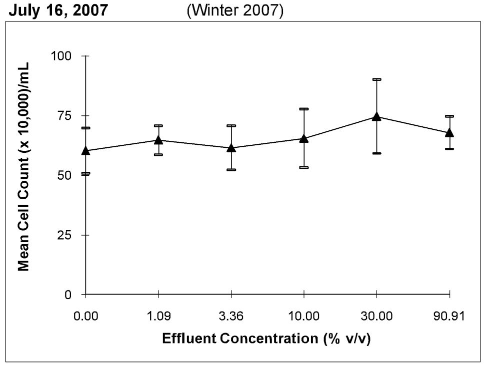
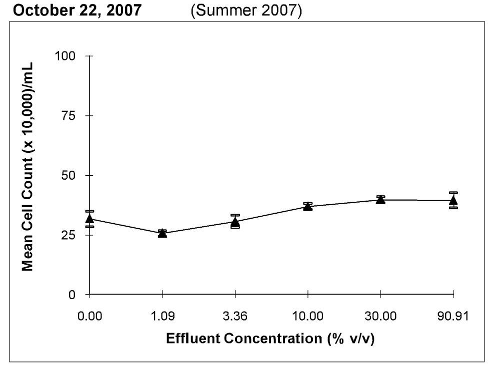


Figure A1.6 **Mean cell counts (± standard deviation) of *Pseudokirchneriella subcapitata* following exposure to effluent, Canfor Pulp Limited Partnership PG/IC Division, Upper Fraser River EEM Cycle Five.**

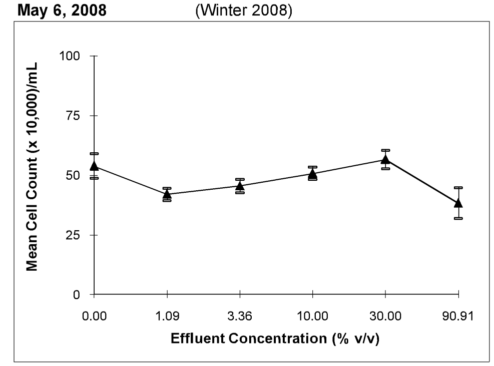
July 16, 2007 (Winter 2007)



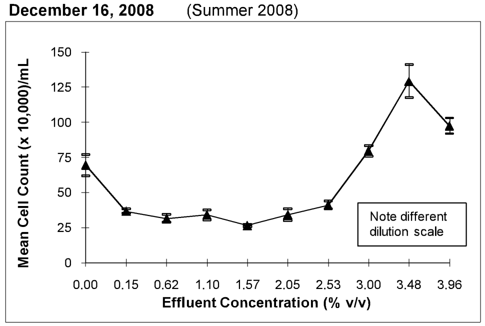
October 22, 2007 (Summer 2007)



May 6, 2008 (Winter 2008)

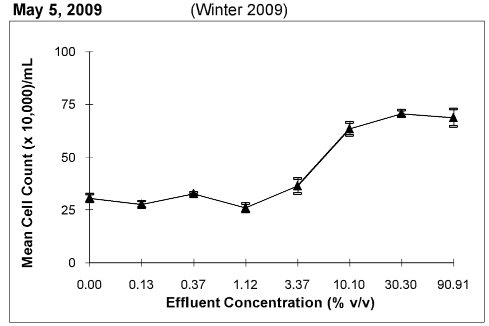


December 16, 2008 (Summer 2008)



The IC25 calculation and test results for Summer 2008 are under review by Environment Canada.

May 5, 2009 (Winter 2009)



October 27, 2009 (Summer 2009)

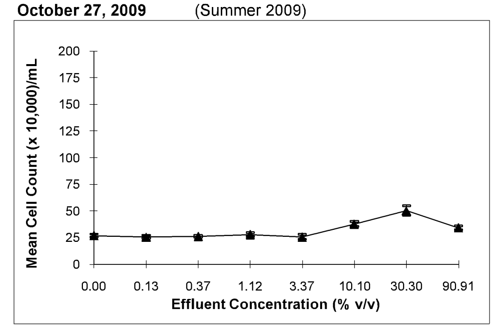


Figure A1.7 **Mean percent viable rainbow trout embryos (± 1 standard deviation) in test concentrations and controls for effluent sublethal toxicity tests, Quesnel River Pulp Company, Upper Fraser River EEM Cycle Five.**

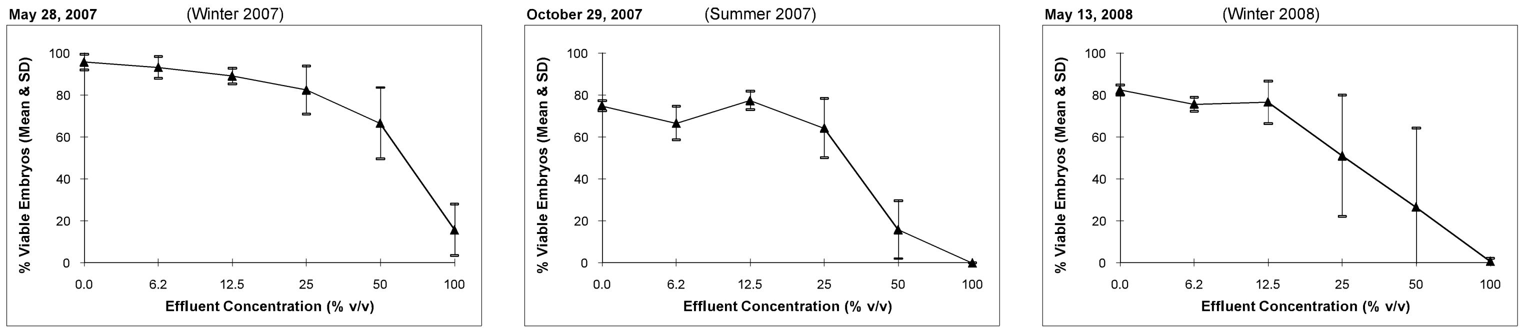
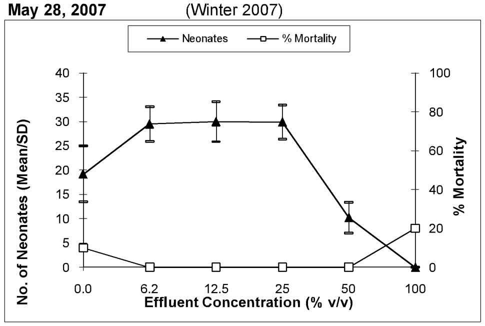
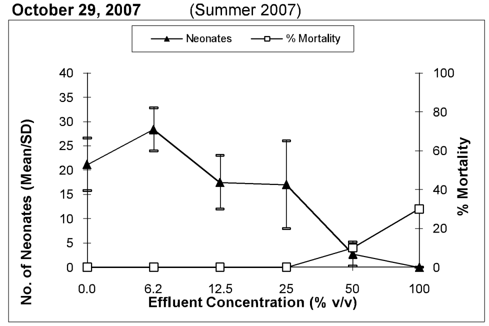


Figure A1.8 **Mean mortality and number of *Ceriodaphnia dubia* neonates (± 1 standard deviation) in test concentrations and controls for effluen sublethal toxicity tests, Quesnel River Pulp Company, Upper Fraser River EEM Cycle Five.**

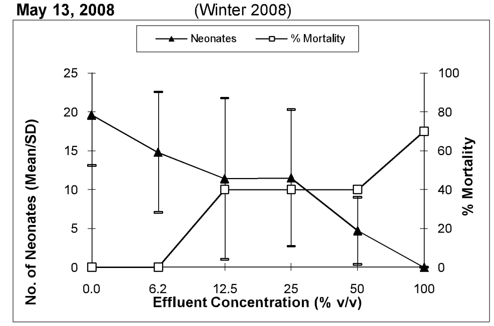
May 28, 2007 (Winter 2007)



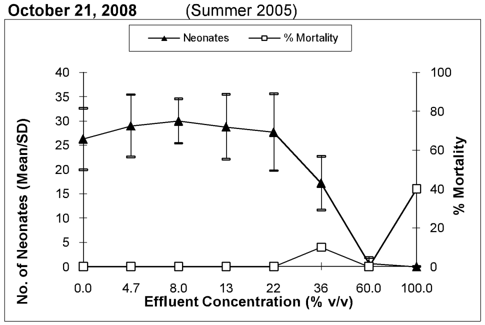
October 29, 2007 (Summer 2007)



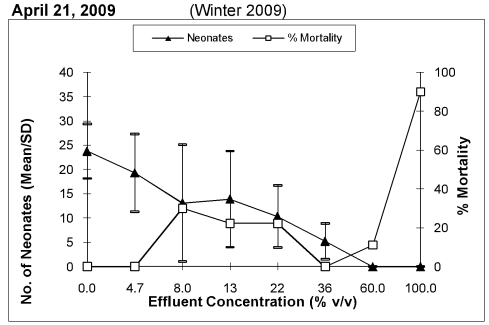
May 13, 2008 (Winter 2008)



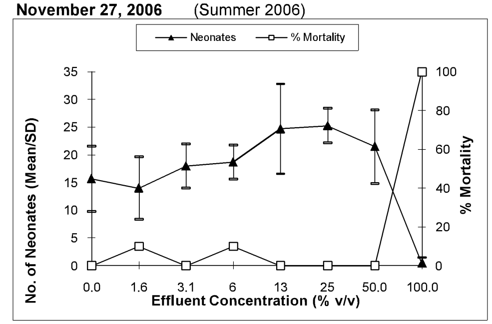
October 21, 2008 (Summer 2005)



April 21, 2009 (Winter 2009)

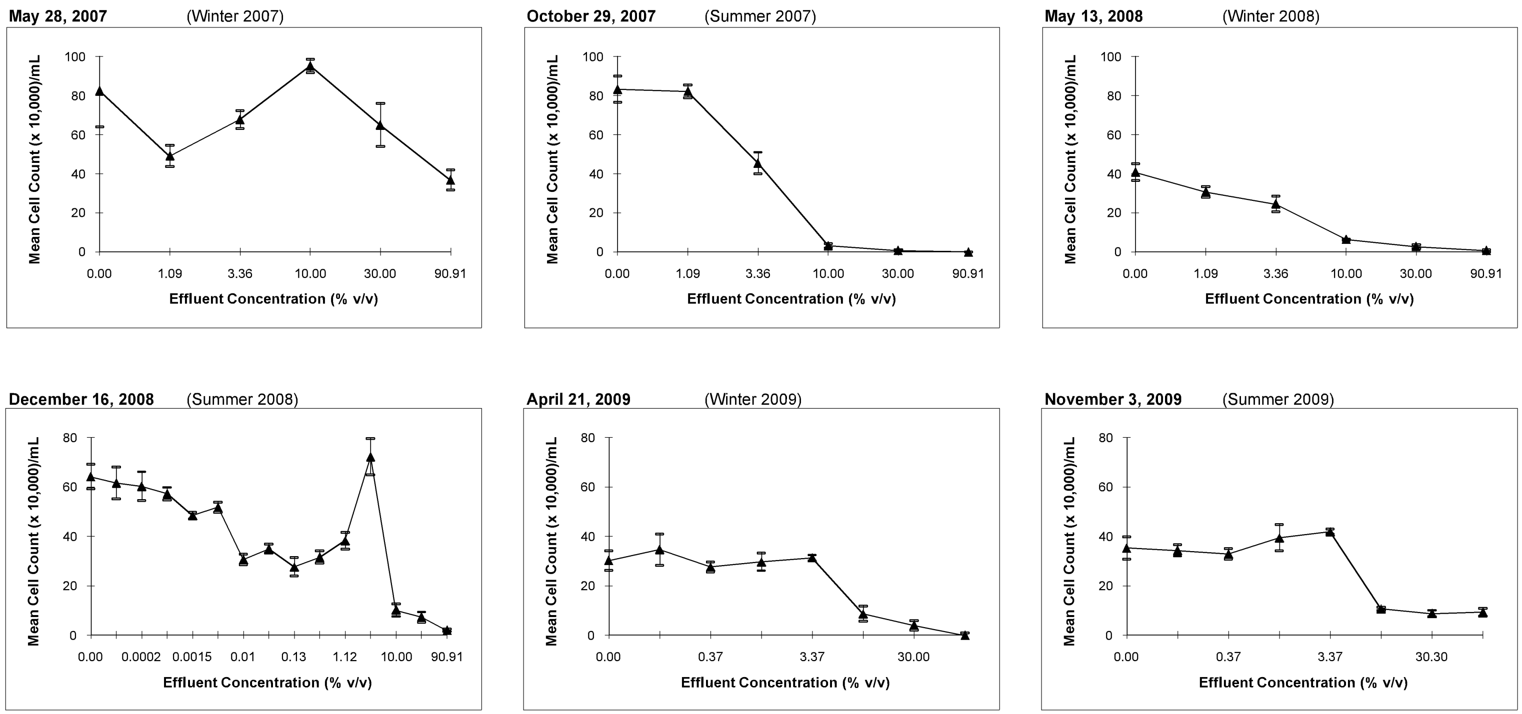


November 27, 2006 (Summer 2006)



SD = Standard deviation, noted as one SD above and below the mean.

Figure A1.9 **Mean cell counts (± 1 standard deviation) of *Pseudokirchneriella subcapitata* in test concentrations and controls for effluent sublethal toxicity tests, Quesnel River Pulp Company, Upper Fraser River EEM Cycle Five.**



SD = Standard deviation, noted as one SD above and below the mean.

Figure A1.10 **Mean percent (± 1 standard deviation) viable rainbow trout embryos in test concentrations and controls for effluent sublethal toxicity tests, Cariboo Pulp and Paper Company, Upper Fraser River EEM Cycle Five.**

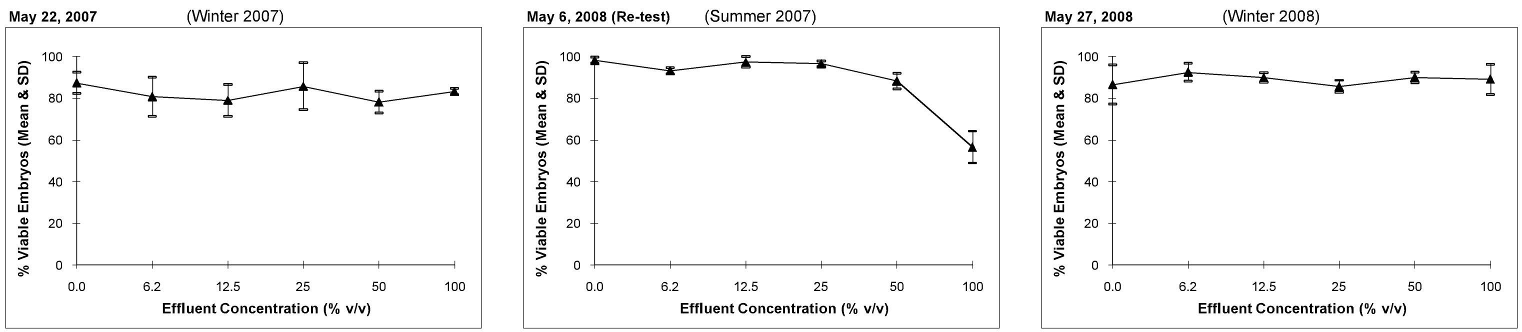
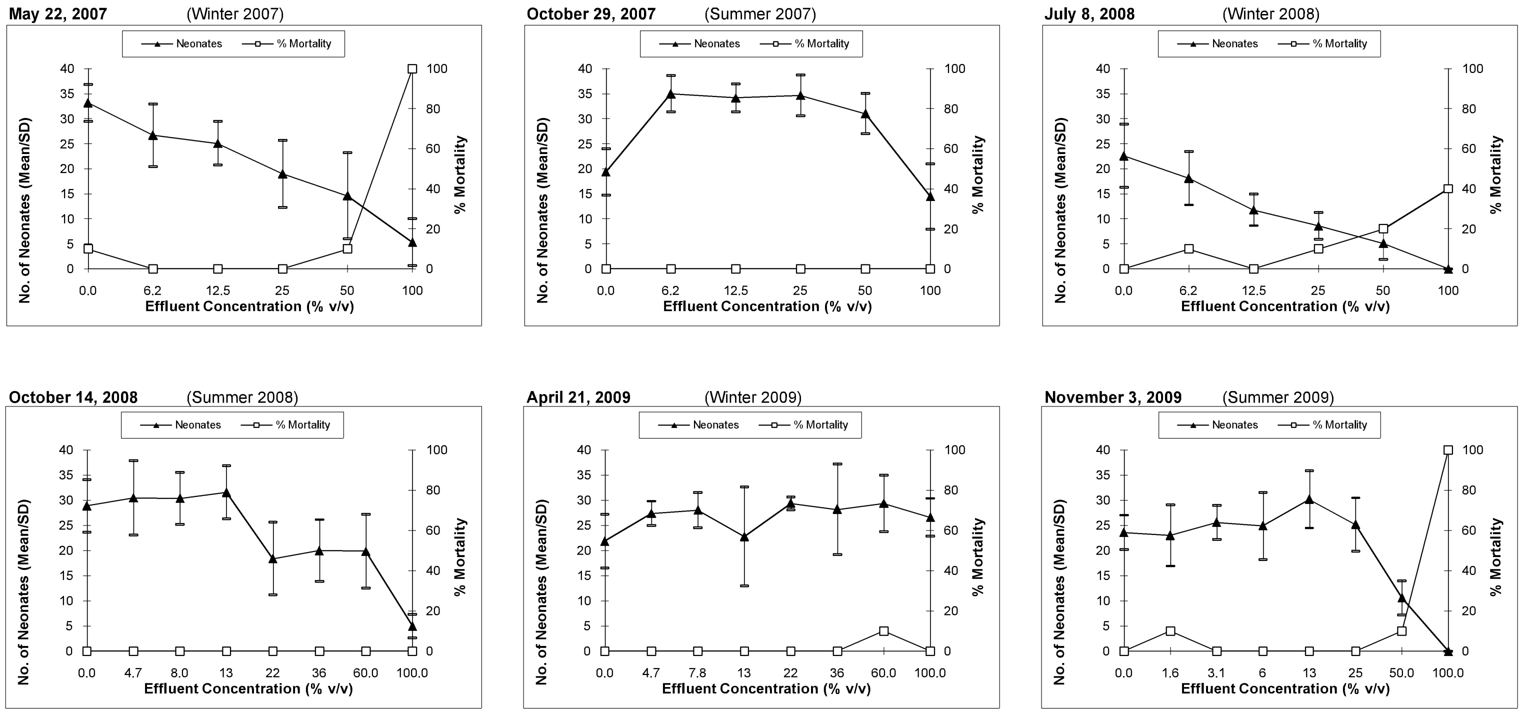
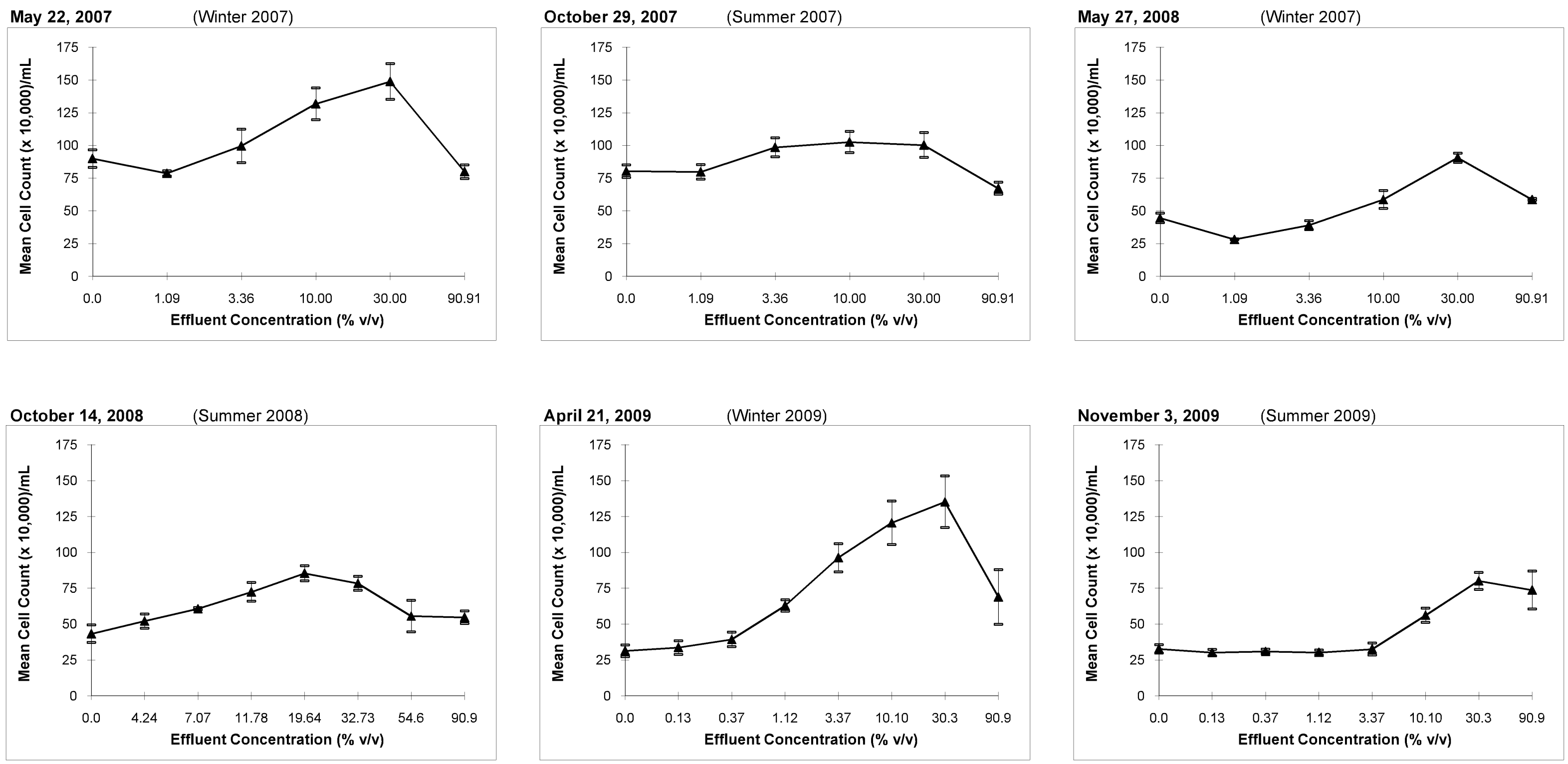


Figure A1.11 Mean mortality and number of *Ceriodaphnia dubia* neonates (± 1 standard deviation) in test concentrations and controls for effluent subletha toxicity tests, Cariboo Pulp and Paper Company, upper Fraser River EEM Cycle Five.



SD = Standard deviation, noted as one SD above and below the mean.

Figure A1.12 **Mean cell counts (± 1 standard deviation) of *Pseudokirchneriella subcapitata* in test concentrations and controls for effluent sublethal toxicity tests, Cariboo Pulp and Paper Company, Upper Fraser River EEM Cycle Five.**



SD = Standard deviation, noted as one SD above and below the mean.

Appendix A2

Fish Survey Data

Table A2.1 Juvenile chinook salmon measurements and indices, collected for the Upper Fraser River EEM Cycle Five fish survey.

Date	Fish Number	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Condition (g/cm3)	LSI	Effort (# seines)
Shelley - Reference area for Prince George								
24-Sep-09	1	83	7.55	0.065	6.21	1.32	1.05	8
	2	77	3.87	0.033	3.31	0.85	1.00	
	3	64	3.38	0.024	2.8	1.29	0.86	
	4	68	4.23	0.033	3.61	1.35	0.91	
	5	71	4.54	0.032	3.79	1.27	0.84	
	6	57	2.72	0.029	2.21	1.47	1.31	
	7	66	3.68	0.042	3.09	1.28	1.36	
	8	67	4.04	0.039	3.43	1.34	1.14	
	9	61	3.25	0.04	2.54	1.43	1.57	
	10	79	6.24	0.04	5.57	1.27	0.72	
	11	78	5.78	0.035	5.27	1.22	0.66	
	12	77	5.94	0.038	5.26	1.30	0.72	
	13	55	2.43			1.46		
	14	78	5.93	0.049	5.29	1.25	0.93	
	15	63	3.31	0.035	2.72	1.32	1.29	
	16	64	3.7	0.028	3.29	1.41	0.85	
	17	58	2.51	0.019	2.11	1.29	0.90	
	18	53	1.81	0.017	1.48	1.22	1.15	
	19	61	2.94	0.03	2.37	1.30	1.27	
	20	72	5.56	0.03	4.41	1.49	0.68	
	21	72	4.75	0.033	4.04	1.27	0.82	
	22	63	3.38			1.35		
	23	64	3.5			1.34		
	24	67	3.95			1.31		
	25	67	3.81			1.27		
	26	67	4.24			1.41		
	27	70	4.53			1.32		
	28	73	5.08			1.31		
	29	63	3.19			1.28		
	30	64	3.53			1.35		
	31	70	4.27			1.24		
	32	67	3.93			1.31		
	33	55	2.26			1.36		
	34	72	4.57			1.22		
	35	63	3.19			1.28		
	36	74	5.19			1.28		
	37	71	4.43			1.24		
	38	65	3.6			1.31		
	39	72	4.76			1.28		
	40	64	3.55			1.35		
	41	67	3.66			1.22		
	42	69	3.94			1.20		
	43	69	4.01			1.22		
	44	75	5.35			1.27		
	45	66	3.82			1.33		
	46	57	2.54			1.37		
	47	66	3.57			1.24		
	48	60	3.01			1.39		
	49	64	3.41			1.30		
	50	68	4.23			1.35		
	51	61	2.85			1.26		
	52	62	2.99			1.25		
	53	74	5.38			1.33		
	54	68	4.38			1.39		
	55	59	2.66			1.30		
	56	74	5.34			1.32		
	57	68	4.01			1.28		
	58	60	2.63			1.22		
	59	78	6.19			1.30		
	60	76	5.61			1.28		
	61	70	4.25			1.24		
	62	63	2.75			1.10		
	63	67	3.58			1.19		
	64	58	2.52			1.29		
	65	57	2.37			1.28		
	66	73	4.61			1.19		
	67	66	3.38			1.18		
	68	60	2.86			1.32		
	69	64	3.7			1.41		
	70	63	3.24			1.30		
	71	67	4.12			1.37		
	72	61	2.84			1.25		
	73	62	3.16			1.33		
	74	67	3.61			1.20		
	75	60	2.91			1.35		
	76	57	2.38			1.29		
	77	63	3.29			1.32		
	78	67	3.92			1.30		
	79	63	3.28			1.31		
	80	58	2.79			1.43		
	81	53	2.02			1.36		
	82	64	3.37			1.29		
	83	64	2.64			1.01		
	84	63	3.25			1.30		
	85	68	4.09			1.30		
	86	73	4.59			1.18		
	87	65	3.77			1.37		
	88	65	3.67			1.34		
	89	71	4.53			1.27		
	90	79	5.05			1.02		
	91	75	5.67			1.34		
	92	62	3.26			1.37		
	93	63	3.69			1.48		
	94	65	3.43			1.25		
	95	62	3.11			1.30		
	96	67	3.5			1.16		
	97	69	4.52			1.38		
	98	65	3.48			1.27		
	99	55	2.25			1.35		
	100	58	2.42			1.24		
Maximum		***83***	***7.55***	***0.065***	***6.21***	***1.49***	***1.57***	
Median		***65.5***	***3.64***	***0.033***	***3.37***	***1.30***	***0.92***	
Minimum		***53***	***1.81***	***0.017***	***1.48***	***0.85***	***0.66***	
Mean		***66.1***	***3.81***	***0.035***	***3.64***	***1.29***	***1.00***	
SD		***6.4***	***1.06***	***0.010***	***1.32***	***0.09***	***0.26***	
SE		***0.64***	***0.11***	***0.002***	***0.30***	***0.01***	***0.06***	

Table A2.1 Juvenile chinook salmon measurements and indices, collected for the Upper Fraser River EEM Cycle Five fish survey.

Date	Fish Number	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Condition (g/cm3)	LSI	Effort (# seines)
Prince George Exposure Area								
25-Sep-09	1	63	3.26	0.031	2.79	1.30	1.11	7
	2	82	6.9	0.062	6.11	1.25	1.01	
	3	68	4.1	0.032	3.68	1.30	0.87	
	4	67	4.12	0.055	3.62	1.37	1.52	
	5	62	2.86	0.033	2.45	1.20	1.35	
	6	62	2.84	0.03	2.44	1.19	1.23	
	7	68	4.01	0.039	3.53	1.28	1.10	
	8	61	2.61	0.035	2.25	1.15	1.56	
	9	63	3.41	0.033	3.02	1.36	1.09	
	10	62	2.74	0.028	2.41	1.15	1.16	
	11	63	3.22	0.033	2.89	1.29	1.14	
	12	59	2.7	0.038	2.54	1.31	1.50	
	13	79	6.54	0.055	5.88	1.33	0.94	
	14	73	4.75	0.054	4.35	1.22	1.24	
	15	75	5.35	0.049	4.74	1.27	1.03	
	16	74	5	0.038	4.56	1.23	0.83	
	17	79	6.14	0.054	5.54	1.25	0.97	
	18	68	3.9	0.069	3.42	1.24	2.02	
	19	72	4.05	0.032	3.78	1.09	0.85	
	20	79	6.21	0.048	6.19	1.26	0.78	
	21	57	2.47			1.33		
	22	76	5.61			1.28		
	23	71	4.77			1.33		
	24	69	4.14			1.26		
	25	61	2.96			1.30		
	26	57	2.47			1.33		
	27	57	2.51			1.36		
	28	63	2.93			1.17		
	29	53	1.98			1.33		
	30	59	2.74			1.33		
	31	63	3.28			1.31		
	32	61	2.81			1.24		
	33	59	2.49			1.21		
	34	57	2.56			1.38		
	35	62	3.1			1.30		
	36	70	4.75			1.38		
	37	65	3.39			1.23		
	38	61	3.61			1.59		
	39	71	4.35			1.22		
	40	66	3.88			1.35		
	41	62	3.07			1.29		
	42	68	3.62			1.15		
	43	70	3.86			1.13		
	44	63	3.49			1.40		
	45	84	7.23			1.22		
	46	56	2.52			1.43		
	47	62	2.83			1.19		
	48	65	3.45			1.26		
	49	62	3.14			1.32		
	50	72	4.8			1.29		
	51	65	3.59			1.31		
	52	58	2.56			1.31		
	53	63	3.31			1.32		
	54	58	2.69			1.38		
	55	70	4.64			1.35		
	56	57	2.38			1.29		
	57	49	1.49			1.27		
	58	54	2.22			1.41		
	59	63	2.87			1.15		
	60	67	3.8			1.26		
	61	71	4.69			1.31		
	62	62	3.03			1.27		
	63	55	2.21			1.33		
	64	66	3.89			1.35		
	65	69	4.3			1.31		
	66	65	4.04			1.47		
	67	63	3.25			1.30		
	68	55	2.21			1.33		
	69	67	3.87			1.29		
	70	68	3.22			1.02		
	71	67	4.5			1.50		
	72	61	3.27			1.44		
	73	57	2.43			1.31		
	74	53	1.9			1.28		
	75	63	3.23			1.29		
	76	60	2.77			1.28		
	77	53	2.23			1.50		
	78	60	3.47			1.61		
	79	62	2.89			1.21		
	80	67	3.99			1.33		
	81	63	3.7			1.48		
	82	53	1.98			1.33		
	83	62	3.39			1.42		
	84	62	3.79			1.59		
	85	60	2.82			1.31		
	86	60	2.88			1.33		
	87	52	1.68			1.19		
	88	72	5.03			1.35		
	89	70	4.15			1.21		
	90	61	2.96			1.30		
	91	55	2.51			1.51		
	92	63	3.48			1.39		
	93	62	2.99			1.25		
	94	62	3.19			1.34		
	95	60	2.94			1.36		
	96	53	1.78			1.20		
	97	65	4.01			1.46		
	98	68	4.28			1.36		
	99	67	3.83			1.27		
	100	60	3.15			1.46		
Maximum		***84***	***7.23***	***0.069***	***6.19***	***1.61***	***2.02***	
Median		***63***	***3.27***	***0.038***	***3.575***	***1.30***	***1.11***	
Minimum		***49***	***1.49***	***0.028***	***2.25***	***1.02***	***0.78***	
Mean		***63.8***	***3.49***	***0.042***	***3.81***	***1.31***	***1.17***	
SD		***6.8***	***1.11***	***0.012***	***1.31***	***0.10***	***0.30***	
SE		***0.68***	***0.11***	***0.003***	***0.29***	***0.01***	***0.07***	

Table A2.1 Juvenile chinook salmon measurements and indices, collected for the Upper Fraser River EEM Cycle Five fish survey.

Date	Fish Number	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Condition (g/cm3)	LSI	Effort (# seines)
Cottonwood - Reference area for Quesnel								
27-Sep-09	1	93	9.23	0.073	8.19	1.15	0.89	
	2	94	9.15	0.08	8.4	1.10	0.95	
	3	85	6.68	0.042	6.02	1.09	0.70	
	4	83	6.86	0.034	6.17	1.20	0.55	
	5	86	7.37	0.054	6.61	1.16	0.82	
	6	86	7.31	0.051	7.53	1.15	0.68	
	7	90	7.85	0.07	7.1	1.08	0.99	
	8	88	7.63	0.07	6.83	1.12	1.02	
	9	88	7.42	0.043	6.61	1.09	0.65	
	10	84	6.44	0.054	5.65	1.09	0.96	
	11	77	5.05	0.029	4.4	1.11	0.66	
	12	78	5.33	0.048	4.7	1.12	1.02	
	13	84	7	0.069	6.11	1.18	1.13	
	14	83	6.81	0.053	6.02	1.19	0.88	
	15	79	5.81	0.056	5.13	1.18	1.09	
	16	83	6.24	0.047	5.33	1.09	0.88	
	17	83	6.23	0.065	5.35	1.09	1.21	
	18	78	5.46	0.033	4.77	1.15	0.69	
	19	80	5.68	0.03	4.81	1.11	0.62	
	20	78	5.43	0.05	4.57	1.14	1.09	
	21	73	4.54			1.17		
	22	75	4.18			0.99		
	23	72	4.21			1.13		
	24	75	4.6			1.09		
	25	75	4.82			1.14		
	26	76	4.9			1.12		
	27	79	5.34			1.08		
	28	72	4.53			1.21		
	29	75	4.5			1.07		
	30	79	5.87			1.19		
	31	71	3.94			1.10		
	32	72	4.23			1.13		
	33	69	3.5			1.07		
	34	80	5.46			1.07		
	35	70	3.74			1.09		
	36	62	2.64			1.11		
	37	77	5.14			1.13		
	38	66	3.2			1.11		
	39	73	4.43			1.14		
	40	76	4.55			1.04		
	41	69	3.29			1.00		
	42	62	2.37			0.99		
	43	68	3.2			1.02		
	44	68	3.22			1.02		
	45	72	3.92			1.05		
	46	69	3.89			1.18		
	47	64	3.32			1.27		
	48	73	4.66			1.20		
	49	72	4.78			1.28		
	50	77	6.19			1.36		
	51	73	5.09			1.31		
	52	80	6.53			1.28		
	53	66	3.9			1.36		
	54	67	3.81			1.27		
	55	72	4.54			1.22		
	56	73	4.58			1.18		
	57	82	6.81			1.24		
	58	69	4.05			1.23		
	59	75	5.41			1.28		
	60	73	5.27			1.35		
	61	70	4.42			1.29		
	62	67	4.03			1.34		
	63	61	2.91			1.28		
	64	60	2.64			1.22		
	65	62	3.06			1.28		
	66	60	2.62			1.21		
	67	70	4.26			1.24		
	68	73	5.06			1.30		
	69	75	5.27			1.25		
	70	69	4.51			1.37		
	71	69	4.29			1.31		
	72	72	4.75			1.27		
	73	60	2.75			1.27		
	74	68	3.89			1.24		
	75	68	4.22			1.34		
	76	69	4.6			1.40		
	77	68	3.84			1.22		
	78	73	5.05			1.30		
	79	67	3.72			1.24		
	80	52	1.87			1.33		
	81	70	4.47			1.30		
	82	65	3.54			1.29		
	83	63	3.32			1.33		
	84	77	5.72			1.25		
	85	73	5.03			1.29		
	86	73	4.89			1.26		
	87	75	5.19			1.23		
	88	75	5.3			1.26		
	89	57	2.46			1.33		
	90	68	4.13			1.31		
	91	77	5.61			1.23		
	92	68	4.18			1.33		
	93	76	5.47			1.25		
	94	66	3.63			1.26		
	95	80	5.91			1.15		
	96	70	4.05			1.18		
	97	78	5.09			1.07		
	98	67	3.31			1.10		
	99	70	4.14			1.21		
	100	69	3.53			1.07		
Maximum		***94***	***9.23***	***0.08***	***8.4***	***1.40***	***1.21***	
Median		***73***	***4.57***	***0.052***	***6.02***	***1.19***	***0.89***	
Minimum		***52***	***1.87***	***0.029***	***4.4***	***0.99***	***0.55***	
Mean		***73.2***	***4.79***	***0.053***	***6.02***	***1.19***	***0.87***	
SD		***7.7***	***1.42***	***0.015***	***1.18***	***0.10***	***0.19***	
SE		***0.77***	***0.14***	***0.003***	***0.26***	***0.01***	***0.04***	

Table A2.1 Juvenile chinook salmon measurements and indices, collected for the Upper Fraser River EEM Cycle Five fish survey.

Date	Fish Number	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Condition (g/cm3)	LSI	Effort (# seines)
Quesnel Exposure								
26-Sep-09	1	70	4.75	0.032	4.21	1.38	0.76	8
	2	71	5.57	0.036	4.9	1.56	0.73	
	3	86	7.82	0.052	6.98	1.23	0.74	
	4	85	7.45	0.046	6.4	1.21	0.72	
	5	78	5.5	0.063	4.74	1.16	1.33	
	6	90	8.49	0.06	7.56	1.16	0.79	
	7	79	5.52	0.043	4.68	1.12	0.92	
	8	90	8.01	0.052	6.95	1.10	0.75	
	9	88	7.69	0.056	6.71	1.13	0.83	
	10	82	6.34	0.042	5.42	1.15	0.77	
	11	85	6.33	0.062	5.39	1.03	1.15	
	12	75	5.15	0.05	4.13	1.22	1.21	
	13	92	9.33	0.067	7.98	1.20	0.84	
	14	79	5.73	0.068	4.66	1.16	1.46	
	15	74	4.65	0.043	4.15	1.15	1.04	
	16	76	4.9	0.052	4.02	1.12	1.29	
	17	72	4.38	0.029	3.65	1.17	0.79	
	18	79	5.76	0.042	4.79	1.17	0.88	
	19	82	6.44	0.05	5.32	1.17	0.94	
	20	73	4.39	0.035	3.59	1.13	0.97	
	21	74	4.46			1.10		
	22	78	5.26			1.11		
	23	74	4.62			1.14		
	24	75	4.78			1.13		
	25	70	4.18			1.22		
	26	72	4.23			1.13		
	27	78	5.06			1.07		
	28	82	5.75			1.04		
	29	77	5.31			1.16		
	30	71	3.86			1.08		
	31	69	3.96			1.21		
	32	63	3.06			1.22		
	33	75	4.54			1.08		
	34	76	4.95			1.13		
	35	67	3.35			1.11		
	36	68	3.58			1.14		
	37	67	3.15			1.05		
	38	63	2.68			1.07		
	39	73	3.74			0.96		
	40	66	3.31			1.15		
	41	75	4.72			1.12		
	42	76	5.1			1.16		
	43	64	2.86			1.09		
	44	77	5.16			1.13		
	45	65	3.16			1.15		
	46	78	5.73			1.21		
	47	70	2.88			0.84		
	48	69	3.73			1.14		
	49	69	4.04			1.23		
	50	71	3.88			1.08		
	51	79	5.75			1.17		
	52	68	3.47			1.10		
	53	62	2.71			1.14		
	54	73	4.43			1.14		
	55	71	4.26			1.19		
	56	62	3.02			1.27		
	57	74	4.87			1.20		
	58	66	3.15			1.10		
	59	82	6.55			1.19		
	60	68	3.64			1.16		
	61	71	4.14			1.16		
	62	66	3.23			1.12		
	63	65	3.07			1.12		
	64	70	3.62			1.06		
	65	69	3.47			1.06		
	66	67	3.43			1.14		
	67	71	4.53			1.27		
	68	73	4.07			1.05		
	69	85	7.54			1.23		
	70	72	4.04			1.08		
	71	72	4.3			1.15		
	72	68	3.35			1.07		
	73	72	4.66			1.25		
	74	75	4.73			1.12		
	75	65	3.19			1.16		
	76	69	3.65			1.11		
	77	69	3.3			1.00		
	78	70	4.22			1.23		
	79	71	4.17			1.17		
	80	71	3.98			1.11		
	81	73	4.2			1.08		
	82	64	2.83			1.08		
	83	65	3.09			1.13		
	84	67	3.47			1.15		
	85	72	3.8			1.02		
	86	70	3.61			1.05		
	87	65	2.64			0.96		
	88	68	3.51			1.12		
	89	78	6.03			1.27		
	90	81	5.86			1.10		
	91	76	5.09			1.16		
	92	75	4.92			1.17		
	93	67	3.44			1.14		
	94	72	4.46			1.19		
	95	82	6.54			1.19		
	96	69	3.68			1.12		
	97	73	4.61			1.19		
	98	76	4.28			0.97		
	99	76	4.82			1.10		
	100	70	4.01			1.17		
Maximum		***92***	***9.33***	***0.068***	***7.98***	***1.56***	***1.46***	
Median		***72***	***4.29***	***0.05***	***4.845***	***1.14***	***0.86***	
Minimum		***62***	***2.64***	***0.029***	***3.59***	***0.84***	***0.72***	
Mean		***73.1***	***4.57***	***0.049***	***5.31***	***1.14***	***0.95***	
SD		***6.5***	***1.37***	***0.011***	***1.33***	***0.09***	***0.23***	
SE		***0.65***	***0.14***	***0.003***	***0.30***	***0.01***	***0.05***	

Appendix A3

ALS Environmental: Water, Effluent and Bile Analytical Reports

Certificate of Analysis

HATFIELD CONSULTANTS LTD
ATTN: DAN MOATS
200-850 HARBOURSIDE
NORTH VANCOUVER BC

Report Date: 30-NOV-09 13:08 (MT)
Version: FINAL REV. 2

Lab Work Order #: **L824282**
Date Received: **29-SEP-09**

Project P.O. #:
Job Reference: FRASER 1333
Legal Site Desc:
CofC Numbers: 09-029316

Other Information:

Comments: ADDITIONAL 24-NOV-09 11:38
ADDITIONAL 24-NOV-09 11:38

Jessica Spira
Senior Account Manager

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L824282-1 COTTONWOOD REFFRENCE							
Sampled By: DAN MOATS on 28-SEP-09 @ 14:45							
Matrix: BILE (FISH)							
Resin and Fatty Acids							
12,14-Dichlorodehydroabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
12-Chlorodehydroabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
14-Chlorodehydroabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Abietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Dehydroabietic acid	<10	DLMB	10	mg/kg	17-NOV-09	22-NOV-09	R1081323
Isopimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Levopimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Neoabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Palustric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Pimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Sandaracopimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Surrogate: 6-Bromo-2-Naphthol	22		4-47	%	17-NOV-09	22-NOV-09	R1081323
Surrogate: Tricosanoic Acid	99		79-126	%	17-NOV-09	22-NOV-09	R1081323
Surrogate: o-Methylpodocarpic Acid	61	SURR-ND	63-107	%	17-NOV-09	22-NOV-09	R1081323
L824282-2 SHELLEY REFERENCE							
Sampled By: DAN MOATS on 28-SEP-09 @ 14:45							
Matrix: BILE (FISH)							
Resin and Fatty Acids							
12,14-Dichlorodehydroabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
12-Chlorodehydroabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
14-Chlorodehydroabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Abietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Dehydroabietic acid	<10	DLMB	10	mg/kg	17-NOV-09	22-NOV-09	R1081323
Isopimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Levopimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Neoabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Palustric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Pimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Sandaracopimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Surrogate: 6-Bromo-2-Naphthol	24		4-47	%	17-NOV-09	22-NOV-09	R1081323
Surrogate: Tricosanoic Acid	108		79-126	%	17-NOV-09	22-NOV-09	R1081323
Surrogate: o-Methylpodocarpic Acid	92		63-107	%	17-NOV-09	22-NOV-09	R1081323
L824282-3 PRINCE GEORGE EXPOSURE							
Sampled By: DAN MOATS on 28-SEP-09 @ 14:45							
Matrix: BILE (FISH)							
Resin and Fatty Acids							
12,14-Dichlorodehydroabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
12-Chlorodehydroabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
14-Chlorodehydroabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Abietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Dehydroabietic acid	<10	DLMB	10	mg/kg	17-NOV-09	22-NOV-09	R1081323
Isopimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Levopimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Neoabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Palustric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Pimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Sandaracopimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Surrogate: 6-Bromo-2-Naphthol	28		4-47	%	17-NOV-09	22-NOV-09	R1081323

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L824282-3 PRINCE GEORGE EXPOSURE							
Sampled By: DAN MOATS on 28-SEP-09 @ 14:45							
Matrix: BILE (FISH)							
Resin and Fatty Acids							
Surrogate: Tricosanoic Acid	101		79-126	%	17-NOV-09	22-NOV-09	R1081323
Surrogate: o-Methylpodocarpic Acid	93		63-107	%	17-NOV-09	22-NOV-09	R1081323
L824282-4 QUESNEL EXPOSURE							
Sampled By: DAN MOATS on 28-SEP-09 @ 14:45							
Matrix: BILE (FISH)							
Resin and Fatty Acids							
12,14-Dichlorodehydroabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
12-Chlorodehydroabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
14-Chlorodehydroabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Abietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Dehydroabietic acid	<10	DLMB	10	mg/kg	17-NOV-09	22-NOV-09	R1081323
Isopimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Levopimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Neoabietic acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Palustric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Pimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Sandaracopimaric acid	<5.0		5.0	mg/kg	17-NOV-09	22-NOV-09	R1081323
Surrogate: 6-Bromo-2-Naphthol	42		4-47	%	17-NOV-09	22-NOV-09	R1081323
Surrogate: Tricosanoic Acid	102		79-126	%	17-NOV-09	22-NOV-09	R1081323
Surrogate: o-Methylpodocarpic Acid	85		63-107	%	17-NOV-09	22-NOV-09	R1081323

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Sample Parameter Qualifier Key:

Qualifier	Description
DLMB	Detection Limit increased due to background in Method Blank.
SURR-ND	Surrogate recovery was slightly outside ALS DQO. Reported non-detect results for associated samples were unaffected.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
RFA-ED	Bile	Resin and Fatty Acids	MSOP 33-GC-MS

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
ED	ALS LABORATORY GROUP - EDMONTON, ALBERTA, CANADA

Chain of Custody Numbers:

09-029316

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mk/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

Chain of Custody / Analytical Request Form
Canada Toll Free: 1 800 668 9878
www.alsglobal.com

L824282

COC # **09 - 029316**

Page 1 of ___

Report To	
Company:	HATFIELD CONSULTANTS
Contact:	DAN MOATS
Address:	200 - 850 HARBOURSIDE NORTH VANCOUVER
Phone:	604-926-3261 Fax: 604-926-5799
Invoice To	Same as Report ? (circle) (Yes) or No (if No, provide details)
	Copy of Invoice with Report? (circle) Yes or No
Company:	
Contact:	
Address:	
Phone:	Fax:

Report Format / Distribution	
Standard:	Other (specify):
Select: PDF ___ Excel ___ Digital ___ Fax ___	
Email 1:	
Email 2:	
Client / Project Information	
Job #:	FRASER 1333
PO / AFE:	
LSD:	
Quote #:	
ALS Contact: NATASHA	Sampler: DAN MOATS

Service Requested: (Rush subject to availability)
Regular (Standard Turnaround Times))
Priority, Date Req'd: ___________ (Surcharges apply)
Emergency (1 Business Day) - 100% Surcharge
For Emergency < 1 Day, ASAP or Weekend - Contact ALS

Analysis Request (Indicate Filtered or Preserved, F/P)

Sample Identification (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	NUTRIENTS	TOC	DOC	GENERAL	METALS (Na: 0.05)	BILE METABOLITES							Number of Containers
COTTONWOOD REFERENCE	29 Sep 09	2:45pm	bile (fish)						✓							
SHELLEY REFERENCE									✓							
PRINCE GEORGE EXPOSURE									✓							
QUESNEL EXPOSURE									✓							

Special Instructions / Regulations / Hazardous Details

~~Best detection limits for sodium (Mass spect)~~ Each vial is a composite of 20 gall bladders

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

Released by:	Date:	Time:	Received by:	Date:	Time:	Temperature:	Verified by:	Date:	Time:	Observations: Yes / No ? If Yes add SIF
			Raul	29-Sep-09	11:39	— °C				

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION WHITE - LABORATORY COPY YELLOW - CLIENT COPY GENF 18.01 Front

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

Certificate of Analysis

HATFIELD CONSULTANTS LTD.
ATTN: DANIEL MOATS
201 - 1571 BELLEVUE AVE.
WEST VANCOUVER BC V7V 1A6

Report Date: 26-OCT-09 18:07 (MT)
Version: FINAL REV. 2

Lab Work Order #: **L824263** **Date Received:** **29-SEP-09**

Project P.O. #:
Job Reference: FRASER 1333
Legal Site Desc:
CofC Numbers: 09-029316

Other Information:

Comments:

Please note that sample identified as NOR-1 was not analyzed for Total-Dissolved Phosphate, Ortho-Phosphate, Nitrate and Nitrite as raw cut was not provided for analysis.

ADDITIONAL 19-OCT-09 15:08
This revision, 2, of the report replaces and supersedes all previous revisions. Dissolved Sodium analysis has been added to all samples except NOR-1. An aliquot of the raw sample was filtered and analyzed for Dissolved Sodium. Please note that aliquot analyzed for Dissolved Sodium was filtered 21 days after the sampling. This should be taken into consideration when reviewing the data. All other data remains unchanged.

Natasha Markovic-Mirovic
Account Manager

ALS Canada Ltd.
Part of the **ALS Laboratory Group**
1988 Triumph Street, Vancouver, BC V5L 1K5
Phone: +1 604 253 4188 Fax: +1 604 253 6700 www.alsglobal.com
A Campbell Brothers Limited Company

ALS LABORATORY GROUP ANALYTICAL REPORT

	Sample ID	L824263-1	L824263-2	L824263-3	L824263-4	L824263-5
	Description					
	Sampled Date	28-SEP-09	28-SEP-09	28-SEP-09	28-SEP-09	28-SEP-09
	Sampled Time	15:00	15:00	15:00	15:00	15:00
	Client ID	QUE-1	QUE-2	QUE-3	COT-1	COT-2
Grouping	**Analyte**					
WATER						
Physical Tests	Hardness (as CaCO3) (mg/L)	77.5	76.1	78.0	71.9	70.3
Anions and Nutrients	Ammonia as N (mg/L)	<0.020	<0.020	<0.020	<0.020	<0.020
	Nitrate (as N) (mg/L)	0.0282	0.0264	0.0269	0.0260	0.0249
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Total Kjeldahl Nitrogen (mg/L)	0.135	0.103	0.116	0.111	0.122
	Total Nitrogen (mg/L)	0.110	0.080	0.080	0.080	0.070
	Ortho Phosphate as P (mg/L)	0.0031	0.0034	0.0043	0.0020	0.0021
	Total Dissolved Phosphate As P (mg/L)	0.0026	0.0028	0.0027	<0.0020	<0.0020
	Total Phosphate as P (mg/L)	0.0299	0.0267	0.0271	0.0217	0.0221
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)	2.77	2.57	2.78	2.48	2.38
	Total Organic Carbon (mg/L)	2.93	3.11	2.89	2.75	2.78
Total Metals	Calcium (Ca)-Total (mg/L)	21.3	21.0	21.5	20.6	20.1
	Magnesium (Mg)-Total (mg/L)	5.90	5.73	5.89	4.97	4.87
	Sodium (Na)-Total (mg/L)	3.10	2.97	2.99	2.58	2.43
Dissolved Metals	Sodium (Na)-Dissolved (mg/L)	2.76	2.67	2.64	2.32	2.37

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS LABORATORY GROUP ANALYTICAL REPORT

Grouping	Analyte	L824263-6	L824263-7	L824263-8	L824263-9	L824263-10
	Description					
	Sampled Date	28-SEP-09	28-SEP-09	28-SEP-09	28-SEP-09	28-SEP-09
	Sampled Time	15:00	15:00	15:00	15:00	15:00
	Client ID	COT-3	SHE-1	SHE-2	SHE-3	PRG-1
WATER						
Physical Tests	Hardness (as CaCO3) (mg/L)	72.9	72.6	72.6	70.4	77.5
Anions and Nutrients	Ammonia as N (mg/L)	<0.020	<0.020	<0.020	<0.020	<0.020
	Nitrate (as N) (mg/L)	0.0242	0.0371	0.0372	0.0434	0.0353
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Total Kjeldahl Nitrogen (mg/L)	0.132	0.064	0.062	<0.050	1.04
	Total Nitrogen (mg/L)	0.060	<0.050	<0.050	<0.050	<0.050
	Ortho Phosphate as P (mg/L)	0.0029	<0.0010	<0.0010	<0.0010	0.0018
	Total Dissolved Phosphate As P (mg/L)	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
	Total Phosphate as P (mg/L)	0.0219	0.0109	0.0151	0.0204	0.0206
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)	2.56	0.95	0.95	0.92	1.27
	Total Organic Carbon (mg/L)	2.68	1.20	1.16	1.20	1.66
Total Metals	Calcium (Ca)-Total (mg/L)	20.9	20.9	21.0	20.2	21.9
	Magnesium (Mg)-Total (mg/L)	5.05	4.98	4.92	4.83	5.52
	Sodium (Na)-Total (mg/L)	2.53	0.744	0.736	0.728	2.76
Dissolved Metals	Sodium (Na)-Dissolved (mg/L)	2.36	0.650	0.647	0.679	2.32

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS LABORATORY GROUP ANALYTICAL REPORT

	Sample ID	L824263-11	L824263-12	L824263-13	L824263-14	L824263-15
	Description					
	Sampled Date	28-SEP-09	28-SEP-09	28-SEP-09	28-SEP-09	28-SEP-09
	Sampled Time	15:00	15:00	15:00	15:00	14:30
	Client ID	PRG-2	PRG-3	TES-1	TRIP BLANK	NOR-1
Grouping	**Analyte**					
WATER						
Physical Tests	Hardness (as CaCO3) (mg/L)	76.1	76.6	<1.0	<1.0	156
Anions and Nutrients	Ammonia as N (mg/L)	<0.020	<0.020	<0.020	<0.0050	1.03
	Nitrate (as N) (mg/L)	0.0386	0.0348	<0.0050	<0.0050	
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	
	Total Kjeldahl Nitrogen (mg/L)	0.067	1.18	<0.050	<0.050	6.09
	Total Nitrogen (mg/L)	0.060	0.050	<0.050	<0.050	5.45
	Ortho Phosphate as P (mg/L)	0.0020	0.0019	<0.0010	<0.0010	
	Total Dissolved Phosphate As P (mg/L)	<0.0020	<0.0020	<0.0020	<0.0020	
	Total Phosphate as P (mg/L)	0.0217	0.0211	<0.0020	<0.0020	1.04
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)	1.22	1.29	<0.50	<0.50	164
	Total Organic Carbon (mg/L)	1.67	1.58	<0.50	<0.50	141
Total Metals	Calcium (Ca)-Total (mg/L)	21.6	21.8	<0.050	<0.050	51.6
	Magnesium (Mg)-Total (mg/L)	5.39	5.36	<0.10	<0.10	6.58
	Sodium (Na)-Total (mg/L)	2.53	2.59	<0.050	<0.050	377
Dissolved Metals	Sodium (Na)-Dissolved (mg/L)	2.39	2.45	<0.050	<0.050	

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS LABORATORY GROUP ANALYTICAL REPORT

Grouping	Analyte	L824263-16	L824263-17	L824263-18		
	Sample ID	L824263-16	L824263-17	L824263-18		
	Description					
	Sampled Date	28-SEP-09	28-SEP-09	28-SEP-09		
	Sampled Time	14:30	14:30	14:30		
	Client ID	PG1C-1	QRP-1	CAR-1		
WATER						
Physical Tests	Hardness (as CaCO3) (mg/L)	93.7	162	305		
Anions and Nutrients	Ammonia as N (mg/L)	0.381	0.086	1.98		
	Nitrate (as N) (mg/L)	<0.10 *	<0.25 *	0.18		
	Nitrite (as N) (mg/L)	<0.020 *	<0.050 *	0.354		
	Total Kjeldahl Nitrogen (mg/L)	11.7	37.9	4.00		
	Total Nitrogen (mg/L)	10.1	26.0	3.84		
	Ortho Phosphate as P (mg/L)	0.0106	1.15	0.579		
	Total Dissolved Phosphate As P (mg/L)	0.069	1.56	0.643		
	Total Phosphate as P (mg/L)	2.03	4.04	0.870		
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)	91	212	72.7		
	Total Organic Carbon (mg/L)	166	404	80.2		
Total Metals	Calcium (Ca)-Total (mg/L)	27.0	43.5	110		
	Magnesium (Mg)-Total (mg/L)	6.38	12.9	7.21		
	Sodium (Na)-Total (mg/L)	285	903	298		
Dissolved Metals	Sodium (Na)-Dissolved (mg/L)	309	1060	303		

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

Additional Comments for Sample Listed:

Samplenum	Matrix	Report Remarks	Sample Comments

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjustment For Sample Matrix Effects

Samples with Qualifiers for Individual Parameters as listed above:

Sample Number	Client Sample ID	Parameters	Qualifier
L824263-16	PG1C-1	Nitrite (as N) Nitrate (as N)	DLM
L824263-17	QRP-1	Nitrate (as N) Nitrite (as N)	DLM

Methods Listed (if applicable):

ALS Test Code	Matrix	Test Description	Analytical Method Reference(Based On)

ANIONS-NO2-IC-VA | Water | Nitrite by Ion Chromatography | APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Specifically, the nitrite detection is by UV absorbance and not conductivity.

ANIONS-NO3-IC-VA | Water | Nitrate by Ion Chromatography | APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Specifically, the nitrate detection is by UV absorance and not conductivity.

CARBONS-DOC-VA | Water | Dissolved organic carbon by combustion | APHA 5310 "TOTAL ORGANIC CARBON (TOC)"

This analysis is carried out using procedures adapted from APHA Method 5310 "Total Organic Carbon (TOC)". Dissolved carbon (DOC) fractions are determined by filtering the sample through a 0.45 micron membrane filter prior to analysis.

CARBONS-DOC-VA | Water | Dissolved organic carbon by combustion | APHA 5310 TOTAL ORGANIC CARBON (TOC)

This analysis is carried out using procedures adapted from APHA Method 5310 "Total Organic Carbon (TOC)". Dissolved carbon (DOC) fractions are determined by filtering the sample through a 0.45 micron membrane filter prior to analysis.

CARBONS-TOC-VA | Water | Total organic carbon by combustion | APHA 5310 "TOTAL ORGANIC CARBON (TOC)"

This analysis is carried out using procedures adapted from APHA Method 5310 "Total Organic Carbon (TOC)".

CARBONS-TOC-VA | Water | Total organic carbon by combustion | APHA 5310 TOTAL ORGANIC CARBON (TOC)

This analysis is carried out using procedures adapted from APHA Method 5310 "Total Organic Carbon (TOC)".

HARDNESS-CALC-VA | Water | Hardness | APHA 2340B

Hardness is calculated from Calcium and Magnesium concentrations, and is expressed as calcium carbonate equivalents.

MET-DIS-LOW-MS-VA | Water | Dissolved Metals in Water by ICPMS(Low) | EPA SW-846 3005A/6020A

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures involves preliminary sample treatment by filtration (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

MET-TOT-ICP-VA | Water | Total Metals in Water by ICPOES | EPA SW-846 3005A/6010B

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United

Reference Information

Methods Listed (if applicable):

ALS Test Code	Matrix	Test Description	Analytical Method Reference(Based On)

States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotblock or microwave oven (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MET-TOT-LOW-MS-VA	Water	Total Metals in Water by ICPMS(Low)	EPA SW-846 3005A/6020A

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotblock or microwave oven, or filtration (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

N-TOT-COMBUST-VA	Water	Total Nitrogen by Combustion	ASTM D5176-91, EN12260 (EU STD Method)

This analysis is carried out using procedures adapted from ASTM Method D 5176-91 "Standard Test Method for Total Chemically Bound Nitrogen in Water by Pyrolysis and Chemiluminescence detection." Total Nitrogen is determined directly by pyrolysis with chemiluminescence detection using automated instrumentation. Total Kjedahl Nitrogen is determined by calculation.

NH3-COL-VA	Water	Ammonia by Colour	APHA 4500-NH3 "Nitrogen (Ammonia)"

This analysis is carried out, on unpreserved samples, using procedures adapted from APHA Method 4500-NH3 "Nitrogen (Ammonia)". Ammonia is determined using the phenate colourimetric method.

NH3-COL-VA	Water	Ammonia by Colour	APHA 4500-NH3 Nitrogen (Ammonia)

This analysis is carried out, on unpreserved samples, using procedures adapted from APHA Method 4500-NH3 "Nitrogen (Ammonia)". Ammonia is determined using the phenate colourimetric method.

NH3-SIE-VA	Water	Ammonia by SIE	APHA 4500 D. - NH3 NITROGEN (AMMONIA)

This analysis is carried out, on sulphuric acid preserved samples, using procedures adapted from APHA Method 4500-NH3 "Nitrogen (Ammonia)". Ammonia is determined using an ammonia selective electrode.

PO4-DO-COL-VA	Water	Dissolved ortho Phosphate by Colour	APHA 4500-P "Phosphorous"

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". All forms of phosphate are determined by the ascorbic acid colourimetric method. Dissolved ortho-phosphate (dissolved reactive phosphorous) is determined by direct measurement. Total phosphate (total phosphorous) is determined after persulphate digestion of a sample. Total dissolved phosphate (total dissolved phosphorous) is determined by filtering a sample through a 0.45 micron membrane filter followed by persulfate digestion of the filtrate.

PO4-DO-COL-VA	Water	Dissolved ortho Phosphate by Colour	APHA 4500-P Phosphorous

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". All forms of phosphate are determined by the ascorbic acid colourimetric method. Dissolved ortho-phosphate (dissolved reactive phosphorous) is determined by direct measurement. Total phosphate (total phosphorous) is determined after persulphate digestion of a sample. Total dissolved phosphate (total dissolved phosphorous) is determined by filtering a sample through a 0.45 micron membrane filter followed by persulfate digestion of the filtrate.

PO4-T-COL-VA	Water	Total Phosphate P by Color	APHA 4500-P "Phosphorous"

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". All forms of phosphate are determined by the ascorbic acid colourimetric method. Dissolved ortho-phosphate (dissolved reactive phosphorous) is determined by direct measurement. Total phosphate (total phosphorous) is determined after persulphate digestion of a sample. Total dissolved phosphate (total dissolved phosphorous) is determined by filtering a sample through a 0.45 micron membrane filter followed by persulfate digestion of the filtrate.

PO4-T-COL-VA	Water	Total Phosphate P by Color	APHA 4500-P Phosphorous

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". All forms of phosphate are determined by the ascorbic acid colourimetric method. Dissolved ortho-phosphate (dissolved reactive phosphorous) is determined by direct measurement. Total phosphate (total phosphorous) is determined after persulphate digestion of a sample. Total dissolved phosphate (total dissolved phosphorous) is determined by filtering a sample through a 0.45 micron membrane filter followed by persulfate digestion of the filtrate.

PO4-TD-COL-VA	Water	Total Dissolved Phosphate by Colour	APHA 4500-P Phosphorous

Reference Information

Methods Listed (if applicable):

ALS Test Code	Matrix	Test Description	Analytical Method Reference(Based On)

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". All forms of phosphate are determined by the ascorbic acid colourimetric method. Dissolved ortho-phosphate (dissolved reactive phosphorous) is determined by direct measurement. Total phosphate (total phosphorous) is determined after persulphate digestion of a sample. Total dissolved phosphate (total dissolved phosphorous) is determined by filtering a sample through a 0.45 micron membrane filter followed by persulfate digestion of the filtrate.

PO4-TD-COL-VA	Water	Total Dissolved Phosphate by Colour	APHA 4500-P " Phosphorous"

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". All forms of phosphate are determined by the ascorbic acid colourimetric method. Dissolved ortho-phosphate (dissolved reactive phosphorous) is determined by direct measurement. Total phosphate (total phosphorous) is determined after persulphate digestion of a sample. Total dissolved phosphate (total dissolved phosphorous) is determined by filtering a sample through a 0.45 micron membrane filter followed by persulfate digestion of the filtrate.

TKN-CALC-VA	Water	TKN by Calculation via TN combustion	BC MOE LABORATORY MANUAL (2005)

This analysis is carried out using procedures adapted from ASTM Method D 5176-91 "Standard Test Method for Total Chemically Bound Nitrogen in Water by Pyrolysis and Chemiluminescence detection." Total Nitrogen is determined directly by pyrolysis with chemiluminescence detection using automated instrumentation. Total Kjedahl Nitrogen is determined by calculation.

TKN-SIE-VA	Water	Total Kjeldahl Nitrogen by SIE	APHA 4500-Norg (TKN)

This analysis is carried out using procedures adapted from APHA Method 4500-Norg "Nitrogen (Organic)". Total kjeldahl nitrogen is determined by sample digestion at 367 celcius with analysis using an ammonia selective electrode.

** Laboratory Methods employed follow in-house procedures, which are generally based on nationally or internationally accepted methodologies.
The last two letters of the above ALS Test Code column indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location	Laboratory Definition Code	Laboratory Location
VA	ALS LABORATORY GROUP - VANCOUVER, BC, CANADA		

GLOSSARY OF REPORT TERMS
Surr - A surrogate is an organic compound that is similar to the target analyte(s) in chemical composition and behavior but not normally detected in enviromental samples. Prior to sample processing, samples are fortified with one or more surrogate compounds.
The reported surrogate recovery value provides a measure of method efficiency.
mg/kg (units) - unit of concentration based on mass, parts per million
mg/L (units) - unit of concentration based on volume, parts per million
N/A - Result not available. Refer to qualifier code and definition for explanation

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Although test results are generated under strict QA/QC protocols, any unsigned test reports, faxes, or emails are considered preliminary.

ALS Laboratory Group has an extensive QA/QC program where all analytical data reported is analyzed using approved referenced procedures followed by checks and reviews by senior managers and quality assurance personnel. However, since the results are obtained from chemical measurements and thus cannot be guaranteed, ALS Laboratory Group assumes no liability for the use or interpretation of the results.

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ANALYTICAL CHEMISTRY & TESTING SERVICES

Environmental Division

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L824263

COC # **09 - 029316**

Page 1 of ___

Report To	
Company:	HATFIELD CONSULTANTS
Contact:	DAN MOATS
Address:	200 - 850 HARBOURSIDE NORTH VANCOUVER
Phone:	604-926-3261 Fax: 604-926-5399
Invoice To	Same as Report ? (circle) (Yes) or No (if No, provide details)
	Copy of Invoice with Report? (circle) Yes or No
Company:	
Contact:	
Address:	
Phone:	Fax:
Lab Work Order # (lab use only)	

Report Format / Distribution	
Standard: ___	Other (specify): ___
Select: PDF ___ Excel ___ Digital ___ Fax ___	
Email 1:	
Email 2:	
Client / Project Information	
Job #:	FRASER 1333
PO / AFE:	
LSD:	
Quote #:	
ALS Contact: NATASHA	Sampler: DAN MOATS

Service Requested: (Rush subject to availability)	
	Regular (Standard Turnaround Times))
	Priority, Date Req'd: ___ (Surcharges apply)
	Emergency (1 Business Day) - 100% Surcharge
	For Emergency < 1 Day, ASAP or Weekend - Contact ALS

Analysis Request
(Indicate Filtered or Preserved, F/P)

Sample #	Sample Identification (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	NUTRIENTS (P)	TOC (P)	DOC	GENERAL	METALS (Na: 0.05) (P)								Number of Containers
	QUE-1	28 Sep 09	2:00 pm	Water	✓	✓	✓	✓	✓								
	QUE-2	"	3:00 pm	Water	✓	✓	✓	✓	✓								
	QUE-3	"	"	Water	✓	✓	✓	✓	✓								
	COT-1	"	"	Water	✓	✓	✓	✓	✓								
	COT-2	"	"	Water	✓	✓	✓	✓	✓								
	COT-3	"	"	Water	✓	✓	✓	✓	✓								

Special Instructions / Regulations / Hazardous Details

Low detection limits for sodium (Mass spect) DOC - not filtered nor preserved

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by:	Date:	Time:	Received by: HD	Date: 09/09/29	Time: 8:42	Temperature: 1 °C	Verified by:	Date:	Time:	Observations: Yes / No ? If Yes add SIF

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Environmental Division

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L804263

COC # **09-029316**

Page 2 of 2

Report To		**Report Format / Distribution**	
Company:	HATFIELD CONSULTANTS	Standard: ___ Other (specify): ___	
Contact:	DAN MOATS	Select: PDF ___ Excel ___ Digital ___ Fax ___	
Address:	200 - 850 HARBOURSIDE NORTH VANCOUVER	Email 1:	
Phone:	604-926-3261 Fax: 604-926-5399	Email 2:	
Invoice To	Same as Report ? (circle) (Yes) or No (if No, provide details)	**Client / Project Information**	
	Copy of Invoice with Report? (circle) Yes or No	Job #:	FRASER 1333
Company:		PO / AFE:	
Contact:		LSD:	
Address:			
Phone:	Fax:	Quote #:	
Lab Work Order # (lab use only)		ALS Contact: NATASHA	Sampler: DAN MOATS

Service Requested: (Rush subject to availability)
Regular (Standard Turnaround Times)
Priority, Date Req'd: ___ (Surcharges apply)
Emergency (1 Business Day) - 100% Surcharge
For Emergency < 1 Day, ASAP or Weekend - Contact ALS

Analysis Request
(Indicate Filtered or Preserved, F/P)

Sample #	Sample Identification (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	NUTRIENTS (F)	TOC (P)	DOC	GENERAL	METALS (Na 0.05) (P)								Number of Containers
	NOR-1	28 Sep 09	2:30pm	effluent	✓	✓	✓	✓	✓								
	~~NOR~~ PGIC-1	"	"	effluent	✓	✓	✓	✓									
	QRP-1	"	"	effluent	✓	✓	✓	✓	✓								
	CAR-1	"	"	effluent	✓	✓	✓	✓	✓								
	TES-1	28 Sep 09	2:30pm	water	✓	✓	✓	✓	✓								
	~~TRIP BLANK~~	~~28 Sep 09~~	~~2:30pm~~	~~water~~	~~✓~~	~~✓~~	~~✓~~	~~✓~~	~~✓~~								
	~~TRAVEL BLANK~~	~~28 Sep 09~~	~~2:30pm~~	~~water~~	~~✓~~	~~✓~~	~~✓~~	~~✓~~	~~✓~~								

Special Instructions / Regulations / Hazardous Details

Low detection limits for sodium (Mass spect) NOR-1 DOC - filtered + preserved, all other DOC not filtered and not preserved

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

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SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by:	Date:	Time:	Received by: HD	Date: 09/09/29	Time: 8:41	Temperature: 1 °C	Verified by:	Date:	Time:	Observations: Yes / No ? If Yes add SIF

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

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COC # **09 - 029316**

Page 1 of ___

Report To	
Company:	HATFIELD CONSULTANTS
Contact:	DAN MOATS
Address:	200 - 850 HARBOURSIDE NORTH VANCOUVER
Phone:	604-926-3261 Fax: 604-926-5799
Invoice To	Same as Report ? (circle) (Yes) or No (if No, provide details)
	Copy of Invoice with Report? (circle) Yes or No
Company:	
Contact:	
Address:	
Phone:	Fax:
Lab Work Order # (lab use only)	

Report Format / Distribution	
Standard: ___	Other (specify): ___
Select: PDF ___ Excel ___ Digital ___ Fax ___	
Email 1:	
Email 2:	
Client / Project Information	
Job #:	FRASER 1333
PO / AFE:	
LSD:	
Quote #:	
ALS Contact: NATASHA	Sampler: DAN MOATS

Service Requested: (Rush subject to availability)
Regular (Standard Turnaround Times))
Priority, Date Req'd: ___ (Surcharges apply)
Emergency (1 Business Day) - 100% Surcharge
For Emergency < 1 Day, ASAP or Weekend - Contact ALS

Analysis Request (Indicate Filtered or Preserved, F/P)

Sample #	Sample Identification (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	NUTRIENTS (P)	TOC (P)	DOC	GENERAL	METALS (Na: 0.05) (R)								Number of Containers
	SHE-1	28 Sep 09	3:00pm	Water	✓	✓	✓	✓	✓								
	SHE-2	"	"	water	✓	✓	✓	✓	✓								
	SHE-3	"	"	water	✓	✓	✓	✓	✓								
	PRG-1	"	"	water	✓	✓	✓	✓	✓								
	PRG-2	"	"	water	✓	✓	✓	✓	✓								
	PRG-3	"	"	water	✓	✓	✓	✓	✓								
	TES-1	"	"	water	✓	✓	✓	✓	✓								
	TRIP BLANK	"	"	water	✓	✓	✓	✓	–								

Special Instructions / Regulations / Hazardous Details

(R) Low detection limits for sodium (Mass spect) DOC - not preserved nor filtered

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SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by:	Date:	Time:	Received by: HD	Date: 09/09/29	Time: 9:42	Temperature: °C	Verified by:	Date:	Time:	Observations: Yes / No ? If Yes add SIF

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION — WHITE - LABORATORY COPY — YELLOW - CLIENT COPY — GENF 18.01 Front

Appendix A4

Fish Survey Miscellaneous Statistical Analysis

SYSTAT Rectangular file V:\Data\Projects\FR1333\Data & Analysis\Systat\FraserFish_CycleFive.SYD, created Wed Dec 30, 2009 at 11:04:35, contains variables:

CASE$	AREA$	SITE$	LENGTH	WEIGHT	K
LIVER	LSI	LOGWEIGHT	LOGLENGTH	LOGLIVER	

```
Data for the following results were selected according to:
      SITE$='PG' or site$='Shelley'

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
SITE$ (2 levels)
   PG, Shelley

Dep Var: LOGWEIGHT   N: 200   Multiple R: 0.96778   Squared multiple R: 0.93660
```

Estimates of effects $B = (X'X)^{-1} X'Y$

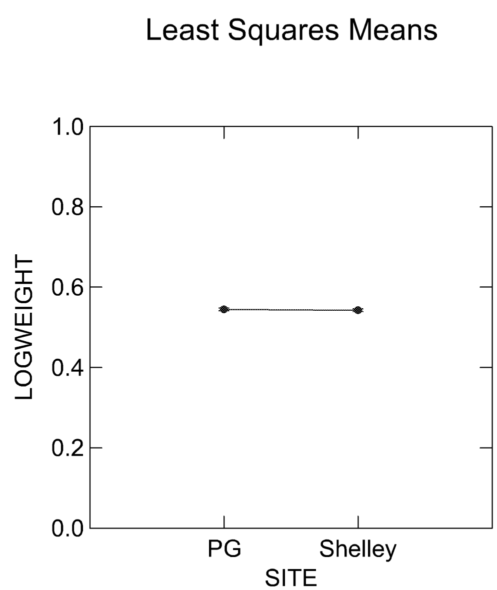
		LOGWEIGHT
CONSTANT		-4.49706
LOGLENGTH		2.78460
SITE$	PG	-0.05807
SITE$	PG	
LOGLENGTH		0.03265

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOGLENGTH	2.90050	1	2.90050	2782.04497	0.00000
SITE$	0.00038	1	0.00038	0.36865	0.54444
SITE$*LOGLENGTH	0.00040	1	0.00040	0.38246	0.53701
Error	0.20435	196	0.00104		

Adjusted least squares means

		Adj. LS Mean	SE	N
SITE$	PG	0.54473	0.00328	100
SITE$	Shelley	0.54266	0.00329	100




```
*** WARNING ***
Case            2 is an outlier        (Studentized Residual =     -5.58928)

Durbin-Watson D Statistic        2.10542
First Order Autocorrelation     -0.06056



Data for the following results were selected according to:
      SITE$='PG' or site$='Shelley' and case$<>'2'

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
SITE$ (2 levels)
   PG, Shelley

Dep Var: LOGWEIGHT   N: 199   Multiple R: 0.97228   Squared multiple R: 0.94532

                              -1
```

Estimates of effects B = (X'X) X'Y

		LOGWEIGHT
CONSTANT		-4.55832
LOGLENGTH		2.81876
SITE$	PG	0.00319
SITE$	PG	
LOGLENGTH		-0.00151

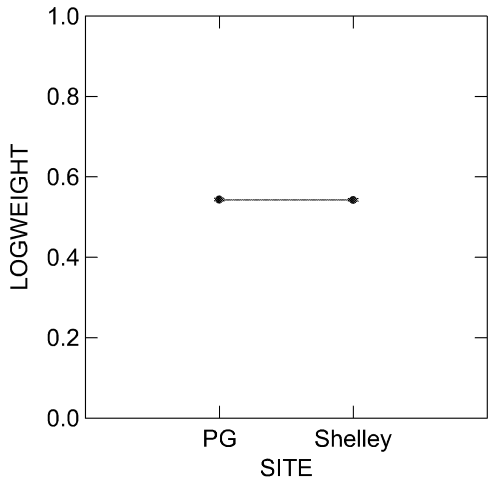
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOGLENGTH	2.92682	1	2.92682	3240.41707	0.00000
SITE$	0.00000	1	0.00000	0.00127	0.97165
SITE$*LOGLENGTH	0.00000	1	0.00000	0.00094	0.97563
Error	0.17613	195	0.00090		

Adjusted least squares means

		Adj. LS Mean	SE	N
SITE$	PG	0.54365	0.00305	100
SITE$	Shelley	0.54275	0.00307	99

Least Squares Means




```
*** WARNING ***
Case           83 is an outlier        (Studentized Residual =     -3.83536)

Durbin-Watson D Statistic        2.07430
First Order Autocorrelation     -0.04472


Data for the following results were selected according to:
      SITE$='PG' or site$='Shelley' and case$<>'2'

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
SITE$ (2 levels)
   PG, Shelley

Dep Var: LOGWEIGHT   N: 199   Multiple R: 0.97228   Squared multiple R: 0.94532

                               -1
```

Estimates of effects B = (X'X) X'Y

		LOGWEIGHT
CONSTANT		-4.55802
LOGLENGTH		2.81860
SITE$	PG	0.00045

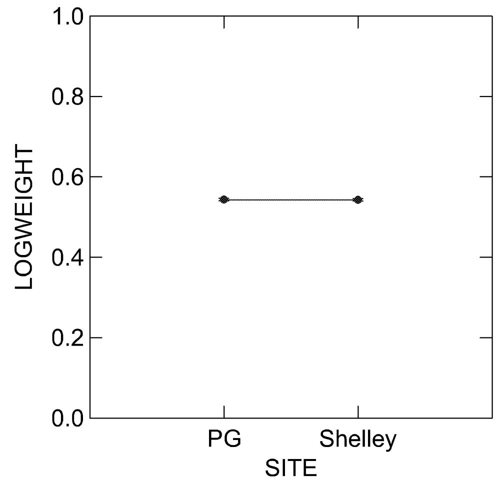
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOGLENGTH	2.95926	1	2.95926	3293.11369	0.00000
SITE$	0.00004	1	0.00004	0.04326	0.83546
Error	0.17613	196	0.00090		

Adjusted least squares means

		Adj. LS Mean	SE	N
SITE$	PG	0.54366	0.00302	100
SITE$	Shelley	0.54277	0.00304	99

Least Squares Means




```
*** WARNING ***
Case          83 is an outlier        (Studentized Residual =     -3.84505)

Durbin-Watson D Statistic        2.07380
First Order Autocorrelation     -0.04451


Data for the following results were selected according to:
      SITE$='Quesnel' or site$='Cottonwood'

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
SITE$ (2 levels)
   Cottonwood, Quesnel

Dep Var: LOGWEIGHT   N: 200   Multiple R: 0.96486   Squared multiple R: 0.93096

                               -1
```

Estimates of effects B = (X'X) X'Y

		LOGWEIGHT
CONSTANT		-4.74557
LOGLENGTH		2.89826
SITE$	Cottonwood	0.35088
SITE$	Cottonwood	
LOGLENGTH		-0.18307

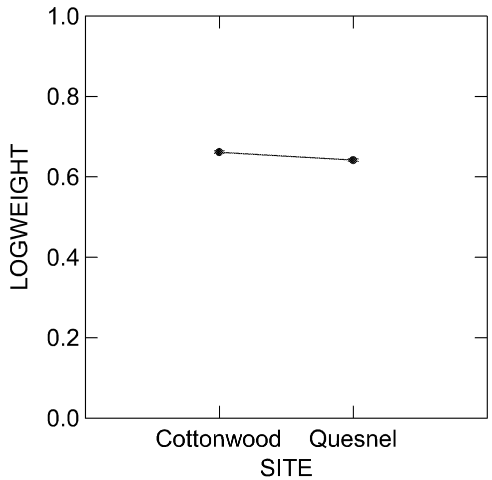
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOGLENGTH	2.84476	1	2.84476	2579.55757	0.00000
SITE$	0.01202	1	0.01202	10.89614	0.00114
SITE$*LOGLENGTH	0.01135	1	0.01135	10.29230	0.00156
Error	0.21615	196	0.00110		

Adjusted least squares means

		Adj. LS Mean	SE	N
SITE$	Cottonwood	0.66180	0.00332	100
SITE$	Quesnel	0.64191	0.00332	100

Least Squares Means




```
*** WARNING ***
Case          202 is an outlier        (Studentized Residual =      4.36575)
Case          247 is an outlier        (Studentized Residual =     -4.07707)

Durbin-Watson D Statistic        1.06719
First Order Autocorrelation      0.44271


Data for the following results were selected according to:
      case$<>'202' and case$<>'247' and (SITE$='Quesnel' or site$='Cottonwood')

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
SITE$ (2 levels)
   Cottonwood, Quesnel

Dep Var: LOGWEIGHT   N: 198   Multiple R: 0.97033   Squared multiple R: 0.94154
```

Estimates of effects $B = (X'X)^{-1} X'Y$

		LOGWEIGHT
CONSTANT		-4.74099
LOGLENGTH		2.89578
SITE$	Cottonwood	0.34631
SITE$	Cottonwood	
LOGLENGTH		-0.18059

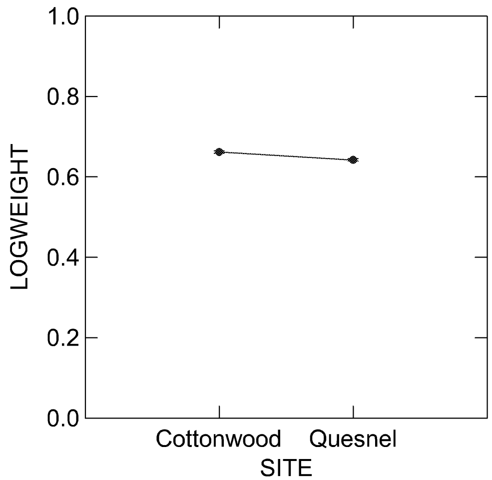
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOGLENGTH	2.83469	1	2.83469	3049.44106	0.00000
SITE$	0.01168	1	0.01168	12.56616	0.00049
SITE$*LOGLENGTH	0.01102	1	0.01102	11.85992	0.00070
Error	0.18034	194	0.00093		

Adjusted least squares means

		Adj. LS Mean	SE	N
SITE$	Cottonwood	0.66219	0.00305	100
SITE$	Quesnel	0.64226	0.00308	98

Least Squares Means




```
Durbin-Watson D Statistic        0.99295
First Order Autocorrelation      0.47513


Data for the following results were selected according to:
      case$<>'202' and case$<>'247' and (SITE$='Quesnel' or site$='Cottonwood')

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
SITE$ (2 levels)
   Cottonwood, Quesnel

Dep Var: LOGWEIGHT   N: 198   Multiple R: 0.96849   Squared multiple R: 0.93797

                               -1
Estimates of effects  B = (X'X)   X'Y
```

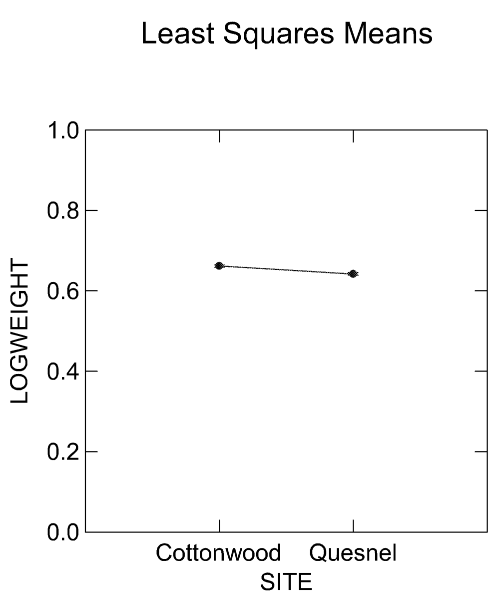
		LOGWEIGHT
CONSTANT		-4.67477
LOGLENGTH		2.86025
SITE$	Cottonwood	0.00996

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOGLENGTH	2.87691	1	2.87691	2931.60167	0.00000
SITE$	0.01962	1	0.01962	19.99230	0.00001
Error	0.19136	195	0.00098		

Adjusted least squares means

		Adj. LS Mean	SE	N
SITE$	Cottonwood	0.66223	0.00313	100
SITE$	Quesnel	0.64232	0.00316	98



Durbin-Watson D Statistic 0.93081
First Order Autocorrelation 0.51040

Data for the following results were selected according to:
SITE$='PG' or site$='Shelley'

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
SITE$ (2 levels)
PG, Shelley
160 case(s) deleted due to missing data.

Dep Var: LOGLIVER N: 40 Multiple R: 0.78252 Squared multiple R: 0.61234

Estimates of effects $B = (X'X)^{-1} X'Y$

		LOGLIVER
CONSTANT		-1.82069
LOGWEIGHT		0.63721
SITE$	PG	0.05442
SITE$	PG	
LOGWEIGHT		-0.01420

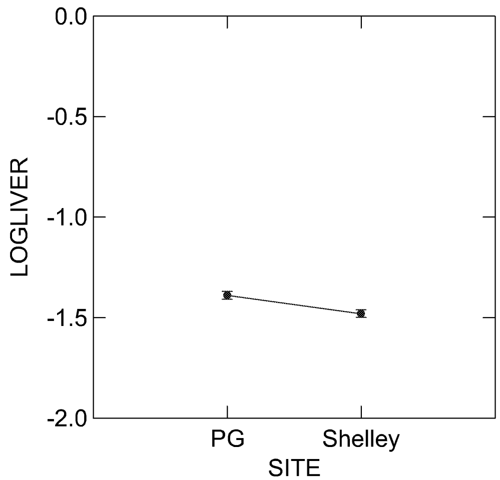
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOGWEIGHT	0.32615	1	0.32615	44.63084	0.00000
SITE$	0.00614	1	0.00614	0.83957	0.36562
SITE$*LOGWEIGHT	0.00016	1	0.00016	0.02216	0.88251
Error	0.26308	36	0.00731		

Adjusted least squares means

		Adj. LS Mean	SE	N
SITE$	PG	-1.38850	0.01912	20
SITE$	Shelley	-1.48012	0.01912	20

Least Squares Means




```
*** WARNING ***
Case          118 is an outlier        (Studentized Residual =      3.18464)

Durbin-Watson D Statistic        1.96045
First Order Autocorrelation     -0.00998


Data for the following results were selected according to:
      SITE$='PG' or site$='Shelley'

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
SITE$ (2 levels)
   PG, Shelley
160 case(s) deleted due to missing data.

Dep Var: LOGLIVER   N: 40   Multiple R: 0.78237   Squared multiple R: 0.61210
```

Estimates of effects $B = (X'X)^{-1} X'Y$

		LOGLIVER
CONSTANT		-1.82170
LOGWEIGHT		0.63888
SITE$	PG	0.04581

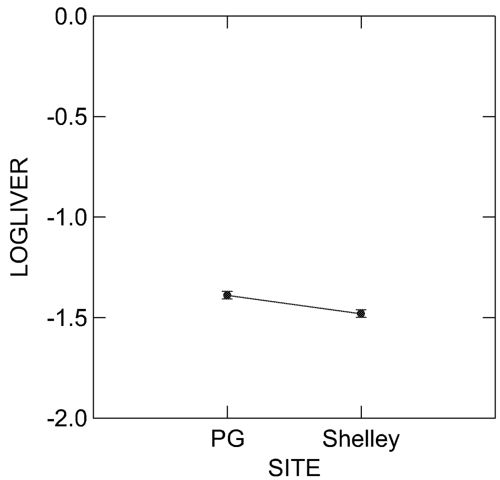
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOGWEIGHT	0.33249	1	0.33249	46.73304	0.00000
SITE$	0.08394	1	0.08394	11.79811	0.00148
Error	0.26324	37	0.00711		

Adjusted least squares means

		Adj. LS Mean	SE	N
SITE$	PG	-1.38850	0.01886	20
SITE$	Shelley	-1.48012	0.01886	20

Least Squares Means




```
*** WARNING ***
Case          118 is an outlier        (Studentized Residual =      3.23192)

Durbin-Watson D Statistic        1.95504
First Order Autocorrelation     -0.00932



Data for the following results were selected according to:
      SITE$='Quesnel' or site$='Cottonwood'

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
SITE$ (2 levels)
   Cottonwood, Quesnel
160 case(s) deleted due to missing data.

Dep Var: LOGLIVER   N: 40   Multiple R: 0.66558   Squared multiple R: 0.44300
```

Estimates of effects $B = (X'X)^{-1} X'Y$

		LOGLIVER
CONSTANT		-2.06980
LOGWEIGHT		0.94021
SITE$	Cottonwood	-0.22539
SITE$	Cottonwood	
LOGWEIGHT		0.27185

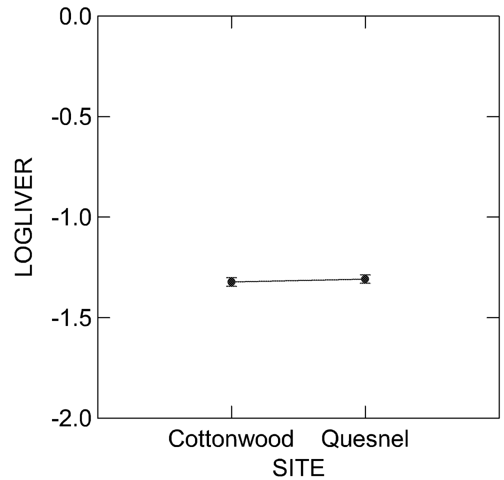
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOGWEIGHT	0.23549	1	0.23549	27.93461	0.00001
SITE$	0.02048	1	0.02048	2.42909	0.12785
SITE$*LOGWEIGHT	0.01969	1	0.01969	2.33530	0.13521
Error	0.30349	36	0.00843		

Adjusted least squares means

		Adj. LS Mean	SE	N
SITE$	Cottonwood	-1.32230	0.02135	20
SITE$	Quesnel	-1.30794	0.02099	20

Least Squares Means




```
Durbin-Watson D Statistic        1.91494
First Order Autocorrelation      0.00749


Data for the following results were selected according to:
      SITE$='Quesnel' or site$='Cottonwood'

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
SITE$ (2 levels)
   Cottonwood, Quesnel
160 case(s) deleted due to missing data.

Dep Var: LOGLIVER   N: 40   Multiple R: 0.63786   Squared multiple R: 0.40687

                                  -1
Estimates of effects  B = (X'X)   X'Y
```

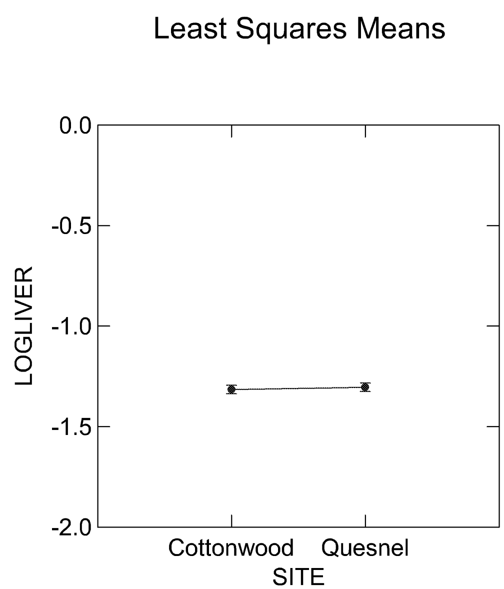
		LOGLIVER
CONSTANT		-2.00150
LOGWEIGHT		0.86206
SITE$	Cottonwood	-0.00558

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOGWEIGHT	0.21581	1	0.21581	24.70772	0.00002
SITE$	0.00118	1	0.00118	0.13455	0.71585
Error	0.32317	37	0.00873		

Adjusted least squares means

		Adj. LS Mean	SE	N
SITE$	Cottonwood	-1.31511	0.02120	20
SITE$	Quesnel	-1.30396	0.02120	20



Durbin-Watson D Statistic 1.98098
First Order Autocorrelation -0.00912

Data for the following results were selected according to:
SITE$='Quesnel' or site$='Cottonwood'

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
SITE$ (2 levels)
Cottonwood, Quesnel

Dep Var: LOGLENGTH N: 200 Multiple R: 0.00336 Squared multiple R: 0.00001

Estimates of effects $B = (X'X)^{-1} X'Y$

		LOGLENGTH
CONSTANT		1.86230
SITE$	Cottonwood	-0.00014

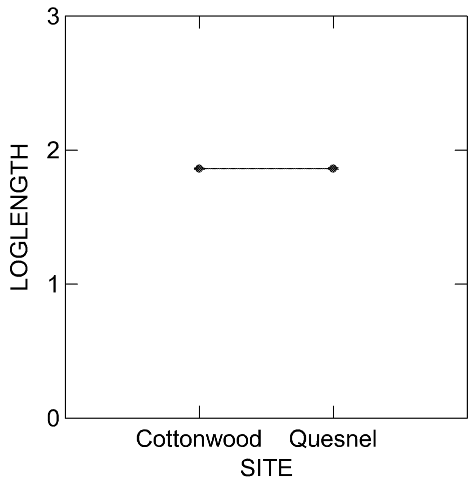
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITE$	0.00000	1	0.00000	0.00224	0.96230
Error	0.35209	198	0.00178		

Least squares means

		LS Mean	SE	N
SITE$	Cottonwood	1.86216	0.00422	100
SITE$	Quesnel	1.86244	0.00422	100

Least Squares Means




```
Durbin-Watson D Statistic        1.06200
First Order Autocorrelation      0.46780


Data for the following results were selected according to:
      SITE$='Quesnel' or site$='Cottonwood'

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
SITE$ (2 levels)
   Cottonwood, Quesnel

Dep Var: LOGWEIGHT   N: 200   Multiple R: 0.07625   Squared multiple R: 0.00581

                               -1
Estimates of effects  B = (X'X)  X'Y
```

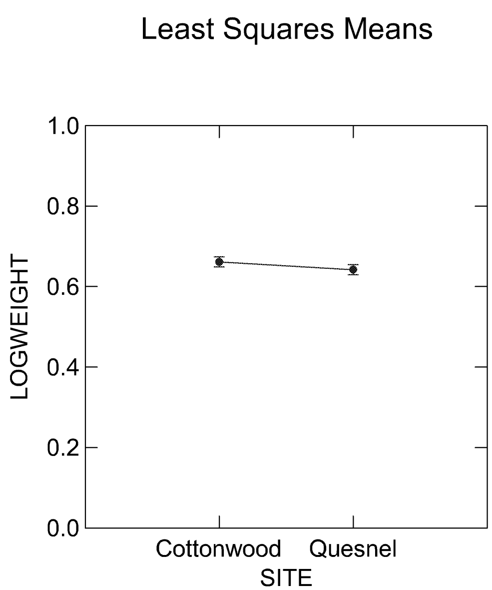
		LOGWEIGHT
CONSTANT		0.65188
SITE$	Cottonwood	0.00954

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITE$	0.01820	1	0.01820	1.15801	0.28319
Error	3.11252	198	0.01572		

Least squares means

		LS Mean	SE	N
SITE$	Cottonwood	0.66142	0.01254	100
SITE$	Quesnel	0.64234	0.01254	100



Durbin-Watson D Statistic 1.09938

```
First Order Autocorrelation      0.44805


Data for the following results were selected according to:
      SITE$='PG' or site$='Shelley'

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
SITE$ (2 levels)
   PG, Shelley

Dep Var: LOGLENGTH   N: 200   Multiple R: 0.17821   Squared multiple R: 0.03176
```

Estimates of effects $B = (X'X)^{-1} X'Y$

		LOGLENGTH
CONSTANT		1.81023
SITE$	PG	-0.00787

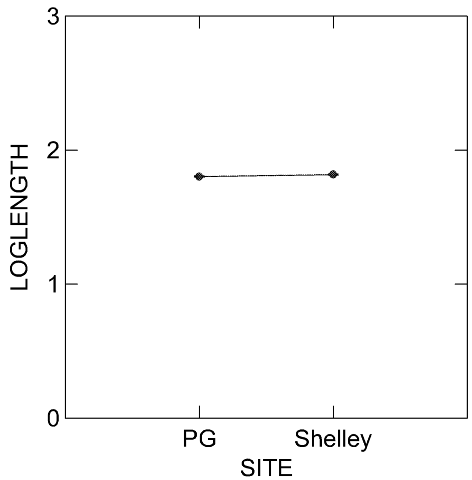
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITE$	0.01237	1	0.01237	6.49446	0.01158
Error	0.37722	198	0.00191		

Least squares means

		LS Mean	SE	N
SITE$	PG	1.80236	0.00436	100
SITE$	Shelley	1.81809	0.00436	100

Least Squares Means




```
Durbin-Watson D Statistic        1.53412
First Order Autocorrelation      0.21865


Data for the following results were selected according to:
      SITE$='PG' or site$='Shelley'

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
SITE$ (2 levels)
   PG, Shelley

Dep Var: LOGWEIGHT   N: 200   Multiple R: 0.16436   Squared multiple R: 0.02702

                               -1
Estimates of effects  B = (X'X)   X'Y
```

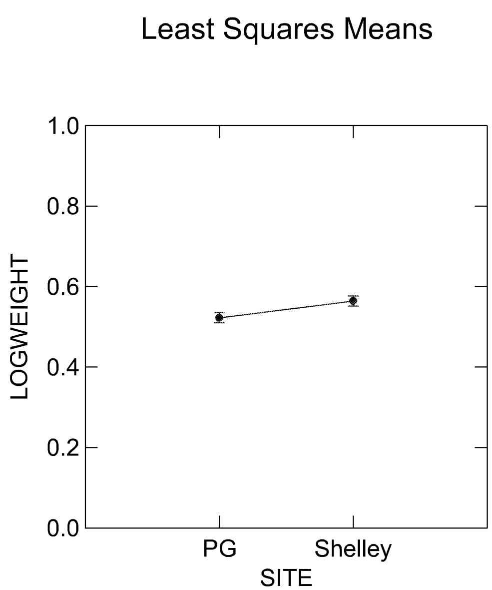
		LOGWEIGHT
CONSTANT		0.54344
SITE$	PG	-0.02087

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITE$	0.08707	1	0.08707	5.49765	0.02003
Error	3.13594	198	0.01584		

Least squares means

		LS Mean	SE	N
SITE$	PG	0.52257	0.01258	100
SITE$	Shelley	0.56430	0.01258	100



Durbin-Watson D Statistic 1.60206

First Order Autocorrelation 0.18319