TEMBEC
ENVIRONMENTAL EFFECTS MONITORING (EEM) CYCLE FIVE INTERPRETIVE REPORT

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ACKNOWLEDGEMENTS

Project management at Hatfield was provided by Mr. John Wilcockson and Mr. Martin Davies. Mr. Brian Stevenson of Tembec Industries Inc. planned and conducted the Investigation of Solutions study. Mr. John Wilcockson coordinated sublethal toxicity testing; Ms. Susan Stanley provided GIS/drafting support. Hatfield Consultants would also like to acknowledge Cantest Inc., who provided toxicity bioassays for the program.

The Local Monitoring Committee (LMC) for Tembec Industries Inc., Skookumchuck Mill, Cranbrook, British Columbia, (Tembec) consists of representatives from the federal and provincial governments, environmental managers from Tembec and Hatfield Consultants Ltd. LMC meetings and discussions provided a valuable forum for reviewing results from previous cycles, the Technical Guidance Document, and the Cycle Five design document. Hatfield would like to acknowledge the following members of the LMC for their assistance:

- Ms. Janice Boyd, Environment Canada;
- Mr. Jody Frenette, BC Ministry of Water, Land and Air Protection;
- Ms. Alison Neufeld, BC Ministry of Water, Land and Air Protection; and
- Mr. Brian Stevenson, Tembec Industries Inc.

EXECUTIVE SUMMARY

Tembec Industries Inc., Skookumchuck mill (Tembec) operates a bleached Kraft pulpmill near Cranbrook, British Columbia, which produces approximately 720 ADMt/d of bleached Kraft pulp. This interpretive report presents results of the environmental effects monitoring (EEM) Cycle Five program for Tembec, undertaken from 2007 and 2009. This program included assessment of sublethal toxicity of final effluent, and an Investigation of Solutions (IOS) focused on reduction of nutrient discharges in final effluent. This IOS was undertaken because previous EEM cycles at the Tembec mill have indicated enrichment effects in the Kootenay River.

SUBLETHAL EFFECTS OF EFFLUENT

Sublethal toxicity of process effluent was assessed six times in Cycle Five (i.e., two test periods per year). Results were highly variable. Effluent affected the survival of rainbow trout embryos at a mean concentration of 54% (EC25). Invertebrate survival was not affected by effluent, but reproduction was, at a mean effluent concentration of 13.9% (IC25). Algal growth was affected at a mean concentration of 18.8% (IC25). Several algal tests exhibited some degree of enrichment on reproductive success or growth. Generally, sublethal toxicity of effluent was slightly higher in Cycle Five than in Cycle Four, but similar to earlier cycles.

Environment Canada's predictive dilution model suggests maximum potential zones of sublethal effect from the effluent discharge point of 93 m for fish survival, 359 m for invertebrate reproduction, <50 m for invertebrate survival, and 266 m for algal growth.

INVESTIGATION OF SOLUTION

The IOS study was divided into several phases:

The IOS study was divided into three components:

1. **Review of current conditions:** Documentation of current and historical mill operations data, and identification of sources of nutrients, including process flow and nutrient balance, with emphasis on major process contributors to mill-generated nutrients.

2. **Benchmarking**: Comparisons of Tembec nutrient discharges and management strategies against Best Management Practices identified by the Forest Products Association of Canada (FPAC 2008), and against those for other, similar pulpmills in British Columbia, and assessment of potential nutrient-reduction practices/technologies at other mills that might be applicable to Tembec.

3. **Identification of nutrient-reduction strategies:** Review of potential strategies for reducing nutrient discharges from the Tembec mill, including the application of Best Management Practices, and possible mill processes changes that would reduce influent BOD and ASB nutrient requirements.

Recommendations arising from the IOS included:

1. Improved use of fertilizer blends.

   - A new fertilizer blend with lower phosphorus content should be tested. Careful monitoring of residuals at the end of the active zone (end of Pass #2) will assist in assessing the success of the change. The goal will be to increase the ammonia residual concentrations and decrease the ortho-P concentrations. Current plans are to purchase a fertilizer blend consisting of 24-10-0 (N-P-K) in the spring of 2010. After initial assessment, the addition rate or blend can be adjusted. A winter blend will be considered as well.

   - A new sampling point at the end of the active zone should be established. A sample dock is required which will allow the technician to safely obtain a well-mixed sample. Current plans are to purchase a ready-made dock in spring 2010 and begin sample collection immediately.

2. An improved nutrient control strategy.

   - The current nutrient control strategy is very basic in nature. One lesson learned from the 2009 survey is that sampling at the end of Pass #1 does not provide sufficient information alone about the active zone of the aeration basin. A sampling dock at the end of Pass #2 will allow for building an important effluent data base to augment data from Pass #1.

   - The addition of instrumentation to this site, such as dissolved oxygen and residual-nutrient meters, will be explored.

3. Recycle of treated effluent from Cell #3 back to Cell #1.

   - Recycle of treated effluent has been successful in controlling ammonia generated in the aeration basin. This will continue to be an important tool in the reuse of ammonia within the system and the potential benefit of ammonia reduction. To date, effluent recycle has been used solely for control of high ammonia-N residuals at the end of the treatment system. The beneficial re-use and reduction of ortho-P residual through this means will be explored. The use of recycle effluent beyond the summer months will be trialed and assessed.

DISTRIBUTION LIST

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Brian Stevenson	Tembec			✓

1.0 INTRODUCTION

The Environmental Effects Monitoring (EEM) program was developed to assess the adequacy of effluent regulations under the federal *Fisheries Act*. Specifically, EEM addresses possible effects of pulp and paper mill effluents on fish, fish habitat, and use of fisheries resources, and examines the sublethal toxicity of process effluents. The program has been designed to achieve national uniformity in monitoring of effects, while taking into consideration site specific factors.

The EEM program was implemented in 1992 as a requirement of the 1992 Pulp and Paper Effluent Regulations (PPER); Cycle One was conducted between 1993 and 1996. Following a general review of Cycle One, program requirements for Cycle Two were revised in Aquatic Environmental Effects Monitoring Requirements EEM/1997/1, and specifically in Annex 1 to EEM/1997/1: Pulp and Paper Aquatic Environmental Effects Monitoring Requirements (Environment Canada 1997). Pulp and Paper Technical Guidance for Aquatic Environmental Effects Monitoring EEM/1998/1 (Environment Canada 1998a) further described the program for Cycle Two (1997 to 2000). These documents also were in effect for Cycle Three (2000 to 2004).

On May 4, 2004, the Regulations Amending the Pulp and Paper Effluent Regulations (Government of Canada 2004) were approved. The amendments dealt mainly with monitoring and reporting requirements, and focused on streamlining and improving the original Pulp and Paper Effluent Regulations (PPER). In addition to the amended regulations, the Pulp and Paper EEM Technical Guidance Document was revised (Environment Canada 2005). These documents were used to design and implement Cycle Four.

On July 28th, 2008 a further set of amendments, entitled Regulations Amending the Pulp and Paper Effluent Regulations (Government of Canada 2008) were approved. The 2008 amendments reduced monitoring requirements for mills that do not show measureable effects and introduced the Investigation of Solutions (IOS) process for mills with demonstrated effects. It also included removal of the fish early-life-stage test, reducing the number of mandated sublethal toxicity tests to invertebrate and algal species.

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. EEM studies usually include:

- A fish population survey to assess the health of fish;
- 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;

- Supporting water quality data to help interpret findings from fish and benthic invertebrate surveys; and

- Sublethal toxicity testing to assess effects of effluent on growth and reproduction of representative aquatic organisms.

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.

This report presents results from the EEM Cycle Five program for the Tembec Industries Inc. Skookumchuck mill. The program, previously described in the study design (Hatfield Consultants 2009), included sublethal toxicity testing of mill effluent, and an Investigation of Solutions (IOS) focusing on approaches to minimize the release of nutrients with the release of treated effluent. Information on changes in mill processes, effluent treatment, and/or the receiving environment that occurred during Cycle Five is also presented. The sections in this report include:

- Section 2 – Mill, Study Area, and Cycle Five Design Update;

- Section 3 – Sublethal Toxicity Testing of Mill Effluent;

- Section 4 – Investigation of Solutions;

- Section 5 – Conclusions;

- Section 6 – References;

- Section 7 – Glossary; and

- Appendices.

2.0 MILL, STUDY AREA AND CYCLE FIVE DESIGN UPDATE

2.1 MILL OPERATIONS

2.1.1 Process Description and Update

Tembec Industries Inc., Skookumchuck Mill (Tembec), is located north of the city of Cranbrook on the Kootenay River, British Columbia, Canada (Figure 2.1). Operation of the pulpmill commenced in 1968 with a production capacity of 345 ADMt/d of bleached Kraft pulp. Various modifications over time (Hatfield Consultants 1994) have increased capacity to 720 ADt/d pulp (Figure 2.2), with some daily production records in excess of 900 ADt/d.

A $300-million Asset Renewal program was undertaken between 1992 and 1994 (Hatfield Consultants 1996), which included complete substitution of chlorine gas with chlorine dioxide in the bleaching process. Bleaching involves a five-step process using oxygen, chlorine dioxide, sodium hydroxide, and hydrogen peroxide. A detailed explanation of this process is presented in Hatfield Consultants (1994). All effluent undergoes secondary treatment in aeration stabilization basins. After secondary treatment, effluent can be directed to tertiary treatment when required. Tertiary treatment removes color from effluent prior to discharge to the Kootenay River. Annual effluent flow has decreased since 1992 to approximately 30,000 m^3/d in 2009.

The mill uses wood chips from sawmills in and around the East Kootenays, Alberta, Montana and Saskatchewan. The major tree species used for furnish include lodgepole pine (47%), interior Douglas fir and western larch (16%), Engelmann spruce (31%), and small volumes of hemlock and subalpine/balsam fir (6%).

2.1.2 Effluent Quality

Effluent quality variables are routinely measured according to provincial and federal requirements; annual average levels are presented in Table 2.1 for 2004 to 2009.

Effluent flow has decreased since 1985, although daily production has generally increased (Figure 2.2). Biochemical oxygen demand (BOD), total suspended solids (TSS) and adsorbable organic halogens (AOX) levels have remained stable since 1994 (Figure 2.3). 2,3,7,8-tetrachlorodibenzodioxin (TCDD) has not been detected in effluent for several years; 2,3,7,8-tetrachlorodibenzofuran (TCDF) concentrations are low compared to 927 pg/L in 1989.

Tembec regularly undertakes acute toxicity testing using rainbow trout and the cladoceran Daphnia magna. During Cycle Five there were no incidence of acute toxicity to either species (i.e., LC50 endpoints were below <100%) (Table 2.1).

Figure 2.1 Upper Kootenay River in the vicinity of Tembec Industries Inc., Skookumchuck Mill.

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Figure 2.2 Daily production and effluent flow (annual averages) at Tembec Industries Inc., Skookumchuck Mill, 1969 to 2009.

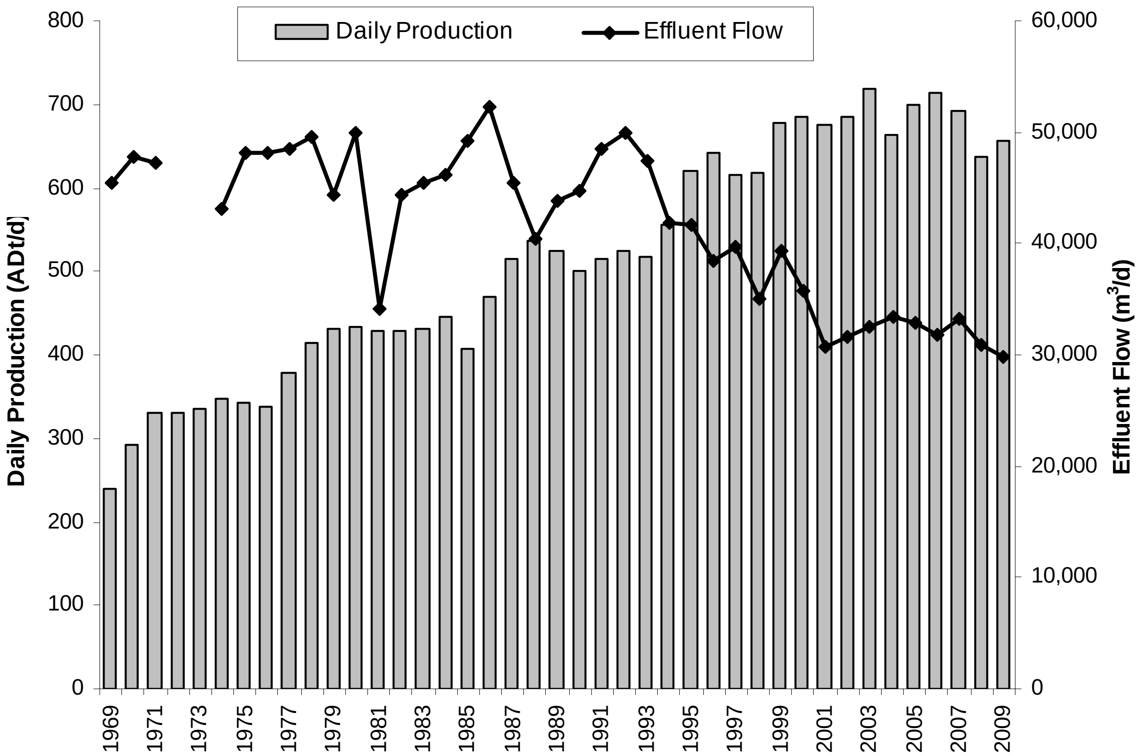


Table 2.1 Annual average values for process effluent quality variables, Tembec Industries Inc., Skookumchuck mill, 2002 to 2009.

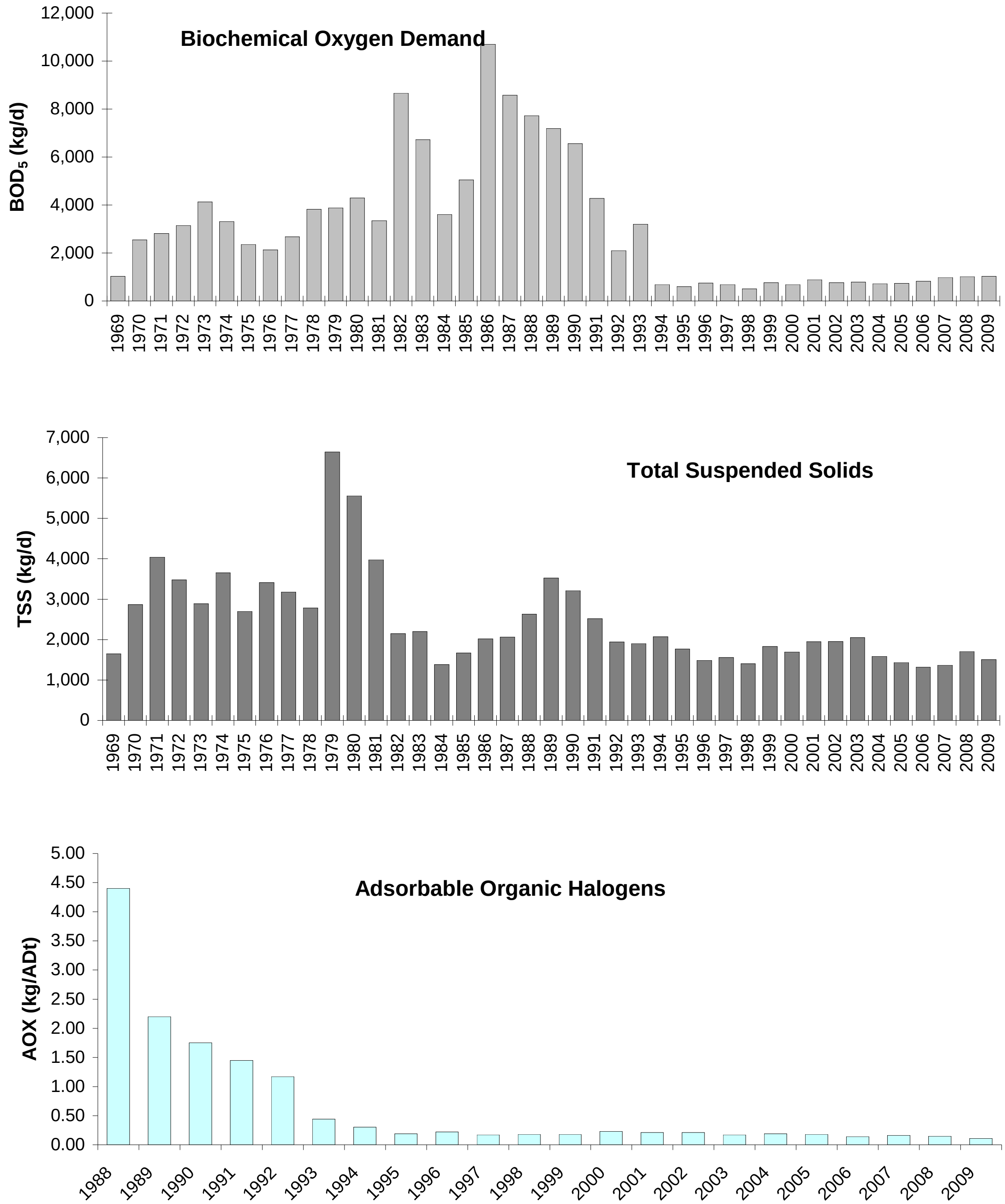
Variable	Unit	2002	2003	2004	2005	2006	2007	2008[2]	2009[3]
Total production	ADmt/d	684	719	664	700	713	693	637	657
Effluent flow	m^3/d	31,670	32,578	33,384	32,882	31,752	33,222	30,904	29,829
pH	-	7.3	7.4	8.0	7.8	7.6	7.6	7.6	7.3
Conductivity	µS/cm	4,071	3,884	3,706	38,47	3,988	3,710	3,650	2,862
TSS	kg/d	1,953	2,052	1,582	1,434	1,314	1,372	1,709	1,505
BOD	kg/d	762	788	718	728	822	983	1,016	1,030
AOX	kg/ADt	0.21	0.17	0.19	0.18	0.14	0.16	0.15	0.11
2,3,7,8-TCDD (Dioxin)	ppq	ND	ND	ND	ND	ND	ND	ND	ND
2,3,7,8-TCDF (Furan)	ppq	8	12	13	11	7	3	7	4
Rainbow trout 96-hr LC50	% effluent	>100[1]	>100	>100	>100	>100	>100	>100	>100
Daphnia magna 48-hr LC50	% effluent	>100	>100	>100	>100	>100	>100	>100	>100

[1] One test failure, July 24, 2002, related to high ammonia levels in effluent.

[2] Average calculated from 359 measurements representing all days when effluent was discharged. In the same period, the mill operated 336 days.

[3] Mill was down for production curtailment from February 23 to April 19, 2009.

Figure 2.3 Biochemical oxygen demand (BOD5), total suspended solids (TSS) and absorbable organic halogens (AOX) in effluent at Tembec Industries Inc., Skookumchuck (annual averages), 1969 to 2009.



The BC Waste Permit level for TSS (4,950 kg/d) was exceeded on one occasion during Cycle Five, due to upset conditions at the removal of the colour clarifier (May 6, 2005). On May 10 and 11, 2005, the final effluent BOD5 was measured above the permit value of 3,720 kg/g due to poor start-up conditions during a major shutdown of the mill (Stevenson pers. comm. 2007).

2.1.3 Spills to the Receiving Environment

No spills to the receiving environment (Kootenay River) have occurred since 1996. Various spills have occurred to the ground and been treated by removal to the landfill site, rehabilitated with clean soil, cleaned up with a vacuum truck, or gradually released to the treatment ponds for treatment.

2.2 CYCLE FIVE STUDY DESIGN UPDATE

The August 2008 amendment to the PPER (Government of Canada 2008) stipulated the removal of the fish sublethal toxicity test from all EEM programs. In accordance, the rainbow trout embryo test was discontinued following the Winter 2008 test period.

No other changes were made to the Cycle Five design during the implementation of the Cycle Five program.

3.0 SUBLETHAL TOXICITY TESTING OF MILL EFFLUENT

Summary of Cycle Five Sublethal Toxicity Testing (Winter 2007 through Summer 2009) for Tembec Industries Inc., Skookumchuck Mill:

- Fish embryo development and algal growth results were highly variable among test periods.
- No effect of effluent on invertebrate survival (LC50) was observed.
- Effects on invertebrate reproduction (IC25) were observed at a geometric mean concentration of 13.9%.
- Effects on algal growth (IC25) were observed at a geometric mean concentration of 18.8%.
- Effects on rainbow trout embryo viability (EC25) were observed at a geometric mean concentration of 53.9%.

Environment Canada's predictive dilution model suggests maximum potential zones of sublethal effect from the effluent discharge point of 93 m for fish survival, 359 m for invertebrate reproduction, <50 m for invertebrate survival, and 266 m for algal growth.

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 and fish habitat. Current EEM regulations require the use of sublethal toxicity tests to help meet the Following objectives (Environment Canada 2005):

- 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 Tembec Industries Inc., Skookumchuck EEM Cycle Five included the following tests, as stipulated in the *Pulp and Paper EEM Guidance Document* (Environment Canada 2005):

- Fish early life stage development test using rainbow trout (*Oncorhynchus mykiss*). This test was excluded from the EEM testing requirements in August 2008 as stated in amendments to the *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* (previously named *Selenastrum capricornutum*).

Sublethal toxicity testing was undertaken by Cantest Ltd. (formerly Vizon SciTec Inc. in Vancouver, British Columbia). A summary of reported endpoints is included with this Cycle Five interpretive report.

3.1 METHODS

3.1.1 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 2005) stipulates sublethal toxicological testing of process effluent during both winter and summer seasons each year. Testing for Cycle Five was initiated in Winter 2007 and continued until Summer 2009.

In Cycle Five, test seasons assigned were not necessarily representative of the date the test was conducted. The first test period each year (the "winter" test period) was usually carried out in May or June. The second test period (the "summer" test period) was usually carried out in October or November. The apparent discrepancy in the naming of test seasons was due to delays that occurred in Cycle Three, resulting from retesting combined with the restrictions associated with test organism availability. Figures presented in this section provide both the test season name and actual test date to prevent any confusion. This naming discrepancy has not been corrected because it has no effect on the validity of toxicity results, and because correcting the naming would require that two sequential test periods be conducted too close to each other.

On each test date, a grab sample of effluent was collected by mill personnel according to the methodology described in the *Pulp and Paper EEM Guidance Document* (Environment Canada 2005) and shipped to Cantest Ltd. for testing. Sublethal toxicity testing involved 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 reported EEM Cycle Five test endpoints, controls met or exceeded all test protocol requirements.

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 organisms. Confidence limits are given for each endpoint where possible.

3.1.2 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)*, Second Edition (EPS 1/RM/28) (Environment Canada 1998b). The fish early-life-stage test is conducted as a static-renewal, seven-day embryo test using newly fertilized rainbow trout eggs exposed to a series of effluent concentrations. The resulting endpoint is the effluent concentration for a 25% effect measured as percent viable embryos (EC25) relative to controls.

The invertebrate reproduction test was conducted as three brood (7±1 day) static renewal tests using the cladoceran *Ceriodaphnia dubia*. General 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*, Second Edition (EPS 1/RM/21) (Environment Canada 2007a). Daphnids less than 24 hours old are exposed to a series of effluent concentrations to estimate both the daphnids survival (survival LC50) and ability to produce viable offspring (reproduction IC25) during a 7±1 day period. The reproductive success of the parent daphnids exposed to effluent are compared directly to those of controls. The LC50 endpoint is the estimated percent effluent concentration at which 50% of the daphnid mothers survive. The IC25 endpoint is the estimated percent effluent concentration resulting in a 25% reduction of reproduction relative to the controls.

Algal growth test was conducted as a 72-hour algal growth inhibition test using the freshwater alga *Pseudokirchneriella subcapitata*. The general procedures used for conducting tests and culturing algae were based on Environment Canada's *Biological Test Method: Growth Inhibition Test Using a Freshwater Alga,* Second Edition (EPS 1/RM/25) (Environment Canada 2007b). Algal cells are grown in various concentrations of effluent for 72 hours, after which cell populations of each replicate are calculated. The test result for growth (IC25) represents the algal cell growth of the experimental concentrations compared to the growth of a control. Test effluent concentrations that indicate an enrichment response 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 2005 including June 2007 amendments). To calculate the IC25, the control value was assigned to all concentrations showing hormesis (i.e., an enrichment response).

3.1.3 Zones of Effluent Concentration

A zone of effluent mixing was predetermined by a plume delineation study undertaken for the Cycle One pre-design study (Hatfield Consultants 1995a). This survey determined the maximum extent of effluent concentrations of 1% (i.e., 100:1 dilution) or greater potentially present in the receiving water environment. This 1% effluent zone originally was used to conservatively define near-field and far-field study areas for environmental sampling.

The 1% effluent zone represents conditions of minimum dilution, maximum extent, and long-term average conditions (Environment Canada 2005), and therefore represents worst-case effluent dilution conditions. In riverine systems, such conditions usually occur in late winter when river flows are seasonally low.

For the Tembec Industries Inc., Skookumchuck EEM study, the maximum extent of 1% effluent was defined as extending approximately 5.0 km downstream of the pulpmill diffusers (Hatfield Consultants 1995a).

A maximum potential zone of sublethal effect was calculated for each test species from the geometric mean of the IC25, EC25, or LC50 results and the extent of the 1% effluent concentration zone, as per Environment Canada (2005). This potential zone of sublethal effect describes the downstream area where the effluent concentration exceeds 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. The maximum potential zone of sublethal effect was calculated as follows:

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

This model assumes simple, linear dilution of effluent downstream of the diffuser, which is not realistic for this situation since Tembec Industries effluent is discharged through a multi-port diffuser that rapidly dilutes effluent into the river flow upon release.

3.2 RESULTS AND DISCUSSION

Tembec Industries Inc., Skookumchuck conducted six sublethal toxicity tests between Winter 2007 and Summer 2009. Several issues were encountered, and several corrections to statistical calculations were applied during laboratory sampling in Cycle Five, including:

- **Summer 2007 invertebrate reproduction and survival tests**: Final temperatures in some dilution replicates fell slightly below the recommended range of 24 to 26°C (this test was not repeated);

- **Winter 2008 invertebrate reproduction and survival tests**: Controls did not meet test protocol requirements due to poor culture health (this test was repeated);

- **Winter 2007 algae test:** This test was repeated at Tembec's request, after the original test reported uncharacteristically low IC25s with no obvious mill-related changes in effluent to explain the low IC25 (results of original test can be found in Appendix A1);

- **Summer 2008 algae test:** Results exhibited a paradoxical dose-response curve, with a negative effect at very low effluent concentrations and no effect or a positive effect at higher concentrations; results were inconsistent with those observed during all other test periods of Cycle Five (the IC25 calculation for these results is currently under review by Environment Canada); and

- **Summer 2009 algae test**: The lowest six concentrations exhibited significant reduction in cell yield, resulting in these concentrations (0.014% to 3.367%) being excluded from statistical calculations (the result obtained from this calculation is currently under review by Environment Canada).

Appendix A1 summarizes Cycle Five sublethal toxicity test results for Tembec, including dose-response curves for all tests conducted.

3.2.1 Rainbow Trout Early-Life-Stage Development

Rainbow trout early life stage development tests were conducted for the Winter 2007 through Winter 2008 test periods. Consistent with amendments to the *Pulp and Paper Effluent Regulations* (Government of Canada 2008), this test was no longer required after Winter 2008.

Figure 3.1 presents a summary of Cycle Five EC25 results for the rainbow trout embryo viability test. Effects of effluent on the viability of rainbow trout embryos were observed in all test periods. EC25s decreased over the three tests conducted during this cycle, from 76.4% v/v effluent in Winter 2007 to 32.9% in Winter 2008. These results yielded a geometric mean EC25 of 53.9% effluent. The results of Cycle Five indicated greater effluent toxicity towards trout embryo than in previous cycles (Figure 3.2).

Figure 3.1 Effect of exposure to Tembec Industries Inc., Skookumchuck mill effluent on rainbow trout early life stage development expressed as EC25 ±95% confidence limits, EEM Cycle Five.

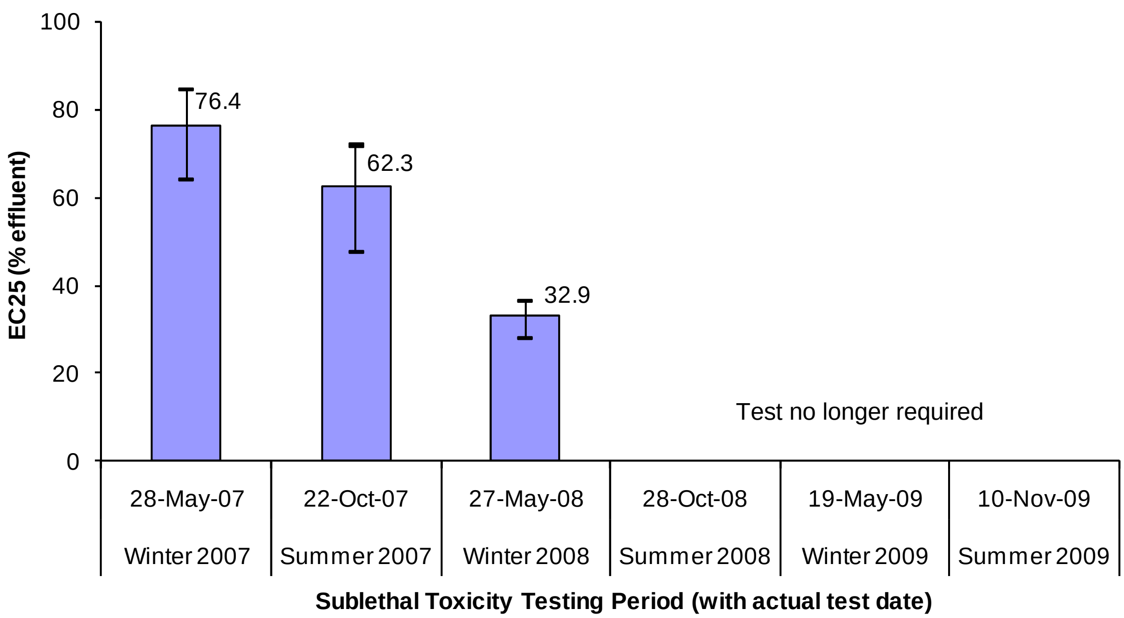
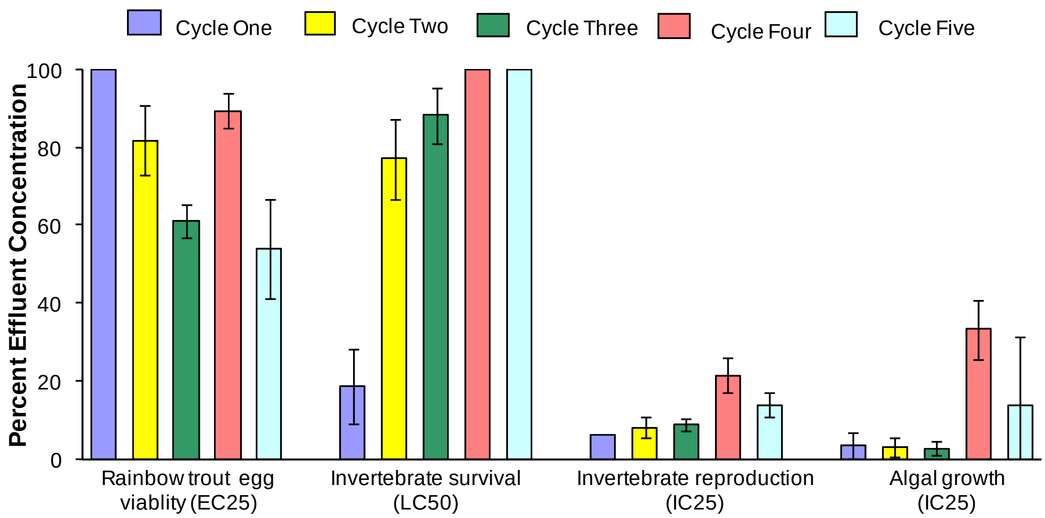


Figure 3.2 Geometric means of IC25, EC25, and LC50 results from sublethal toxicity tests of Tembec Industries Inc., Skookumchuck mill effluent for EEM Cycle One through Cycle Five.



3.2.2 Invertebrate Survival and Reproduction

IC25 reproduction and survival results and confidence limits from Cycle Five tests for *Ceriodaphnia dubia* are summarized in Figure 3.3 and Figure 3.4.

Reproduction IC25 results ranged from 6.8% to 25.9% v/v effluent with a geometric mean of 13.9% (Figure 3.3). This mean IC25 for the cycle was in the range of observations from previous cycles (Figure 3.2).

Similar to all previous cycles, no effect of effluent was observed on invertebrate survival in Cycle Five (Figure 3.4).

Figure 3.3 Effect of exposure to Tembec Industries Inc., Skookumchuck mill effluent on invertebrate reproduction expressed as IC25 ±95% confidence limits, EEM Cycle Five.

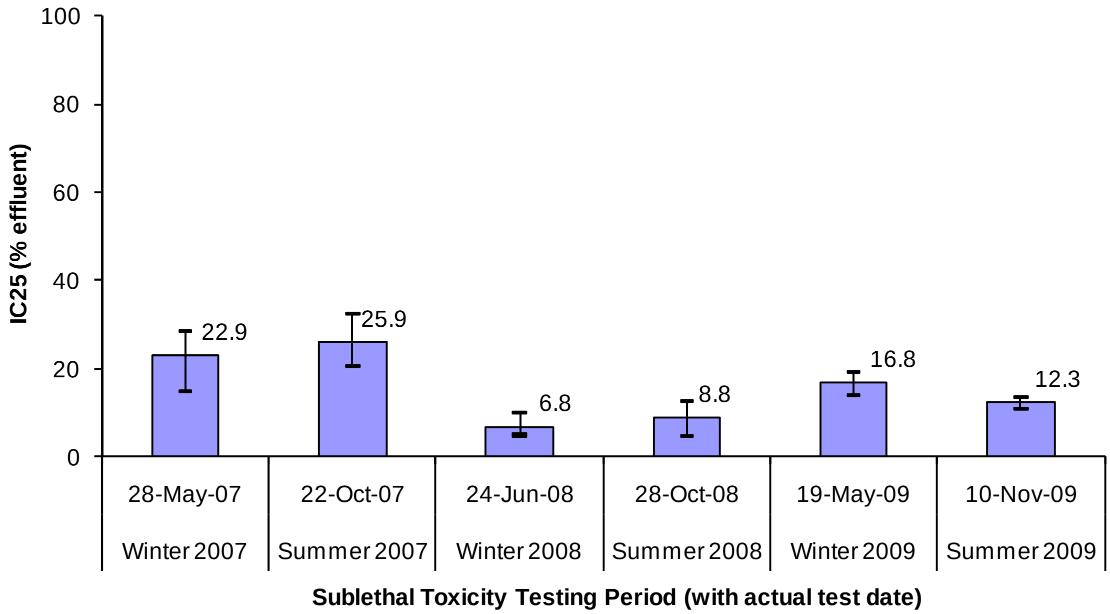
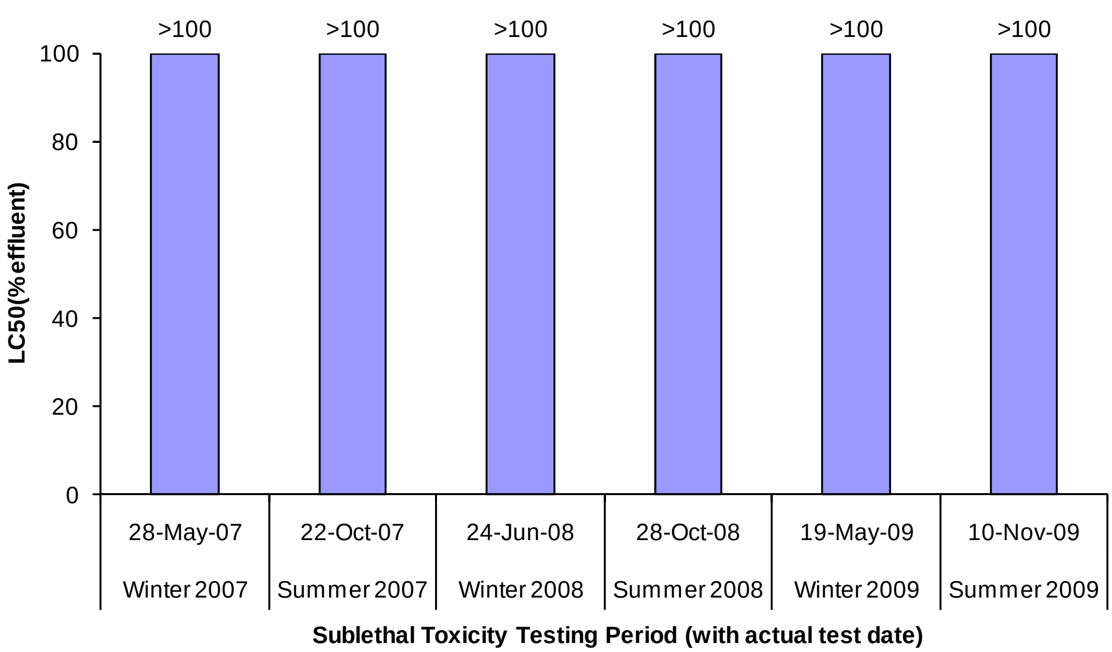


Figure 3.4 Effect of exposure to Tembec Industries Inc., Skookumchuck mill effluent on invertebrate survival expressed as LC50 ±95% confidence limits, EEM Cycle Five.



3.2.3 Algal Growth

The IC25 results and confidence limits for Cycle Five tests for algal growth tests using *Pseudokirchneriella subcapitata* are summarized in Figure 3.5.

Growth IC25 results ranged from 0.034% to >90.91% v/v effluent for a geometric mean concentration of 18.8%. The lowest IC25 was observed in Winter 2008. Three IC25 results exceeding 90.91% v/v effluent (i.e., no observed toxicity) were reported for Cycle Five, in the Summer 2007, Summer 2008, and Winter 2009 test periods. The geometric of IC25s for Cycle Five suggest a dramatic decrease in effluent quality relative to Cycle Four, although indicate greater toxicity to algae compared to Cycles One through Cycle Three. However, several unusual results requiring reassessments in Cycle Five are discussed below.

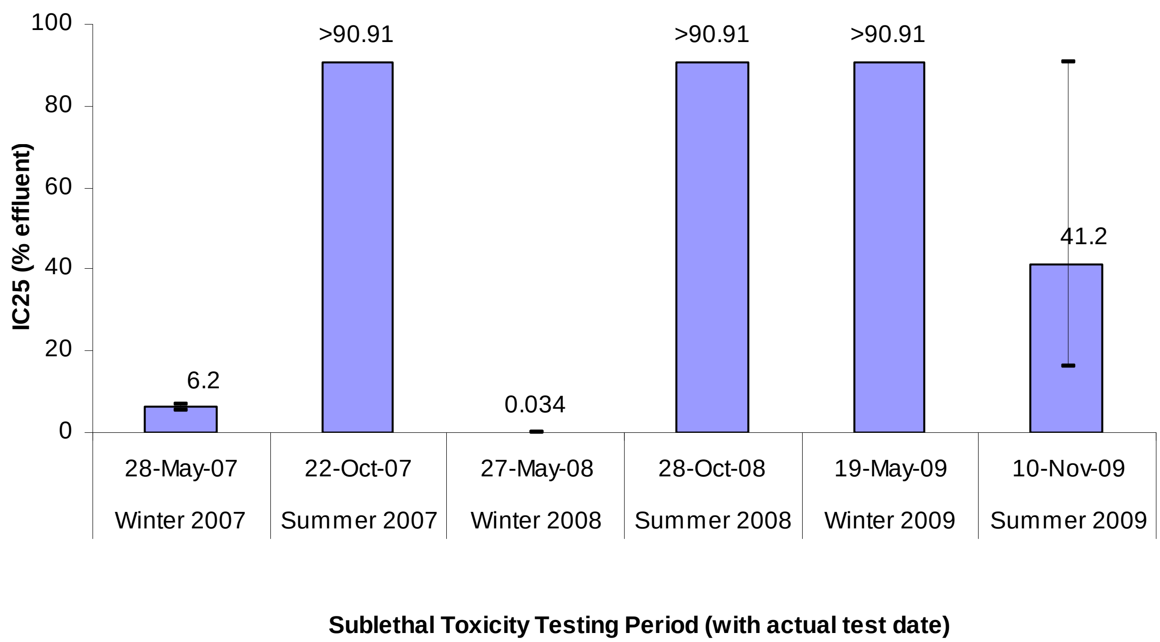
After the Winter 2007 test period, an additional voluntary test was conducted at the request of Tembec Industries Inc. to re-assess the low IC25 reported during the initial test (6.2%) in May 2007. This retest conducted on October 1, 2007, resulted in a higher IC25 (41.8% v/v effluent) indicating that the original result may have either been a testing artifact, or represented short-term conditions. There were no changes in mill condition that explained the low IC25. The original test result (6.2%) as reported to Environment Canada has been included in this report. Results and dose response curves for the voluntary re-test are available in Appendix A1.

The reported IC25 for the Winter 2008 test period is currently under review by Environment Canada and may be revisited in the Cycle Six Interpretive Report. These test displayed unusual dose-response curves (Appendix A1), showing inhibited algal growth at very low effluent concentrations, but not at higher concentrations. This is inconsistent with results obtained for all other test periods in Cycle Five, as well as dose-response curves from earlier cycles. A modified regression model was unavailable to accurately interpret these results; therefore, the IC25 calculated is exceedingly low, and likely overstates effluent toxicity. Excluding this value from the Cycle Five data results in a geomentric mean IC25 for the cycle of 45.4% v/v effluent and a potential zone of sublethal effect of 110.2 m.

The Summer 2009 test period results (Appendix A1) also displayed algal growth inhibition at very low effluent concentrations. Similar to Winter 2008, this curve appeared to display three distinct response phases: (1) from concentrations of 0.014 to 0.374%, the mean cell yield decreased; (2) between 0.374 to 10.101%, the mean cell yield increased until it was not significantly different from that of the control; and (3) all concentrations higher than 10.101% once again displayed a decrease in cell yield.

The approach Cantest Ltd. used for the Summer 2009 results was to exclude the lowest six concentrations (0.014% to 3.367%) from the IC25 statistical calculations. Regression model fitting excluding these data points resulted in the best model fit. This resulted in an IC25 value of 41.2% v/v effluent, with a broad range of error (16.1% to 90.91%). The IC25 calculation is currently under review by Environment Canada and may be revisited in the Cycle Six Interpretive Report.

Figure 3.5 Effects of exposure to Tembec Industries Inc., Skookumchuck mill effluent on algal growth expressed as IC25 ±95% confidence limits, EEM Cycle Five.



3.2.4 Maximum Potential Zone of Sublethal Effect

The 1% zone of effluent concentration for Tembec Industries Inc., Skookumchuck varies seasonally based on river flows. The pre-design study for Tembec mill identified a zone of incomplete effluent mixing from the mill diffusers in Kootenay River to the Skookumchuck highway bridge, 2.5 km downstream. This section of river constitutes the 1% zone of effluent concentration from May to October. However, under low-flow conditions, effluent concentrations of 1% or greater may extend as far as Fort Steele and Wardner, 35 and 60 km downstream, respectively (Hatfield Consultants 1994a). The regional report by Environment Canada assigned the 1% effluent concentration zone as 5 km downstream of the outfall (Colodey *et al*. 1999), and this distance has been applied to potential zone of sublethal effect calculations.

Table 3.1 presents the geometric means of the IC25, EC25, and LC50 endpoints for each test species for Cycle One through Cycle Five, and the resulting maximum potential zones of sublethal effect calculated using the defined 1% effluent zone (5,000 m). Calculations of geometric means and maximum potential zones of sublethal effects can be found in Appendix A1.

Table 3.1 Maximum potential zone of sublethal effect for the Tembec Industries Inc., Skookumchuck mill, EEM Cycle Five.

Sublethal Toxicity Test Species	IC25, EC25 or LC50 Geometric Mean (% v/v)					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[2]	>100%	81.8%	61.2%	89.4%	53.9%	<50m	61m	82m	56m	93m
Invertebrate										
Reproduction IC25	6.2%	8.1%	8.8%	21.5%	13.9%	806m	621m	566m	232m	359m
Survival LC50	18.6%	77.0%	88.2%	>100%	>100%	270m	65m	57m	<50m	<50m
Algal Growth IC25	3.5%	3.0%	2.6%	33.2%	18.8%	1,429m	1,682m	1,924m	151m	266m

[1] Based on a 1% effluent zone of 5,000 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.

The potential zone of sublethal effect for invertebrate survival cannot be calculated with any accuracy, as the LC50 concentrations in Cycle Five were always greater than the highest concentration tested. Consequently, the zone is shown as being less than the distance calculated (<50 m), assuming that the LC50 was equal to the highest concentration tested (Table 3.1).

Potential zones of sublethal effect for rainbow trout embryo viability, invertebrate reproduction, and algal growth all were higher in Cycle Five than in Cycle Four, but were generally within the range of historical observations. Complex dose-response curves observed in the algal growth test yielded IC25s that may have overestimated effluent toxicity, and therefore the zone of potential effect as well.

3.3 CONCLUSIONS

Toxicity assessments contribute to the overall weight-of-evidence used to assess potential environmental effects of effluent discharges. When interpreting sublethal toxicity data, it is important to keep in mind that laboratory results may not accurately predict toxicity in receiving environments. Laboratory tests involve single species that may or may not be found in the study area, and there is an assumption that there is no background toxicity in the area. Furthermore, effluent plume dispersion and dilution vary due to seasonal changes, and in other ways that could affect toxicity levels.

Cycle Five tests indicated high variability in inhibition of trout embryo development and algal growth, and generally greater effects on all test species relative to results observed in Cycle Four, although results were typically similar to or less than those observed in earlier EEM cycles.

Effluent concentrations equal to the geometric means of the IC25, EC25, or LC50 results have not been observed downstream of the Tembec diffuser under any river flow conditions. The highest concentration of effluent observed in the near-field area during the pre-design study conducted in September 1993 was 2.92% effluent based on measured colour, shortly downstream of the effluent diffuser

(Hatfield Consultants 1994a). During Cycle One, the highest concentration of effluent reported in the near-field area was 1.86% based on sodium concentrations (Hatfield Consultants 1996). In contrast, the lowest mean inhibition endpoint observed in Cycle Five was 13.9% (IC25 for invertebrate reproduction), which is well above any previously measured concentrations of effluent in the Kootenay River.

4.0 INVESTIGATION OF SOLUTIONS

4.1 BACKGROUND

Federal Ecological Effects Monitoring (EEM) field monitoring programs up to and including Cycle Four have demonstrated an enrichment effect in benthic community and fish populations in the Kootenay River downstream of the Tembec Skookumchuk Mill.

Benthic invertebrate communities exhibited higher total densities and greater taxonomic richness downstream of the pulpmill. Chemical analysis of final effluent and Kootenay River water indicated that phosphorus is the limiting nutrient in the river and additions of this nutrient via mill effluents is the probably cause of observed enrichment effects.

Consistent with study options provided in the recent ***Amendments to the Pulp and Paper Regulations*** (Government of Canada 2008), an Investigation of solutions (IOS) study was initiated to determine the sources of nutrient (ammonia and phosphorus) in the mill, in particular phosphorus. The fate and effect of these nutrients in the wastewater treatment system was also of interest.

The IOS study was divided into three components:

4. **Review of current conditions:** Documentation of current and historical mill operations data, and identification of sources of nutrients, including process flow and nutrient balance, with emphasis on major process contributors to mill-generated nutrients.
5. **Benchmarking**: Comparisons of Tembec nutrient discharges and management strategies against Best Management Practices identified by the Forest Products Association of Canada (FPAC 2008), and against those for other, similar pulpmills in British Columbia, and assessment of potential nutrient-reduction practices/technologies at other mills that might be applicable to Tembec.
6. **Identification of nutrient-reduction strategies:** Review of potential strategies for reducing nutrient discharges from the Tembec mill, including the application of Best Management Practices, and possible mill processes changes that would reduce influent BOD and ASB nutrient requirements.

4.2 NUTRIENT REQUIREMENTS FOR SECONDARY TREATMENT

It is understood that secondary effluent bacteria use nitrogen (bioavailable as ammonia-nitrogen) and phosphorus (bioavailable as ortho-phosphate) to metabolize BOD (as soluble organic carbon) into new cells. Numerous types of bacteria will develop as numerous types of enzymes are manufactured by the bacteria cells to break down suspended organic compounds in effluent. Effluents that are deficient in nutrients will inhibit these metabolic processes, reducing the ability to convert BOD into new cell growth. Simpler organic compounds may be broken down where nutrients are slightly deficient, but more complex and potentially toxic organic compounds may pass through the system untreated. When nutrient concentrations are too low, BOD removal efficiency will drop, and in some cases, toxic effluent will result.

Nitrogen and phosphorus requirements vary from summer to winter. Usually, warmer summer conditions provide an overall warmer and more efficient aeration basin. BOD removal efficiencies can improve by up to 10%. Supplemental nutrient addition to the basin can be reduced or eliminated during these times. Monitoring of nutrient residuals relative to past, successful operations is critical to ensure that removal efficiencies are not compromised when supplemental nutrients are reduced or eliminated.

Winter operation of an aeration basin in cold climates is always challenging. Effluents reporting to the secondary treatment systems are colder. Surface aerators mix in ambient air with sub-zero temperatures, further reducing effluent temperature as it moves through the system. The colder temperatures reduce metabolic rates and associated BOD conversion. During winter months, supplemental nutrient addition is almost always required. Monitoring of nutrient residuals is still very important, but operational comparisons must be made to performance in comparable winter conditions.

4.3 CURRENT CONDITIONS AT SKOOKUMCHUCK

An assessment of the current conditions at the Tembec pulpmill included a review of current management practices, studies to determine the primary sources of nutrients in the mill process chain, studies to determine concentrations and cycling of nutrients within the effluent treatment system, and review of historical nutrient concentrations in mill effluent.

4.3.1 Current Nutrient Management Practices

Generally, nutrient management at Skookumchuck involves regular monitoring of nutrient residuals in the effluent treatment system, and adjustment of nutrient additions according to mill practices. As with other mills, the challenge for addressing nutrient management is to maintain acceptable effluent treatment while at the same time minimizing nutrient residuals. If nutrient concentrations become too low, treatment efficiency drops, resulting in poor effluent quality (i.e., higher TSS, BOD and toxicity). Excess TSS in particular is undesirable because it may rise to unwanted or uncontrolled concentrations, and because high TSS in itself may generate higher nutrient residuals in effluent, due to nutrients bound in cell biomass.

Mill processes alone generate sufficient nutrient loads to the treatment system in the summer months for effective ASB operation. However, during the winter months, nutrients supplied by mill processes are inadequate, requiring supplemental addition of a liquid nutrient blend. A common fertilizer blend of urea ammonium nitrate (UAN) solution and ammonium polyphosphate is used to supplement nutrient mass, with a N-P-K nutrient blend equivalent to 16-24-0.

Nutrient residuals are measured at least weekly from two locations in the secondary treatment system: at the end of the Pass #1 in Cell #1; and at the end of secondary treatment at the Lift Station. Nutrient-residual testing at the end of Pass #1 is important for assessing the consumption of nutrients by biological activity. Adjustments to supplemental fertilizer additions are made based on this testing, to ensure optimum biological activity. No in-plant process-line modifications have been identified (by mill staff?) as capable of adjusting mill-generated nutrient contributions.

Residual nutrient testing at the end of secondary treatment at the Lift Station is important to assess nutrient releases from biomass due to endogenous decay and benthal feedback, and to understand the release of nutrients to the Kootenay River. Tracking of residual ammonia-N at the Lift Station is considered important to ensure toxic concentrations (low nutrient concentrations leading to toxicity?) are not reached.

Given the aeration basin may generate ammonia from endogenous decay, management of residual concentrations at the end of treatment is important. One significant management tool is the option to redirect a portion of treated effluent, high in residual ammonia, back to the start of Pass #1 of the aeration basin. This option is generally only exercised in summer months when higher ammonia concentrations are present. Approximately 20 to 30% of treated effluent may be re-circulated this way so that nutrients can be recycled and to extend the period of BOD treatment within the system as a function of hydraulic loading. This method has been successfully used since 2003.

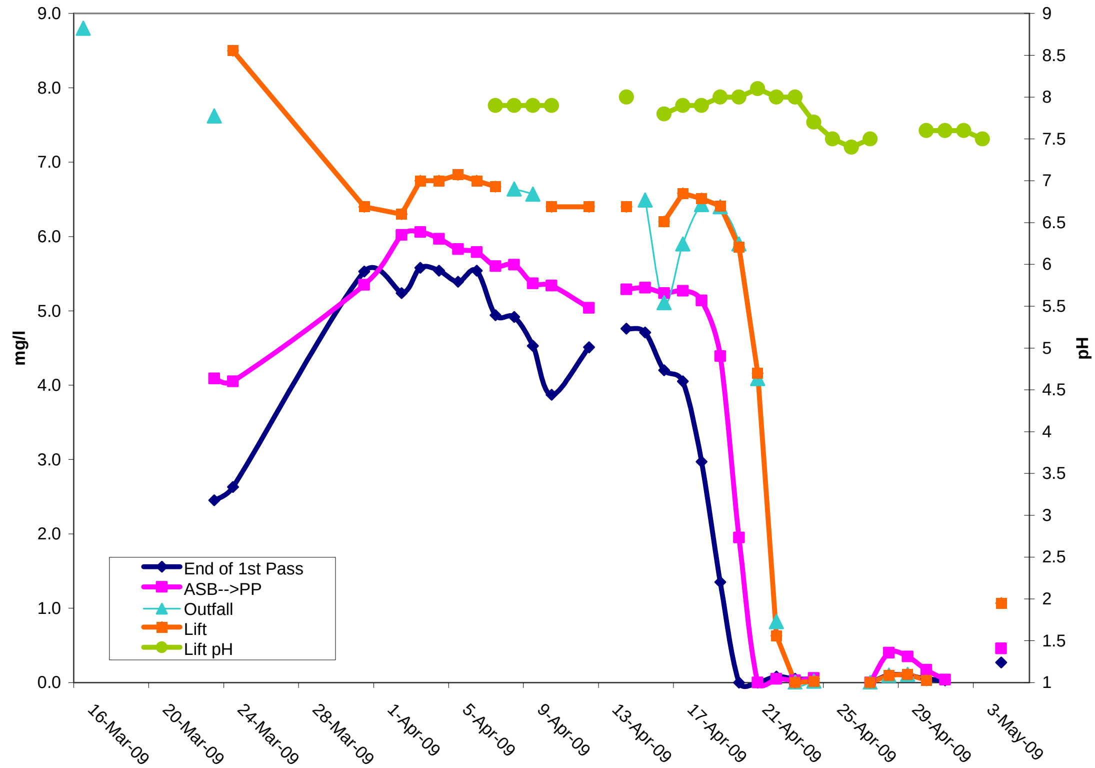
4.3.2 Ammonia Generated by Biomass

A production curtailment at the Skookumchuck Mill began in early February 2009, leading to a mill shutdown from February 22 to mid-April. Effluent flow to the Kootenay River ceased on February 24. Effluent from the mill to the aeration basin from that date onward consisted of cold water used for mill compressor cooling and some clean-up water. The production curtailment provided an opportunity to study ammonia generated by benthal feedback mechanisms. Since there was little or no BOD loading to the aeration basin, ammonia measured at the Lift Station would be assumed to be released by endogenous decay and benthal feedback.

Ammonia concentrations were measured at various points within the ASB system (Figure 4.1) on a daily basis (mill-based testing started on March 31 and continued until the end of April 2009).

Endogenous decay of benthic matter was determined to be the source of rising ammonia concentrations through the system.

Figure 4.1 Ammonia nitrogen through ASB System.



4.3.3 Mechanisms of Nutrient Uptake and Release

Microorganisms in effluent initially utilize nitrogen to synthesize BOD into biomass, with nitrogen sequestered within the biomass as organic nitrogen. The biomass is then broken down via bacteria-mediated endogenous respiration and the nitrogen is released back to the effluent as ammonia. If there is a food source available (measured as soluble BOD) then this ammonia is re-utilized as a nutrient to generate new biomass. However, if soluble BOD is negligible, the ammonia cannot be re-utilized, and ammonia concentrations in the aeration basin will increase. In the treatment system, ammonia is also continually released from the breakdown of benthal matter in the bottom sludge layers of the aeration basins.

To assist aeration basin start-up, April 2009, effluent was re-circulated from the end of the treatment system back to Pass #1 at a rate of 1,000 to 2,000 USGPM (3.8 to 7.6 m^3/minute). The intention of effluent recirculation was to re-use the available ammonia as a nutrient at the end of the treatment system. Discharge to the Kootenay River was intermittent until April 17, 2009, but discharge was continuous thereafter. The recovery biological activity was slow, therefore ammonia consumption did not occur. Instead, an equalization of ammonia concentrations occurred throughout the treatment system.

Ammonia concentrations decreased significantly beginning April 17. This decrease coincided with the production of mill effluent and the supplemental addition of molasses, a simple carbohydrate, to the aeration basin. The sugars in the molasses served to accelerate the recovery of biological activity in the basin. A few days after molasses addition, all available nutrients in the system were consumed. The resulting low concentrations of ammonia in the treatment system necessitated the addition of nutrient fertilizer beginning on April 22.

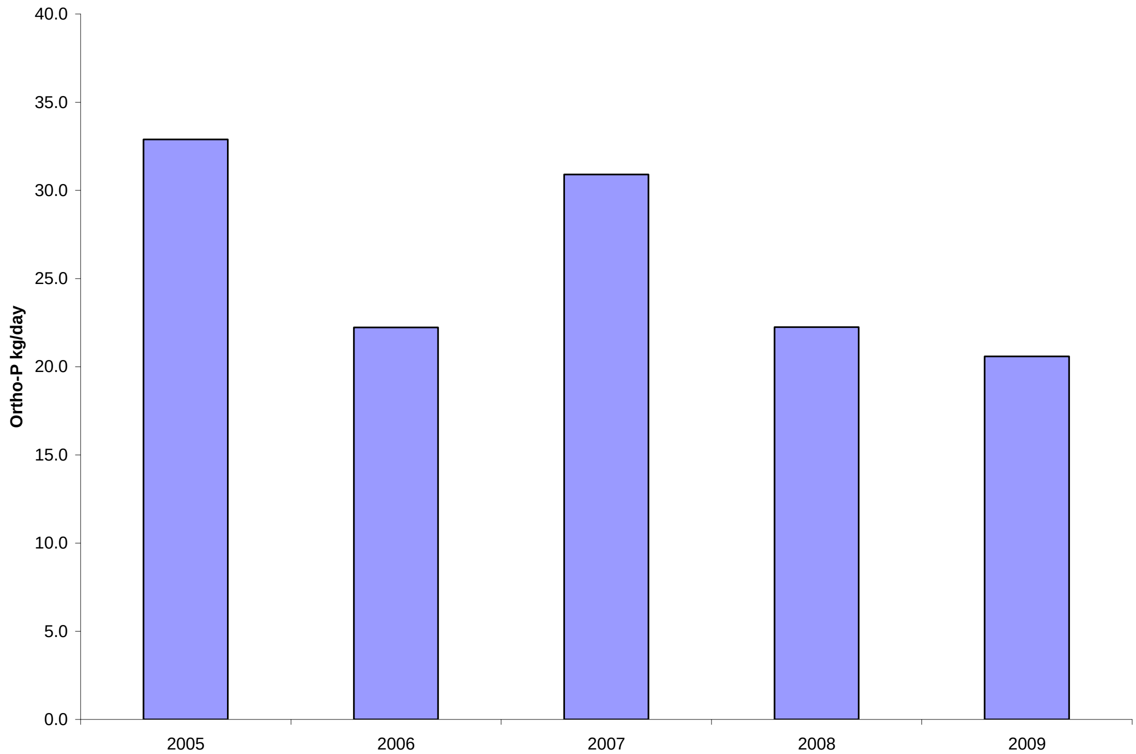
An estimate of ammonia from benthal feedback can be calculated from the 2009 mill shutdown. In general, concentrations of approximately 6.5 mg/L ammonia were measured at the Lift Station during April 2009 before molasses addition. Effluent release to the Kootenay River was intermittent during this time; however, for those days when there was effluent flow, the mass release of ammonia was equivalent to approximately 60 kg/d. This is a significant mass of ammonia released back to the effluent.

4.3.4 Historical Nutrient Discharges

The mill has recorded concentrations of ammonia-N and ortho-P in effluent at the Lift Station since 2005. Testing is done in the mill main laboratory. The mill does not have historical data describing in-mill sources of nutrients.

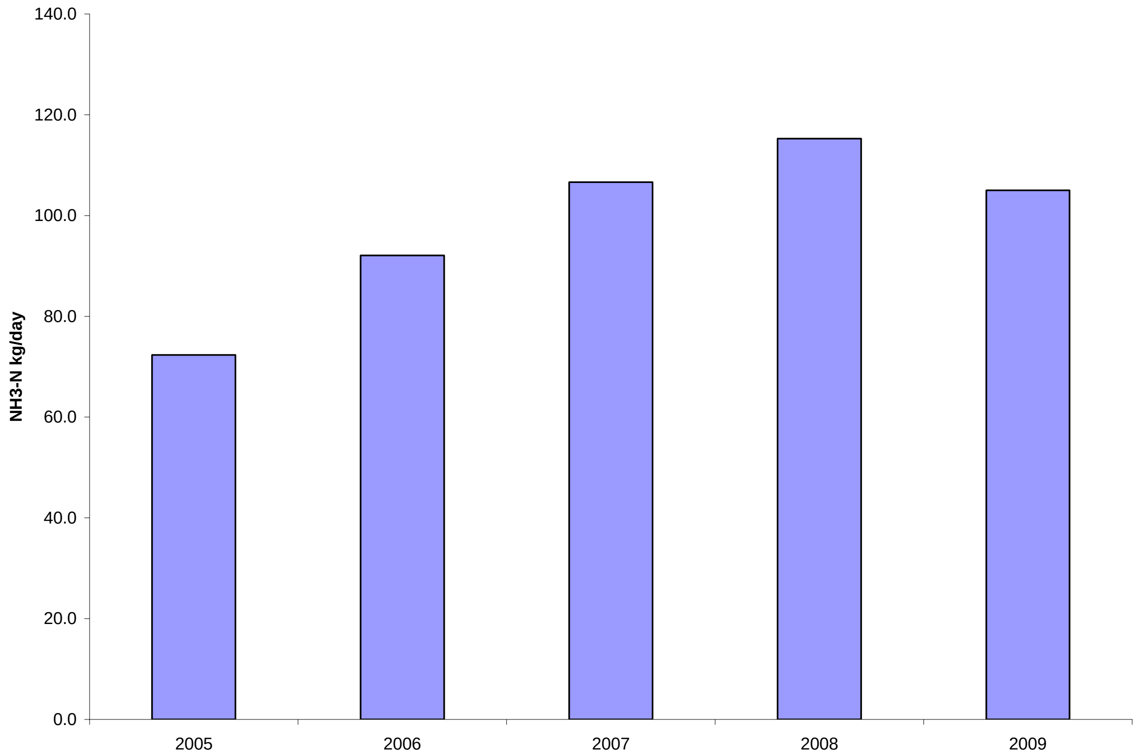
Ortho-P loadings to the receiving environment (kg/day) declined by approximately 1/3 from 2005 to 2009, although results were variable across these years (Figure 4.2). If nutrients are assumed to be released from sludge in a consistent fashion over time, it appears that ortho-P is not released at the same rate as is ammonia (Brian—I'm not sure what you mean here).

Figure 4.2 Ortho-P concentrations in effluent at the Lift Station.



Nitrogen loadings (measured as ammonia) have increased from 2005 to 2009 (Figure 4.3). One possible explanation for this is a potential increase of released ammonia from benthal feedback. Bottom sludge layers have likely increased over time in the later reaches of the aeration basin cells, providing a greater resource of this nutrient.

Figure 4.3 Ammonia-nitrogen concentrations in effluent at the Lift Station.

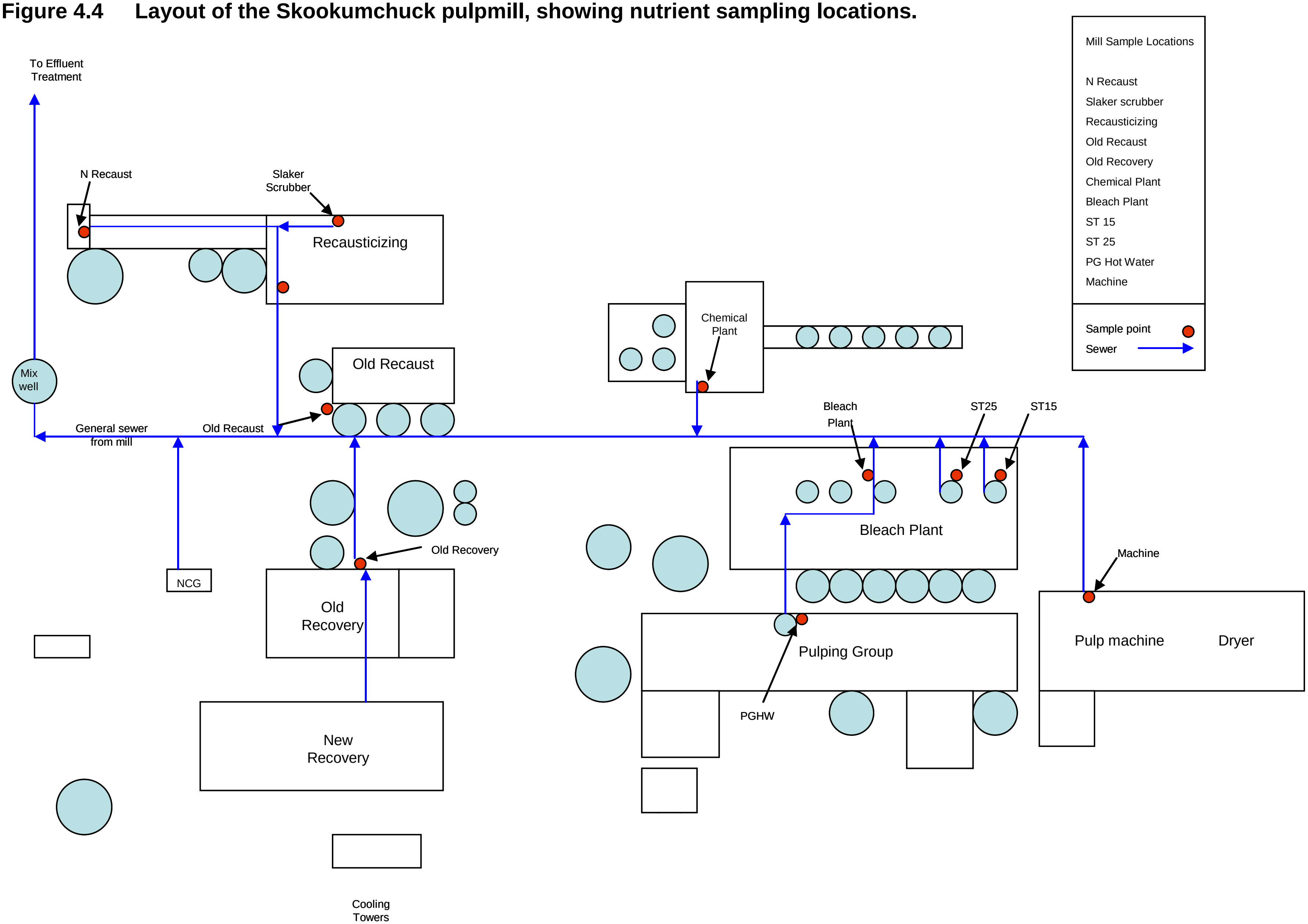


4.4 IN-MILL NUTRIENT SURVEY

4.4.1 Initial Assessment of Nutrients Sources

All major mill sewers were sampled during July and August 2009 to determine which areas of the mill were responsible for significant nutrient loadings (Figure 4.4)

Figure 4.4 Layout of the Skookumchuck pulpmill, showing nutrient sampling locations.



There are ten spill sumps located at strategic locations throughout the mill. These sumps were designed to direct fibre and filtrate spills to spill-recovery tanks. The recovered liquids are recycled into the liquor cycle while recovered fibre is separated in a rotary drainer and discharged to a bunker for disposal at an onsite landfill.

The centre corridor of the mill site has been graded and paved to contain all spills. To facilitate the containment, a number of entranceways to various buildings have been bermed. Outside spills within the main corridor of the mill are contained in a sewer trench. The sewer trench has an automatic valve that is designed to close and capture any spills, allowing spills to be metered back to the treatment system in a controlled manner.

On occasion, mill condensates may be directed to sewer until processes are stabilized and the condensates can be redirected back into the process. These occasions are rare and do not represent normal or sustained operation. The contribution of sporadic sewering of condensates on mill generated nutrient loading was assumed to be low.

The initial survey also identified mill sewers that did not contribute significantly to the total mass loading of mill-generated nutrients. Remaining mill sewers were advanced for additional investigation. Sewers not found to contribute substantial amounts of nutrients to the treatment system included:

- **Pulp machine:** pulp machine white water overflow and vacuum pump water;
- **Bleach plant:** bleach plant, pulping group, oxygen delignification area sewer which, when combined, form mill general sewer;
- **Chemical plant:** chemical plant sewer, mainly compressor cooling water and gland water;
- **Impregnation building:** gland water and clean-up water;
- **Old recaust sewer:** gland water, flush water, overflow from new recaust sewers, north and south recaust sump flows; and
- **Old recovery sewer**: flush water, gland water.

Sewers that were not part of this initial screening included the recovery and demineralizer sealed sewers. Contents of the recovery sewer are pumped to a spill tank, and contents of the spill tank are routed back to the mill process. The demineralizer sewer is typically a sluiced saltcake solution and is directed through a sealed sewer. This sewer is not expected to contribute nutrients. The non-condensable gas incinerator building has a sealed sewer which is not accessible for sampling. However, as with the demineralizer sewer, it is not expected to contribute nutrients.

4.4.2 Stream-Specific Nutrient Survey

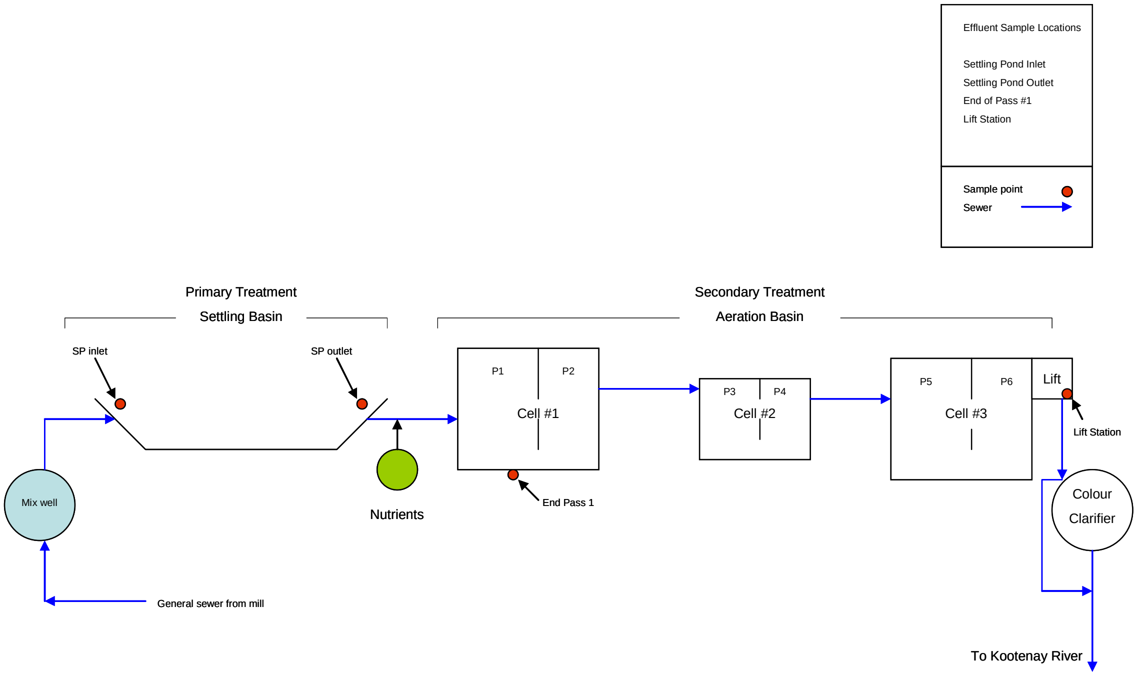
Once an initial understanding was gained for mill generated nutrients, a more detailed series of samples was taken from process streams thought to be specific contributors to the mill effluent system. These specific streams included:

- **Seal tank 15:** Bleach plant first stage acid filtrate which includes the addition of other acid stage filtrates from the bleach plant;
- **Seal tank 25:** Bleach plant second stage caustic filtrate which includes the addition of other caustic stage filtrates from the bleach plant;
- **#1 Causticizer scrubber:** Flow from small scrubber located at #1 causticizer;
- **Slaker scrubber sewer**: Recausticizing slaker scrubber flow to south recaust sump;
- **North recausticizing sump**: north sump containing a collection of sewers from the lime mud vacuum seal water, lime mud spills, and lime mud slurry drain; and
- **Pulping Group hot water**: Pulping group hot water is used as pond water in the compaction baffle filters and excess is directed to sewer via overflow of the pulping group hot water tank (this overflow stream joins the mill general sewer in the vicinity of the bleach plant).

4.4.3 Wastewater Treatment System Survey

In conjunction with the initial survey, the combined mill sewer and the effluent treatment system were sampled to establish mass loadings from the mill to the treatment system (Figure 4.5). Samples were taken at various stations throughout the treatment system to understand the fate and effects of nutrients and to estimate the production of biomass-derived nutrients after the active first cell (Cell #1). During the 2009 survey, the colour removal clarifier (tertiary treatment) was not in operation.

Figure 4.5 The Wastewater Treatment System Layout and location of sample stations.



The sample station descriptions are as follows:

- **Settling pond inlet:** Combined mill effluent, as received from the mix well
- **Settling pond outlet:** Combined mill effluent at the end of the settling basin, inflow to the aeration basin
- **End of Pass #1:** Aeration basin, end of Pass #1 of Cell #1
- **Lift Station:** End of secondary treated effluent (also inflow to the colour removal clarifier, when required to operate to meet Kootenay River colour requirements).

An aerial photograph of the mill (background and looking west) and the mill effluent treatment systems (foreground) is presented in Figure 4.6.

Figure 4.6 Tembec Skookumchuck pulpmill in background and effluent treatment system in foreground.

4.4.4 Survey Methodology

Samples for all of the series of the survey were collected in Nalgene sample containers. A portion of the sample series was testing for ammonia-N and ortho-P in the mill laboratory, and at a contract laboratory (which lab?). Samples analyzed in the mill lab were tested on the same day as they were collected. Samples shipped to the contract lab were shipped on the same day as they were collected. Testing was performed within one or two days of receipt of the samples. No preservatives were used on samples sent to the contract lab but a cool pack was used to stabilize activity of the wastewater treatment samples.

The analytical method used by both the contract lab and the mill lab were identical. Methods for nutrient analysis were developed specifically for mill effluents. In each lab, samples were filtered to remove organic solids. A colorimetric method was then used to determine a nutrient concentration for each sample. The detection limit was 0.01 mg/l for both ammonia-N and ortho-P.

Duplicate testing was performed at the contract lab as part of the regular QA/QC performance of the lab. Duplicate testing was not performed in the mill lab.

The nutrient survey was interrupted in September 2009 for the annual mill shutdown. Samples were not taken during the shutdown, given non-typical operations were outside the scope of this study. The shutdown lasted from September 13 to September 22, inclusive.

4.4.5 Nutrient Survey Results

4.4.5.1 Mill Sources of Nutrients

Ortho-Phosphate

The highest contributor to mill-generated phosphate was the Seal Tank 15 overflow, accounting for 83.7% of the mill total. Phosphate originates from organically bound phosphorus in wood fibre. Phosphorus is retained in the fibre until it is released in the first acid-stage of bleaching. Ortho-P is one of the forms of phosphate release at this source.

Smaller percentages of ortho-P were found in Seal Tank 25 overflow effluent (14.5%). Carry-over of fibre-bound phosphorus in subsequent stages of bleaching is the likely source of ortho-P at this point.

Another potential source of phosphorus considered was lime make-up to the recausticizing system. However, this source was not found to be significant. Lime make-up to the Skookumchuck mill process is low (i.e., 15 kg/ADt of pulp) compared to other mills.

Ortho-P sources as a percentage of the total were:

- **Seal Tank 15**: 83.7%
- **Seal Tank 25:** 14.5%
- **Other:** 1.8%

Ammonia

Several significant sources of ammonia were discovered during the 2009 survey. The three largest sources of ammonia were the Seal Tank 15 overflow, slaker scrubber water, and pulping-group hot water tank overflow. These accounted for a total of 76% of ammonia generated from mill sources. Ammonia-N sources as a percentage of the total were:

- **Seal Tank 15:** 34.0%
- **Slaker scrubber:** 28.8%
- **Pulping-group hot water:** 23.3%
- **North Recaust sump:** 7.2%
- **Seal Tank 25:** 6.1%
- **Other** 0.5%

Seal Tank 15 filtrate overflow contributed 34% of mill-generated ammonia. Ammonia concentrations in this filtrate most likely resulted from dilution of stock entering the bleach plant by pulping-group hot water, at rates as high as 1,200 gallons (USGPM?) per minute. Seal Tank 15 contains all wash filtrate from the first stage of the bleach plant, and also will contain some overflow from other acid-stage filtrates.

The slaker scrubber solution represented 28.8% of total mill-generated ammonia to sewer. The slaker scrubber solution drains to the south recaust sewer sump. The scrubber solution is cold mill water. Ammonia in scrubber water would originate be generated through exothermic chemical reactions in the slaker vessel, and from ammonia in the green-liquor feed to the slaker.

Overflow from the pulping-group hot water tank contributed 23.3% of total mill-generated ammonia to sewer. This hot water is primarily clean condensates from the evaporator area of the mill. Mill condensates are a known source of ammonia and would originate from the black-liquor recovery process. Process black liquor is a source of nitrogen, and condensates from the associated processing of black liquor are expected to generate ammonia compounds. The production of these condensates exceeds the mill capacity for reuse. The pulping-group hot water tank overflows excess water to the pulping-group sewer. This joins the general mill sewer in the vicinity of the bleach plant. The overflow has been measured at 375 USGPM (1.42 m^3/min).

4.4.5.2 Wastewater Treatment Nutrient Concentrations

Ortho-Phosphate

Loads of ortho-P from the mill (inlet to the settling basin) averaged 49.7 kg/d during the 2009 survey. Ortho-P loads at the exit of the basin were slightly lower, at 47.5 kg/d. As with ammonia, anaerobic activity in a full settling basin may be responsible for the apparent consumption of ortho-P.

Ortho-P concentrations at the end of Pass #1 of Cell #1 of the aeration basin were lower than concentrations measured at the settling-basin outlet. The average load during the survey was 4.3 kg/d. In contrast to ammonia concentrations measured at this location, ortho-P concentrations appeared sufficient for biological activity.

Loads of ortho-P at the Lift Station averaged 6.3 kg/d, a slight rise from samples taken at the end of Pass #1.

Ammonia Nitrogen

Ammonia-N loads from the mill (inlet to the settling basin) averaged 48.3 kg/d during the 2009 survey. Interestingly, loads measured at the outlet from the settling basin were consistently lower than the basin inlet. Here, ammonia-N loads averaged 35.5 kg/d. It is possible that anaerobic activity in the basin was responsible for the apparent consumption of ammonia. During the survey, the settling basin was full of solids, which may have maximized the probability for anaerobic consumption.

Ammonia-N loads at the end of Pass #1 of Cell #1 of the aeration basin, were consistently low, averaging only 0.7 kg/d. Some samples indicated non-detectable concentrations of ammonia during the survey, suggesting that the treatment system is ammonia-limited at times.

Samples taken from the Lift Station represent the end of secondary treatment. Higher values for ammonia-N were consistently measured at this survey location. The average load was 88.2 kg/d, and ranged from 39.9 to 120.2 kg/d. Here, as expected, the high ammonia-N loads were the result of endogenous decay and benthal feedback to the effluent.

4.5 BENCHMARKING

4.5.1 Comparison to Best Management Practices Guide

General

The Best Management Practices Guide for Nutrient Management in Effluent Treatment document was released by the Forest Products Association of Canada (FPAC) in April 2008 (FPAC 2008). The document was written to provide a detailed overview and understanding of nutrient management for Canadian pulpmills discharging effluents to receiving environments.

The document was developed as a follow up to the recommendations made by the multi-stakeholder Smart Regulation Project group in its report entitled *Improving the Effectiveness and Efficiency of Pulp and Paper Environmental Effects Monitoring*.

Environment Canada supported the use of this Guide as a valuable resource for mills working towards addressing mill-related enrichment.

The Best Management Practices Guide states: "The challenge for mills addressing management is to maintain a sufficient degree of effluent treatment while at the same time minimizing nutrient residuals. If nutrient concentrations get too low, treatment efficiency drops resulting in higher effluent TSS and BOD. Interestingly, however, this can also temporarily result in higher nitrogen and phosphorus residuals because of the nitrogen and phosphorus contained in the biological solids being lost to the final effluent".

Ratio of BOD to N and P

The Best Management Practices Guide suggests a typical ratio of aeration basin inlet BOD-to-nitrogen-to-phosphorus (BOD:N:P) of 100:2.5-3.0:0.5-0.8. The range in nutrients is intended to account for different mill operations and differences in summer and winter operations.

The Tembec mill effluent has sufficient nutrient loading for efficient removal of BOD compounds during summer months. However, winter operation necessitates the addition of supplemental nutrients. Summer and winter BOD:N:P ratios at Skookumchuck relative to the Guide are as follows:

- **FPAC BMP Guide:** 100 : 2.5-3.0 : 0.5-0.8
- **Skookumchuck (summer):** 100 : 1.4 : 0.7
- **Skookumchuck (winter):** 100 : 1.5 : 1.1

In the summer months, the Skookumchuck aeration basin has the ability to operate without the addition of fertilizer. The ammonia requirement is less than what is suggested by the Guide. The phosphorus requirements fall within the range suggested by the Guide.

During winter operations, the addition of fertilizer to mill-generated nutrients increases ratios of ammonia and phosphorus. The BOD:N ratio rises slightly to 100 : 1.5, still within the range suggested by the Guide. However, the BOD:P rises to 1.1 which is above the recommended range.

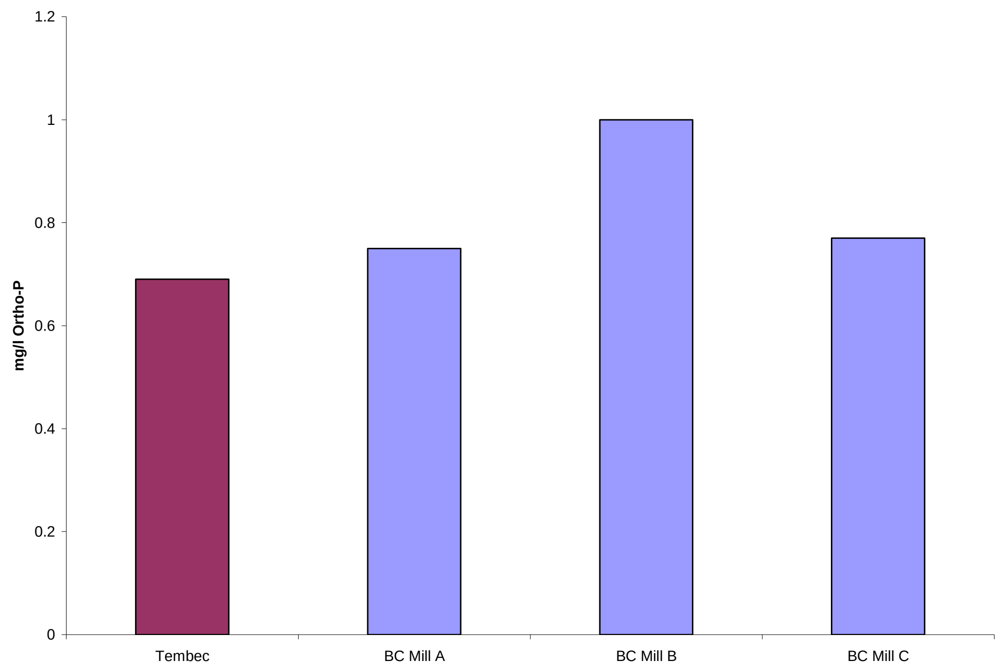
There is opportunity to assess the current fertilizer blend and adjust the percentage of phosphorus and ammonia with the intent to maintain good biological health and, at the same time, minimize the quantity of phosphorus addition.

4.5.2 Comparisons with Other Mills

An e-mail survey of BC pulpmills was conducted in early 2010. Contacted BC pulpmills were requested to provide information regarding nutrient residual concentrations in final effluent for 2009. Although only three mills responded to the survey, valuable information was obtained. Mill A is a BC coastal mill with an activated-sludge effluent treatment system. Mills B and C are BC interior mills with conventional aeration basins. Data from these mills were compared to the Tembec final effluent residual nutrient data (ortho-P and ammonia-N in particular).

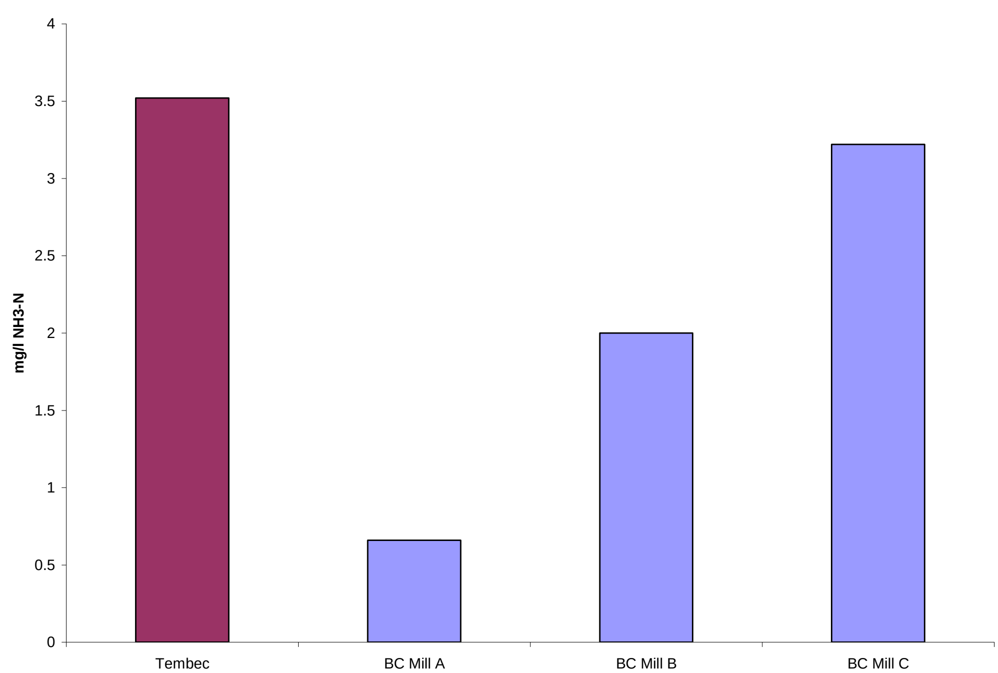
The average residual ortho-P concentrations in Tembec final effluent of 0.69 mg/L was lower than other BC mills. Mill A (the coastal mill) was next at 0.75 mg/L. The highest ortho-P residual was recorded by Mill B, at 1.0 mg/ L. Mills C was 0.77 mg/ L (Figure 4.7).

Figure 4.7 Ortho-phosphate concentrations in effluent (residual), results of informal BC mill survey.



Tembec ammonia-N residual concentrations were the highest in the survey, at 3.52 mg/L. Mill A was the lowest at 0.66 mg/L. Mills B and C were 2.0 mg/L and 3.22 mg/L, respectively (Figure 4.8).

Figure 4.8 Ammonia nitrogen concentrations in effluent (residual), results of informal BC mill survey.



4.6 STRATEGIES FOR NUTRIENT REDUCTION

4.6.1 Comparison to Strategies to Control N and P in the Guide

The BMP Guide reviews a number of control strategies that mills may employ to manage the addition of nutrients. The strategy that best fits the Tembec Skookumchuck mill is the Control-to-Residual-Targets Strategy. Under this strategy the Guide states:

Most effluent treatment systems measure nutrient residuals and control their nutrient feed based on the residuals versus residual control targets. This can be an acceptable control strategy assuming that the proper residuals are measure in the proper location at a proper frequency. (pg. 16)

This strategy is simple and is referred to as a reactive strategy. Operators will measure a sample of effluent taken from one or more designated sample points within the aeration basin. The residual ammonia-N and ortho-P will be calculated. If the residuals are higher than the target, the nutrient addition is lowered. If the residuals are lower than the target, the nutrient addition is raised.

Tembec Skookumchuck has historically used the end of Pass #1 of Cell #1 as a convenient point to measure residuals. It is a single sample point. The benefit of this strategy is the minimal change to nutrient addition required from week to week. Residual concentrations can be easily predicted if BOD loading and other conditions have not changed. However, where mill upsets or process conditions change, a reactive strategy will not adjust quickly to changing nutrient needs of the aeration basin.

Aeration basins have a buffering capacity. A nutrient increase or deficiency may take several weeks to develop. The aeration basin at Tembec Skookumchuck is considered a serpentine system. But, as with all these types of systems, there are small quiescent zones and historic sludge layers that provide significant cycling of nutrients from these areas.

The 2009 survey data indicates that the Skookumchuck aeration basin operates relatively well, with minimal nutrient addition. Non-toxic effluent is produced on a consistent basis.

However, this basin should be considered in two separate major sections with respect to nutrient dynamics:

- The requirement of nutrients for healthy biological activity and soluble BOD reduction in the active zone (Cell #1); and
- The production of nutrients from endogenous decay and benthal feedback in Cell #3.

Review of the Control-to-Residual-Targets Strategy and comparison with more advanced strategies requires further investigation.

Other control strategies mentioned in the Guide could necessitate an increase in technical resources and instrumentation. These strategies should be considered, given the complexity of the nutrient issues of this aeration basin.

4.6.2 Opportunities to Reduce Nutrient Load to the Kootenay River

Fertilizer Blend Changes

The current supplemental nutrient is a blended liquid fertilizer with a N-P-K ratio of 16-24-0. A review of recent practices shows that there is generally a deficiency of ammonia-N in the active zone of the aeration basin and, in contrast, there is a healthy residual of ortho-P at this site. A revised blend of this fertilizer could bring the nutrient requirements more into line with overall requirements. Also, a summer blend and a winter blend of fertilizer, tailored to the seasonal requirements, can be considered.

Nutrient Control Strategy Assessment

The current control strategy has limitations. There is only one sample point in the active zone as a reference for decision making. It is proposed that the use of only one historic sample point be reassessed. The end of Pass #1 in Cell #1 has been a convenient sample point and may still serve the purpose of relating test results to a historic data base. There would be benefits to establish the end of Pass #2 in Cell #1 as the sample point which represents the end of the active zone. There is no historic data to compare results with. However, over time, this second sampling location would better represent the end of the active zone of the aeration basin.

The production of nutrients, particularly ammonia, in Pass #3 requires particular close management. Lack of management can result in high concentrations of ammonia which are toxic to fish.

Tembec Skookumchuck has been successful in recycling treated effluent from the end of the Pass #3 to the start of the Pass #1. Generally, this recycling has been done only in summer months.

As mentioned, other control strategies mentioned in the Guide will have to carefully assessed, considering the complexity of the nutrient issues in this aeration pond. The employment of continuous residual measurement or other instrumentation may be beneficial.

4.6.3 Future Strategy Solutions for Nutrient Reduction

The 2009 nutrient survey provided a detailed assessment of the sources and effects of mill-generated nutrients released to the effluent treatment system. Also, a better understanding was gained of the fate of nutrients within the aeration basin.

Almost all ortho-P originates with fibre entering the mill, and is released to effluent through the bleaching process. Fibre-bound phosphorus, originating from wood chips, is released mainly from the Seal Tank 15 overflow effluent and smaller amounts are released with Seal Tank 25 effluent. Other potential sources of phosphorus, such as lime make-up, are negligible at the mill. There does not seem to be an opportunity to alter the production and release of ortho-P into the effluent system.

The survey demonstrated that ammonia-N is generated from two sources:

1. The black liquor steam condensate system which is used as hot water in the bleach plant process, and

2. The slaker scrubber solution.

Although there does not seem to be an opportunity to alter the generation and release of ammonia-N from either of these systems at the present time, there may be creative ways to redirect the slaker scrubber solution to another process point. This would, however, remove a portion of ammonia-N currently used in the aeration basin. Impacts of eliminating ammonia-N from this source on the treatment system will be considered with other nutrient management strategies.

Nutrients generated from the sources mentioned above provide the majority of nutrient requirements for the aeration basin during the summer months. If process changes were available to minimize or eliminate mill-generated nutrients, the reduction would most likely have to be made up with purchased liquid fertilizer to meet aeration basin needs.

4.6.4 Recommended Strategies

Future improvements aimed at the reduction of nutrients, particularly phosphorus, to the receiving stream will involve:

1. Improved use of fertilizer blends.

- A new fertilizer blend with lower phosphorus content should be tested. Careful monitoring of residuals at the end of the active zone (end of Pass #2) will assist in assessing the success of the change. The goal will be to increase the ammonia residual concentrations and decrease the ortho-P concentrations. Current plans are to purchase a fertilizer blend consisting of 24:10:0 (N:P:K) in the spring of 2010. After initial assessment, the addition rate or blend can be adjusted. A winter blend will be considered as well.

- A new sampling point at the end of the active zone should be established. A sample dock is required which will allow the technician to safely obtain a well-mixed sample. Current plans are to purchase a ready-made dock in spring 2010 and begin sample collection immediately.

2. An improved nutrient control strategy.

- The current nutrient control strategy is very basic in nature. One lesson learned from the 2009 survey is that sampling at the end of Pass #1 does not provide sufficient information alone about the active zone of the aeration basin. A sampling dock at the end of Pass #2 will allow for building an important effluent data base to augment data from Pass #1.

- The addition of instrumentation to this site, such as dissolved oxygen and residual-nutrient meters, will be explored.

3. Recycle of treated effluent from Cell #3 back to Cell #1.

- Recycle of treated effluent has been successful in controlling ammonia generated in the aeration basin. This will continue to be an important tool in the reuse of ammonia within the system and the potential benefit of ammonia reduction. To date, effluent recycle has been used solely for control of high ammonia-N residuals at the end of the treatment system. The beneficial re-use and reduction of ortho-P residual through this means will be explored. The use of recycle effluent beyond the summer months will be trialed and assessed.

5.0 CONCLUSIONS

5.1 SUBLETHAL EFFECTS OF EFFLUENT

Sublethal toxicity of process effluent was assessed six times in Cycle Five (i.e., two test periods per year). Generally, results were highly variable, particularly for fish early-life-stage and algal-growth end points. Effluent affected the survival of rainbow trout embryos at a mean concentration of 54% (EC25). Invertebrate survival was not affected by effluent, but reproduction was, at a mean effluent concentration of 13.7% (IC25). Algal growth was affected at a mean concentration of 18.8% (IC25). Several tests exhibited some degree of enrichment on reproductive success or growth. Generally, sublethal toxicity of effluent was higher in Cycle Five than in Cycle Four, but similar to earlier cycles.

Environment Canada's predictive dilution model suggests maximum potential zones of sublethal effect from the effluent discharge point of 93 m for fish survival, 359 m for invertebrate reproduction, <50 m for invertebrate survival, and 266 m for algal growth.

5.2 INVESTIGATION OF SOLUTIONS

Future improvements aimed at the reduction of nutrients, particularly phosphorus, to the receiving stream will involve:

1. Improved use of fertilizer blends.

    - A new fertilizer blend with lower phosphorus content should be tested. Careful monitoring of residuals at the end of the active zone (end of Pass #2) will assist in assessing the success of the change. The goal will be to increase the ammonia residual concentrations and decrease the ortho-P concentrations. Current plans are to purchase a fertilizer blend consisting of 24-10-0 (N-P-K) in the spring of 2010. After initial assessment, the addition rate or blend can be adjusted. A winter blend will be considered as well.

    - A new sampling point at the end of the active zone should be established. A sample dock is required which will allow the technician to safely obtain a well-mixed sample. Current plans are to purchase a ready-made dock in spring 2010 and begin sample collection immediately.

2. An improved nutrient control strategy.

    - The current nutrient control strategy is very basic in nature. One lesson learned from the 2009 survey is that sampling at the end of Pass #1 does not provide sufficient information alone about the active zone of the aeration basin. A sampling dock at the end of Pass #2 will allow for building an important effluent data base to augment data from Pass #1.

- The addition of instrumentation to this site, such as dissolved oxygen and residual-nutrient meters, will be explored.

3. Recycle of treated effluent from Cell #3 back to Cell #1.

- Recycle of treated effluent has been successful in controlling ammonia generated in the aeration basin. This will continue to be an important tool in the reuse of ammonia within the system and the potential benefit of ammonia reduction. To date, effluent recycle has been used solely for control of high ammonia-N residuals at the end of the treatment system. The beneficial re-use and reduction of ortho-P residual through this means will be explored. The use of recycle effluent beyond the summer months will be trialed and assessed.

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7.0 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.
ASB	Airated Stabilization Pond; common secondary treatment system used to treat effluents from pulpmills. The primary purpose of ASBs is to lower the BOD and TSS (biomass of effluents) and consequently reduce toxicity of effleuents.
Benthal	Refers to the sediments at the bottom of the effluent treatment system. Consists primarily of wood residues and bacterial biomass.
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.
BMP	Best Management Practices. Defined recommended industry operating procedures, generally focused on ways to reduce environmental impacts.
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).
BOD:N:P	Ratio of biological oxygen demand (BOD) of untreated pulpmill effluent to nutrients (nitrogen and phosphorus) added to treat the BOD.
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.

Color | True color of water is the color of a filtered water sample (and thus with turbidity removed), and results from materials which are dissolved in the water. These materials include natural mineral components such as iron and calcium carbonate, as well as dissolved organic matter such as humic acids, tannin, and lignin. Organic and inorganic compounds from industrial or agricultural uses may also add color to water. As with turbidity, color hinders the transmission of light through water, and thus "regulates" biological processes within the body of water.

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).

Dioxins/Furans | Polychlorinated dibenzo-para-dioxins (PCDDs) and dibenzofurans (PCDFs) are often simply called dioxins, although they are two separate groups of substances with similar effects. There are 210 different compounds, of which 17 are the most toxic.

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 which is higher than this saturation point, whereas respiration may cause it to exist at a level which 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.
EC*p*	A point estimate of the concentration of test material that causes a specified percentage effective toxicity (sublethal or lethal). In most instances, the EC*p* 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.
FPAC	Forestry Products Association of Canada
Gonad	A male or female organ producing reproductive cells or gametes (i.e., female ovum, male sperm). The male gonad is the testis, the female gonad is the ovary.
GSI	Gonadosomatic Index. Calculated by expressing gonad weight as a percentage of whole body weight.
Hardness	Total hardness is defined as the sum of the calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per litre.
IOS	Investigation Of Solution.
IC*p*	A point estimate of the concentration of test material that causes a specified percentage inhibition in a quantitative biological test which measures a change in rate, such as reproduction, growth, or respiration.

LC_{50}	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 LC_{50}).
LSI	Liver Somatic Index. Calculated by expressing liver weight as a percent of whole body weight.
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 (H_30^+) 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.
Redox Potential (Eh)	In marine sediments, the measurement of reduction and oxidation by testing electron movement and, consequently, available oxygen.
Reference Toxicant	A chemical of quantified toxicity to test organisms, used to gauge the fitness, health, and sensitivity of a batch of test organisms.
Resin Acids	Any of a class of vegetable substances, composed chiefly of esters and ethers of organic acids, that occur as a sticky yellow or brown substance exuded on the bark of various plants and trees, such as the pine and fir.
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.
T_4CDD	2,3,7,8-tetrachlorodibenzo-para-dioxin, the most toxic dioxin.
TEQ	Toxic Equivalents.
TN	Total nitrogen.
TOC	Total organic carbon (TOC).

Total-TEQs	TEQs are calculated by multiplying the concentration of each congener with its respective International Toxicity Equivalency Factor (ITEF), to normalize concentrations to the level that would be produced by an equivalent amount of 2,3,7,8-T_4CDD, then summing all the concentrations.
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.
usgpm	United States Gallon per Minute is a flow rate measurement used in pulp and paper mills. Roughly equivalent to 3.8 L/min.
v/v	volume/volume - used to define dilution ratios for two liquids.

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: ________________________ 23 March 2010

John Wilcockson — Date
Project Manager

Approved by: ________________________ 23 March 2010

Martin Davies — Date
Project Director

APPENDICES

Appendix A1

Summary of Sublethal Toxicity Test Results

Appendix A2

Data Collected for the IOS