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SKEENA CELLULOSE INC.
ENVIRONMENTAL EFFECTS MONITORING (EEM)
CYCLE THREE DESIGN DOCUMENT

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1.0 INTRODUCTION

The Environmental Effects Monitoring (EEM) program was developed to assess the adequacy of effluent regulations under the federal *Fisheries Act*. Specifically, the *Pulp and Paper Effluent Regulations* (PPER) prescribe limits for discharge of biochemical oxygen demand (BOD) and total suspended solids (TSS) in effluent and acute lethality of effluent to rainbow trout. The EEM program was designed to assess fish, fish habitat, use of fish resources, and sublethal toxicity of process effluents. This program has been designed to achieve national uniformity in monitoring of effects, while taking into consideration site-specific factors.

The EEM program for Skeena Cellulose Inc. (Skeena) was implemented in 1993 with requirements for the first cycle to document mill and receiving environment conditions in a pre-design report (Hatfield Consultants Ltd. 1994), followed by a design report for Cycle One (Hatfield Consultants Ltd. 1995). Field monitoring and sample collection at Skeena Cellulose Inc. was conducted during spring 1995; the interpretive report was submitted by April 1, 1996 (Hatfield Consultants Ltd. 1997).

Following a general review of Cycle One by Environment Canada, 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 1997a). The *Pulp and Paper Technical Guidance for Aquatic Environmental Effects Monitoring EEM/1998/1* (Environment Canada 1998) further describes the program for Cycle Two. The proposed design for Cycle Two was submitted in January 1998 (Hatfield Consultants Ltd. 1999), field monitoring was conducted in summer 1998, and results were reported on April 1, 2000 (Hatfield Consultants Ltd. 2000).

Cycle Three EEM studies must comply with current regulatory requirements as prescribed in the current regulations and associated Aquatic Environmental Effects Monitoring Requirements (i.e., *Annex 1* and *Technical Guidance*, Environment Canada 1997, 1998). An amendment to Section 32 of the *Pulp and Paper Effluent Regulations* on April 1, 1999 requires that interpretive reports for Cycle Three must be submitted no later than April 1, 2004.

The design of Cycle Three is provided in this document. The purpose of this design document is to summarize and update mill process information and results from previous cycles and other studies, and to provide a rationale for the design of the Cycle Three program. Five elements of the EEM program will be discussed: fish survey, effects on the use of fisheries resources (dioxins/furans and tainting), invertebrate community survey, chemical tracers, and sublethal toxicological testing of process effluent. In addition, this design document includes a tentative schedule for execution of field surveys and report submission, QA/QC program, Standard Operating Procedures (SOPs), and qualifications of HCL staff. The Cycle Three interpretive report is due by April 1, 2004.

2.0 PRE-DESIGN UPDATE AND SUMMARY OF PREVIOUS CYCLES

The following topics have been presented previously in the Skeena Environmental Effects Monitoring (EEM) pre-design reference document (Hatfield Consultants Ltd. 1994) as per *Annex I* of the *Pulp and Paper Aquatic Environmental Effects Monitoring Requirements* (Environment Canada 1997a). The requirement was to present historical and pre-design information once, at the beginning of Cycle One, provided that mill operations, effluent loading, discharge location or receiving environment conditions do not change. For subsequent cycles, pre-design information should be summarized and updated as part of EEM design submissions.

In addition, results of monitoring programs for Cycles One and Two (Hatfield Consultants Ltd. 1997, 2000) and any additional monitoring studies conducted at Skeena are to be summarized in the new design document. This section of the Cycle Three design document provides summary information and conclusions as they apply to the receiving environment and the proposed Cycle Three design for Skeena.

2.1 DELINEATION OF ZONE OF EFFLUENT MIXING

No changes have occurred in the discharge of process effluent either in volume or location of the outfall since publication of the pre-design document for Cycle One (Hatfield Consultants Ltd. 1994). Near-field dispersion of effluent is dominated by strong tidal mixing of the water column in Porpoise Harbour immediately or soon after discharge. Effluent is diluted to less than 1% of release concentrations within approximately 250 m of the diffuser to the south on an ebb tide. An equally rapid mixing of effluent is expected to occur during flood tides, when effluent is carried to the north towards Zanardi Rapids by similarly strong and turbulent tidal flows. During slack tides, effluent dilution in the water column is restricted to the zone near the diffuser. Therefore, the near-field effluent concentration zone of 1% effluent was defined as a circle of 500 m radius from the diffuser in the Cycle One pre-design document.

2.2 HABITAT INVENTORY AND CLASSIFICATION

The pre-design report discussed the physical and biological characteristics of shore zones surrounding the pulp and paper mill and bathymetry in Porpoise Harbour and Wainwright Basin. Descriptions of sampling stations, including Cycle One reference stations in Kitkatla Inlet, were updated in the Cycle One interpretive report (Hatfield Consultants Ltd. 1997). Fish collection areas were described in relation to catch and effort data for Cycle One. Shoreline habitat classification was presented for the inlet and updated at mussel stations during Cycle Two; benthic stations were characterized by sediment quality during each cycle (Hatfield Consultants Ltd. 1997, 2000).

Habitat classification for Cycle Three will be continued as previously reported for shoreline and benthic stations. Data collected from each station will be fully described in the Cycle Three interpretive report.

2.3 RESOURCE INVENTORY

The Cycle One pre-design document described regional and local species that contribute to commercial, native, and sport fisheries in the vicinity of Skeena. The marine, estuarine and fresh waters near the pulpmill are important habitats for many fish and invertebrate resource species. Groundfish, salmon, herring, shrimp, prawn, crab, octopus, sea urchin, sea cucumber, geoduck and intertidal clams are found throughout the area, and several are common in many locations.

Based on that literature search, English sole (*Parophrys vetulus*) and Dungeness crab (*Cancer magister*) were selected as candidate sentinel species for Cycle One. Kitkatla Inlet was selected as the reference area. During Cycle One, insufficient English sole were captured from both the near-field and reference areas (Hatfield Consultants Ltd. 1997); as a result, rock sole (*Lepidopsetta bilineata*) were used as the sentinel finfish species given the larger numbers captured (29 near-field, 37 reference). Most rock sole captured in near-field and reference areas were small and considered sub-adult.

Dungeness crab were collected in sufficient numbers; however, the ratio of male to female crab was different in samples collected from the two locations with few females collected from the near-field location (Hatfield Consultants Ltd. 1997). Some differences in external and internal condition of crab were observed between near-field and reference areas, although it is not known how pulpmill effluent impacts crab condition.

The Cycle Two guidance document suggested that collections of finfish in the marine environment were not recommended, given the movement of fish in the marine environment is not restricted and exposure to pulpmill effluent is uncertain. Therefore, Cycle Two selected only wild blue mussels (*Mytilus edulis*) for the fish survey. Mussels were collected in sufficient number from the Skeena area to complete analyses for condition and chemical tracers (resin acids for pulpmill effluent) (Hatfield Consultants Ltd. 2000).

2.4 HISTORICAL RECEIVING ENVIRONMENT DATA

The Cycle One pre-design report summarized receiving environment data for water and sediment, intertidal and subtidal communities, and biological tissues (Hatfield Consultants Ltd. 1994). A brief summary of these historical data, including results from Cycles One and Two, is presented below (Hatfield Consultants Ltd. 1997, 2000).

2.4.1 Receiving Water Quality

Water quality gradually improved in Porpoise Harbour and Wainwright Basin following the installation of the deep-sea diffuser in 1978. Some slight increases in temperature have been

observed near the diffuser, which may be due to effluent (at depths of 3 to 10 m) or to Skeena River flows introducing warmer surface waters into the region (Hatfield Consultants Ltd. 1994). Dissolved oxygen and salinity appear to be influenced more by Skeena River flows in the summer than by mill effluent. Colour, tannins/lignins, resin acids and organochlorine compounds (i.e., adsorbable organic halide [AOX]) have indicated historically the presence of pulpmill effluent in Porpoise Harbour and Wainwright Basin.

During Cycle One, chloroform (used as an effluent tracer in the water column) was not detected at any Skeena station (Hatfield Consultants Ltd. 1997). The following variables were also not detected: total phenol, tannins/lignins, resin/fatty acids and chlorinated phenolics. Colour and total suspended solids were detected in low concentrations (6 to 9 CU and 1 to 23 mg/L, respectively) in water samples from Porpoise Harbour and Wainwright Basin.

Water quality variables (i.e., dissolved oxygen, temperature, salinity) for Cycle Two did not indicate the presence of pulpmill effluent at any station where mussels or benthic invertebrates were collected.

2.4.2 Sediment Quality

Sediments collected in the vicinity of Skeena consisted predominantly of sand or silt/clay. Historically, fibre mats were observed in Wainwright Basin and northern Porpoise Harbour, resulting in higher organic carbon levels in sediments from these stations. Resin acid levels appeared to reflect mill effluent effects, with highest values occurring near the diffuser in Porpoise Harbour and near the old discharge location in Wainwright Basin.

In 1977, a PCB spill in Porpoise Harbour resulted in very high concentrations in sediments (to 75,000 mg PCB/kg) at the spill site. In follow-up studies conducted in 1982 and 1987, PCBs were either not detected, or were found in very low concentrations in sediments used to cap the spill. However, a survey of the site in 1995 observed the presence of sinkholes along the edge of the cap. Conclusions of an intensive survey conducted in 1996 (Hatfield Consultants Ltd. 1996) include:

- PCBs were detected in 156 of 161 samples collected (154 sediment, seven mussel tissue).
- The eight highest concentrations (>10 mg PCB/kg dry weight of sediment) were located within a 3 m radius of the sinkhole edge. This result suggested that elevated levels of PCBs remain trapped under the hog fuel cap within the sinkhole area.
- There is evidence indicating the hog fuel cap is eroding.
- Mussel tissue concentrations were below the human consumption criteria for edible fish/shellfish (2.0 µg PCB/g wet weight); however, the mussels collected near the spill site exceeded wildlife consumption criteria of whole fish (0.1 µg PCB/g wet weight).

Sediment variables measured during Cycle One included particle size, moisture, loss on ignition, total organic carbon, resin/fatty acids, and chlorinated phenolics. Particle size varied between

stations, primarily due to differences in tidal action between the various basins (Hatfield Consultants Ltd. 1997). Sediments collected from Porpoise Harbour and SW Wainwright Basin generally exhibited higher levels of total organic carbon, resin/fatty acids and chlorinated phenolics relative to other far-field and reference stations. The far-field station at South Morse Basin exhibited chlorinated phenolic levels more indicative of near-field impacts. In contrast, the NE Wainwright Basin station exhibited levels similar to other far-field stations, which partially may be a function of particle size (i.e., large sand component). Results of dioxin and furan monitoring near Skeena indicate that organochlorine levels in sediment are higher at Morse Basin South relative to Porpoise Harbour. Elevated organochlorine concentrations in Wainwright and Morse basins may be associated with differences in sedimentation rate, particle size distribution, organic content, or historical effluent discharges to Wainwright Basin (Dwernychuk *et al.* 1997).

Dioxin and furan monitoring of sediment in the vicinity of Skeena in recent years indicated relatively stable levels (Dwernychuk *et al.* 1997); however, levels remain higher at South Morse Basin relative to Porpoise Harbour. For example, averages of 2,3,7,8-TCDD toxic equivalents (TEQs) from 1995 to 1997 were 49.7 pg/g in South Morse Basin sediments and 20.2 pg/g in Porpoise Harbour. 1998 TEQ levels were 16.2 pg/g in Morse Basin and 13.8 pg/g in Porpoise Harbour (Dwernychuk *et al.* 1998). In 1999, the Morse Basin station was discontinued; a new station in northwest Wainwright Basin exhibited a TEQ level of 46.0 pg/g, while near the diffuser the TEQ was 15.0 pg/g (Dwernychuk *et al.* 1999).

2.4.3 Intertidal and Subtidal Communities

The intertidal community has been characterized by annual surveys of the macroalgae community and the occasional invertebrate study from the mid-1970s to 1990 (Hatfield Consultants Ltd. 1994). The algal community has improved over time near the old discharge in Wainwright Basin; no impact of mill effluent released from the Porpoise Harbour diffuser has been noted. Macroalgae have been the most stressed at a station opposite the diffuser, probably due to sedimentation caused by log boom activities.

Subtidal benthic macroinvertebrates have generally increased in density and number of taxa since 1979 in the vicinity of Skeena. Densities of *Capitella capitata*, indicative of organic pollution, were greatest near the diffuser in 1981; numbers have since dropped. Nematodes have, at times, dominated subtidal communities, but their presence may be influenced by habitat (particle size) rather than stress induced by mill effluents.

The Cycle One subtidal benthic invertebrate survey was conducted in the vicinity of Skeena and in Kitkatla Inlet (reference) during April and May 1995. Four subsamples from each station were collected using a Smith-McIntyre grab from the commercial fishing boat or a Ponar grab from a smaller boat within the basins. All samples were sieved at 180 μm.

Cycle One data indicated some differences between stations and areas which may be due to pulpmill effluent, although a number of habitat conditions (e.g., sediment particle size, tidal currents) also differed among stations (Hatfield Consultants Ltd. 1997). The benthic

communities in Wainwright Basin and South Morse Basin exhibited moderate density and number of taxa (area mean 27,720 organisms/m^2, 49 taxa), and were co-dominated by nematodes and harpacticoids. Densities of invertebrates were greater at Porpoise Harbour and Channel, North Morse Basin and Kitson Island stations (density ranged from 112,452 to 384,008 organisms/m^2); nematodes dominated the communities, followed by harpacticoids and polychaetes. No significant density of organic pollution-tolerant taxa was observed at any station. Taxonomic richness was slightly higher at Porpoise Harbour stations (54 to 60 taxa) relative to other exposed stations (44 to 62 taxa). Benthic communities at reference stations in Kitkatla Inlet exhibited the highest density and number of taxa (mean 524,019 organisms/m^2, 69 taxa). These communities also were dominated by nematodes and harpacticoids. Intertidal benthic samples were also collected in Lagoon No. 2; density was low and variable (3,766 to 12,700 organisms/m^2), and taxonomic richness was very low (8 taxa).

Discriminant analysis and multivariate statistics provided in Cycle One for Skeena and other marine reference stations indicated that differences existed between exposed and reference stations; these differences were probably due to the inclusion of Lagoon No. 2 intertidal invertebrate data with subtidal data in the near-field area. Differences in density between the exposed areas and the reference area (Kitkatla Inlet) were primarily due to high nematode densities in the reference area.

Cycle Two benthic invertebrate samples were collected during August 1998 using a 23-cm Ponar grab. Samples were sieved at 1 mm and enumerated in their entirety. Densities ranged from 3,791 to 10,979 organisms/m^2 except at SCB4 (SW Wainwright Basin, 359 organisms/m^2) and SCB12 (Kitson Island, 21,065 organisms/m^2) (see Table 3, Section 3.3.2). Numbers of taxa were greater for Cycle Two (74 to 164 taxa) relative to Cycle One, except in Wainwright Basin (26 to 57 taxa). Biomass at near-field stations (76 to 108 g/m^2) was relatively high compared with most of the gradient stations (21 to 167 g/m^2, except SCB4). Regression analyses did not indicate significant differences among stations using benthic statistics versus distance from the diffuser, or any sediment variable as a measure of effluent exposure. ANOVA tests comparing stations in a near-field area versus far-field and reference areas were not significant. No impacts to benthic invertebrate communities were observed or could be directly related to current discharges of pulpmill effluent.

2.4.4 Fish Health Studies

Rock sole captured for Cycle One in near-field and reference areas were small and considered sub-adult. Among large rock sole retained for laboratory examination, fish from the near-field area were generally smaller and younger than rock sole from the reference area. Measures of fish condition (e.g., gonadosomatic index) were similar between areas. No pulpmill impact is indicated from this survey, although it is noted that insufficient numbers of fish were used in these calculations.

Blue mussels (*Mytilus edulis*) collected in the vicinity of Skeena during Cycle Two exhibited no observable evidence of disease, parasites, or predation impacts (Hatfield Consultants Ltd. 2000). Condition index was highest at Porpoise Channel and lowest at Coast Island; near-field stations

(i.e., Diffuser and North Porpoise Harbour) exhibited slightly higher condition indices relative to Wainwright Basin, Coast Island and Kitson Island (Table 1). Shell density was highest for mussels collected from Porpoise Channel and Kitson Island. Given a large variation in indices at distant stations, mussel condition and shell density were not significant ($p=0.542$ and $p=0.202$, respectively) along a gradient of distance from the pulpmill diffuser. No evidence of pulpmill effluent impact was observed.

Table 1 Mean variables of wild blue mussels (*Mytilus edulis*) (n=30), Skeena EEM Cycle Two, August 1998.

Variable	Diffuser	N. Porpoise Harbour	Porpoise Channel	Wainwright Basin	Coast Island	Kitson Island
Distance from diffuser	0.5 km	1.7 km	2.7 km	3.8 km	5.2 km	5.9 km
Length (mm)	23	25	27	23	22	27
Whole wet weight (g)	1.19	1.58	2.16	1.38	1.24	2.29
Condition index (g/cm^3)	44.9	48.5	75.9	41.7	37.6	42.8
Shell density (g/cm^3)	1.01	1.16	1.30	1.06	1.19	1.34
Percent lipid (%)	1.89	2.13	2.78	1.83	1.67	2.10
Resin acids (µg/g)	0.10	0.11	0.07	0.09	0.44	0.06

A tracer compound for fish and crab tissues was not used specifically for Cycle One. Resin acids were analyzed in mussel tissues for Cycle Two; levels did not relate to distance from the diffuser ($p=0.486$) and were not useful in identifying exposure to pulpmill effluent.

2.4.5 Biological Tissue Studies

Mussel, crab and fish tissues were contaminated as a result of the PCB spill into Porpoise Harbour in January 1977 (Section 2.4.2) (Hatfield Consultants Ltd. 1994). Following containment of the spill in 1978, levels declined rapidly (i.e., crab tissues contained a maximum of 2,700 ppb in 1977, 340 ppb in 1978, and 50 ppb in 1980). Other biota also exhibited high levels of PCBs in 1997, including isopods and algae.

PCB concentrations in Porpoise Harbour crab tissues were monitored during the 1998 dioxin/furan program. Total-PCB concentrations (240 and 260 ng/g in hepatopancreas) and Total Aroclor concentrations (250 and 296 ng/g) were well below the BCMELP guideline of 2,000 ng/g for human consumption of edible tissues of fish and shellfish.

Biological tissues have been analyzed for organochlorine compounds (e.g., dioxins and furans) since 1989, which resulted in the closure of the crab and shrimp fisheries in November 1989 in the vicinity of Skeena and Prince Rupert. The shrimp fishery reopened in February 1995 following low concentrations of dioxin levels in tissues. The entire crab fishery remains closed in Porpoise Harbour and Wainwright Basin; however, in 1995 and 1997 various areas beyond

Porpoise Harbour and Wainwright Basin were reopened without health consumption advisories (Government of Canada 1997).

In 1996 and 1997, 2,3,7,8-T_4CDD toxic equivalence (TEQ) levels in crab hepatopancreas ranged from 69.0 to 188.5 pg/g in Wainwright Basin, 21.1 to 34.2 pg/g in Porpoise Harbour, 11.0 to 36.7 pg/g in South Morse Basin, and 5.1 to 6.6 pg/g in Kloiya Bay (Morse Basin) (Dwernychuk *et al.* 1997). The 1998 dioxin/furan monitoring program indicated similar TEQ levels in crab tissues (Dwernychuk *et al.* 1998). TEQs in crab hepatopancreas were highest in NW Wainwright Basin (56.9 to 68.9 pg/g) relative to Porpoise Harbour (18.5 to 24.7 pg/g) and Morse Basin (3.6 pg/g). For the 1999 monitoring program, crab hepatopancreas tissues exhibited TEQs of 44.8 pg/g from NW Wainwright Basin and 33.9 and 69.1 pg/g from Porpoise Harbour (Dwernychuk *et al.* 1999). All 1999 composite samples exceeded the Health Canada consumption guideline of 30 pg/g for hepatopancreas tissues; TEQs in Porpoise Harbour were higher than anticipated based on historical trends.

Crab muscle tissues have exhibited TEQ levels less than the consumption guideline of 15 pg/g at all stations since 1990.

Rock sole, starry flounder and flathead sole livers from fish collected in Porpoise Harbour analyzed in 1995 to 1997 exhibited TEQs in liver tissues ranging from 1.8 to 23.1 pg/g. The 1998 TEQ in grey cod was 1.1 pg/g; the 1999 TEQ in Pacific halibut liver tissues was 15.0 pg/g. Since 1990, dioxin and furan concentrations in bottom fish livers have indicated relatively low levels of dioxins and furans that appear to differ based on fish species. All TEQs since 1995 have been below the Health Canada consumption guideline of 30 pg/g for liver tissue.

2.5 MILL OPERATIONS

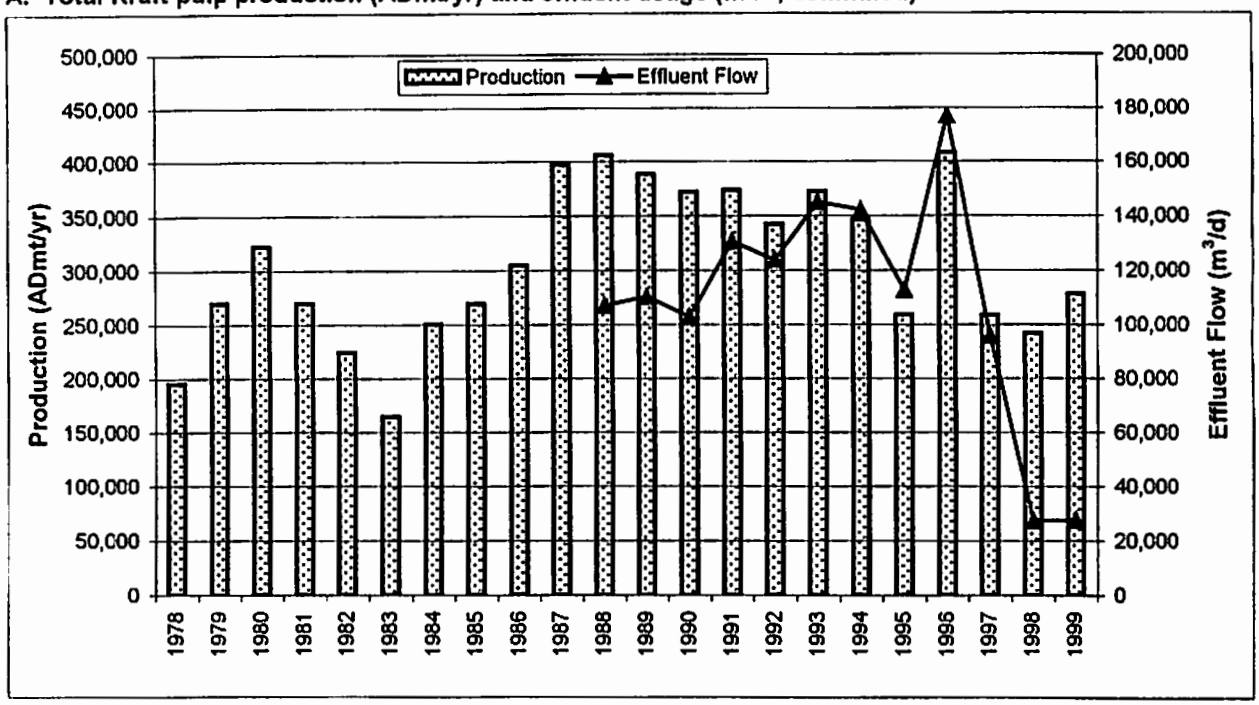
2.5.1 Update

Skeena Cellulose Inc. commenced operation in 1951 using the sulphite process to produce cellulose acetate grade wood pulp. The mill continued the sulphite operation until 1976. Prior to this, in 1966, a Kraft mill (A-mill) commenced operation with a pulp production rate of 750 ADmt/d. A second Kraft mill (B-mill) commenced operation in 1978 with a pulp production capacity of 500 ADmt/d. These two sub-mills constitute the present pulping operations of Skeena Cellulose Inc. Current total pulp production capacity is approximately 1,200 ADmt/d. Total annual Kraft production is approximately 350,000 ADmt/year when the mill is operating fully (Figure 1A). Annual process effluent volume since 1988 is presented on Figure 1A; volume in 1999 was approximately 36 million m^3/y.

Wood furnish has not changed significantly at the mill since Cycle One (Hatfield Consultants Ltd. 1994). The relative proportions of wood chips used are hemlock (52%), balsam (22%), spruce (15%), pine (8%) and cedar (3%).

Figure 1 **Historical summary of Skeena Cellulose Inc. Kraft pulp production and effluent quality variables (annual averages), 1973 to 1999.**

A. Total Kraft pulp production (ADmt/yr) and effluent usage (m^3/d, estimated)



Note: Reduced production in 1995 due to strike; in 1997 due to shutdown.

B. Total suspended solids (TSS, kg/d)

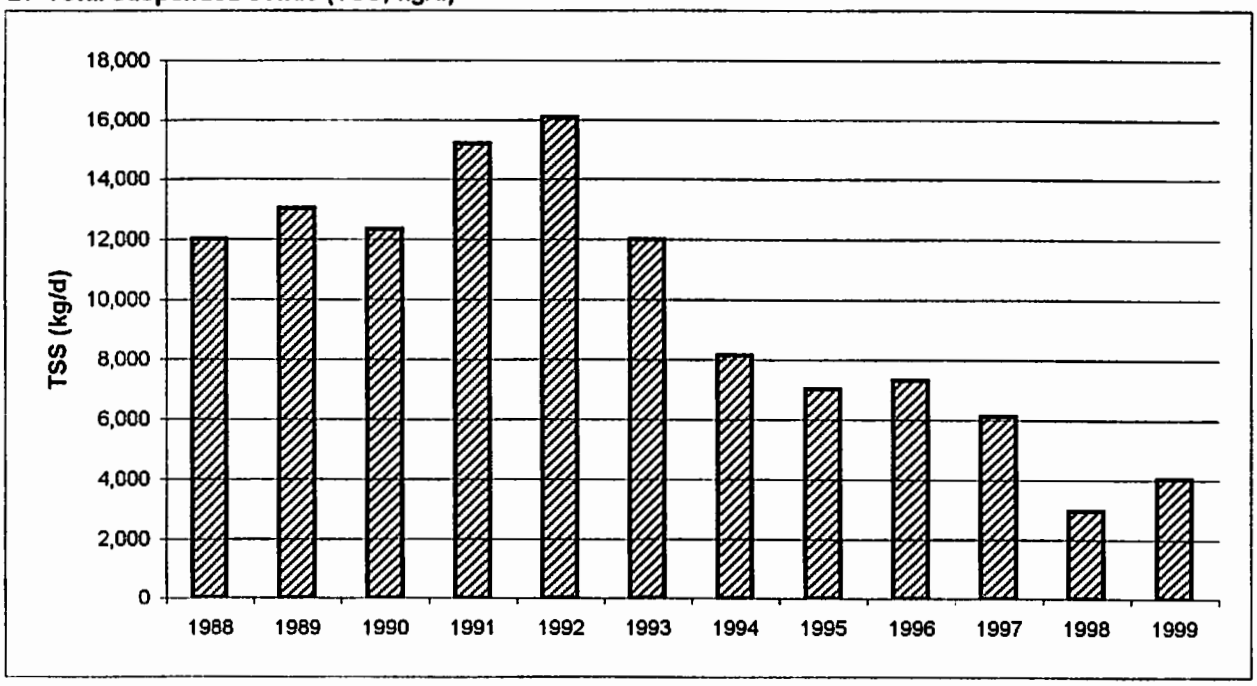
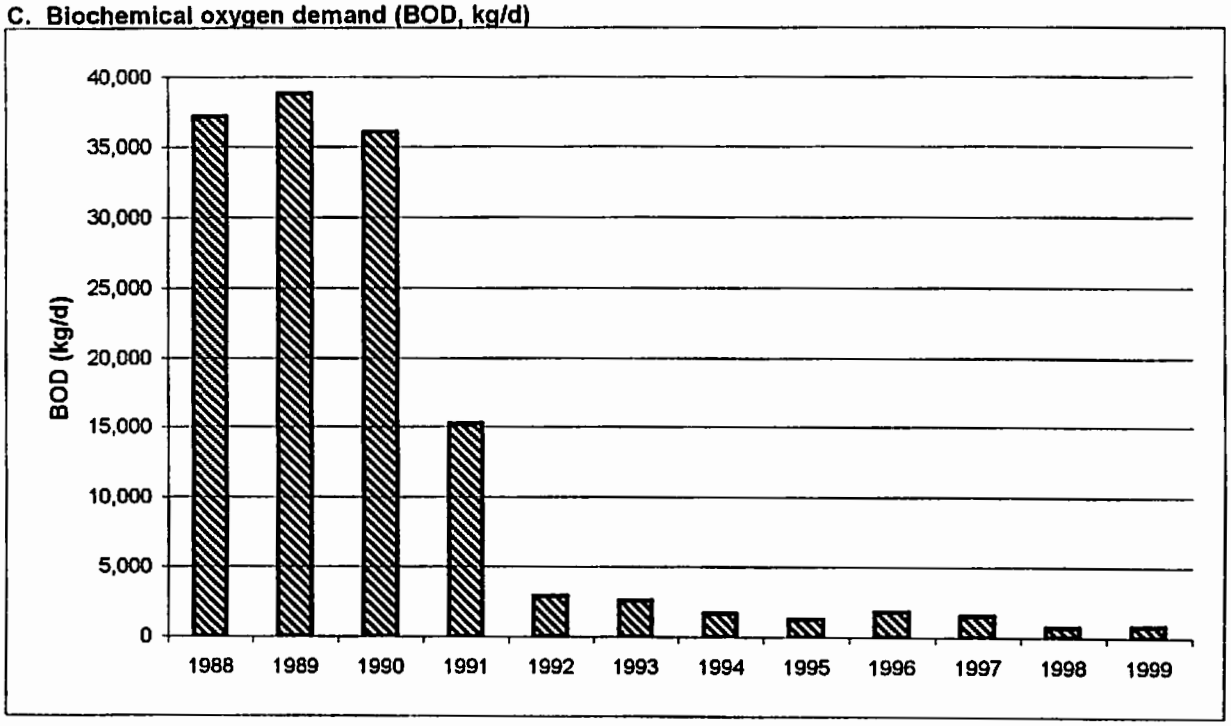
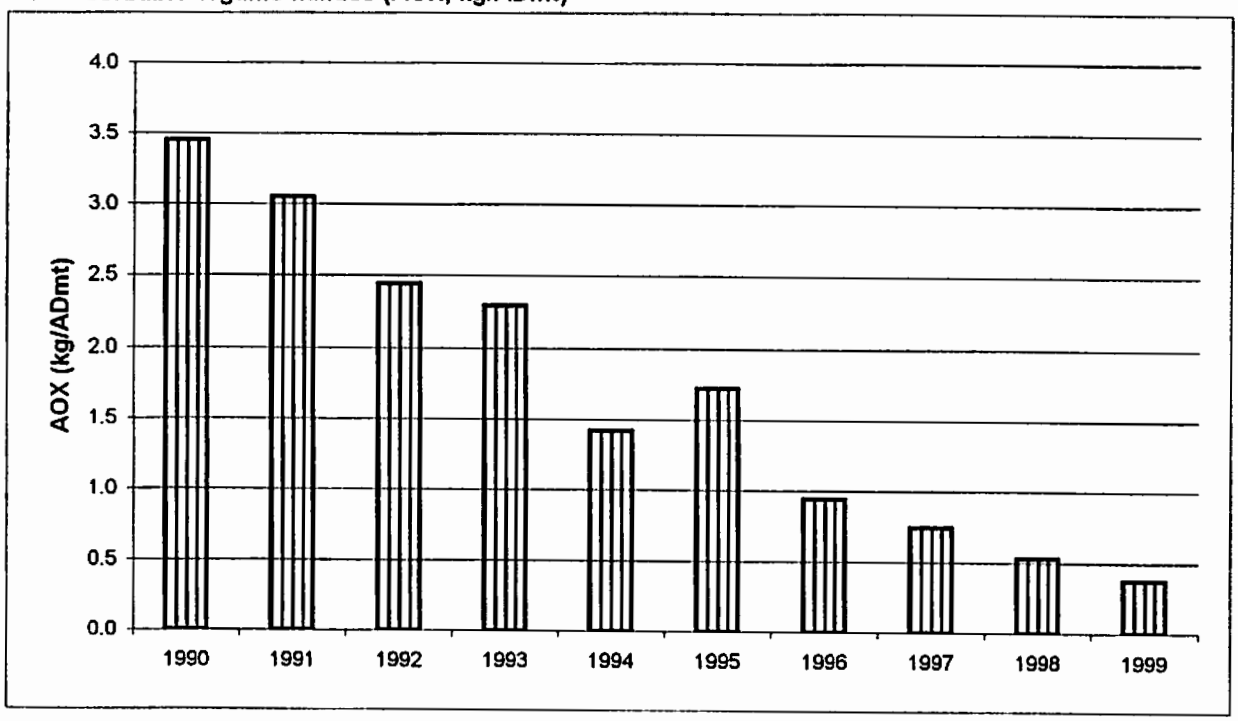


Figure 1 (cont'd)

C. Biochemical oxygen demand (BOD, kg/d)



D. Adsorbable organic halides (AOX, kg/ADmt)



In 1990, the company built primary and secondary treatment plants that greatly improved effluent quality. The UNOX effluent treatment system, fully operational since April 1991, has a retention time of 14 hours. In particular, total suspended solids (TSS) and biochemical oxygen demand (BOD) have decreased substantially since the implementation of secondary effluent treatment (Figures 1B and 1C).

Some recent operational changes in the bleaching process have occurred at Skeena. In particular, A-mill ran at ≥60% chlorine dioxide substitution from 1994 until August 2000. A new chlorine dioxide generator was installed during summer 2000. Currently, both mills run at 100% substitution (since 1996 for B-mill), with a bleaching sequence of DE_oDED. This reduction in the use of chlorine in bleaching appears to have resulted in substantially reduced levels of adsorbable organic halogens (AOX) (Figure 1D) and dioxin and furan levels, with the exception of measurements of 2,3,7,8-TCDD in 1996 (Table 1, Section 2.5.2).

Effluent is discharged to Porpoise Harbour through 18 ports along the final 75 m of the diffuser, into water approximately 20 m deep. Non-process water is discharged to Lagoon No. 1 (cooling water, filter backwash and raw water weir overflow) and Zanardi Ditch (storm runoff and hog fuel leachate).

2.5.2 Effluent Quality

Effluent quality variables are routinely measured according to provincial and federal requirements; annual average levels are presented in Table 2 for 1996 to 1999.

Table 2 Annual average values for process effluent quality variables, Skeena Cellulose Inc., 1996 to 1999.

Variable	1996	1997	1998	1999
Total production (ADMt/y)	404,874	256,856	241,421	277,812
Effluent flow (m^3/d)	158,144	111,027	113,000	99,000
pH	6.9	6.8	6.9	6.9
TSS (mg/L)	46.9	35.1	32.9	40.5
BOD (mg/L)	11.9	9.4	6.6	7.8
AOX (mg/L)	6.8	7.2	6.0	5.7
Rainbow trout 96-hr LC50 (% effluent)	>100	>100	>100	>100
Daphnia 48-hr LC50 (% effluent)	>100	>100	>100	>100
Temperature (°C)	36.2	28.6	31.0	33.1
2,3,7,8-TCDD (ppq)	16	ND	ND	ND
2,3,7,8-TCDF (ppq)	55	20	28	27

ND = non-detect.

As observed in Table 2 and Figure 1, total suspended solids, biochemical oxygen demand and adsorbable organic halogens have decreased in recent years. 2,3,7,8-TCDD and TCDF were detected in effluent in 1996; however, TCDD has not been detected since 1996.

Skeena Cellulose Inc. was in compliance with the Pulp and Paper Effluent Regulations at all times during the Cycle Two EEM program.

2.5.3 Sublethal Toxicity Tests

Sublethal toxicity tests were conducted as part of the EEM Cycle One program at Skeena (Hatfield Consultants Ltd. 1997). The following tests were used: fish early life stage (*Menidia beryllina*), invertebrate egg fertilization (*Strongylocentrotus purpuratus* or *Dendraster excentricus*), and algal reproduction tests (*Champia parvula*). Three discharges were tested: secondary-treated kraft pulp process effluent, cooling water and other discharges to Lagoon No. 1, and storm runoff and leachate discharge to Zanardi Ditch. A total of four tests were conducted from May 1995 to January 1996 for each effluent.

Process effluent indicated no toxicity to fish early life stage survival and growth (LC50 and IC25 endpoints were greater than maximum effluent concentration) in three tests; however, one test indicated lower survival but no impact on growth. Echinoderm egg fertilization and *Champia* algal reproduction IC25 endpoints were low (2.8 to 6.6% effluent) for all process effluent tests. Based on an effluent plume delineation study conducted in 1990 using rhodamine dye as a tracer, the 1% effluent zone extended approximately 0.3 km south of the diffuser on a large ebb tide (Hatfield Consultants Ltd. 1994). Therefore, effluent concentrations of 2.8% or greater would most likely occur in the initial dilution zone in Porpoise Harbour.

The cooling water discharge to Lagoon No. 1 was non-toxic to fish and most echinoderm fertilization tests; algal reproduction tests exhibited high variability (IC25 endpoints ranged from 1.6 to >64.9% effluent).

The Zanardi Ditch outfall exhibited slight toxicity to *Menidia* during the January 1996 tests; however, no difference was observed in growth between effluent concentrations. *Champia* algal reproduction endpoints were variable; IC25 endpoints ranged from 2.9 to >64.9% effluent. IC25 endpoints for echinoderm fertilization tests ranged from 0.7 to 16.8 % effluent.

During Cycle Two, only process effluent was tested for sublethal toxicity. Testing was conducted during four periods between March 1998 and April 2000. Topsmelt (*Atherinops affinis*) replaced *Menidia;* no toxicity was observed with Skeena effluent (survival LC50 endpoints >67% v/v effluent, growth IC25 endpoints >67% v/v effluent), except the LC50 in March 2000 was 62.09% effluent. Echinoderm egg fertilization IC25 endpoints ranged from 1.61 to 19.58% v/v effluent. *Champia* algal reproduction IC25 endpoints ranged from 2.47 to 15.52% effluent. A potential zone of sublethal effect was calculated based on the geometric mean of the first four endpoints; the maximum zone of potential effects was 70 m from the diffuser for *Champia*. This zone is considerably smaller than the proposed 1% zone of effluent concentration of 500 m from the diffuser.

2.5.4 Spills to the Receiving Environment

The following spills to the aquatic environment were reported to Environment Canada between 1996 and 1999 by Skeena Cellulose Inc.:

- January 3, 1996 Foam released to Porpoise Harbour;
- January 12, 1996 Foam released to Porpoise Harbour;
- August 27, 1996 Golden pond overflowed to Porpoise Harbour;
- March 17, 1997 Acid discharged (5,000 gallons) to Porpoise Harbour during ETP "bypass"; TSS > permit (161 vs. 146 mg/L); trout bioassay failed; and
- October 6, 1997 Acid released (10.9 gallons) to Porpoise Harbour during startup.

Reportable environmental incidents for 1998 and 1999 involved untreated effluent to porous ground, not to Porpoise Harbour or other waterbodies.

3.0 DESIGN OF CYCLE THREE FOR SKEENA CELLULOSE INC.

When designing the Cycle Three study, it is necessary to review the five elements of the EEM program for inclusion at a specific site; these five elements are:

- fish survey;
- effects on the use of fisheries resources: dioxins/furans and tainting evaluation;
- invertebrate community survey (and supporting environmental variables);
- chemical tracers; and
- sublethal toxicological testing of process effluent.

Decision trees and associated tables that have been provided in *Annex 1* (Environment Canada 1997) and *Technical Guidance* (Environment Canada 1998) are used to decide which elements must be included in a mill's site-specific EEM study design given no documents specifically relating to Cycle Three are available. It is important to note that decision trees, where applicable, include consideration of effect size and the significance of observed differences between exposed and reference areas.

The Cycle Three monitoring program for Skeena Cellulose Inc. was designed using results from previous cycles and decision trees presented in *Annex 1*. The various surveys to be conducted for Cycle Three are presented below.

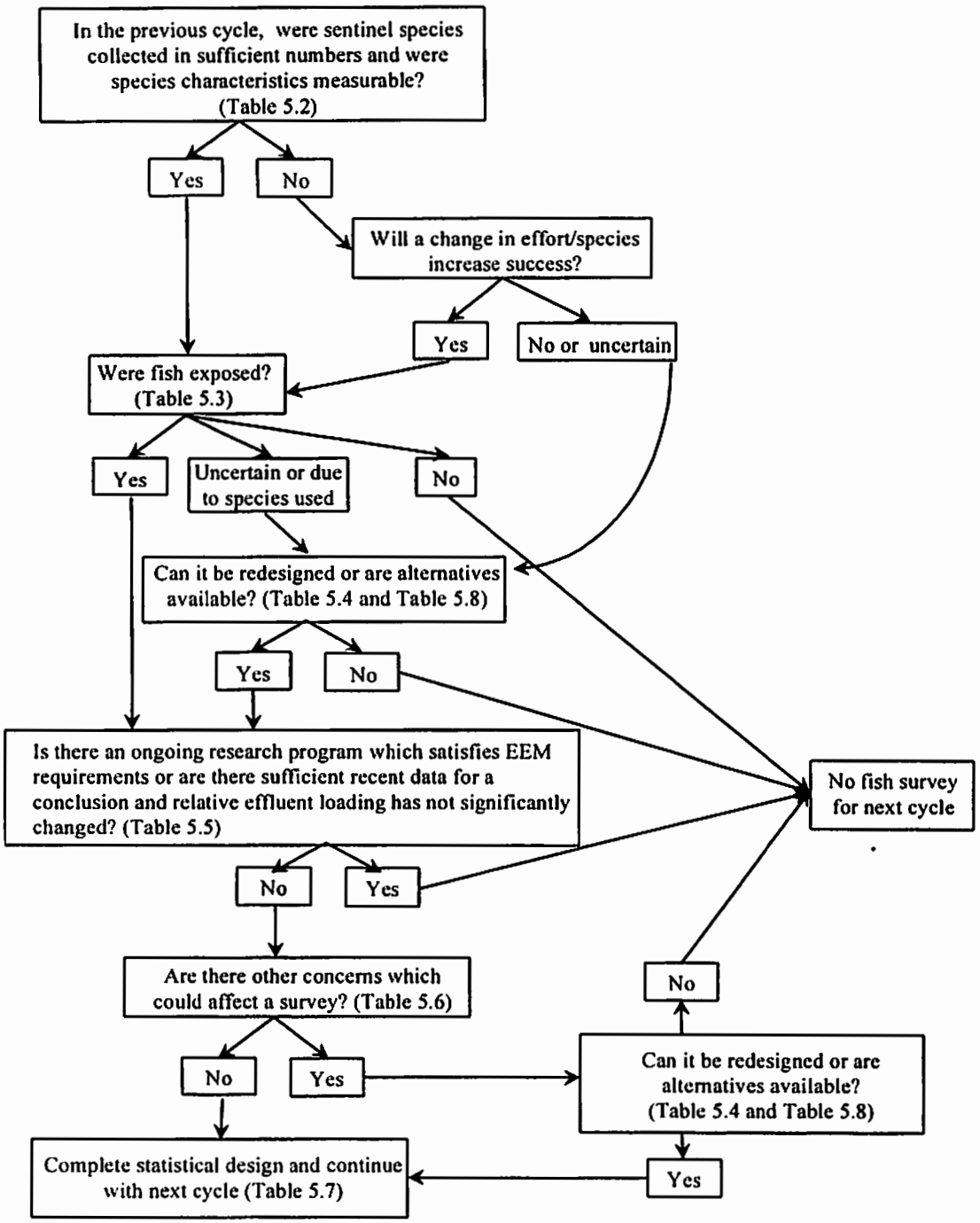
3.1 FISH SURVEY

The fish survey provides an assessment of whether differences exist in fish characteristics between exposed and reference areas. The study design should be based on the ability to detect a difference of 20 to 30% in relative gonad size between reference and exposed areas at a statistical power of 0.80. Other variables (e.g., liver weight, external condition) are also measured or observed. A reasonable level of fishing effort should be expended to collect the minimum number of individuals specified (20 males, 20 females) at each area.

3.1.1 Fish Survey Decision Tree

Figure 2 presents the fish survey decision tree for Cycle Three. Table numbers in the tree refer to tables presented in *Technical Guidance*.

Figure 2 Fish survey decision tree.



3.1.2 Results from Cycle One and Cycle Two Fish Surveys

For Cycle One, English sole and Dungeness crab were identified as sentinel species for Skeena; as an alternate species, blue mussels were collected but not analyzed due to their small size. Insufficient English sole were captured from both near-field and reference (Kitkatla Inlet) areas (Hatfield Consultants Ltd. 1997). Rock sole were used as the sentinel finfish species given the larger numbers captured (29 near-field, 37 reference). Most rock sole captured were small and considered sub-adult. Measures of fish condition (e.g., gonadosomatic index) were similar among areas. No pulpmill impact was indicated using rock sole in Cycle One.

A large increase in effort may be successful in capturing more fish; however, the movement of fish in the marine environment is not restricted, and exposure to pulpmill effluent is uncertain. Surveys in the marine environment cannot be redesigned to prohibit the movement of finfish. Therefore, Skeena LMC members agreed that a finfish survey in the receiving environment of Skeena Cellulose Inc. would not be required for Cycle Two.

Dungeness crabs were collected in sufficient numbers for Cycle One; however, higher numbers of male crabs were collected in the near-field relative to females. The use of crustaceans, such as crab, during Cycle One was confounded by the lack of aging techniques and limited information on possible effects of pulpmill exposure on crustaceans. Therefore, Dungeness crab were not recommended for use in Cycle Two given limited knowledge on the effects of pulpmill effluent on crab relative to life history and movement.

For Cycle Two, blue mussels were collected from six *in situ* stations ranging from Wainwright Basin to Kitson Island. Mussels were small and located in the high intertidal zone. Spatial trends of mussel condition and shell density were not significant along a gradient of distance from the pulpmill diffuser; resin acid levels in mussel tissues were not correlated to distance from the mill.

Cycle Two *Technical Guidance* does not provide approved alternatives for the fish survey. As noted above, large finfish and Dungeness crab have been eliminated as sentinel species in marine receiving environments. Blue mussels collected *in situ* have not proven useful at Skeena for detecting differences among exposure areas given their small size and limited availability. The effectiveness of using caged bivalves for monitoring pulpmill effluent impacts is being researched in two pilot caged mussel studies; results are pending.

The fish expert working group recommends that the following types of surveys in marine environments be considered for future cycles, given in order of preference (S. Courtier, *pers. comm.*, ATW 2002): small-bodied, forage finfish; wild bivalves (if age and reproductive data are collected); caged bivalve studies; mesocosms; and extended sublethal toxicity tests.

3.1.3 Cycle Three Fish Survey

For the design of the Cycle Three fish survey, the decision tree leads to a change in species/effort given an insufficient number of sentinel fish were collected during Cycle One. Mussels were

successfully collected in Cycle Two; however, age and sex could not be determined. A change in effort and species may produce sufficient numbers of small-bodied finfish.

HCL proposes to conduct a preliminary finfish survey using beach seining and/or set lines to target sculpins, threespine stickleback or other small-bodied finfish. Beach seining was successfully conducted at several locations in the vicinity of Skeena during the 1987 receiving environment study; however, only salmonid species and herring and smelt were reported (Dwernychuk 1988). Reference was made to sculpins, particularly Pacific staghorn sculpins; it is also possible that threespine stickleback may be present.

3.1.3.1 Pacific Staghorn Sculpin Ecology

Pacific staghorn sculpins (*Leptocottus armatus*) are found in shallow to moderate depths throughout British Columbia (Hart 1973). They are not necessarily small; length may be as great as 46 cm. Staghorns are voracious feeders, consuming predominantly invertebrates. Hart (1973) reported that spawning takes place in February.

Pacific staghorn sculpins were collected from Yaquina Estuary, Oregon, using beach seines (Bayer 1985). Staghorns were mostly collected in upper intertidal seines, either in daylight or darkness, throughout the year. They were most common from February through July 1976, with peak abundance in June. Staghorns may grow to 11 to 14 cm by the end of one year.

3.1.3.2 Threespine Stickleback Ecology

Threespine sticklebacks (*Gasterosteus aculeatus*) are found in fresh and salt water through the north temperate area, from Baja California to the Aleutian Islands (Hart 1973). These small fish (to 10 cm) have been found schooling in eelgrass and around wharves in harbours; they are very generally distributed and abundant throughout British Columbia. Food of adults consists predominantly of copepods, although crustaceans, insects, and young fishes have been found in stomachs. Marine-dwelling sticklebacks migrate into fresh water in spring to spawn (Scott and Crossman 1973). Sexual maturity is attained during the first year; the life span is approximately three years.

3.1.3.3 Preliminary Finfish Survey

A preliminary fish collection will be attempted during spring 2001 when the dioxin/furan monitoring program is conducted, and/or summer 2001 when the benthic invertebrate survey will be conducted. Beach seining, gill nets and longlines may be set in near-field (Porpoise Harbour) and reference (Inverness Passage) areas to determine possible sentinel species, catch effort, size of fish, spawning cycle, possible tracer use and overall feasibility of a finfish survey. Based on the success of the preliminary survey, the final fish survey design would be conducted with agreement from Environment Canada.

Collection of fish bile will be undertaken for resin acid analyses to test the usefulness of that chemical tracer in the finfish survey.

3.1.3.4 Design of Finfish Survey

The target species for the Skeena Cycle Three program is a small-bodied fish, to be determined following field trials during spring/summer 2001. Pacific staghorn sculpin were reported in the near-field area at Skeena during Cycle One; however, numbers were low, possibly due to fishing effort that did not attempt to capture sculpins. At the ad-hoc marine sentinel species meeting in 1993, sticklebacks were rated second highest and staghorn sculpin rated fourth highest of finfish species considered (Forsyth 1993).

If small-bodied species are successfully captured during a preliminary survey, a complete EEM survey will be conducted. Fish will be collected from stations/beaches within near-field (Porpoise Harbour near the diffuser) and reference (Inverness Passage) areas (Figure 3). A total of 20 males and 20 females will be targeted from each area per species.

3.1.3.5 Methods

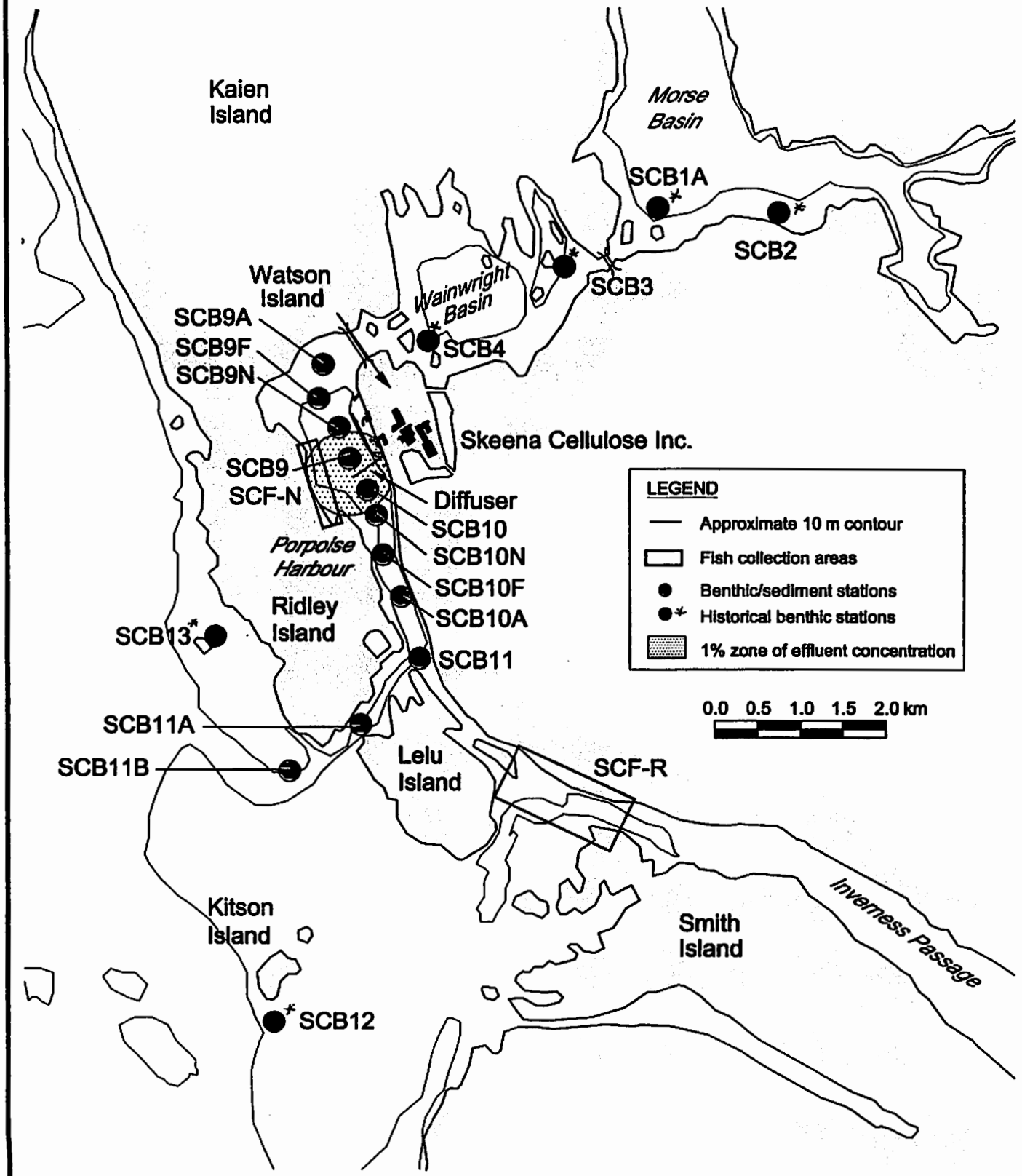
Stations will be chosen on the basis of suitability with beach areas of even gradients and a lack of obstructing debris near the high tide mark. Areas of high tidal current velocity will be avoided. A 20 m x 3 m beach seine with 1 cm mesh openings will be deployed from one shore using a skiff. A semicircular set will be made back to shore, and the seine pulled in. Only target fish will be retained; all others will be returned following enumeration.

Sentinel species will be retained in a large bin with oxygenated seawater until dissected. Dissection will proceed as soon as a sufficient number of fish have been collected to assure that the fish survey has the likelihood of being successful. The near-field station will be sampled first to determine species. If the same species is not captured at the stations designated above, fishing will be conducted at alternate areas.

3.1.3.6 Data Collection and Analysis

All measurements will be taken as outlined in *Technical Guidance*: length, weight, age, liver weight, gonad weight, egg size, sex, and external condition. Fecundity, condition factor, and other indices will be calculated. Statistical analyses will include ANOVA, ANCOVA and power. Relative gonad size will be evaluated and compared to determine if there is a 20 to 30% effect size between near-field and reference fish.

Figure 3 Proposed radial gradient sampling stations for subtidal benthic invertebrates, sediment and water; fish collection areas; Skeena EEM Cycle Three, Summer 2001.



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3.1.3.7 *Alternative Survey*

If the fish survey is not successful, consideration should be given to a caged bivalve study for summer 2002, if approved methods are available within a reasonable time period, and mussels can be deployed within the 500 m 1% effluent concentration zone; however, shipping traffic in Porpoise Harbour requires consideratin to determine if near-field stations would create navigational hazards.

3.2 TISSUE ANALYSES AND TAINTING EVALUATION

3.2.1 Tissue Analyses: Chlorinated Dioxin and Furan Congeners

Mills which use or have used chlorine bleaching may be required to conduct an analysis of tissue levels of chlorinated dioxin and furan congeners on edible portions of fish if dioxins and furans are an issue for the receiving environment. Given that there is an annual monitoring program for fish liver and crab hepatopancreas in place as per Environment Canada regulations, the annual program takes precedence over the EEM program provided that data meet EEM requirements.

The dioxin and furan decision tree is based on consumption guidelines. Dioxin and furan levels (TEQs) in Dungeness crab muscle tissues have been below Health Canada consumption guidelines since 1992; however, some levels in crab hepatopancreas exceeded guidelines at Porpoise Harbour and Wainwright Basin between 1997 and 1999 (Dwernychuk *et al.* 1997, 1998, 1999). Bottomfish liver tissues have exhibited TEQ levels below consumption guidelines since 1995.

Annual dioxin/furan monitoring programs are likely to continue as per directives from the Regional Office of Environment Canada. Results of the 2000 to 2003 programs will be reported in the Cycle Three Interpretive Report.

3.2.2 Tainting Evaluation

Tainting evaluations were not conducted during Cycle One or Cycle Two for Skeena. An evaluation would only be conducted if a new record of complaint has been received since 1992. No complaints of tainting have been received relating to Skeena effluent; consequently, no tainting program is proposed for Cycle Three at Skeena Cellulose Inc.

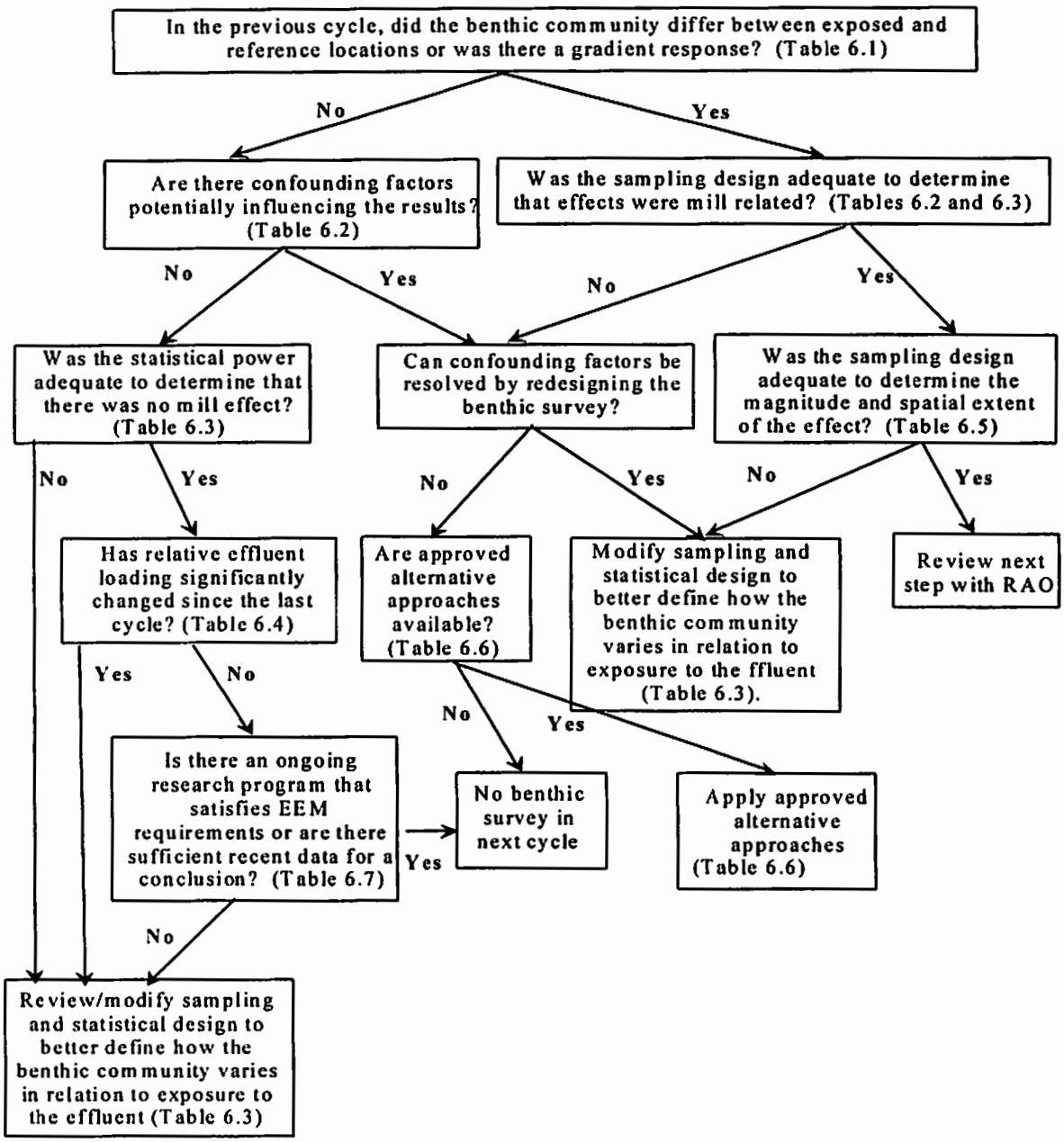
3.3 INVERTEBRATE COMMUNITY SURVEY

Invertebrate community assessments are used to delineate the magnitude and spatial extent of habitat degradation due to organic enrichment or other forms of physical and chemical contamination by pulpmill effluent. Additional objectives include the comparison of current invertebrate data with historical data (i.e., Cycles One and Two and previous studies).

3.3.1 Invertebrate Survey Decision Tree

Figure 4 presents the invertebrate survey decision tree for Cycle Three. Table numbers in the tree refer to tables presented in *Technical Guidance*.

Figure 4 Invertebrate survey decision tree.



3.3.2 Results from Cycle One and Cycle Two Invertebrate Surveys

The Cycle One benthic invertebrate survey was conducted in the vicinity of Skeena and Kitkatla Inlet (reference) during April/May 1995 (Hatfield Consultants Ltd. 1997). Four samples from each station were collected using a Smith-McIntyre grab from a commercial fishing boat, or a Ponar grab from a smaller boat within the basins. Benthic invertebrate data from Kitkatla Inlet and Lagoon No. 2 will not be discussed here given differences between the reference area and Porpoise Harbour, the intertidal habitat of Lagoon No. 2, and a change in the invertebrate survey to a gradient design rather than a control/impact design.

To provide somewhat comparable data with Cycle Two, mean total densities (at 180 µm sieve size) for Cycle One were adjusted by subtracting densities of Nematoda, Copepoda and unidentified polychaetes (Table 3). These taxonomic groups were removed for this discussion from Cycle One density data originally reported, given these taxa were not used for invertebrate statistics in Cycle Two. Also provided in the table for comparison are total density and number of taxa for >1 mm size fractions per station for Cycle Two. Time of sampling, grab used, sieve size and sample splitting are included for each cycle.

Adjusted Cycle One densities were generally higher relative to Cycle Two; this most likely relates to the difference in sieve size. Higher densities at near-field stations indicated possible habitat differences between the inner basins and Porpoise Harbour, or nutrient enrichment. Number of taxa was high at near-field stations. Regression analyses on adjusted Cycle One densities and number of taxa indicated no significant differences related to distance from the diffuser ($p=0.241$ and $p=0.756$, respectively).

The Cycle Two benthic invertebrate survey for Skeena indicated lower densities relative to Cycle One (Table 3), which is expected given the change in sieve size. Density was higher at Kitson Island during Cycle Two [note that a Ponar grab was used rather than the Smith-McIntyre]. Total mean density at SCB4 (SW Wainwright Basin) was unusually low during Cycle Two, and probably indicates a change in location from Cycle One and less suitable substrate. Near-field stations exhibited higher densities relative to inner basin stations during Cycle Two, as has been observed in historical and Cycle One surveys. Number of taxa was higher for Cycle Two relative to Cycle One; this may be the result of a change in taxonomists and/or a difference in level of sample splitting.

Regression analyses were conducted with invertebrate data for all stations except SW Wainwright Basin. Density, number of taxa and biomass versus distance from the diffuser were all non-significant ($p=0.760$, $p=0.537$, and $p=0.669$, respectively).

In summary, the benthic invertebrate survey does not indicate that communities differ along a gradient or between exposed and reference areas. No clear impact of current pulpmill effluent, in terms of enrichment or toxic effects, was observed in invertebrate surveys for Cycles One and Two.

Table 3 **Summary of benthic invertebrate density, number of taxa, biomass, and methods, Skeena EEM Cycles One (adjusted) and Two.**

	Cycle One		Cycle Two		
Station	Adjusted Density[1] (N/m^2)	No. of Taxa	Total Density[2] (N/m^2)	No. of Taxa	Total Biomass (g/m^2)
Northeast Gradient (Inner Basins)					
SCB2 (S Morse Basin)	6,752	41	4,424	74	30.3
SCB1A (W Morse Basin)	NS		7,462	112	62.8
SCB3 (NE Wainwright Basin)	7,337	44	5,141	57	186.6
SCB4 (SW Wainwright Basin)	6,132	53	359	26	6.4
Near-field (Porpoise Harbour)					
SCB9A (N Porpoise Harbour)	NS		10,262	91	114.9
SCB9 (N of diffuser)	20,728	51	6,689	81	99.7
SCB10 (S of diffuser)	28,248	57	8,468	94	133.7
SCB10A (S Porpoise Harbour)	NS		9,340	117	137.6
South Gradient					
SCB11 (Porpoise Channel)	26,699	42	10,726	112	85.7
SCB11A (S Ridley Island)	NS		10,979	106	69.5
SCB13 (Coast Island)	NS		3,791	87	38.7
SCB12 (Kitson Island)	15,359	59	21,065	164	183.8
Methods	**Cycle One**		**Cycle Two**		
Timing	April/May 1995		August 1998		
Grab	Smith-McIntyre: SCB9, 10, 11, 12 Ponar: SCB2, 3, 4		Ponar		
Depth	8 to 36 m		3.5 to 11.3 m		
Sieve	180 µm in lab		0.5 mm in field; 0.5 and 1 mm in lab		
Laboratory subsampling	1/2 to 1/128		None		
Taxonomist	Dr. Charles Low		Biologica Environmental Services		

NS = not sampled.
[1] Cycle One: sieved at 180 µm; mean total density less nematodes, copepods and unidentified polychaetes (4 samples/station).
[2] Cycle Two: sieved at 1 mm; mean adult and juvenile density and biomass (3 samples/station).

3.3.3 Cycle Three Invertebrate Survey

The first question on the invertebrate decision tree asks whether benthic communities differed between exposed and reference areas, or if there was a gradient response. As described above, Cycle One adjusted invertebrate densities and number of taxa were not different along gradients from the mill.

Cycle Two exhibited no correlation of density, number of taxa or biomass with distance from the diffuser, as discussed above. Given two cycles have indicated no difference along a gradient, a benthic invertebrate survey for Cycle Three may not be required.

However, the Cycle One survey used different methods from Cycle Two and may not be considered comparable or as quantitatively accurate, given sample splitting to 1/128 fractions. If LMC members determine that a benthic invertebrate survey is required for Cycle Three, methods used during Cycle Two will be generally repeated (sieve size 1 mm; two rather than three field samples; no laboratory splitting of samples). Stations located in inner basins will be dropped given confounding effects of historical contamination and log booming; stations will be added to near-field and far-field areas to provide a tighter gradient design.

3.3.3.1 Sampling Design and Location of Stations

If a subtidal benthic invertebrate survey is required, HCL proposes to conduct a revised gradient survey using eleven stations in the vicinity of Skeena Cellulose Inc. Stations have been selected along a gradient of exposure from north of the outfall in Porpoise Harbour to approximately 4 km to the south along Porpoise Channel.

Recent discussions concerning benthic invertebrate surveys have highlighted that statistical analyses are improved if more stations are added to the design, with fewer samples per station. *Technical Guidance* states that a minimum of two samples is required; therefore, we propose collecting two samples during the Cycle Three invertebrate survey (rather than three as in Cycle Two). The following stations are proposed; many correspond to stations sampled during Cycle Two and previous studies (Table 4; Figure 3):

Table 4 Location of benthic sampling stations for Cycle Three, Skeena Cellulose Inc., August 2001.

Design	Distance from Diffuser	Benthic Stations (Historical Station)	
Gradient	1.5 km	SCB9A	1.5 km north of diffuser (Station 4)
	1.0 km	SCB9F	1 km north of diffuser*
	0.5 km	SCB9N	500 m north of diffuser*
	0.2 km	SCB9	200 m north of diffuser (Station 5)
	0.2 km	SCB10	200 m south of diffuser (Station 6)
	0.5 km	SCB10N	500 m south of diffuser*
	1.0 km	SCB10A	1 km south of diffuser (Station 7)
	1.5 km	SCB10F	1.5 m south of diffuser*
	2.0 km	SCB11	Porpoise Channel (Station 8)
	3.0 km	SCB11A	South Ridley Island (Station 9)
	4.2 km	SCB11B	Outer Porpoise Channel*

* New stations added for Cycle Three.

3.3.3.2 *Number of Samples and Field Methods*

The Cycle Three program proposes to collect two samples from each station using a 23-cm Ponar grab. Depth range of samples will be the same as in Cycle Two: between 5 and 12 m. Each sample will be field sieved at 0.5 mm, placed into solid-walled containers, and preserved with buffered formalin. Samples will be shipped in a cooler or plastic bin to the consulting taxonomist (standard operating procedures in Appendix A1).

3.3.3.3 *Laboratory Methods and Data Analysis*

Samples will be sieved in the laboratory using 1 mm and 0.5 mm stacked sieves. All organisms will be sorted from debris at the 1-mm size and biomass measurements will be made on representative specimens for determining total biomass of the sample. All 0.5 mm to 1 mm-sized fractions will be archived for use if insufficient numbers of organisms are retained in the 1 mm sieve. For more detail, see Appendix A1 and *Technical Guidance* (Environment Canada 1998).

Cycle Three data will be compared with Cycle Two data, and qualitatively related to adjusted Cycle One data. Any major changes in taxonomic groups will be discussed in relation to pulpmill exposure and habitat characteristics. Given that organisms >1 mm constitute 95% of the biomass of the community (Reish 1959, *cited in* Environment Canada 1998), the presence of macrobenthic organisms will provide information as to the degree of contamination or disturbance at any station.

Statistical analyses will be used in conjunction with tabular and graphical presentation of the data. Suggested statistical analyses include regression using distance and sediment variables, and possible groupings of stations based on exposure (ANOVA tests). In addition, community indices (i.e., Simpson's Diversity and Bray-Curtis), will be included to provide weight-of-evidence.

3.4 SUPPORTING ENVIRONMENTAL VARIABLES

3.4.1 Water Quality

Several key variables must be measured to aid in the interpretation of benthic invertebrate data. In addition, site-specific variables may be measured where applicable. Based on Table 20 of *Annex 1*, the following key variables will be measured for water quality, just above the depth of the substrate for benthic samples:

- dissolved oxygen;
- temperature; and
- salinity.

3.4.2 Sediment Quality

Given that benthic samples will be collected from depositional sediments, the following key variables, including site-specific chlorinated phenolics, will be measured in sediment from each sample/station:

- total organic carbon (TOC);
- total nitrogen (TN, for C/N ratio);
- redox (Eh);
- total sulfides (TS);
- particle size (one per station); and
- chlorinated phenolic compounds (one per station).

In addition, a photograph will be taken of the sediment surface of each grab prior to processing. Depth and station coordinates will be recorded on field data sheets.

One sediment subsample from each benthic sample will be collected for redox and total sulfide measurements by marking off a 16 cm^2 area by 1 cm deep on the surface of the sediment and carefully filling a 7 mL vial (see Appendix A1 for standard operating procedures). Another subsample, 16 cm^2 area by 2 cm deep, will be collected from the surface of the grab from each benthic sample for TOC and total nitrogen (approximately 15 mL). The known surface area of sediment extracted from each benthic sample will be subtracted from the total grab area to provide a net area for benthic invertebrate density calculations.

Two additional sediment grabs will be taken separately from benthic invertebrate samples; sediment from the upper 2 cm of these grabs will be used for particle size and chlorinated phenolic analyses (two 250 mL glass jars). Standard operating procedures are presented in Appendix A1. Laboratory analyses will be conducted by Analytical Service Laboratories (ASL) Ltd., Vancouver, BC (Appendix A2).

3.5 CHEMICAL TRACERS

Mills are required, where practical, to provide confirmation at the time of field sampling that the samples collected are representative of areas exposed to effluent, or are free from effluent (reference areas). The selection of a tracer will depend on the type of mill involved and the complexity of the receiving environment. Resin acids have been identified as a useful tracer in fish bile in some cases, but other tracers may be substituted if proven to be effective (Environment Canada 1997b). Also, tracers in other media (e.g., sediment) may be useful as part of site-specific monitoring studies.

The decision tree regarding the use of a chemical tracer is limited to resin acid accumulation in fish bile if a finfish survey is conducted. It is questionable if resin acids would be a good tracer in fish bile or mussel tissues given the variability of total resin acid concentration in Skeena

process effluent (e.g., resin acids totaled 6, 26, 214 and 1,478 µg/L during 1995 effluent characterization analyses). Average concentrations of total resin acids in effluent should exceed 50 µg/L for bile measurements to be effective.

Resin acids were analyzed in mussel tissues during the Cycle Two fish survey. Total resin acid concentrations ranged from 0.06 µg/g at Kitson Island, to 0.11 µg/g at North Porpoise Harbour, and 0.44 µg/g at Coast Island. Levels were slightly higher at near-field stations; however, no significant relationship was observed ($p=0.120$) between resin acid levels in mussels and distance, with Coast Island removed from the analysis.

If a finfish survey is conducted for Cycle Three, fish bile should be collected for resin acid analyses, if this proved useful during the preliminary survey (see Appendix A1). Resin acids in bile will be analyzed by EnviroTest Laboratories, Edmonton, AB. If a caged bivalve program is conducted, the approved methods should provide guidance regarding a chemical tracer.

Chlorinated phenolic compound analyses in sediments are proposed for Cycle Three given these compounds are still found in sediments, although they most likely relate to historical discharges from the pulpmill. Chlorinated phenolic compounds were non-detect or trace in effluent analyzed in 1995 (Hatfield Consultants Ltd. 1997).

3.6 SUBLETHAL TOXICOLOGICAL TESTING OF PROCESS EFFLUENT

The objectives for using sublethal toxicity testing in EEM are:

- to contribute to the field program as part of the weight-of-evidence approach;
- to compare process effluent quality between mill types Canada-wide and to measure changes in effluent quality as a result of effluent treatment and process changes; and
- to contribute to the understanding of the relative contributions of the mill in multiple discharge situations.

Sublethal toxicity tests which have been selected for the British Columbia coastal mills for Cycle Three include:

- fish early life stage development test using topsmelt (*Atherinops affinis*);
- invertebrate reproduction test using echinoderms (*Dendraster excentricus*); and
- plant toxicity test using the red alga *Champia parvula*.

For Cycle Three, a total of eight periods have been established, consisting of summer and winter terms from summer 2000 to winter 2004. The suite of three tests will be conducted once during each period. Analyses with topsmelt and echinoderms will be conducted by BC Research Inc., Vancouver, BC. The *Champia* test is subcontracted to Saskatchewan Research Council, Saskatoon, SK. Test results will be reported to Environment Canada within 90 days of test completion.

3.7 SCHEDULE FOR CYCLE THREE AND SUMMARY OF ANALYSES

Table 5 provides the proposed schedule for Cycle Three activities. Table 6 summarizes the areas to be sampled and specific stations within these areas. Numbers of samples/samples to be collected are also presented. A summary of sediment, water and mussel variables to be measured during the Cycle Three program are presented in Table 7.

Table 5 Schedule of Cycle Three activities, Skeena Cellulose Inc.

Summer 2000 to Winter 2004	Sublethal toxicity testing of final effluent.
November 2000	Submission of Cycle Three proposed design to LMC members; final design document to Environment Canada.
April 2001	Annual dioxin/furan monitoring program; preliminary finfish survey (or in summer).
August 2001	Cycle Three benthic invertebrate and supporting environmental variables collection; preliminary finfish survey (if not conducted in April).
Winter 2001	Small-bodied finfish survey.
April 1, 2004	EEM Cycle Three interpretive report submitted to Environment Canada.

Table 6 Summary of test media and number of stations and samples per study area, Skeena EEM Cycle Three program.

Study Area	Finfish Survey	Subtidal Benthic Community Survey (Ponar grab)	Subtidal Sediment[1]	Water[2]
Replication	20 males and 20 females per species/area	2 samples/station	2 samples/station 1 composite/station	1 measurement/ station or area
Radial Gradient North of diffuser South of diffuser	 1 1	 4 stations 7 stations	 4 stations 7 stations	 5 stations 8 stations
Total # Stations	**4**	**11**	**11**	**13**
Total # Samples	**160 per species**	**22**	**22 or 11**	**13**

[1] Sediment variables measured in each subtidal benthic sample include total organic carbon, total nitrogen, redox and total sulfides. A composite sample from each station will be analyzed for particle size and chlorinated phenolics.

[2] Water quality measurements will be taken at subtidal benthic (near-bottom) stations and fish areas.

Table 7 **Summary of water and sediment variables to be measured during the Skeena EEM Cycle Three program.**

Variables	Fish Survey	Benthic Survey
Water Quality		
Dissolved oxygen	X	X
Temperature	X	X
Salinity	X	X
Sediment Quality		
Redox potential (Eh)[1]	-	X
Total sulphides[1]	-	X
Total organic carbon[1]	-	X
Total nitrogen[1]	-	X
Particle size[2]	-	X
Chlorinated phenolics[2]	-	X

[1] Variables measured in each benthic sample.
[2] Variables measured in composite of two grabs from each station.

4.0 QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

Quality assurance (QA) encompasses a wide range of management and technical practices designed to ensure an end product of known quality commensurate with the intended use of the product. Quality control (QC) is an internal aspect of quality assurance. It includes the techniques used to measure and assess data quality and remedial actions to be taken when data quality objectives are not realized. Mills and their consultants must ensure that a reliable method of sample tracking, logging and data recording is practiced and documented to establish continuity between the sample collected and the results reported. Standard operating procedures for field and laboratory activities should also be available, as required. *Technical Guidance* (Environment Canada 1998) presents more information on QA/QC and provides checklists for aquatic studies.

The purpose of this section of the design report is to summarize and compile approaches proposed for the Skeena Cycle Three EEM program which contribute to quality assurance.

4.1 FIELD DATA COLLECTION AND METHODS

The primary method of quality assurance in the field involves completion of data sheets to provide a record and hardcopy of relevant observations. Data sheets prepared for use in the field include:

- Benthic/Sediment/Water Collection;
- Fish Collection/Water Data;
- Fish Dissection Sheet;
- Caged Mussel Dissection Sheet (optional);
- Water/Effluent Collection Sheet; and
- Chain of Custody/Analysis Request Form.

Detailed descriptions of the data sheets, examples, as well as procedures for completion, are provided in Appendix A1.

The primary concerns for sample collection in the field center around use of equipment and prevention of contamination. Consistency in sampling equipment, proper calibration methods, and collection of replicate and blank samples will be specified for each program. See Appendix A1, Standard Operating Procedures, for more information.

4.2 LABORATORY PROCEDURES

4.2.1 Biota Tissue Analyses

Analytical Service Laboratories Ltd. (ASL), Vancouver, BC, will be the primary contractor for lipid analyses (mussels). Quality assurance associated with biota tissues analyses is presented in Appendix A2. If resin acids are analyzed in fish bile, EnviroTest Laboratories, Edmonton, Alberta, will conduct the tests.

4.2.2 Benthic Invertebrate Analyses

Biologica Environmental Services, Victoria, British Columbia, or Columbia Science, Royston, British Columbia, will be the invertebrate taxonomist for Skeena's EEM Cycle Three survey (Appendix A3). The primary quality assurance functions relate to sample splitting and invertebrate taxonomy. Organisms are identified using keys as outlined in the standard operating procedures (Appendix A1) and *Technical Guidance* (Environment Canada 1998). Identifications are generally reported to the lowest taxonomic level that can be conveniently achieved.

Technical Guidance outlines procedures for splitting (subsampling), verifying identifications, establishing a reference collection, and data reporting. These procedures will be followed by the consulting taxonomists.

4.2.3 Sediment Analyses

A detailed quality assurance description associated with analyses of sediment chemistry parameters is provided by ASL (Appendix A2).

4.2.4 Water Measurements

Water quality measurements made in the field are recorded immediately on field data sheets. Equipment used in the field is calibrated according to manufacturers protocols (Appendix A1).

4.2.5 Sublethal Toxicity Tests

BC Research Inc. (BCRI), Vancouver, BC, will conduct and/or coordinate sublethal toxicity tests for Skeena Cellulose Inc. (*Champia* tests are subcontracted to Saskatchewan Research Council, Saskatoon, Saskatchewan.) QA/QC details are presented in Appendix A4. All tests will be conducted using methods approved by the EEM program.

4.3 HCL PERSONNEL

All HCL personnel are qualified, experienced biologists with project experience in monitoring pulp and paper mill effluents, including environmental effects monitoring and/or organochlorine monitoring. For further information, see Appendix A5.

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