MINISTRY OF ENVIRONMENT, LANDS AND PARKS
PROVINCE OF BRITISH COLUMBIA

LOWER COLUMBIA RIVER
HUGH KEENLEYSIDE DAM TO BIRCHBANK
WATER QUALITY ASSESSMENT AND OBJECTIVES

TECHNICAL APPENDIX

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1. INTRODUCTION

This is the first of two reports documenting water quality and setting water quality objectives for the lower Columbia River, from the Hugh Keenleyside Dam to the U.S. border. To complete this study, the lower Columbia River has been divided into two reaches: from the dam to Birchbank, and from Birchbank to the border.

The reach of the lower Columbia River sub-basin covered in this first report extends for 27.5 km from the Hugh Keenleyside Dam to Birchbank (Figure 1). The Keenleyside Dam at the upper end of this reach is approximately 700 km downstream from the headwater source of the Columbia River and approximately 60 km upstream from the B.C.-Washington border. The purpose of this report is to examine the water quality of this reach, as well as input from the Kootenay River to develop water quality objectives.

The 52 m high Hugh Keenleyside Dam became operational in 1968 providing downstream flow regulation. The dam at present has no hydroelectric facilities; however, installation of generators (240 MW capacity) is being planned for the future. The reservoir, approximately 230 km long, includes the former Upper and Lower Arrow Lakes. The Brilliant Dam is the furthest downstream of five dams on the Kootenay River and is located 2.5 km upstream from the Columbia River confluence. The Brilliant Dam (34 m high) was completed in 1944 and operates as a run-of-the-river hydroelectric facility. Other dams located upstream from this reach of the Columbia River but exerting some influence include the Revelstoke Dam and Mica Dam upstream from the City of Revelstoke.

The major urban centre in this portion of the sub-basin is the City of Castlegar located 38 km southwest of the City of Nelson and 24 km north of the City of Trail. Castlegar (including Kinnaird) had a population in 1986 of 6385. The surrounding settlements outside of Castlegar in Electoral Area J (Blueberry, Ootischenia, Robson, Fairview, Raspberry, Gibson Creek) had a 1986 population of 3095. The population of this area has declined by 7.5-8 % over the last five years. The population is expected to stabilize or decline at a similar rate over the next five years (G. Isherwood, personal communication). The Arrow Reservoir Basin upstream from the reach studied in this report is sparsely populated and relatively undeveloped, with logging as the main economic activity. The Village of Nakusp is the largest population centre in the Arrow Reservoir Basin (located 140 km upstream from the Keenleyside Dam) with a population of 1400 during the last census (1986).

The Celgar Ltd. bleached kraft pulp mill and the Westar Ltd. sawmill are the major long-term industrial activities within this portion of the lower Columbia River sub-basin. These mills are situated on the south bank of the river starting at a point 2 km downstream from the Keenleyside Dam. Construction of the Keenleyside powerplant and rebuilding the Celgar pulp mill will add to the industrial activity in this sub-basin until the mid-1990's. Forestry and agricultural activities have little significant land use impact in the area at present.The main point-source effluents are untreated sawmill effluent, untreated pulp mill effluent (treatment is now being installed), and treated municipal sewage from the City of Castlegar and Selkirk College.

2. HYDROLOGY

2.1 FLOW REGIME

Streamflow regulation of the Columbia River upstream from the Kootenay River began in 1968 with the completion of the 52 m Hugh Keenleyside Dam at Castlegar. This first dam was built to provide flood control for downstream (U.S.A.) power generation. This was followed by two dams north of Revelstoke: the 243 m Mica Dam completed in 1973 and the 175 m Revelstoke Dam completed in 1984.

Two run-of-the-river hydroelectric dams have been proposed for the Columbia River downstream from the Kootenay River: one at Murphy Creek, 3 km upstream from the City of Trail, and one at the International Border. At present, both sites are under active consideration with construction proposed to begin in 2004 at Murphy Creek and in 2000 at the border (G. Ash, personal communication). These projects would create reservoirs in the last free-running reach of the Columbia River and raise water levels back to Keenleyside Dam. The proposed addition of the powerplant to the Keenleyside Dam is not expected to change the current flow regime.

Prior to 1968, the natural flow regime was typical for Interior rivers and was characterized by low winter flows, peak flows in late spring and early summer due to headwater snowmelt, and gradually reducing flows during the late summer and early fall. Since regulation, the winter flows (November to March) have increased 1.6-3.1 times as water is released for power generation. The summer floods are stored in the reservoir behind the Keenleyside Dam. The August to October flows are roughly equal to pre-regulated levels (Table 1).

2.2 COLUMBIA RIVER UPSTREAM FROM KOOTENAY RIVER

An annual hydrograph showing maximum, minimum, and average flows for the Columbia River at the High Keenleyside Dam is shown in Figure 2. These are predicted streamflows based on hydroelectric Assured Operating Plans as developed under the Columbia River Treaty (McFarlane, 1987).

B.C. Hydro reduces the Columbia River flow annually to fill the Arrow Reservoir according to a formula which considers snowpack, projected U.S. power demand, and maintenance requirements. The period of low flow can be variable between years and may occur for up to two months between early March and late June. As specified by the Columbia River Treaty, the average weekly outflow from the Keenleyside Dam is to be greater than 142 m^3/s, except if agreed otherwise by the Treaty signatories. On average, flows of about 142 m^3/s are expected to occur approximately 3.5 % of the time or 13 days per year (W.I.B., 1979). Flows of less than 142 m^3/s (ranging from 138-141 m^3/s) have occurred on 29 days in the last five years (Table 2) during the period April to July.

The mean annual discharge of the Columbia River between the Keenleyside Dam and the confluence with the Kootenay River is 1 143 m^3/s. Mean annual inflow from the Kootenay River increases this by 75 % or 890 m^3/s, thus providing significant dilution potential for upstream effluent discharges.

The Kootenay River has been purported to act as a weak hydraulic dam at the confluence causing the width and depth of the Columbia River to increase and flow velocities to decrease slightly between the Keenleyside Dam and the Kootenay River (W.I.B., 1979). Observers have claimed that occasionally the river flow at the Celgar pulp mill appears to reverse with the ponding effect being greatest when Kootenay River flows exceed Columbia River flows during low flow (April - June). Assuming a maximum Kootenay River flow of 3000 m^3/s and a minimum Columbia River flow of 142 m^3/s, the water level in the Columbia River could increase by up to 3 m in the reach upstream from the confluence (W.I.B., 1979). Consultants to Celgar (1990) created a computer model to evaluate this possibility. The model showed that the Columbia River adjusted instantaneously, relative to the Kootenay River flow change, so that a reverse current flowing upstream could not occur. The hydraulic damming effect was found to be negligible. One possible explanation for the observations of upstream water movement, as offered by Celgar's consultants, is that it could be due to surface currents created by wind action.

B.C. Hydro is also currently considering dredging the Columbia River bed between Pass Creek and the Kootenay River (Tin Cup Rapids area) for the Keenleyside Powerplant Project (G. Ash, personal communication). This would involve the excavation of 0.5-2.0 x 10^6 m^3 of sediment for the purpose of lowering the Keenleyside tailwater by 0.5 - 1.5 m. This should increase the current velocity and reduce the hydraulic effect of the Kootenay River; however, such predictions require further refinement with hydraulic modelling.

2.3 COLUMBIA RIVER DOWNSTREAM FROM KOOTENAY RIVER

Annual hydrographs using data predicted from Assured Operating Plans are given in Figures 3 and 4 for the Columbia River at Birchbank and for the Kootenay River at the Brilliant Dam outflow.

The minimum and maximum mean monthly flows for the Kootenay River at Brilliant Dam are 207 m^3/s and 2696 m^3/s, respectively (McFarlane, 1987). Flow regulation on the Kootenay River prevents flows from exceeding 3000 m^3/s. During the period April to June, Kootenay River flows exceed Columbia River flows at the confluence. For the remainder of the year, Kootenay River flows are lower than Columbia River flows. This augmentation of Columbia River flows downstream from the Kootenay River is predicted to prevent the minimum mean monthly flow at Birchbank from dropping below 630 m^3/s. The frequency of occurrence for such a low flow is one month in 40 years (i.e., 0.2 % of the time). The period of lowest flow in the Columbia River at Birchbank is predicted to be from mid-February to the end of April (Figure 3).

2.4 ANNUAL STREAMFLOW BALANCE

An annual streamflow balance for the Columbia River from the Keenleyside Dam to the International Border is summarized in Figure 5. The Kootenay River and the Pend D'Oreille River are the largest tributaries within this reach contributing, respectively, 30% and 27% of the mean annual flow (M.A.F.) at the International Border. The Kootenay River contributes 43% of the M.A.F. at Birchbank and the smaller tributaries (Norns Creek, Blueberry Creek, China Creek, and Champion Creek) contribute approximately 2%. The Columbia River M.A.F. increases from 1110 m^3/s at the Keenleyside Dam to 2020 m^3/s at Birchbank, and to 2850 m^3/s at the International Border. The smaller tributaries between Birchbank and the International Border contribute approximately 2% to the M.A.F. at the Border.

3. WATER USES

3.1 WATER WITHDRAWALS

A summary of licensed consumptive water withdrawals from the Columbia River mainstem between the Keenleyside Dam and Birchbank is given in Table 3. It is important to note that the water license specifies the maximum rate of withdrawal and, since the actual quantity used may be far less, the quantity of present water use may be overestimated. The licensed withdrawals (2.53 m^3/s) represent 1.8 % of the minimum outflow from the Keenleyside Dam as specified by the Columbia River Treaty and 0.4 % of the minimum mean monthly flow at Birchbank.

The largest portion of the withdrawal (69.2 %) of Columbia River water within this reach is for industrial purposes at the Westar Timber Ltd. sawmill and the Celgar pulp mill. Irrigation (hay crops, gardens) accounts for 30.5 % of the withdrawal and only 0.01 % is used for domestic purposes. The City of Castlegar has drawn its water supply from the Arrow Reservoir via a 9 km pipeline since 1980. Water users between the Celgar pulp mill and the Kootenay River include: 1) B. McInnes who lives opposite the mill and withdraws 2.27 m^3/d from a shoreline (groundwater) well for domestic consumption; and 2) the nine residences in the West Brilliant Community who take 20.4 m^3/d for domestic use from a common submerged intake.

Water users in the downstream reach, Birchbank to Waneta, that are important relative to the industrial discharges in this upstream reach include the communities of Warfield and Tadanac that withdraw drinking water from the river. The City of Trail also holds the river as a reserve water supply and presently is undertaking a predesign study of the extraction of river water (Walton, 1991). The use of Columbia River water for industrial purposes by Cominco Ltd. would not be affected by upstream discharges including the Celgar discharge.

3.2 FISH RESOURCE

A total of 22 species of fish are known to inhabit the Columbia River between the Keenleyside Dam and the U.S. border (Table 4). Of these, six can be considered as major sport fish species in terms of abundance: rainbow trout, bull trout (Dolly Varden char), kokanee, burbot, yellow walleye and mountain whitefish; and another four can be considered as minor sport fish species: brook trout, chinook salmon, white sturgeon, and lake whitefish. The order of preference for the main sport fish species (on a scale of 0-10) by the sport fishery users is: rainbow trout (6.0), yellow walleye (2.9), and mountain whitefish (0.1) (G. Ash, L. McDonald; personal communication).

The order of fish species abundance reported from the most recent survey were redside shiners (78 %), suckers (11.7 %), mountain whitefish (4.7 %), sculpins (2.2 %) and peamouth chub (1.5 %). Each of the other species contributed less than one percent of the catch, including kokanee and rainbow trout, which are two of the most preferred sport fish species (Ash et. al., 1982). Sampling methods may have underestimated the abundance of the larger, open-water species such as the salmonids.

The reach between the Keenleyside Dam and the Kootenay River appears to be preferred habitat for many of the valued sport species. Over 100 000 fish, comprised of 18 species, were captured or observed during sampling of this reach in 1980 and 1981. This substantial habitat use is likely due to a combination of factors including: 1) entrainment out of Arrow Reservoir; 2) the presence of suitable spawning/rearing habitat; 3) an extensive littoral area with aquatic vegetation; 4) the availability of food and nutrients near the outlet of the Hugh Keenleyside Dam and; 5) the lower gradient and greater depth compared to the higher gradient and swifter flow downstream from Castlegar. Much remains to be learned about the habitat use and distribution of fish in the Columbia River, although some pattern (as follows) is presently available from consultant data (Ash et. al., 1982).

Rainbow trout congregate upstream from the Kootenay River and in various creeks during the spring. Spawning activities have been observed in Norns and Champion Creeks and in the Kootenay River below the Brilliant bridge, and it is believed that spawning also occurs in Blueberry and China Creeks. Spawning activities were observed in the mainstem at Genelle by consultants to B.C. Hydro (G. Ash, personal communication, 1990). Rainbow trout rearing also occurs in these tributary creeks.

Kokanee have been found to be most abundant upstream from Castlegar. Ash et al. (1982) estimated this population to be approximately 9800 fish. Two distinct populations of kokanee occur within this upper reach: one migrating up from Roosevelt Reservoir; and another moving downstream from the Arrow Reservoir. Kokanee spawning has been extensively recorded from Norns Creek and China Creek (late August to mid-September), and some spawning is suspected to occur in the mainstem upstream from Norns Creek. Kokanee rear and feed in the Columbia River between the Hugh Keenleyside Dam and Castlegar.

Walleye were introduced (source unknown) to the Roosevelt Reservoir in the 1970's. They migrate upstream during the spring/summer at least as far as the Keenleyside Dam providing a popular sport fishery (with best fishing in the Keenleyside tailrace). Walleye spawning has not been observed to occur in the Keenleyside to Birchbank reach, although suitable habitat is available.

Bull trout are generally scarce but are most abundant in the farthest upstream section of this reach, i.e., below Hugh Keenleyside Dam. Spawning has been observed in Norns Creek. Burbot appear to be concentrated below the dam, where it is believed that they spawn. White sturgeon have also been found in low numbers in this upper reach, primarily between the Hugh Keenleyside Dam and the Castlegar ferry and between the Brilliant Dam and the Kootenay River confluence. According to the former Regional Fisheries Biologist (H. Andrusak), sturgeon may spawn in the Kootenay River just downstream from Brilliant Dam and at the tailrace of the Keenleyside Dam. The fishery for white sturgeon increased dramatically during the 1980's, but the catch has recently (1988-1990) dropped (J. Hammond, submission to Celgar Hearings).

Mountain whitefish are the most abundant of the sport species and are common throughout this upper reach. Spawning has been observed in Norns Creek and is believed to occur in the Columbia River mainstem. Yellow walleye have been captured between Hugh Keenleyside Dam and Castlegar, and in the Kootenay River, but spawning has not been documented. According to local reports, they are becoming abundant (R. Crozier, personal communication, 1989).

The three remaining sport species (brook trout, lake whitefish, and chinook salmon) all occur in very low numbers. A self-sustaining population of brook trout is confined to Norns Creek. Chinook salmon, originating from stocks established in Roosevelt Reservoir, are seldom encountered and very little is known of their habitat use. Lake whitefish have been captured in the mainstem upstream from Castlegar, but again little is known of their life history requirements in the Columbia River.

Fish productivity in this reach of the Columbia River has been limited by the Keenleyside Dam which has blocked migration routes, inundated historic spawning areas, and caused water fluctuations (with consequent redd dewatering) and dissolved gas supersaturation. On the positive side, fish productivity may be enhanced by the increased number of zooplankton (mysids) spilling from the Arrow Reservoir. The former Regional Fisheries Biologist (H. Andrusak, personal communication) identified habitat degradation as a result of sunken logs and wood debris, and water quality degradation resulting from the effluent discharge at the Celgar pulp mill, as factors constraining fish production. No studies have been conducted on the fish population to quantify these effects. In support of this contention, the consultants who conducted the fish survey (Ash et. al., 1982) noted that kokanee were less abundant along the south bank compared to the north bank (upstream from Castlegar), and that this likely reflected Celgar's activities, i.e., log booming and the effluent discharge plume.

Organized swimming occurs at Pass Creek Regional Park. At various small sites casual swimming/wading areas are used by local families and neighborhoods. Local residents disdain swimming between Celgar and Castlegar because of the discolouration of the water from Celgar's effluent discharge and the perception of the water as dirty or unhealthy (Stephenson, 1981).

4. WASTE DISCHARGES

The most important waste discharges in this reach of the Columbia River between Hugh Keenleyside Dam and Birchbank are the industrial effluent from the Celgar pulp mill (PE 1272) and the treated sewage effluent from the City of Castlegar (PE 80, PE 4008). Also reviewed in this report are several smaller discharges which are not considered priority problems: the treated sewage effluent from Celgar (PE 1273), the treated sewage effluent from a neighborhood pub (PE 7622), and the treated effluent from Selkirk College (PE 141) (Table 5). The locations of these discharges are shown in Figure 1. Waste discharges to land (i.e., Westar and Celgar landfills) and non-point source discharges are included for review where impact on surface water quality is possible. Assessment of groundwater quality is outside the purview of this study.

Background (control) concentrations in this report are taken to be those upstream from the anthropogenic waste sources in this reach, i.e. upstream from the Westar/Celgar industrial complexes. Background levels are taken to mean operational background levels, i.e., they reflect existing control levels which may not be the same as natural or pre-development levels (see Section 6). It can be argued that there are anthropogenic disturbances upstream from the river reach covered in this report, and that these alter the background concentrations. The author has reviewed the upstream uses and determined that the water quality of Arrow Reservoir has not been affected by man to the extent that it impacts on the water quality downstream from the Keenleyside Dam. The Village of Nakusp and B.C. Hydro both discharge treated domestic effluent to Arrow Reservoir; however, these have been judged to have no effect on water quality (W.I.B., 1977). Significant changes to these discharges have not been made since the time of this conclusion.

The term "initial dilution zone" used in this report is taken as defined by the Pollution Control Objectives (PCB, 1977), i.e., as extending up to 100 m downstream from the point of discharge, but not exceeding 50 % of the width of the waterbody. B.C. Environment does not apply water quality objectives to this zone. Although sublethal effects on aquatic life may occur within this zone, acutely toxic conditions, objectionable sludge deposits, harmful bioconcentrations in biota, and nuisance conditions should not occur. The term "mixing zone" is defined as extending downstream from the point of discharge to a point where complete mixing of the effluent and river water occurs. The latter zone is longer than the former zone in the Columbia River. Provincial water quality objectives apply within the mixing zone outside of the initial dilution zone.

4.1 DIFFUSE CONTAMINANT SOURCES

4.1.1 MILL LANDFILL AND CHIP PILES

Westar Timber Ltd. presently operates two landfills west of the sawmill/pulp mill complex for the disposal of solid waste. The total landfill area is approximately 25 000 m^2. Waste Management Branch permit PR-1768 (Celgar) authorizes the discharge of 70 m^3/d of lime mud, sand, slaker grits, scrap metal, and combustibles such as bark, waste pulp, waste paper, dredged wood and scrap lumber. Other materials not mentioned in the permit that have been landfilled from the existing mill have included: ash, domestic garbage, and waste asbestos (Celgar, 1990). No monitoring data are available describing either the quantitiy or chemical nature of the above wastes.

The leachate is collected at the base of the landfill and routed to a small exfiltration pond where it either evaporates or infiltrates into the ground leaving a solid residue. The average leachate production rate has been estimated at 0.05 L/s (4 320 L/d) and the annual production at 1577 m^3 (Celgar, 1990). Analysis of the leachate in 1976 (permit file) showed that it was highly coloured (15 000 colour units), high in alkalinity (8700 mg/L total alkalinity), hard (454 mg/L as $CaCO_3$) and high in organics (700 mg/L tannin and lignin; 0.06 mg/L phenol). Further leachate analysis in 1985 indicated that levels of phenol, sulphide, and resin acids were undetectable (Ministry permit file). Organochlorines could be expected to be found in the leachate; however, to date, analyses of such (e.g., AOX; Adsorbable Organic Halides) have not been conducted. It is recommended that dioxin, furan, and chlorophenol levels be measured in the Westar landfill leachate.

It is unknown if the leachate could be reaching the river in any quantity. The landfills are located approximately 150 m south of the Columbia River shoreline approximately 30 m above the river level over sandy gravel. Surface run-off draining toward the site is entrained in ditches and diverted away. Additionally, the groundwater table is reported to be about 30 m below the site (permit file). There are no groundwater wells in the vicinity to test whether or not there is flow to the river. To date, leachate has not been observed visually along the shoreline of the Columbia River. Receiving water monitoring along the shore has not been conducted.

Further study into the potential for groundwater contamination at the landfill site appears warranted. A groundwater well should be installed with monitoring for the variables previously analyzed from the leachate as well as metals and organochlorines, (AOX*, dioxin/furans, chlorophenols, chloroguaiacols)

4.1.2 LOG STORAGE AND HANDLING

The south shore adjacent to the sawmill and pulpmill has been the storage site for log booms since these industrial operations began. As a result, the bottom in this area is covered with sunken logs, branches and bark debris. In 1986, Ministry of Environment scuba divers determined that the sunken logs and debris extended for approximately 3 km along the south shore (see map, Figure 7). At a point 100 m off the old woodroom of the pulp mill, the natural river bottom could not be found because of the accumulation of sunken logs and bark (Kinrade, 1986).

Apart from the gross habitat alterations due to groundings and benthic smothering, the sunken log debris can degrade the quality of the water column in a variety of ways. These include: dissolved oxygen depression, darkening of water colour, nutrient enrichment, and the release of organic constituents from the wood. The effects could be subtle, and may be masked by the larger effect of the nearby pulp mill discharge. Receiving water monitoring of this diffuse source has not been conducted to date.

*AOX = adsorbable organic halogens, a measure of the halogens (e.g. chlorine, fluorine, bromine, iodine) attached to organic molecules. The sample is filtered through an adsorbent (i.e., activated carbon).

In 1988, the woodroom closed and the wood supply for the pulp mill changed to chips delivered by truck and conveyor from the Westar sawmill. This has reduced the log storage and handling effects on water quality over the past several years; however, the proposal for expansion of the Celgar pulp mill calls for the reactivation of the woodroom and resumption of log handling and storage in front of the pulp mill. The exact quantity of logs arriving by water as opposed to overland trucking is unknown at this time, although it is known that the modernized mill will process 512 476 logs each year.

The Department of Fisheries and Oceans has recommended that the company investigate land and barge transportation options to avoid water handling of logs (Celgar Expansion Review Panel, 1990). The Ministry of Environment, Lands and Parks, as outlined to the Review Panel, is prepared to accept historical levels of log booming because of the environmental and social costs associated with increased trucking and highway use; however, the Ministry will not accept unnecessary introduction of logs into water at the mill site, i.e., logs transported by truck should not be dumped into the river for storage. Should booming and water storage resume and should land-based log storage and handling alternatives be rejected, water quality monitoring will be needed to assess this diffuse source. The Celgar Expansion Review Panel has recommended that Celgar, in conjunction with the Federal and Provincial government agencies, develop log storage and handling procedures for minimizing the deposition of wood debris and fibre into the aquatic environment (Recommendation 34).

4.1.3 AGRICULTURE

Agriculture is not an important non-point source to this reach of the Columbia River. Agricultural potential is limited to only small pockets between Castlegar and Birchbank. Irrigated hay crops and small-scale livestock production are the main activities pursued mainly on a part-time basis. The nutrient loading input to the Columbia River from such fertilized croplands and livestock wastes was estimated in 1977 to be small and of insignificant consequence to the river's water quality (W.I.B., 1977). There have been no significant agricultural changes in the area since these calculations were made.

4.1.4 DOMESTIC EFFLUENT

Domestic effluent discharge to the Columbia River at Robson is of particular concern. This area has had a history of poor soil suitability for ground disposal systems. In the 1950's, the government granted permission to certain residents and businesses to discharge their effluent through a series of holding tanks directly into the Columbia River. At present, there are two businesses (a gas station and a grocery store) and approximately six houses discharging without treatment and without Waste Management Branch permission in this manner (M. Harnadek, personal communication). There are also two other houses on the riverside which may discharge directly in some manner to the river. In addition, many residences in the area with proper tile fields are suspected to have surfacing problems due to the clay soils and periodic high groundwater levels. Potential localized fecal contamination along the north shore downstream from the ferry landing is of concern relative to shoreline recreational activity. Receiving water monitoring of this potential problem has, to date, not been conducted but should be a future priority. All present and future sewage discharges must be permitted and be required to install treatment if river discharge is allowed.

4.2 WESTAR LTD. SAWMILL/CELGAR PULP MILL DOMESTIC EFFLUENT (PE 1273)

4.2.1 DESCRIPTION OF DISCHARGE

Domestic sewage from the woodroom/sawmill complex and pulp mill are combined to receive secondary treatment prior to discharge to the Columbia River. The effluent is not chlorinated. The outfall is located 500 m upstream from the industrial effluent outfall (PE 1272). Waste Management Branch permit PE 1273 was originally issued August 18, 1972, and authorizes an average discharge of 115 m^3/d with BOD_5 of 45 mg/L and suspended solids of 60 mg/L.

4.2.2 PRESENT WASTE LOADS

Effluent monitoring data for the period 1981-1987 are summarized in Table 8. Effluent flow exceeded the permitted maximum flow 56 out of 243 times (23 %). Dilution of this small discharge in the Columbia River under low flow conditions (142 m^3/s) would be greater than 68 x 10^3:1. Predictions of the increases in the receiving water concentrations for permitted characteristics are given in Table 6. Results of the analysis indicate that this discharge is not expected to have any measurable effect on downstream water quality.

4.2.3 FUTURE WASTE LOADS

There is no expected future increase in the discharge quantity authorized by permit PE 1273. Future waste loads can be presumed to be equal to present waste loads. The proposed expansion and modernization of the pulp mill will not entail changes to the sanitary sewage treatment plant. However, the effluent will be added to the acid sewer and after treatment returned to the foam tank at the mill site, combined with the cooling water, and discharged through the existing pulp mill outfall diffuser (EVS/Cirrus, 1989).

4.3 CELGAR PULP OPERATIONS (PE 1272)

4.3.1 DESCRIPTION OF PRESENT DISCHARGE

Power Consolidated (China) Pulp Inc. and CITIC B.C. Inc.. operate a single line bleached kraft pulp mill at Castlegar with a present nominal capacity of 550 ADt/d*. The present owners purchased the Celgar mill from Westar Timber Ltd. in 1986. Notice was given to the Waste Management Branch in 1989 that the owners planned to double this capacity in the near future.

* Air dried metric tonnes per day of fully bleached pulp off the machine.

A prospectus document was prepared as a Stage I Environmental Impact Assessment by E.V.S/Cirrus (1989) reviewing the present and proposed mill processes and aquatic impacts. After Federal and Provincial regulatory agency review of this document, certain deficiencies were identified. In response to a request from the Province's Major Project Review Process (MPRP) Steering Committee, Celgar submitted a Stage II report in 1990. A three member panel (the Celgar Expansion Review Panel), convened jointly by the Federal and Provincial Governments, studied the Stage II report, held public and technical hearings, and issued its recommendation of approval in principle for the project in December, 1990. The final report and recommendations were released in February, 1991.

Detailed process descriptions of the present mill and a summary of effluent flow were given in the Kootenay Air and Water Quality Study reports (W.I.B., 1977, 1979) and are given here as Figures 8-10. There has been no significant modification of mill processes or effluent flow rates over the past decade since these studies were conducted (C. Johnson, personal communication). The woodroom with its two hydraulic debarkers was closed in January 1988. Currently, the wood supply is in the form of chips delivered by truck and from the Westar sawmill via conveyor.

Wood chip feedstock for the present pulp mill comes either from the sawmill complex (dry debarking) or is purchased from outside sources. The key mill components which best summarize the pulping and bleaching processes include

- two Kamyr continuous digesters
- three-stage brown stock washers
- a chemical recovery boiler (presently operated under overloaded conditions)
- one recausticizing rotary kiln
- a bleach plant of the conventional five-stage CEDED sequence with a Kajaani control system
- Fourdrinier type wet end Flakt air-borne drier

Chlorine consumption to date has been high: 53 kg/ADt (C. Johnson, personal communication). At maximum production, this usage would equate to 29.6 tonnes of chlorine per day or approximately 10 000 tonnes of chlorine per year. Chlorine dioxide consumption is presently 13.5 - 14 kg/ADt.

Process effluents are collected in three separate sewers, known as the general, alkaline, and acid sewers. The acid sewer (28 000 m^3/d) contains acidic effluent from the chlorine (C) and chlorine dioxide (D) bleaching stages, and the alkaline sewer (25 500 m^3/d) contains wash water from the two caustic extraction (E) stages. The general sewer (60 500 m^3/d) contains effluent from the woodroom and sawmill clarifier (when operating) and effluent from the pulping, recausticizing, and recovery processes. The effluent from the general sewer may contain high levels of residual black liquor and organic material from the washers representing high BOD, colour, and resin acids. The bleach plant is the most important single source of the characteristic brown colour of bleached kraft effluent (McCubbin, 1983). Some mill studies have shown that bleach plant wastes account for half of the acute toxicity of whole mill effluent (Sprague, 1988). The general, acid, and alkaline sewers are combined in a foam tank which discharges up to 204 000 m^3 of untreated effluent per day (maximum present level) to the Columbia River via a submerged diffuser located 3.3 km downstream from the Hugh Keenleyside Dam.

The recovery boiler of this mill has been operating at over-capacity for a number of years, causing less than optimal black liquor recovery (permit file). This has resulted in high BOD loadings and toxic effluent. Although effluent treatment has not yet been implemented, there have been modest process changes over the past decade which have improved some characteristics of the effluent and mitigated its toxic nature. These have included:

- effluent pH neutralization system (control to the range of 6.0 - 8.5) which commenced in 1988.
- chlorine reductions through introduction of 20 - 40 % chlorine dioxide substitution, the installation of high shear mixers in the CE and D stages of bleaching, and the addition of another caustic extraction (E) stage.
- elimination of debarker effluent with the closure of the woodroom in 1988.
- installation of spill recovery systems, power boiler fly ash screens, and a recausticizing effluent clarifier, have contributed to reducing the suspended solids load.

By present industry standards, the Celgar pulp mill is functionally obsolescent, with rudimentary effluent control facilities. The mill's high chemical consumption has resulted in poor effluent quality and high manufacturing costs (Sandwell and Co. Ltd., 1985). As specified by the Variance Order (see Section 4.3.2) and as outlined in the mill expansion environmental impact assessment report (EVS/Cirrus, 1989), the Company is committed to a program of modernization and expansion which will provide both economic benefits and significant effluent improvement by 1996. The expected result of this modernization program would be for the effluent to meet or be better than Level A Pollution Control Objectives (PCB, 1977).

4.3.2 DESCRIPTION OF PROPOSED EXPANSION AND DISCHARGE

Celgar received government approval to rebuild and expand its present pulp mill increasing production from 560 to 1200 ADt/d (annual production would be 420 000 ADt) in December, 1990. The expansion involves construction of an almost new mill at the existing site (E.V.S. Consultants Ltd. and Cirrus Consultants Ltd., 1989; Celgar Pulp Co. 1990). The Celgar Expansion Review Panel recommended approval of the proposed process technology because it accords the "best available control technology" for minimizing environmental effects and because it exceeds the most stringent standards of the Federal and Provincial governments.

Only some of the existing mill will be retained, including the paper machine, the chip facility, and a power boiler. Some of the specific changes to the mill's process which will reduce effluent loading to the river include:

- lower chlorine consumption which will drop to: 8.8 kg/Adt of chlorine and 17.8 kg/Adt of chlorine dioxide.
- modified or extended continuous pulp cooking (extended delignification) and oxygen delignification which will remove more lignin from the wood fibres. The residual lignin content will decrease to 7 %, which is a 50 % improvement over the existing digestors. This will result in a reduced waste organic loading to the sewers. Less lignin will enter the bleaching stage, thereby reducing the production of organochlorines (AOX).
- more efficient brownstock washing which will minimize chemical use in the bleaching stages and reduce loss of cooking liquor to the sewer.
- high chlorine dioxide substitution in the first bleaching stage (70 %). The mill will have the capacity to increase the substitution level beyond 70 % in the

future. The activated sludge treatment system proposed for the Celgar mill is reported to have the capability of producing a non-toxic effluent (i.e., 96-h LC50 $\geq$ 100 %) and of reducing BOD by approximately 90 % and AOX by approximately 40 % (Celgar Pulp Co., 1990). Microbial degradation (via dehalogenation) is largely responsible for reducing the chlorinated organic compound content. Secondary clarification after biological treatment is expected to produce low suspended solids concentrations in the discharge: 28 mg/L in summer and 31 mg/L in winter (after the addition of cooling water). The biosolids that are sedimented by the secondary clarifiers will be recycled to the biotreatment basin and eventually combined with the primary sludge, thickened, dewatered, and then burned in the power boiler. These biosolids that are to be incinerated are estimated to contain 47 kg AOX/d (equivalent to 0.04 kg AOX/Adt. The biosolids that remain suspended and are discharged to the river with the treated effluent are estimated to contain 15 kg AOX/d or 0.013 kg AOX/Adt. Further discussion of projected effluent quality achievement from the modernized mill will be discussed in detail in Section 4.3.3. The fate of the treated effluent from the modernized mill (as currently proposed) in the receiving waters will be further discussed in Section 5.

- installation of foul condensate stripping which will mean that more contaminants are burned in the lime kiln instead of being sewered. Reductions in BOD and toxicity will result.
- improvements to spill recovery and recycling inside the mill and installation of a 24-hour emergency spill control basin with a capacity of 100 000 m^3.

Modernization means that mean effluent flow will be reduced from 116 000 m^3/d to 93 600 m^3/d (summer) and 80 400 m^3/d (winter), chlorine usage will drop by at least 40 %, and dioxins/furans should be reduced to levels below current detection limits. The process effluent will receive secondary treatment for the first time in the mill's history. The effluent will be pumped 2.5 km west of the mill to a proposed activated sludge treatment system with 48-hour retention. The treatment system will include a primary clarifier, an aerated activated sludge bioreactor for cooling the effluent and biological treatment, and two secondary clarifiers. The treated effluent will be piped back to the mill site, mixed with the uncontaminated cooling water in the existing foam tank and discharged to the Columbia

River through the existing diffuser. Primary and secondary (biological) sludge will be piped back to the mill for dewatering and incineration in the hog fuel boiler.

Modernization of the mill will also include features to minimize leachate generation such as dykes and continuous curbs to contain accidental spills, and clay lining the biotreatment system to minimize leakage. Celgar is committed to groundwater well monitoring prior to the modernization at four locations: 1) the landfill site, 2) the chip and hog fuel piles, 3) chemical handling facilities, and 4) the biotreatment ponds. The chemical analysis will include general characteristics as well as AOX and resin acids (Celgar,1990). Celgar is committed to continuing this well monitoring after expansion. It is recommended that groundwater well monitoring of the landfill also include dioxins and furans.

4.3.3 PERMIT HISTORY

The Castlegar pulp mill was the first kraft mill built in the B.C. Interior with operations commencing in 1961. Waste Management Branch Permit PE 1272 was issued September 17, 1973 authorizing primary treatment measures including a clarifier and a foam tank for the combined effluent discharging through a single submerged outfall with a diffuser.

Permitted effluent characteristics for the original permit are shown in Table 7. The permit required the Company to meet Level B Objectives for the Forest Products Industry by the end of 1975. Biological treatment of the effluent would have been required. This was not done and the Company was allowed to defer the effluent upgrading pending the results of the Kootenay Air and Water Quality Study (W.I.B. 1977, 1979). The report recommended achievement of better than Level B for effluent toxicity (40 % instead of 30 %).

Negotiations between the Company and Waste Management Branch during 1981 and 1982 resulted in agreement to upgrade to Level B through biological treatment including biobasins, settling ponds, pH control, and spill control works. Biological treatment was deemed essential to reduce effluent acute toxicity, especially because of its effectiveness at degrading resin and fatty acids. The permit was amended May 26, 1982, to reflect the proposed changes and established interim levels at Level B and target levels at Level A to be implemented by December 31, 1984 (Table 7).

The amended permit was appealed in 1983 on economic grounds. The Environmental Appeal Board granted the Company a further deferment for the effluent upgrading to December 31, 1987, by which time the effluent was to meet Level A. The Board also required that the Waste Management Branch and the Company negotiate acceptable interim levels that the Company could meet using existing treatment works. The permit was amended January 5, 1984, reflecting the above ruling and incorporated interim effluent levels lower than Level B (Table 7).

Shortly after this amendment, the Company proposed a ten-year program of upgrading based on an oxygen delignification scheme involving modifications to the pulping and bleaching processes. The Company requested that the Minister accept a ten year Mill Modernization Program and on July 10, 1986, a Variance Order was issued under the signature of the Minister allowing the Company ten years to meet the effluent characteristics in the amended permit by June 30, 1996. The Variance Order did not specify interim effluent requirements. As of the end of 1991, the Celgar pulp mill was the only Interior mill in the province without the secondary treatment works necessary to bring the effluent quality up to Level B of the current Objectives. As with all other pulp mills in B.C. using chlorine bleach, Celgar was required by the Minister of Environment to reduce effluent organochlorines (AOX) to 2.5 kg/ADt by the end of 1991 (announced on May 12, 1989). The new Minister of Environment, Lands and Parks changed this value to 1.5 kg/ADt by the end of 1995 (announced January 16, 1992). With mill modernization proceeding, Celgar is expected to meet the 1.5 kg/ADt objective by July 1, 1994.

The Celgar Expansion Review Panel (1990) concluded that the historical record of non-compliance and the past practise of variance to the effluent discharge permit are unacceptable and that future inspection and enforcement should be rigorous.

4.3.4 PRESENT WASTE LOADS

a) Flow

Only three out of 1695 effluent measurements over the period of 1983-1988 exceeded the target level of 170 000 m^3/d. None of the effluent flow values measured between 1986 and 1990 have exceeded this value. The mean effluent flow for the years 1981 to 1988 was 116 000 m^3/d (1.3 m^3/s). At a minimum river flow of 142 m^3/s, the minimum dilution ratio of effluent to river water would be 1:109 (0.9% effluent), once mixing is complete.

At the maximum recorded effluent flow of 204 000 m^3/d (Table 9), the Columbia River would provide dilution of 60:1 (1.6% effluent) during a low river flow of 142 m^3/s. This worst-case calculation assumes that maximum effluent flow and low river flow occur simultaneously. This dilution would be achieved only after complete mixing, which would likely occur several kilometers downstream since the river is quite wide (approximately 336 m at low flow) at the outfall. The authors of the Kootenay Study (W.I.B., 1979) estimated that complete mixing would only occur 4 km downstream at the ferry crossing. Within the 100 m initial dilution zone, the minimum dilution is estimated to be greater than 30:1 (3.3% effluent) (Figure 11). This was calculated using the method presented in W.I.B. (1979) and is based on a maximum effluent flow of 204 000 m^3/d, a river velocity (mid channel) of 0.049 m/s, and a cross-sectional area of the effluent plume equal to 1500 m^2 at 100 m downstream from the outfall.

As mentioned previously (Section 4.3.2), effluent flow is predicted to drop to 93 600 m^3/d (summer) and 80 400 m^3/d (winter) with the expansion and modernization of the pulp mill. At a low river flow of 142 m^3/s, effluent dilution after complete mixing would be 131:1 (summer) and 152:1 (winter). Using a computer dilution model (UMERGE), Celgar (1990) has predicted a worst-case dilution at the end of the initial dilution zone to be 60:1.

b) BOD_5

BOD concentrations for the recent period of measurement (1981 - 1990) have remained consistent with those measured in the 1975 - 1977 W.I.B. study. (Table 9). In the April, 1990 sampling, the effluent BOD averaged 127 mg/L and for the period 1981 to 1988, BOD averaged 182 mg/L. This compares to the 1975 - 1977 average concentration of 195 mg/L. Total organic carbon (TOC) concentrations (a measure of BOD - producing materials) have also remained at high levels (averaging 275 mg/L) compared to those in the 1970's (averaging 220 mg/L).

The BOD load in untreated bleached kraft mill effluent such as Celgar's is a function of the quantity of lignin in the pulp entering the bleach plant and the efficiency of in-plant sytems in containing and recycling spills (EVS/Cirrus, 1989). With poor performance in both these areas, Celgar's past BOD_5 loads have consistently exceeded the permit level of 5600 kg/d. Over the years 1986-1989, all BOD_5 measurements of the pulp mill effluent have exceeded this level. In April, 1990, EVS Consultants measured a maximum BOD load of 14 893 kg/d. Approximately nine percent (23 out of 268) of the BOD_5 measurements over the period 1983-1989 exceeded the interim level of 40 000 kg/d given in the 1984 amended permit. During the last two years of sampling, a maximum BOD_5 load of 57 800 kg/d was recorded on July 21, 1987 (Table 10).

Present maximum BOD loadings from the pulp mill are theoretically high enough to have some effect on the dissolved oxygen levels in the Columbia River using simplistic dilution calculations. During a low flow of 142 m^3/s, the predicted maximum increase in receiving water BOD_5 concentration is estimated to be 4.6 mg/L. At the edge of the initial dilution zone (i.e., within the zone of influence), we would expect a higher BOD_5 concentration. The minimum dissolved oxygen level measured in the Columbia River upstream from the paper mill was 11.7 mg/L (Table 11). Under present worst-case conditions presented in Table 10, dissolved oxygen outside the mixing zone would be reduced to 11.7 - 4.6 = 7.1 mg/L. The CCREM (1987) guideline for dissolved oxygen (cold water biota with salmonid early life stages present) is 9.5 mg/L.

The above predictions overestimate considerably the potential for dissolved oxygen depletion since they do not consider the positive effects of supersaturated conditions, reaeration, lower temperatures, and time-dependent BOD exertion during the travel time from the waste source. The travel time from Celgar to Kootenay River is estimated to be a maximum of 1.5-2 days, and thus only a portion of the five day BOD could be exerted (W.I.B., 1979). In actual fact, the available dissolved oxygen monitoring of the Columbia River receiving waters in this reach downstream from Celgar indicates minimum surface dissolved oxygen levels of >10 mg/L (Table 11; B.C. Hydro, 1985) and no serious reduction in dissolved oxygen downstream from the pulp mill. All measurements have been fully saturated levels. Dwernychuk (1988) found that waters below the Keenleyside Dam contained 124 % dissolved oxygen and that this declined to 116 % 500 m downstream from Celgar due to the high BOD-containing effluent. This is still higher than the 111 % of the Kootenay River input. Although a definite decline is observable, it is not critical and it allows sufficient assimilative capacity for the downstream Castlegar discharges.

With the proposed pulp mill expansion and modernization, effluent BOD loading is expected to be reduced to an annual average of 2.0 kg/ADt (Celgar Pulp Co., 1990). The current B.C. Level A objective for kraft mill BOD is 7.5 kg/ADt (monthly average and daily maximum). At Celgar's proposed daily production of 1200 Adt/d, the average daily BOD discharge is projected to be 2400 kg/d. The BOD concentration in the final effluent (after cooling water addition) is expected to be 26 mg/L in summer and 30 mg/L in winter. Considering seasonal dilution [Section 4.3.3 (a)], the BOD concentration in the river after complete mixing would be 0.2 mg/L. Such a level would not have a measurable effect on the D.O. regime of the Columbia River.

The attainment of 2.0 kg BOD/ADt assumes that the proposed effluent treatment system can achieve a BOD removal efficiency of 90 %. Levels of up to 97 % BOD removal are being achieved currently at Consolidated Papers, Wisconsin Rapids, a bleached kraft mill with an activated sludge treatment system similar to that proposed for Celgar (Celgar Pulp Co., 1990).

c) Suspended Solids

Suspended solids discharged from pulp mills are largely comprised of cellulose fibres, wood chips, and bark fines, with a smaller portion being inorganics such as boiler ash and calcium carbonate (Colodey et.al.,1991). Suspended solids loading for the seven-year period from February 1983 to February 1990 ranged from 2.2 to 96.2 t/d and averaged 8.7 t/d. The maximum suspended solids load was recorded on September 9, 1986. Mill efficiency as it relates to fibre loss can be calculated by dividing suspended solids loading by tonnes of production. For Celgar, dividing the range of suspended solids loadings by the daily pulp production gives an efficiency range of 3-172 kg per tonne of pulp produced (average of 15.5 kg/t). Values for B.C. coastal mills range from 7.7 to 17.7 kg per tonne of production (Colodey et.al.,1991), thus indicating that under present conditions the Celgar mill is up to an order of magnitude more inefficient. It is also up to 4.4 times more inefficient than the Cornerbrook Pulp and Paper Ltd. mill in Newfoundland, which was reported by Colodey et.al. to have the highest fibre loss of all Canadian mills.

Over the period of January, 1987 to January, 1989, 49 of the 100 loadings measured exceeded the target loading level of 7450 kg/d given in the 1984 amended permit. Under conditions of the maximum loading during a low flow of 142 m^3/s, the predicted maximum increase in the receiving water suspended solids is estimated to be 7.8 mg/L after complete mixing (Table 10) and approximately 15 mg/L at the edge of the initial dilution zone. This predicted increase within the mixing zone exceeds the B.C. criterion of a maximum 10 mg/L increase for waters with background suspended solids levels of <100 mg/L. Actual measurements of suspended solids in the Columbia River at site 0200200 (at Castlegar) for the period 1980 - 1984 ranged from 1 to 7 mg/L (n = 28) (Table 11). Dwernychuk (1988) found suspended solids at a point 1.6 km downstream from Celgar to be slightly elevated (3.3 mg/L compared to upstream control levels (<1 mg/L). These actual increases may be significant relative to the observed ambient suspended solids levels, but such augmentations would not cause water quality impairment. The effects of suspended solids loading on bottom sedimentation is discussed in Section 5.1.1 (b).

The modernized Celgar mill, as currently proposed, is predicted to discharge an average annual suspended solids load of 2.13 kg/ADt (or 2.6 tonnes/d at a production rate of 1200 ADt/d) (Celgar, 1990). This means that the fibre loss would be 2.2 kg/t, i.e., approximately seven times more efficient than at present (see above). Since a large portion of the hydrophobic organic compounds (e.g. dioxins) is associated with suspended solids, these future mill improvements could be expected to limit the release of particulate-associated contaminants.

The concentration of suspended solids in the final effluent (after cooling water addition) is projected to be 28 mg/L in summer and 31 mg/L in winter. Given the available river dilution (Section 4.3.3 a), suspended solids levels in the river after complete mixing would be expected to increase by only approximately 0.2 mg/L.This assumes that the treatment system clarifiers can achieve concentrations of less than 50 mg/L, as Celgar has predicted from their review of the literature and data from existing similar systems.

Most of the suspended solids from the proposed secondary treatment process will be biosolids, i.e. fine, non-settleable solids composed of incompletely digested waste with some residual treatment system bacteria. At this time, Celgar is not proposing to use polyelectrolytes in the clarifiers to remove these biosolids completely . If settling aids are deemed necessary by the Regional Environmental Protection Branch, Celgar will add tertiary clarifiers (Celgar, 1990).

d) pH

Pulp mill effluent toxicity is strongly pH-dependent with the lowest toxicity in the range of pH 8.5 - 9.5 (Taylor et. al., 1988, McLeay et. al., 1979). This is attributed to the ability of more acidic pulp mill effluent to increase bioavailability of contaminants and resin acid toxicity. McLeay showed that the toxicity of whole kraft mill effluent to rainbow trout declined as the pH was increased from 5.0 to 9.5. The same relationship held for the toxicity of the resin acid, dehydroabietic acid.

The Celgar pulp mill effluent has been highly variable in the past (ranging from pH 1.1 to pH 12.5), but normally acidic (mean pH of 5.6) (Table 9). Over the period of March, 1987 to March, 1988, 61 % of the daily pH measurements (214 out of 350) were outside of the target pH range of 6.0 - 8.0, as specified by the 1984 amended permit. For the latest period of SEAM data reviewed (January, 1989, to March, 1990) effluent pH ranged from 3.1 to 11.0 and averaged 6.7 (n=332). In April, 1990, EVS Consultants found that pH ranged from 3.2 to 6.7 and averaged 5.6 for seven samples (Celgar, 1990). These data do not indicate the level of improvement in effluent pH as promised by the new effluent neutralization system installed in 1989 to control pH between 6.0 and 8.0. Better pH control would help attain lower effluent toxicity. Celgar (1990) has predicted that the pH of the treated effluent from the modernized mill will fall within the range of 6.5 to 8.0.

e) Temperature

Pulp mill effluent toxicity is greater at elevated temperatures (McLeay, 1976). As well, higher water temperatures can increase the metabolic oxygen demand of the aquatic biota, and add hyperthermia to the stress load.

Temperature of the effluent over six years of record (1983 - 1988) averaged 30°C and ranged up to 39°C (weekly means) (Table 9). Sampling over the past year of record (1989-1990) showed that effluent temperature averaged 26°C and ranged between 20°C and 30°C. In April, 1990, EVS Consultants found that the effluent temperature ranged from 31°C to 36°C and averaged 34°C among seven grab samples (Celgar, 1990). The effect of adding heated effluent to the Columbia River is negligible outside the initial dilution zone. With an effluent temperature of 39°C at a maximum effluent flow of 2.36 m^3/s during a low flow (142 m^3/s) with an ambient water temperature of 16°C, the elevation in temperature after complete mixing would be 0.37°C. If the same volume and temperature of effluent were discharged during the winter with a low flow, an ambient temperature of 3°C would be increased by 0.6°C after complete mixing. Within the initial dilution zone the temperature increase is estimated to be approximately 1°C.

Dwernychuk (1988) observed that mill effluent discharged at a temperature of 28°C into a Columbia River flow of 420 m^3/s did not affect receiving water temperatures at the nearest site 500 m downstream from the diffuser.

In the proposed effluent treatment facility for the modernized mill, the temperature of the effluent will be reduced from an incoming temperature of 55 - 60°C to the recommended maximum of 35°C for proper operation of the biological treatment system. Cooling will be carried out in the first part of the activated sludge lagoon assisted by air spraying the effluent. The temperature of the final treated effluent discharged to the river will be 35°C. As seen above in the projections for 39°C effluent, the temperature increase in the river will be less than 1°C outside the initial dilution zone. Heated effluent is more buoyant in cool receiving waters causing the plume to rise rapidly, thereby promoting mixing. Modernization will mean little change from the present thermal regime.

f) Toxicity

The rainbow trout bioassay data for the period January, 1987, to February, 1989, indicate that the 96-h LC50 of the pulp mill effluent ranged from 2.4 to 19 % effluent concentration. For the period, February, 1989 to March, 1990, the LC50 ranged from 2.6 to 29.7 % and averaged 13 % (SEAM). In April, 1990, the toxicity of three grab samples taken by EVS Consultants ranged from 13 to 24 % (Celgar, 1990). These levels indicate that the Celgar effluent is of moderate toxicity and presently of comparable toxicity to most other untreated kraft mill effluents. Frequency of spills and lack of spill control likely accounts for the variation in toxicity.

All toxicity tests for this recent period failed to meet the Level B objective (96-h LC50) of 30 %). Effluent quality has shown no improvement by comparison to pre-1979 data (range of 7.5 to 35 %) reviewed in the Kootenay Air and Water Quality Study Report (W.I.B., 1979) and in comparison to 1985 data (3.6 to 23 %) reviewed by Dwernychuk (1986).

An estimate of the potential toxicity of the effluent in the Columbia River can be calculated using the method of Esvelt et. al., (1973):

$TCr = \frac{TCe}{\text{dilution ratio}}$, where TCe equals the reciprocal of the 96-h LC50

i.e. $TCe = \frac{100}{96hLC50}$, where TCe equals toxic concentration of effluent

and TCr equals toxic concentration in the river.

The value of TCr, in toxicity units (T.U.) is a relative (i.e., not absolute) toxicity estimate for the river where effluent mixing is complete. A TCr value of 1.0 T.U. would indicate 50 % mortality of the fish in the river after a period of 96 hours. Extrapolation of the effluent toxicity data to the river was based on the following:

- the maximum acute toxicity value for 1987 - 1988 of 2.4 %.

- maximum effluent discharge (2.36 m^3/s) during a low flow (142 m^3/s) giving a dilution ratio of 60:1.

From such extrapolation the TCr in the Columbia River is thus extrapolated to be 0.7 T.U.. This is 7 to 70 times higher than the safe levels of 0.01 and 0.1 T.U. for persistent toxicants recommended by the U.S. National Technical Advisory Committee and the safe level of 0.01 T.U. for cumulative toxicants recommended by the National Academy of Sciences and National Academy of Engineering (cited from Singleton, 1980). Concentrations and hence toxicity would be even greater in the initial dilution zone before complete mixing has occurred.

Sublethal stress of the fish in the Columbia River would be prevented if effluent concentrations in the receiving waters were <0.05 of the 96-h LC50 (static bioassay) according to results from Walden (1976). Under conditions of a mean effluent flow (1.35 m^3/s) and assuming a mean toxicity (13 %), the risk of sublethal effects would be low if the effluent remained at 0.65 % in the water (Table 12). Avoidance of this stress would require a river flow in excess of 208 m^3/s after complete mixing. River flows of less than 208 m^3/s are expected to occur for approximately 5 % of the time. The probability of the occurrence of sublethal stress increases under conditions of greater effluent flow and greater toxicity (Table 12). Thus, for a maximum effluent flow of 2.36 m^3/s with a maximum present effluent toxicity (2.4 %), the flow required to avert sublethality is >1,967 m^3/s which occurs no more than 15 % of the time.

As explained in the Kootenay Air and Water Quality Study (W.I.B., 1979) and as shown in Table 12, total avoidance of sublethal conditions in the receiving waters would require a 96-h LC50 of not less than 40 % effluent concentration in water. The minimum flow required for this situation is 118 m^3/s (Table 12), which is always attained since the minimum Columbia River flow is established at 142 m^3/s.

An improvement in effluent toxicity to 100 % has been predicted for the modernized pulp mill by EVS/Cirrus (1989). Celgar (1990) expects that the acute toxicity standard would be met prior to the addition of cooling water. Similar results were found at other activated sludge treatment systems in present use at other pulp mills that were surveyed by

Celgar (1990). Secondary treatment of kraft mill effluent is capable of eliminating effluent acute toxicity by effective BOD reductions and degradation of the toxic resin acid and fatty acid compounds.

g) Toxic Organic Contaminants

Adsorbable Organic Halogens (AOX)

Most of the acute toxicity of untreated kraft mill effluent can be attributed to the non-persistent, natural components of wood released during pulping, i.e., resin acids and fatty acids (Leach and Thakore, 1973). The chlorination of these and other natural wood products produces a variety of chlorinated organic compounds that are of special concern because they are persistent, mutagenic, and bioaccumulative, besides being toxic. Approximately 300 low molecular weight organochlorines have been identified from bleach plant effluent, representing only 3-10 % of the total organochlorines measured as Adsorbable Organic Halogens (AOX). The identified organochlorines include chlorinated phenolics (chlorinated catechols, guaiacols, phenols), chlorinated resin acids and chlorinated fatty acids. About 80 % of AOX consists of an unknown number of unidentified high molecular weight organochlorines (Sprague, 1988). These have little toxicity, but can gradually decompose to low molecular weight chlorophenolics which may be toxic. Upon discharge to receiving waters these chlorinated organics can become sorbed to particulates, be dispersed, and contaminate an extensive area downstream.

A survey of Celgar's effluent by the CPPA (1989) determined that it contained 4.2 kg AOX/ADt. Subsequent tests by the mill indicated that the present average AOX level was 4.8 kg/ADt (EVS/Cirrus, 1989) i.e., over three times the Minister's mandated level of 1.5 kg/ADt by 1995. With a production of 560 ADt/d, the present AOX loading to the receiving waters would be 2688 kg/d (verified by Celgar's maximum measurement in April, 1990, of 2890 kg/d). With a minimum river flow of 142 m^3/s, the AOX concentration in the Columbia River after complete mixing would be 0.22 mg/L. Actual measurements are in agreement: MOE in 1989 found 0.28 mg AOX/L at a point 4 km downstream from Celgar and 0.21 mg AOX/L just upstream from the Kootenay River confluence.

The modernized Celgar mill has been predicted to meet and better the B.C. effluent objective of 1.5 kg AOX/ADt. Estimates of the quantities of AOX produced and disposed of through the treatment process for the modernized operation are shown in Figure 12. The Stage II report (Celgar, 1990) provides detailed rationale (from the literature or data from similar operating mills) for the assumptions used in generating these AOX estimates. The following briefly summarizes the sources and fate of the AOX as shown in Figure 12 and as detailed in the Stage II document.

Based on a literature review, Celgar has estimated that two areas of the bleach plant will generate all of the AOX in the pre-treated effluent: 62 % in the chlorination stage filtrate (1.24 kg/ADt) and the balance in the extraction stage effluent (0.76 kg/ADt). Thus, a total of 2 kg AOX/ADt is expected to be generated by the bleach plant. However, neutralization (by lime mud) of the bleach plant effluent will reduce AOX by 14 % so that 1.72 kg AOX/ADt is expected to enter the secondary treatment facility. The activated sludge system has been estimated to reduce the AOX by a further 40 %. The AOX in the treated effluent is predicted to be 1.03 kg/ADt (1240 kg/d). This is a reduction of 54 % from present untreated levels at half the production.

The modernized mill is predicted to discharge 1.03 kg AOX/ADt or 1240 kg/d. With a low river flow of 142 m^3/s, the AOX concentration in the Columbia River after complete mixing would be 0.1 mg/L (approximately 3.5 % of the time), i.e., less than half the present calculated level of 0.22 mg/L.

Celgar expects that most of the discharged AOX will be in the high molecular weight fraction (MW>1000), since these are more likely to be resistant to biodegradation. (The removal rate of the non-volatile low molecular weight fraction is approximated to be 80 %). The 1.03 kg/ADt of AOX discharged to the river is expected to contain 0.96 kg/ADt of high molecular weight compounds and 0.07 kg/ADt of the low molecular weight compounds. The identity and character of these high molecular weight compounds is not well understood at present.

The modernized mill is expected to generate 10 800 kg of biosolids per day, of which 24 % (2560 kg/d) will be lost to the receiving environment (the larger portion captured by the clarifiers will be incinerated). The amount of AOX in the biosolids discharged with the effluent is estimated to be 0.013 kg/ADt (or 15 kg/d). This is less than 1 % of the AOX generated in the bleach plant. The reason for such a low discharge has been attributed by Celgar to the dehalogenation of the organochlorines absorbed to the biosolids, apparently via microbial action.

Dioxins and Furans

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) have also been found in bleached kraft pulp mill effluent (Amendola et. al., 1987). Dioxins and furans are believed to be derived from PCP (polychlorinated phenol) contaminated wood chips (used to prevent sap stain fungus from discolouring lumber), and formed as the result of the chlorination of precursor molecules that are found either in the wood itself (especially lignins) or in added chemical defoamers. It is now Celgar's policy not to accept chips that are contaminated with PCP, and since 1989 Celgar has required its suppliers to provide defoamers which do not contain precursors of dioxins/furans.

There are approximately 75 dioxin congeners* and 135 furan congeners - all varying greatly in toxicity. The best known and most toxic dioxin is 2,3,7,8 tetrachlorodibenzo-para-dioxin (TCDD). 2,3,7,8 TCDD is known to have extraordinarily high toxicity to certain experimental animals: the LC50 for the guinea pig was determined to be 0.6 μg/kg body weight. TCDD also causes reproductive effects in experimental animals and is a proven carcinogen in rats and mice (Tschirley, 1986), although not a mutagen (Sprague, 1988). The U.S. EPA (1985) has classed 2,3,7,8-TCDD as a probable human carcinogen. The International Agency for Research of Cancer (IARC) has classified 2,3,7,8 TCDD as a possible carcinogen (as opposed to a probable carcinogen). Results from human studies, however, have not shown definitive carcinogenic effects.

Aquatic organisms are also extremely susceptible to the 2,3,7,8-isomer: Miller et. al., (1979) reported only 47% survival of juvenile coho salmon after 114 days following a 96-h exposure to 5.4 ng/L 2,3,7,8 TCDD. Short -term exposures of fish to TCDD have resulted in chronic effects such as reduced growth, fin necrosis, edema and liver

* a congener is a member of a related family of chemicals and is used for dioxins to mean any isomer of any homologue. Homologues are members of a series of organic compounds where there is a constant difference between each member of the series, and isomers are compounds with identical chemical constituents but in different arrangements.

degeneration. More recently, Mehrle et. al., (1988) reported a 56-d LC50 for rainbow trout of 46 pg/L. Exposure of rainbow trout to 38 pg/L caused growth reduction and abnormal swimming and feeding behavior. The effects of the other chlorinated dioxins and furans on aquatic invertebrates are less well known. Of major concern, is the persistence and bioaccumulation of these compounds: the half-life of fish whole body TCDD residues is in the order of 100-300 days.

Celgar's final effluent was sampled for dioxins and furans for the first time on July 18, 1989, by the Canadian Pulp and Paper Association during the National Mill Dioxin Characterization Survey (CPPA, 1989). Just before this sampling, Celgar took steps to attempt a reduction in dioxin/furan production by: 1) switching to precursor-free defoamers; 2) changing over to 20 or 40 % chlorine dioxide substitution and; 3) by using high shear mixers in the chlorination stages. It is thus probable that dioxin and furan levels in the past were higher in the effluent prior to these process changes.

Table 13 presents the analytical results and the translation into toxic equivalents of 2,3,7,8 TCDD (the toxicity of the various congeners are compared to the toxicity of 2,3,7,8 TCDD by toxic equivalence factors or TEFs; see summary, Table 14). Most of the results are less than the analytical detection limits including that for the most toxic isomer TCDD. The only dioxin detected was the hexachloro-congener (44 pg/L). The only furan detected was the tetrachloro-congener (total 480 pg/L). Each of these detected congeners have 0.1 times the toxicity of 2,3,7,8-TCDD, resulting in a total toxic equivalency of 52 pg/L. Assuming a low-flow dilution of 60:1 (Section 4.3.3(a)), this effluent level would produce a maximum receiving water level of 0.9 pg/L in the Columbia River after complete mixing. This is approximately 15 times lower than the interim national guideline of 15.0 pg/L for drinking water (MOE 1989), 50 times lower than the rainbow trout 56-d LC50 level reported above, and below current detection levels.

More effluent testing for dioxins and furans will be necessary to augment the results of this single sampling before definitive conclusions can be drawn.

Celgar expects that its modernized mill will have non-detectable levels of individual TCDDs and TCDFs in its pulp and bleach plant effluent. This is based on detection limits of 10 ppq which are now routinely achievable (ppq=pg/L in water). However, in terms of aggregate congener toxic equivalence (relative to 2,3,7,8 TCDD), toxic equivalency (TEQ) levels will be detectable, i.e., >11 ppq. The reason that 11 ppq TCDD TEQ's is projected to be present is related to the use of one half of the detection limit being used instead of 0 when all congeners are non-detectable.

With a bleach plant flow rate of 25.2 m^3/ADt at a production rate of 1200 ADt/d, the daily flow will be (25.2 x 1200) 30 240 m^3/d (3.024 x 10^{13} mg/d). The amount of TCDD/TCDF expected in the bleach plant effluent will be (3.024 x 10^{13} x 11 x 10^{-15}) 0.333 mg TEQ/d (Celgar, 1990). Assuming that the suspended solids in this effluent contain 35 % of the TEQs and that the primary clarifier removes 95 % of these suspended solids, the TEQ removed at the primary clarifier will be (0.333 x 0.95 x 0.35) <0.111 mg TEQ/d. The remainder in the aqueous phase (0.333 - 0.111) 0.222 mg TEQ continues on to the treatment system. After biological treatment it is presumed that the biosolids will contain virtually all of the dioxins/furans. Since only 24% of the biosolids are discharged, the quantity of TEQs discharged to the river will be (0.222 x 0.24) <0.053 mg TEQ/d. Based on the above assumptions, this works out to a concentration of <0.57 TEQ ppq in summer and <0.66 TEQ ppq in winter (Celgar, 1990).

Fatty Acids

A variety of chlorinated fatty acids (e.g., dichlorostearic acid) and non-chlorinated fatty acids (e.g., oleic, linoleic, linolenic, epoxystearic acids) have been reported found in untreated bleached kraft mill effluent, though generally at or below the respective individual LC50 values (McLeay, 1987). Fatty acids are readily degraded and are not considered persistent: biotreatment reduces the concentration of fatty acids in mill effluents by over 70 %, to levels that are below acute lethality. Resin and fatty acids are the most acutely toxic component of pulp mill effluent to fish; however, fatty acids are less toxic to aquatic life than resin acids. Fatty acid levels have not been monitored in the Celgar effluent.

The modernization of the mill is expected to result in substantial removal of fatty acids from the pulp prior to the bleaching plant instead of being sewered as practiced presently. Estimates of fatty acid levels in the final treated effluent have not been provided by Celgar.

Resin Acids

Before dioxins and furans were found in pulp mill effluent, resin acids had been reported as being responsible for as much as 70 % of the toxicity of whole mill effluent (Leach and Thakore, 1976). Resin acids, like fatty acids, are released to the effluent stream during the bark removal and pulping stages. The non-chlorinated resin acids are considered to be less persistent than the chlorinated forms: biological treatment in aerated lagoons normally reduces their concentrations by at least 90 % to levels below acute lethality (McLeay, 1987).

Between 1975 and 1977, total (non-chlorinated) resin acid levels in the Celgar effluent were reported (WIB, 1979) to range from 0.4 to 14 mg/L (with a mean of 3 mg/L). Between 1977 and 1990, effluent resin acids were measured four times (Table 15): 1) on June 12, 1988, total resin acids equalled 2.2 mg/L (Dwernychuk, 1988); 2) on May 16, 1989, the Wastewater Technology Centre Laboratory measured a total resin acids level of 10.7 mg/L; 3) during the period April 12 - 14, 1990, samples taken by EVS Consultants showed that total resin acids ranged from 0.464 to 1.168 mg/L; and 4) on May 29, 1990, total resin acids equalled 0.323 mg/L. The recent results thus show a total resin acids range (0.3 - 10.7 mg/L) similar to and unchanged from that recorded in the 1970's.

Concentrations for each of the nine identified resin acids found in Celgar's effluent are given in Table 15. Inspection of the concentrations recorded by the Wastewater Technology Centre Laboratory might suggest that they are anomalously high by comparison to the other two data sets. However, these values are all within the range of concentrations found in other untreated bleached kraft mill effluents according to data compiled by McLeay (1987). These values are likely a good indicator of how high effluent resin acid levels can become at Celgar. With the exceptions of levopimaric acid and the chlorinated resin acids, all the recorded resin acids have been measured at levels exceeding their reported LC50 values, thereby indicating their presence in the effluent at acutely lethal levels. The major non-chlorinated resin acids found in Celgar's effluent include: dehydroabietic acid, abietic acid, and isopimaric acid. These are also the main resin acids found in other untreated bleached kraft mill effluents (McLeay, 1987).

Given an estimated effluent flow of 1.123 m^3/s on June 22, 1988, and assuming a concentration of 2.2 mg/L, the total resin acids loading to the receiving water would be 213 kg/d. With a low river flow of 142 m^3/s, the predicted maximum increase in receiving water total resin acids level is estimated to be 17 µg/L after complete mixing and 34 µg/L just ouside the initial dilution zone (assuming that the effluent mixes with half of the river flow at that point). These predictions have been verified by actual receiving water measurements (Table 15 and Section 5.1.1). Assuming a maximum effluent concentration of 10.7 mg/L, as measured in 1989 by the Wastewater Technology Centre, the total resin acids loading to the river would be five times higher (1038 kg/d), as would be the predicted receiving water levels at low flow (85 µg/L after complete mixing and 170 µg/L at the edge of the initial dilution zone). The resulting resin acid levels in the river would exceed the B.C. working criteria for total resin acids for the protection of aquatic life (9-60 µg/L at pH 6.5-8.5; Pommen, 1991).

With biological treatment at the proposed modernized mill, Celgar has assumed a 90 % reduction in levels of non-chlorinated resin acids. The resin acid load in the treated effluent has been predicted to be 1.1 kg/d (14 µg/L) in the Stage II document (Celgar, 1990). This loading is 200 - 1000 times lower than actual loadings recorded on June 22, 1988, and May 16, 1989, as discussed above. Predictions as to how much of this load will be in the chlorinated state have not been advanced. Data presented by Celgar from a variety of mills indicate that biotreatment may result in chlorodehydroabietic acid levels of <1 - 260 µg/L and dichlorodehydroabietic acid levels of <10 - 152 µg/L. Celgar expects that the concentrations in their final effluent will be near or below the low end of these ranges because of improved technology. With a projected total resin acids load of 1.1 kg/d discharged to a low river flow of 142 m^3/s, the maximum increase in the receiving water total resin acids level would be 0.09 µg/L after complete mixing and 0.2 µg/L just outside the initial dilution zone (i.e., less than current detection limits and less than the B.C. working criteria for total resin acids).

Chlorinated Lignins and Phenolics

Process-derived chlorophenolics and chlorolignins in bleached kraft mill effluent include 2,4-dichlorophenol, 2,4,6-trichlorophenol, dichloroguaiacol, 3,4,5- and 4,5,6-trichloroguaiacol, tetrachloroguaiacol, 4,5-dichlorocatechol, 3,4,5-trichlorocatechol and tetrachlorocatechol (McLeay, 1987). With the possible exception of tetrachloroguaiacol, the concentrations of these compounds in the effluent are generally below their 96-h LC50 values.

Unlike hydrophobic compounds such as dioxins and furans, chlorinated lignins and phenolics are hydrophyllic compounds that are less persistent, that bioaccumulate to a lesser extent, and that partition less to the sediments. They are also not highly persistent compounds, but have demonstrated long-range transport and uptake by fish. Dr. J. Carey (Environment Canada, Burlington) in his study of the mill at La Tuque, Quebec, found that the "half distance" or the distance downstream for a 50% reduction in the concentration of the first five chlorophenols (mono- to penta-) was in the range of 34 to 100 km. The chlorinated phenols and catechols have reported half lives of about a week, and the chlorinated guaiacols have half lives of only a few weeks (Bonsor et al, 1988 as cited by EVS/Cirrus, 1989). Tetrachloroguaiacol and trichloroguaiacol are known to be mutagenic. Secondary treatment can normally reduce these compounds by about 30 % (McLeay, 1987).

Various such chlorinated compounds have been detected in the effluent (Table 16). On May 16, 1989, the detectable chlorophenols included 5.1 µg/L of monochlorophenols (comprised of 1.2 µg/L 2-chlorophenol and 3.9 µg/L 4-chlorophenol) and 12.4 µg/L of trichlorophenol . The di-, tetra-, and penta- forms were not detected. Two chloroguaiacols were detected: the trichloroguaiacols were predominant (3,4,5 - at 97.6 µg/L and 4,5,6 - at 11.7 µg/L) followed by 4-chloroguaiacol (3.1 µg/L).

The effluent sample taken May 29, 1990, showed the presence of all five chlorophenol congeners in contrast to the 1989 sample. (Table16). Trichlorophenols (4.6 µg/L) were more abundant, followed by the dichlorophenols (2.8 µg/L). The trichloroguaiacols (19 µg/L) were most abundant followed by the dichloroguaiacols (14 µg/L) and the monochloroguaiacols (2.1 µg/L). The chlorinated catechols were present in the 1990 sample (total chlorocatechols = 27.2 µg/L), but not in the 1989 sample. At these concentrations, none of these compounds from the two samples would be detectable (at <1 µg/L detection limit) in the receiving waters after complete mixing at low flow, except for 3,4,5 trichloroguaiacol (estimated receiving water level of 1.6 µg/L).

It is expected that the activated sludge treatment system in the modernized Celgar mill will achieve 90 % removal efficiency of chlorinated phenolic compounds from the effluent (determined by comparison to other existing mills; Celgar, 1990). Such a reduction from the existing levels as shown in Table 16 would result in undetectable levels in the receiving waters (at low flow).

Minor Organic Contaminants

Mercaptans, terpenoids, chloroform, and sulphur-containing compounds are present in kraft mill effluent and contribute to the acute toxicity of whole mill effluent. However, their toxic contribution is relatively minor and, because of their non-persistence and volatility, they can be considered as lower priority pollutants. Sulfides have been measured up to 37.6 mg/L and mercaptans up to 28.8 mg/L in Celgar's effluent (W.I.B., 1979 and EVS/Cirrus, 1989).

Chlorinated sulphones and chlorinated acidic compounds (e.g. dichloroacetic acid, trichloroacetic acid) have been reported from bleached kraft mill effluent, but have not been monitored at Celgar. These compounds have higher resistance to biodegradation, and there is some evidence of bioaccumulation, although little is known of their biological action (McLeay, 1987).

With the exception of chloroform, information on the fate of these compounds was not provided by Celgar for its modernized mill. Information from which to make projections was not available in the literature since many of the processes proposed by Celgar are only now being put into commercial operation. Celgar (1990) does expect chloroform to be almost totally removed from the treatment effluent through volatilization into the air above the treatment lagoon. Celgar also expects that approximately 90 % of the chlorinated acidic compounds will be destroyed in the biotreatment system by microbial action.

h) Colour

The Celgar effluent has a dark brown colour, characteristic of bleached kraft mill effluent. The colour originates in the separated lignin fraction, especially the humates which combine with the extracted tannins. The process sources of the effluent colour are the bleach plant (most notably effluent from the caustic extraction stage), poor washing, and black liquor spills (McCubbin, 1983; Celgar, 1990).

In the period 1975 to 1977, W.I.B. (1979) found high levels of true colour in the untreated effluent (440 - 4000 TCU) (true colour is roughly equivalent to single wavelength colour, which is presently preferred for pulp mill effluents). Over the past decade (1980 - 1990) few effluent colour data have been collected; however, no process changes have been instituted during this time which would have caused any improvement in effluent colour. Recent sampling has shown this to be the case. Dwernychuk in 1988 and Celgar in 1989 measured effluent colour at 870 TCU and 2139 TCU (mg/L Co-Pt. units), respectively. Seven samples taken by EVS Consultants in April, 1990, ranged from 750 to 1000 TCU.

Mill measurements during the period November 29, 1989 to March 27, 1990, showed an average effluent colour discharge of 2360 TCU (or 230 000 kg/d) (Celgar, 1990).

The tannin and lignin content of the effluent has also remained correspondingly high. W.I.B. measurements ranged from 50 to 280 mg/L in the period, 1975 - 1977. Since then, Dwernychuk reported a level of 110 mg/L in 1988 and more recently EVS Consultants reported tannin and lignins ranging from 325 to 650 mg/L (mean of 475 mg/L).

Celgar has predicted the colour level in the modernized bleach effluent to average 44 kg/ADUt (ADUt means air-dried unbleached tonne). This was based on a review of laboratory studies which provided correlation of bleach plant effluent colour and kappa number (the latter relates to the pulp's lignin content and is used as a measure of mill process effectiveness). With the proposed 70 % substitution there should be a further 27.5 % reduction in the effluent colour, resulting in 33 kg/ADUt. This quantity will be augmented by other colour sources in the mill, which Celgar has estimated (by comparison to existing mills) to be 40 kg/ADUt. This produces a combined mill effluent colour of 73 kg/ADUt. Since secondary treatment does not effectively reduce colour levels, this is also expected to be the final effluent colour level. At an average production of 1200 ADUt/d, the modernized mill is expected to discharge 87 600 kg/d of colour units, i.e., a 62 % reduction from present levels. Given the varying seasonal effluent flows, Celgar has projected the colour to vary from 936 TCU in summer to 1090 ppm TCU in winter (Celgar, 1990). With a worst-case dilution of 60:1 (Section 4.3.3a), the colour increase in the Columbia River is expected to be 18 ppm TCU in winter and 16 ppm TCU in summer (at the edge of the initial dilution zone). These levels would exceed the B.C. working criteria for colour (15 TCU) for the protection of recreational use and drinking water (aesthetics).

i) Taste and Odour Causing Compounds

There has been no specific study over the past 10 years of compounds in the effluent which could cause taste and odour problems in the receiving waters. These compounds include chlorophenols (and especially their biomethylation products, the chloroanisoles and chloroveratroles), sulphides, phenols, methylethers, aromatic thiols, and mercaptans. W.I.B. (1979) determined that mercaptans were present in the effluent at levels up to 28.8 mg/L. In 1989, chlorinated phenolics were determined to be in the effluent (see Section 4.3.4g); however, there was no determination made of their breakdown products, the anisoles and veratroles, which have higher tainting potential. The Kootenay Study (W.I.B., 1979) reported that several sulphur-containing compounds, phenolics and terpenes, which could cause taste and odour, were present in the effluent and that the pulp mill effluent could impart taste and odour to river water at dilution ratios of at least 1000:1 and 8200:1, respectively.

Modernization of the mill and installation of foul condensate stripping and secondary treatment can be expected to reduce effluent taste and odour levels. However, quantification of such reductions was not attempted by Celgar.

j) Nutrients (Nitrogen and Phosphorus)

Effluent nutrient levels have not been regularly monitored over the past 10 years. Only during June, 1988, and April, 1990, were total phosphorus (0.5 mg/L), total nitrogen (2.0 mg/L), and total Kjeldahl nitrogen (1.31 mg/L; 1.7 mg/L) measured. W.I.B. (1979) reported mean effluent nutrient levels for the period 1975-1977 as follows: ortho-phosphorus 0.74 mg/L, total phosphorus 1.0 mg/L, Kjeldahl nitrogen 2.3 mg/L and nitrite/nitrate 0.44 mg/L. Total phosphorus loading equalled approximately 120 kg/d and total nitrogen loading equalled 350 kg/d.

An effluent total phosphorus concentration of 1.0 mg/L during low river flow could produce a worst-case increase in receiving water total phosphorus of 17 µg/L (after complete mixing; assuming 60:1 dilution). This is a doubling of ambient total phosphorus levels. With upstream ambient total phosphorus levels of 10-14 µg/L (MOE; Dwernychuk, 1988), a downstream total phosphorus level of up to 30 µg/L could be expected. In fact, Dwernychuk recorded downstream levels of up to 23 µg/L (500 m downstream).

With an effluent total nitrogen level of 2 mg/L and total Kjeldahl nitrogen of 1.7 µg/L, the predicted worst-case increases in the receiving waters would be approximately 33 µg/L for total nitrogen and 28 µg/L for Kjeldahl nitrogen. There are insufficient receiving water data (i.e., simultaneous, paired upstream and downstream samples) to prove such increases. However, comparison to the existing upstream data suggests that these are significant increases: up to a 50 % increase in Kjeldahl nitrogen and up to a 20 % increase in total nitrogen over average upstream ambient levels.

Based on published effluent nutrient levels at existing pulp mills, Celgar (1990) has estimated that, on the average, the modernized mill will discharge 511 kg/d nitrogen and 102 kg/d phosphorus. These estimates include both dissolved nutrients and those associated with the biosolids.

With the seasonally varying effluent flow rates, the effluent nutrient concentrations are estimated to be:

		SUMMER	WINTER
Nitrogen, Kjeldahl	mg/L	5.5	6.4
,Ammonia	mg/L	1.6	1.9
Phosphorus, Total	mg/L	1.0	1.2
,Dissolved	mg/L	0.5	0.6

These projected effluent nutrient concentrations represent significant increases over present concentrations: the nitrogen (Kjeldahl) levels are 3-5 times greater than present average concentrations, and the total phosphorus levels are twice as high as present average levels.

With a worst-case receiving water dilution of 60:1 under modernized conditions, the respective increases in Columbia River nutrients would be:

		SUMMER	WINTER
Nitrogen, Kjeldahl	mg/L	0.092	0.107
,Ammonia	mg/L	0.027	0.032
Phosphorus, Total	mg/L	0.017	0.020

The significance of these receiving water levels will be discussed in Section 5.1.1.n.

k) Chloride, Chlorate

The only effluent chloride measurements (1440 mg/L; 253 mg/L) for the present mill situation were reported by Dwernychuk (1988) and Celgar (1990). Under the condition of a worst-case dilution of 60:1, an untreated effluent level of 1440 mg/L could increase Columbia River chloride levels by 24 mg/L, which is below the B.C. water quality criteria for all uses. The present chlorate (ClO^{-3}) content of the untreated effluent has not been determined.

Future chloride levels after mill modernization are not known at this time. However, with the proposed shift to greater chlorine dioxide substitution, effluent chlorate levels are expected to increase, although to what level is not known. Accidental spills of chlorate might also be expected: Colodey et.al. (1991) reported that several such spills have occurred during the past few years at coastal pulp mills. Chlorate discharge is known to adversely affect marine brown algal (Fucus sp.) production (at 10-20 ug/L) (Colodey et.al.,1991), but to date there is no information to indicate the sensitivity of freshwater algae to chlorate or its environmental fate (D.Schindler, M. Bothwell: presentations to Technical Hearings, Celgar Expansion Review Panel).

The Celgar Expansion Review Panel has recommended: "that if chlorate is found to pose a water quality problem, the effluent treatment system be modified by a short anaerobic stage."

4.3.5 FUTURE WASTE LOADS

The following summarizes the expectations for future contaminant loading from the Celgar mill (assuming that modernization proceeds as planned), as reported previously in Section 4.3.4 and as predicted by Celgar (1990).

If the mill modernization and expansion proceed, mean effluent flow will drop from 116 000 m^3/d to 93 600 m^3/d (summer flow) and 76 900 m^3/d (winter flow) (Celgar, 1990). Projections of maximum flow were not available from Celgar. During a low river flow of 142 m^3/s, the worst-case dilution would be 60:1 (1.7 % effluent) at the edge of the initial dilution zone.

With mill expansion the BOD loading to the river is projected to decrease by 50 % from the present permit target level. Dissolved oxygen levels in the Columbia River can be expected to be as high if not higher than at present.

Suspended solids loading will decrease by 65 % from the existing target loading level, if the proposed effluent treatment system is implemented. The Celgar report (1990) estimates this future loading to be 2600 kg/d (average annual) based on a production rate of 1200 ADt/d. Rather than pulp fibres as presently discharged, the suspended solids in the future will be comprised of non-settleable biosolids from the treatment ponds. The chemical nature of these biosolids is poorly understood at present.

Improvement in effluent pH can be expected since the recently installed neutralization system will continue to be used and its operation refined. A future effluent pH of 6.5-8.0 can be expected. The temperature of the future discharge is expected to be considerably warmer: from the existing annual average effluent temperature of 26°C (1989-90 data), future effluent temperatures will average 35°C.

Effluent colour is expected to decrease by 62 % due to changes in the pulp process (extended cooking, oxygen delignification, better washing, etc.) Odour should be lower with the installation of foul condensate stripping. Because of secondary treatment, the effluent is projected to pass the 96-h LC50 tests at full strength, i.e., 100 % by volume. Effluent phosphorus loadings are expected to be 102 kg/d which is similar to known present maximum loading (112 kg/d). Total nitrogen loadings are projected to increase to 511 kg/d from the present 350 kg/d.

Toxic organic compounds will be significantly reduced. Volatile compounds and phenolics are projected to be virtually eliminated. Resin acids are expected to decrease from 213-1038 kg/d to 28 kg/d, and AOX is predicted to decline to less than 1.5 kg/ADt. This means that AOX loading to the river will decline by one third from the present loading of 2688 kg/d (i.e., average AOX of 4.8 kg/ADt x production of 560 ADt/d) to 1800 kg/d, even with the expanded production. With the process changes mentioned earlier, the Company believes that dioxin and furan levels can be reduced to below present detection levels (i.e., <10 ppq).

4.4 THE CITY OF CASTLEGAR (PE 80, PE 4008)

4.4.1 Description of Discharge

The City of Castlegar had a population of 6385 in 1986 after experiencing a population decline of 7.5 % since the census in 1981. Future projections of Castlegar's population are unavailable. However, based on the past decline and the absence of predictions for economic growth, it would be safe (for the purpose of conservative projection) to assume that there will be no permanent population growth over the next five years. Expansion of the Celgar mill would increase Castlegar's population during the construction period; however, modernization is expected to increase Celgar's workforce by only 30 employees (less than a 10 % increase over the present workforce.

Two separate sewage treatment systems serve the City of Castlegar on a year-round basis. The north system (Figure 1) is authorized under Waste Management Branch Permit PE 80 to discharge 2727.6 m^3/d or 45 % of the City's treated effluent to the east side of the Columbia River approximately 1.5 km upstream from the Kootenay River confluence. The treatment facilities for this system include mechanically aerated stabilization ponds followed by polishing lagoons and chlorination equipment. The design capacity of this treatment system can handle on its own a population of 10 000 people.

The south system under Permit PE 4008 treats and discharges 3273 m^3/d (55 %) of the City's effluent to the west side of the Columbia River, approximately 5 km downstream from the Kootenay River confluence. Treatment is via an activated sludge facility. The south system is sized for a population of 6000 people. Thus both the north and south systems have sufficient capacity to provide for at least a doubling of the present population. The outfalls of both discharges have been placed below the minimum low water level.

Both discharge permits (PE 80, PE 4008) require the effluent to meet BOD_5 of 45 mg/L and total suspended solids of 60 mg/L.

4.4.2 Present Waste Loads

Monitoring data for the period January 1986 to January 1988 are summarized in Table 17. There are too few data for reliable assessment. The available data for effluent flow, BOD_5 and suspended solids levels have all been within the permitted maximum values. Combined flow has ranged from 709 to 2214 m^3/d with monthly averages of 1239 and 1266 m^3/d for 1986 and 1987, respectively. Effluent data for nutrient levels are not available. Only one fecal coliform measurement has been recorded for each of these two permits (27 and 33 MPN/100 mL). With a minimum dilution available for the effluent in the Columbia River in excess of 5500:1, no effect on water quality is expected from these discharges.

4.4.3 Future Waste Loads

Effluent volume is not expected to increase nor is effluent quality expected to change in the near future relative to present conditions.

4.5 SELKIRK COLLEGE (PE 141)

Selkirk College is authorized to discharge up to 136 m^3/d of treated effluent to the Columbia River immediately downstream from the confluence with the Kootenay River (Figure 1). The effluent consists of domestic sewage and chemical wastes from photographic laboratories (mainly spent fixer). The chemical wastes pass through a silver recovery unit and two holding tanks before being discharged to an extended-aeration sewage treatment plant.

The treated effluent, at present, is not chlorinated and is discharged through an outfall with no diffuser on the east side of the Columbia River. The outfall is not of sufficient length to place the discharge either below the minimum low water level or into the main river flow. Initial mixing and dispersion are slower than could be obtained at this discharge site with a longer outfall.

Effluent monitoring data are summarized in Table 18. Both BOD_5 and suspended solids were within the permit limits (45 mg/L and 60 mg/L, respectively) for four samples taken over the period January 1986 to January 1988. pH ranged from 5.9 to 7.3 for four measurements. Effluent flow measurements for this same period were not available, but for the period 1982 - 1984, flow ranged from 2.4 - 597 m^3/d. The permitted flow was exceeded 21 times out of 883 measurements and the 90th percentile was 79.3 m^3/d. The worst-case complete dilution for this discharge (maximum effluent flow at minimum river flow) is estimated to be >90 000:1. Increased fecal coliform levels and silver contamination are the potential effects of this discharge; however, these characteristics were not measured. Effluent quantity and quality are not expected to change over the next 5 - 10 years.

4.6 MISCELLANEOUS PERMITTED DISCHARGES

Permit PE 7622

A neighbourhood pub in Robson is authorized to discharge 20 m^3/d of secondary-treated domestic effluent via a 60-m outfall to the Columbia River at the ferry landing. The package sewage treatment plant is capable of meeting the authorized effluent quality of 45 mg/L BOD and 60 mg/L suspended solids. The effluent is not chlorinated.

Effluent data were not available for review.

Permit PE 7623

This permit issued on November 26, 1986, authorizes the discharge of 34 m^3/d of secondary-treated domestic effluent from Raspberry Lodge, a long-term care facility. At the time of writing, the treatment works had not been installed and no discharge had occurred under this permit. The proposed treatment works include a package secondary treatment plant and an outfall extending 150 m into the Columbia River at a point 300 m downstream from the Robson ferry landing. The permitted effluent characteristics include 45 mg/L BOD and 60 mg/L suspended solids. No water quality effects are anticipated by this discharge.

5. WATER QUALITY ASSESSMENT

5.1 COLUMBIA RIVER UPSTREAM FROM KOOTENAY RIVER

Water quality data (both consultant and government) for sites in this reach are reported in Tables 11,15,and 19-30. These data cover the period 1980 to 1990 and thus review the situation since the Kootenay study (W.I.B.; 1977, 1979).

5.1.1 WATER QUALITY

a) pH

W.I.B. (1979) reported significant pH increases and only small pH reductions of Columbia River water downstream from the pulp mill. A review of ambient pH data from the past 10 years indicates that the pulp mill effluent continues to have a slight effect on river pH, generally in the acidic direction. However, receiving water pH has continued to remain in the pH 6.5 - 8.5 range, thereby meeting the approved B.C. criteria for pH, and thus suitable for both aquatic life and drinking water use.

For the most recent period of SEAM data (System for Environmental Assessment and Management) (1980-1984), the ambient pH upstream from the Celgar mill ranged from 7.4 to 8.6. Downstream (to Castlegar) pH levels ranged from 6.7 to 8.1. There were only eight sampling occasions when pH was measured simultaneously at both upstream and downstream sites. On three of these occasions, no difference in pH was recorded. On the five remaining occasions, the downstream pH was lower than the upstream pH, but not by more than 0.4 pH units (Table 21). The pulp mill effluent on these occasions was acidic, pH 1.7 - 6.2.

Dwernychuk (1988) measured only insignificant changes in receiving water pH at a site 500 m downstream from the effluent inflow. B.C. Hydro water quality data for the period 1982-1984 (Table 25) indicate that two thirds of the pH measurements (19 out of 31) at the downstream Castlegar site were lower than the pH measured at the Keenleyside Dam. Upstream pH averaged 7.4 and downstream pH averaged 7.2. Waste Management Branch sampling during low flow in June 1984 (Table 27) also showed a 0.2 to 0.3 pH unit decline between the upstream control site (mean = 7.5, 7.6). Effluent pH over this 1984 period ranged from 5.8 to 6.8.

b) Suspended Solids and Substrate Sedimentation

Suspended Solids

A survey of the last 10 years of data (1980 - 1990) indicates that Celgar's effluent had a significant though minimal effect on the river's suspended solids regime. There is no monitoring evidence that induced suspended solids levels have exceeded 10 mg/L over background levels, B.C.'s approved criteria for the protection of aquatic life, although predictions from effluent data indicate that the criteria could be exceeded at maximum loading/minimum flow at the edge of the dilution zone (see Section 4.3.4 c).

Data collected by Beak (1980) and IEC Beak (1983, 1984) indicated that suspended solids levels at control sites (upstream from Celgar) ranged from <1.0 mg/L to 8.0 mg/L with a maximum of 6 mg/L recorded at the first site downstream from the Celgar diffuser. In the 1984 IEC Beak monitoring program performed during low river flow, an effluent suspended solids concentration of 40.4 mg/L increased the receiving water concentration from <1.0 mg/L to 3.2 and 4.4 mg/L at the first site downstream from the Celgar diffuser. During each of these studies, suspended solids levels near the Kootenay River confluence had returned to background or near background levels. Dwernychuk (1988) reported that effluent suspended solids level of 48 mg/L increased the receiving water concentration from a background of <1 mg/L to 1.3 - 4.7 mg/L (Table 26).

The most recent available data from SEAM (1980 - 1984) show slightly higher levels downstream from Celgar (but upstream from the Kootenay River): 1 - 11 mg/L compared to 1 - 4 mg/L at the upstream control site. A small increase in receiving water suspended solids levels has been predicted from effluent loading levels (Section 4.3.3 c).

Substrate Sedimentation

Underwater surveys of the Columbia River bottom between Keenleyside Dam and Castlegar have been conducted by Associated Engineering Services Ltd. (1975), the

Ministry of Environment (Kinrade, 1986; Crozier, 1989) and Celgar (1990). All of these surveys over the 15-year period have documented serious degradation of the bottom sediments as the result of two practices by the sawmill and pulp mill: 1) the discharge of a high suspended solids load with associated nutrients; and 2) log handling and storage along the south bank causing bark/limb debris, and sunken logs. Deposition of pulp mill wastes physically degrades benthic habitat and can lead to the local extirpation of species, as well as to the elevation of sediment oxygen demand and the production of toxic hydrogen sulfide and methane gas (Colodey et.al., 1991).

1975 Survey

The first diver survey conducted in June, 1975, (Associated Engineering Services Ltd.) concentrated on the area near Celgar's outfall. A fibre mat of 60 - 90 cm depth was reported as extending half way across the river (from the mill side) and up to 0.6 km downstream. This would be equivalent to an area of 96 000 m^2. Outside of this area, the divers reported seeing aquatic plants, invertebrates and fish with no visible effects of the discharge. No bottom samples were taken for analysis.

1986 Survey

The 1986 bottom survey was conducted on April 1 when the river flow was low and the pulp mill was shut down (Kinrade, 1986). The divers mapped the approximate pattern of the deposits (Figure 7) and found that the fibre spread from the diffuser in a fan-like fashion spreading down both shores for up to 2 km downstream from the pulp mill outfall.

At the upstream site off the woodroom, the bottom was obscured by sunken logs and bark debris, but no fibre or fly ash were seen. At the pulp mill diffuser, the bottom was covered with 15 to 30 cm of decomposed material described as "black ooze" overlain with 2 - 5 cm of what appeared to be pulp fibres (1 - 2 cm in length).

As the divers moved downstream, the thickness of the black ooze decreased, but the layer was still apparent 200 m downstream from the outfall. At 750 m downstream, the fibre mat was continuous across the river except for a 30-m stretch in the middle (see

Figure 7). The mat was thicker on the south side (2 cm depth) than the north, and fibre/fly ash was observed on the clear, sandy middle section. At 1 km downstream, the bottom transect displayed three bottom types covering an equal distance: the southern third of the transect had a 1 - 2 cm deep fibre mat covering all rocks; the middle third showed a clear sandy bottom with black fly ash accumulations in small pockets and riffles in the sand; and the northern third again had a fibre mat although not as thick as on the south side. At 2 km downstream fibre accumulations were noted only in a narrow band along the south shore.

The fibre mat consisted of 1 - 2 cm long fibres held together with algae, and was solid enough to be carried to the surface in large pieces. No samples were taken to determine the composition of these deposits. It is in this material that we would expect to find chlorinated organic contamination. Greater than 90 % of the chlorinated organics in bleached kraft mill effluent is associated with the suspended solids (Colodey, 1989).

No fish or aquatic insects were observed in the area covered with fibre mat, although R. Crozier (Waste Management Branch) has found midge larvae (Chironomidae) in dredged samples. Burbot (Lota lota) were not observed over the fibre mat, but were observed and collected over the clean substrate in the centre of the river.

1988 Trout Egg Bioassay

In June, 1988, an in situ rainbow trout egg bioassay afforded some further observation of fibrous material believed to be responsible for covering the bottom sediments. Three Whitlock-Vibert incubation boxes were placed at each of three sites: one site 2.5 km upstream from the pulp mill, one site 6.5 km downstream at the ferry crossing, and one in Pass Creek upstream from its confluence with the Columbia River. During the test, those boxes placed near the ferry crossing were found to be covered heavily with a gray, fibrous, gelatinous mass. This was similar to the fibre mat material and was identified as a combination of filamentous algae, bacteria (Sphaerotilus sp. iron bacteria), diatoms, wood fibre, and possibly fungus (Kinrade and Crozier, 1989). Its cause and origin have yet to be determined accurately; however, its discovery downstream from the pulp mill (and not upstream) indicates an effluent influence. Confusing this issue is the observation of some similar material floating up from the bottom at the Keenleyside Dam boat locks as the locks fill with water (R. Crozier, personal communication).

1989 Survey

Ministry of Environment divers surveyed the river bottom along three transects on March 30, 1989, during the low flow period (Crozier, 1989). At the upstream transect, approximately 2 km upstream from Celgar, sunken logs and bark debris from log handling activities covered the bottom along the south shore to a depth of 10 m (or 15 % of the river width). Across the rest of this transect, the bottom sediments appeared normal and undisturbed with clean sand, gravel and rocks.

At 1.0 km downstream from the pulp mill outfall the transect showed three features: soft gray material covering the bottom and sunken logs on the southern third of the transect; a soft gray mat covering a thicker layer of black material resembling rotting wood and sawdust on the middle third; and clean sand ridges on the northern third with bands of black fly ash accumulating in the low current areas on the northern third. At the Robson ferry crossing, the rocky substrate and aquatic plants on the southern third of the transect were found covered with a fibre/silt mixture and with a 1 - 3 cm growth of "hairy, silty-like" material. Along the rest of the transect toward the north shore, the bottom was described as having a normal covering of sand and gravel. Samples of sediment and freshwater mussels collected along these 1989 transects were analyzed for pulp mill contaminants. The analytical results are discussed in Sections 5.1.2 and 5.1.3.

1990 Survey

A diver survey was conducted for Celgar in May, 1990. Again, all areas with a history of log handling had a build-up of log debris over the bottom. The debris was too thick to be able to determine its exact depth. At the foot of the pulp mill, the debris had a high fine wood content (similar to sawdust), which may have come down the storm sewer from the chip pile area. Celgar has installed a trap in the storm sewer to collect the fines and prevent further accumulation.

Immediately downstream from the diffuser, the divers in 1990 observed a wood fibre mat (up to 30 cm thick) extending 160 m downstream and 200 m wide. This was covered with a thin (<2 cm) layer of silt, slime and fibre, extending from mid-river to the south bank and spreading downstream from the diffuser (see Figure 13). This is the same material described by previous investigators as being the gelatinous cover over the fibre mat. A similar slime coating was observed upstream from the diffuser, but with higher silt content and less slime/fibre. The composition of the slime has not been determined, but Celgar (1990) has speculated that it is likely a biofilm composed of diatoms, bacteria, fungi and protozoa, which is common downstream from sources of organic carbon and nutrients. The Celgar discharge, as such a source, would account for the thicker slime layers downstream from the outfall. Sunken log debris, the upstream domestic sewage (PE 1273) and nutrients coming out of Arrow Reservoir, could account for the thinner slime layer upstream from the outfall. R. Crozier had reported that the slime production becomes more extensive during the summer months (personal communication).

Along the south shore and extending 1.0 km downstream, a variably thick (5 - 70 cm) black fly ash-fibre build-up was observed beneath the silt/slime/fibre mat. This material had a gel-like consistency and is likely the same material as the black "ooze" reported by Ministry of Environment in 1986 and 1989. None was found upstream from the outfall. Celgar (1990) has estimated that an area of 79 200 m^2 is affected, with a volume of 39 600 m^3 (see Figure13). Flow-related bottom scouring and the introduction of the fly ash recovery system in 1988 could be partially responsible for the apparent reduction in the size of the fibre mat compared to earlier surveys. However, without similar and reproducible sampling, it cannot be stated conclusively if the deposition is increasing, decreasing, or in equilibrium. Chemical analysis of the sediments conducted for Celgar in 1990 indicated that the silt/fibre mat contained less than the proposed M.O.E. Special Waste Regulations for TCDD TEQs (10 ng/g), tetrachlorophenol (3 μg/g), and pentachlorophenol (10 μg/g) (K.Hicke, personal communication; Celgar,1990). At these levels the fibre mat material would not be considered a "special waste".

The toxicity of fibre mat materials on the bottom of the Columbia River has not been determined. Chapman and Barlow (1984) reported that degraded sediments from the Port Alberni and Port Mellon mills were toxic to amphipods. It is apparent, however, from the above surveys that there has likely been changes to invertebrate species diversity and abundance in the area of deposition, whether due to direct toxicity or physical unsuitability. The fate of these materials over time is not well understood. Further study of the deposits and interstitial waters is needed to answer these questions, especially after the effluent changes with mill modernization when some recovery and rehabilitation may occur. The results of such sampling could determine the necessity and/or feasibility of removing or managing the fibre mat. As outlined by the Celgar Expansion Review Panel, the remedial options are natural recovery and dredging. The natural processes could be lengthy and dredging disturbance could re-suspend and redistribute toxic contaminants. The Panel has recommended that "Celgar be required to undertake ongoing monitoring and reporting of the extent and toxicity of the fibre mat, as well as chlorinated organics within interstitial waters, sediment, and bottom-dwelling invertebrates, so as to determine the degree of natural degradation and recovery after project construction, and whether remedial action is required".

c) Colour; Tannin and Lignins

Colour measurements have confirmed visual observations of the pulp mill effluent changing the colour of the Columbia River between the mill and the Kootenay River to dark brown. The most recent receiving water colour data from SEAM were for the lower flow periods, July 1983 and June 1984, when 12 concurrent upstream/downstream measurements were taken. All upstream values were <5 single wavelength units (SWU) while downstream values (to Kootenay River confluence) ranged from 9 to 58 SWU (single wavelength colour is approximately equivalent to total absorbance colour, TAC). On June 12, 1985, Regional Waste Management Branch personnel measured colour levels of 7 to 22 SWU within the initial dilution zone and levels of <5-8 SWU further downstream at Robson (Table 20). Colour levels above 15 true colour units would impair the water for downstream recreational use and for drinking water use (without colour removal) (Pommen, 1991).

B.C. Hydro data from 1982 - 1984 showed a 6-fold increase in tannin and lignin levels (to 0.6 mg/L) at Castlegar compared to levels (less than 0.1 mg/L) upstream from Celgar. Dwernychuk (1988) also reported that river colour was markedly affected by the Celgar discharge particularly along the south and west shores. His measurements were taken during a low river flow of 420 m^3/s when the colour from the pulp mill discharge would be more apparent. Colour increased from 8 SWU (background) to 19 SWU at a site 500 m downstream from the diffuser. Effluent colour was 870 SWU at the time of ambient sampling. Colour levels decreased further downstream, returning to background levels at Brilliant.

Organic substances in the pulp mill effluent, as revealed in the analytical characteristic of tannin and lignins, are ultimately responsible for a large portion of the increased colour. W.I.B. (1979) reported background tannin and lignin levels of 0.2 mg/L and downstream levels of up to 1.2 mg/L. The most recent tannin and lignin data available from SEAM were from 1981, and these show increases from 0.1 mg/L upstream to 0.2 - 0.4 mg/L downstream from the pulp mill to Castlegar. Dwernychuk (1988) reported that levels increased from a background of 0.10 - 0.12 mg/L to 0.79 mg/L at a site 500 m downstream from the Celgar diffuser. At sites just upstream from the Kootenay River, tannin and lignins had returned to levels that were only slightly higher than background (0.13 mg/L and 0.18 mg/L). As for colour, tannin and lignin levels were at their highest along the south shore.

A well-defined, dark (tea) coloured plume can be seen surfacing downstream from the diffuser outfall under most flow conditions. This discolouration may extend as far downstream as the confluence with the Kootenay River and it is aesthetically displeasing to both local residents and river recreationists. Under conditions of moderate to high river flows, the plume is entrained hydraulically along the south shore, thus generally relieving the residents of Robson (on the north shore) of this aesthetic blight. Under low flows (approaching 142 m^3/s), however, the plume can reach both shores and extend downstream to the Robson ferry. This can be compounded by the hydraulic dam effect of higher Kootenay River flows. During the extended shutdown of the pulp mill in March, 1984, downstream colour levels returned to the low levels typical of the upstream (control) site near the Keenleyside Dam (B.C. Hydro, 1985).

The proposed mill modernization and expansion (as outlined by Celgar, 1990), projects a 62 % reduction in effluent colour. However, this will not eliminate the present discoloration problems. At the edge of the initial dilution zone under worst-case flow conditions, colour levels are expected to increase by 18 TCU in winter and 16 TCU in summer. Mixing these increases with a maximum background colour level of 5 TCU would give river colour levels of 21-23 TCU immediatlely outside the initial dilution zone. These levels are somewhat in excess of the B.C. working criterion for colour for the protection of recreation and drinking water use (15 TCU). It is doubtful if this criterion level could be met at all times between Celgar and the confluence with the Kootenay River. Based on the river flow-duration relationship given in W.I.B.(1979), it is estimated that the colour criteria would be exceeded less than 10 % of the time.

d) Dissolved Oxygen

All surface dissolved oxygen data for this reach of the Columbia River have been high, exceeding 10 mg/L (Tables 11,19,20,22,25,26). This is in part a result of the mixing and oxygenation occurring at the Keenleyside Dam. The Columbia River has a large capacity to assimilate the BOD wastes from Celgar and the City of Castlegar.

Ambient dissolved oxygen concentrations have been shown to alter the toxicity of resin acids and whole pulp mill effluent (Taylor et al., 1988). Resin acids act to reduce oxygen uptake by the gill lamellae. Fish thus impaired show higher mortality in waters of low oxygen tension than would normally be tolerated. Kruzynski (1979) showed that mortality of sockeye salmon exposed to dehydroabietic acid dropped from 100 % at low dissolved oxygen levels (75 % saturation) to 5 % in well-oxygenated waters (90 % saturation). The consistently high levels of dissolved oxygen (supersaturation) in Columbia River receiving waters likely act in the same manner to ameliorate the toxic effects of Celgar's effluent.

There is some evidence of a small decrease in dissolved oxygen at the downstream site (0200200; at Castlegar) relative to the upstream site (0200183; near the Keenleyside Dam) which could be attributed to the pulp mill effluent, but it is not large enough to suggest an impairment of water quality. Simultaneous measurements of dissolved oxygen upstream and downstream from the discharges in this reach of the river have been taken only during the period 1983 - 1984 (Table 22). Approximately two-thirds of this sampling shows a depression of ambient dissolved oxygen levels. A downstream site closer to the outfall than the Castlegar site (0200200) may have shown a more distinct pattern.

On June 13, 1984 (Table 22), Ministry of Environment measured a depression of ambient dissolved oxygen of 0.5 to 0.6 mg/L at the downstream site (however, B.C. Hydro measured an increase on the same day). Since the Columbia River flow at this time (June 13, 1984) was below average (418 m^3/s, but three times higher than the required minimum, this dissolved oxygen depression, if real, may not represent the worst case. Given an actual effluent BOD loading on June 13, 1984, of 2.91 t/d, the predicted decrease in the ambient dissolved oxygen level is 0.8 mg/L. The difference between actual (M.O.E.) and predicted levels is probably due to re-aeration and only partial BOD exertion during the travel time from the waste source. More simultaneous upstream/downstream monitoring at various flows is needed to confirm this observation of an apparent downstream dissolved oxygen depression.

Studies by Beak (1980), IEC Beak (1983), B.C. Hydro (1985) and Dwernychuk (1988) have shown that the levels of dissolved gases between the Keenleyside Dam and Kootenay River have remained consistently above the 100 % saturation level. Dwernychuk reported that upstream from the Celgar discharge the level of dissolved oxygen was 123-124 % saturation and that this diminished to 117-121 % saturation downstream from the pulp mill diffuser to Castlegar. Clearly, the supersaturated conditions created by the Keenleyside Dam discharge help the receiving waters to assimilate the high BOD loadings from the pulp mill discharge, and offset the debilitating effects of effluent resin acids and other toxic constituents on the physiology of the aquatic biota.

Additional potential sources of BOD loading in this reach of the river include: 1) the bark and wood debris accumulations of the river bottom due to log storage and handling, and 2) the treated and untreated sewage discharges from the City of Castlegar, Selkirk College, and businesses and residences in Robson. Past monitoring of the river water quality was not designed to determine the local effects of such loading; however, the existing data do not indicate significant, large-scale effects of such loadings on the water quality.

Installation of the Keenleyside powerplant (at some future unknown date) will reduce the level of total gas saturation because 70 % of the water will be directed through the turbines. B.C. Hydro (1985) has estimated that saturation levels will range from 102 to 110 % and dissolved oxygen levels will remain high, averaging 13 mg/L. Coupled with a 94 % reduction in BOD loading (from the 1984 permitted level of 40 000 kg/d to 2 400 kg/d) from the modernized pulp mill (as proposed by Celgar), future dissolved oxygen levels downstream from the pulp mill are expected to remain high, i.e., above 10 mg/L. This prediction has been verified by a dissolved oxygen model (based on the Streeter

Phelps equation) which examined the opposing effects of lower dissolved gas saturation in the river and lower pulp mill BOD loading (Celgar, 1990). Under worst-case flow conditions (142 m^3/s) and high water temperatures, the model predicted that dissolved oxygen levels would not fall below a minimum of 9.5 mg/L. This level meets the CCREM (1987) guideline for dissolved oxygen and the B.C. working criterion level of 9 mg/L for slight salmonid production impairment. However, it does not meet the B.C. working criterion level of 11 mg/L which guarantees no production impairment for salmonid embryo and larval stages (Pommen, 1991).

e) Foam

Foam on the river surface in this reach is a recurring aesthetic problem of considerable concern to the public. This has been attributed to both the pulp mill and to unidentified upstream causes (R. Crozier, Celgar Expansion Review Panel Hearings). The Kootenay Report (W.I.B., 1979) presented data showing that the pulp mill discharge could cause foaming between the mill and Robson ferry. This problem remains to be corrected with the mill in its present state. Frothing test results from July, 1983, again confirmed that the pulp mill is a cause. Pronounced and persistent foam trails continue to be generated by motor boat wakes and occasional foam patches have been observed floating downstream from the mill.

Several causes of the foaming have been identified in the past:

1. Soaps are formed during the kraft process by the reaction of wood resins, fatty acids and resin acids with alkaline cooking liquor (permit file). The soaps enter the effluent stream from the sewering of contaminated condensates, black liquor spills and discharges of the screens and deckers. The foam tank breaks down the bubbles; however, the soaps are discharged into the river where turbulence and reaeration can cause foam regeneration.

2. In 1982, a hole in the effluent pipeline was discovered underground which entrained air, thus exacerbating the foaming problem. The hole was sealed and the foaming within the pipe and diffuser disappeared.

3. Occasional overflow of the brown stock washer foam tank to the sewer or overflow of the effluent foam tank onto the river bank continue to contribute to the foaming problem. Most recently, an overflow of foam/soap to the river during low flow on May 11, 1987, caused large patches of white foam along both shores as far downstream as Robson. The foam concentrated in back-eddies where it mixed with debris, pollen and dust creating a disagreeable scum. Water samples taken below the foam showed no evidence of sublethal toxicity in a Daphnia bioassay (48-h LC50).

Foaming due to pulp mill effluent discharge should be eliminated with the installation of secondary treatment.

f) Taste and Odour Problems

The influence of the Celgar pulp mill discharge on the taste and odour of Columbia River water was last studied quantitatively in 1977. As reported in the Kootenay Report (W.I.B., 1979), effluent-containing Columbia River water had a strong odour at a dilution of 1:8200 (Threshold Odour Number = 8200), and a strong off-flavour at 1:1000 dilution. These dilutions exceed the dilution at the low flow of 142 m^3/s (1:60). It was therefore concluded that Columbia River water would not be aesthetically suitable at any time between the mill and Kootenay River as a domestic water supply without treatment to remove the odour-causing compounds.

These taste and odour problems have continued unabated to the present. According to R. Crozier, at some times of the year, a pulp mill odour in the river water can be discerned as far downstream as the Canada / U.S. border. If the proposed mill modernization proceeds, biological treatment of the effluent in combination with foul condensate stripping could reduce the odour to below threshold levels (EVS.Cirrus, 1989).

Volatile organic compounds which occur in pulp mill effluents are known causes of taste and odour problems. Waste Management Branch measurements of total phenols, and tannin and lignin (1981 - 1984) indicate increased levels downstream from the pulp mill (Tables 11 and 20). Total phenols upstream from the mill do not exceed 2 µg/L, the B.C. working criterion for the protection of drinking water, whereas at the downstream site

(0200200, 10 km downstream) 70 % (19 out of 27) of the measurements exceeded the criterion (maximum of 9 µg/L). During a June, 1985, sampling trip, Regional Waste Management Branch personnel found that total phenols ranged from 5 to 15 µg/L within the initial dilution zone (Table 20). Dwernychuk recorded a total phenols level of 5 µg/L at a point 500 m downstream from the Celgar discharge (in 1988).

Tannin and lignin levels measured by the Waste Management Branch upstream from the mill do not exceed 0.1 mg/L, whereas downstream from the mill (but upstream from the Kootenay River) the levels have ranged from 0.2 to 0.4 mg/L. Dwernychuk recorded a tannin and lignin level of 0.8 mg/L at a site 500 m downstream from the pulp mill discharge and B.C. Hydro recorded a level of 0.6 mg/L at the Castlegar site. The threshold level of tannin and lignins for taste, odour and colour is reported to be 0.4 mg/L (Pommen, 1991). Humates can also impart odour to water, but these have not been measured in Columbia River water.

Waste Management Branch personnel documented a strong odour from Columbia River water during a low flow study in June, 1984. The odour was detectable as far downstream from the mill as the Robson ferry landing and site 0200200. Measured phenol levels ranged up to 6 µg/L at site 0200200 and 8 µg/L at the south shore ferry landing (Permit file PE 1272). Tannin and lignins were not measured.

There is some smell associated with decomposing algae (R. Crozier, Celgar Expansion Review Panel hearings) that is not directly related to Celgar's effluent, but which causes public complaint. This happens usually when B.C. Hydro lowers the river level in the spring, exposing the algae which begin to decay.

g) Fish Tainting

Bleached kraft mill effluent can cause off-flavours in fish at effluent concentrations (in the receiving waters) as low as 0.5 and 1.0 % (Sprague, 1988). On this basis, tainting would be expected downstream from the Celgar effluent. The known causes of tainting are largely the condensates from the recovery area, the digestors and the multiple-effect evaporators. These include the chlorophenolics, phenolics, benzene, toluene and naphthalene (McLeay, 1987). The known taint-causing constituents of pulp mill effluent are shown in Table 31 (from McLeay, 1987). To date there has been only one compound measured in Celgar's effluent which exceeds the no-tainting effect concentration: trichlorophenol at 12.4 µg/L. Recent phenol levels (1988-1990) range up to 2,500 µg/L which is within the range of estimated threshold tainting concentrations. Di-, tetra- and pentachlorophenol have all been undetectable in the effluent, and benzene, toluene, and naphthalene have not been monitored. Organo-sulphur compounds, terpenes and resin acids have been proposed as potential tainting agents in pulp mill effluent, but no analytical proof is available (McLeay, 1987).

Recent work by Neilson et. al., (1984) and Allard et. al., (1988) has shown that bacteria under natural conditions can transform tri-and tetrachloroguaiacol (via o-methylation under aerobic conditions) to tri- and tetrachloroveratrole, which are both toxic and have higher tainting potential. A variety of other chlorophenols are predicted to be similarly transformed to compounds with tainting potential (e.g., polychlorinated anisoles). Chlorinated veratroles and anisoles were shown to be a major cause of a fish tainting problem in Finland, and were linked to the chlorine bleaching process. These tainting contaminants in the fish flesh would have resulted either from high bioaccumulation or via transformation from chlorophenols within the fish (Colodey, 1988). Neilson et. al. reported that bioconcentration factors for 3,4,5,-trichloro- and tetrachloroveratrole were 4.7 and 5.2 (on a fat weight basis). Mercaptans, terpenes and organo-sulfides are strong-smelling compounds in kraft mill effluent, but they are not proven to cause off-flavours in fish (Sprague, 1988; McLeay, 1987).

No new information concerning fish flavour impairment has been added since the tainting study conducted for the Kootenay Report (W.I.B. 1979). The results of that study were inconclusive: tainting of a muddy or earthy type was apparent in some fish (rainbow trout, kokanee, largescale sucker), but there were no clear-cut differences between control (Arrow Reservoir) and downstream fish. The fish were captured in May and July, 1976, during relatively high dilution ratios.

Further fish tainting work during low flow conditions would be necessary to confirm a tainting effect by the pulp mill effluent, if effluent treatment works are not initiated in the short-term. Secondary treatment of bleached kraft effluent can cause a 2-to 10-fold decrease in tainting (Sprague, 1988). Celgar expects that the main sources of the tainting substances will be eliminated from the effluent in the modernized mill, and that biological treatment would reduce tainting from 50 to 90 % (1990, Stage II report).

h) Toxicity in the Receiving Waters

In general, acute lethal effects of pulp mill effluents are rarely evident because of the high dilution available in the adjacent receiving waters (Tana, 1988). Similarly, acute toxicity is not a problem in the Columbia River downstream from Celgar's discharge. Under conditions of low river flow (142 m^3/s), the proportion of effluent in river water would be 0.9 % (see Section 4.3.3a). This level is less than half the lowest recorded 96-h LC50 of 2.4 %. The available river dilution thus protects the downstream aquatic organisms against acute toxicity. With even lower future effluent flows from the modernized mill, the effluent concentration in the river should even decrease slightly. To date, invertebrate and/or fish kills have not been reported in the Columbia River near Celgar's operation.

Sublethal stress on aquatic organisms has been calculated to occur in the Columbia River between Celgar and the Kootenay River from the discharge of pulp mill effluent (see Section 4.3.3 (f)). Sublethal effects of bleached kraft mill effluent have been reported at concentrations as low as <1 % (McLeay and Brown, 1979; McLeay, 1987). Sublethality can be expressed as: mutagenic effects; immunological changes (decreased disease resistance); physiological changes affecting metabolism/growth/development; histological damage (i.e., liver enlargement); behavioural modifications (i.e., swimming, habitat use); and most seriously, reproductive impairment and productivity losses. This stress may be enhanced by high dissolved gas levels and the increased residence time of the effluent due to the hydraulic dam effect (see Section 2.0 and 4.0; MOE, 1978; Dwernychuk, 1986, 1988). There have been no significant changes to these causative factors since the Kootenay Study in 1979, and unfortunately there has been little follow-up receiving water monitoring and no study to quantify the degree of sublethality using on-site direct measures (especially on fish).

Receiving water bioassays using Daphnia sp. have been done only infrequently and have not shown the level of toxicity expected from calculations. Daphnids are usually less sensitive to kraft mill effluent than are rainbow trout, salmon, or fathead minnows

(McLeay, 1987; Sprague, 1988). Over the period since the Kootenay Study, static laboratory bioassays have been conducted during low river flow (142 m^3/s): in July, 1983; June, 1984; and June, 1985 (permit file). The acute bioassays (48-h LC50) using water from the initial dilution zone showed no evidence of toxicity. The chronic bioassays (21d) showed mixed results. In 1983, samples near the diffuser did not have a stressful effect, but rather elicited an increase in growth rate and reproductive activity. Of the two samples taken near the diffuser in 1984, one showed a stimulating effect and the other indicated sublethal effects. Samples from the downstream site 0200200 (10km downstream from the outfall) showed variable results: one sample indicated a slight stress to the reproductive capacity of Daphnia sp., and the other two samples indicated stimulation of both growth and reproductive rates. In the 1985 chronic tests, there was no evidence of sublethal effects on either reproduction or growth within the initial dilution zone.

In situ rainbow trout egg bioassays were conducted during June, 1988, at three sites: one impacted site 3 km downstream from the mill discharge and two controls; one upstream from the mill and the other in Norns (Pass) Creek (Kinrade and Crozier, 1989). At each site three Whitlock-Vibert boxes each with 100 eggs were placed in floating spawning gravel cages. Monitoring through to the alevin stage showed no apparent toxicity effects: only one of the eggs died and this was at a control site, the others had hatched or were unfertilized.These results suggest that river-diluted mill effluent does not affect development of rainbow trout eggs (at least in the water column).

There has been a pressing need for study of the sublethal effects of the Celgar pulp mill discharge on the downstream aquatic community. Growth and reproduction studies on the fish populations would extend the present work being done on distribution, productivity and habitat use. Changes in blood chemistry, histology and levels of disease/parasitism would also be relatively easy to monitor. Such work should be done both before and after modernization.

Secondary treatment as proposed by Celgar (1990) would reduce discharged toxicants to less than acutely toxic levels at the point of discharge, largely via the degradation of resin and fatty acids and reduced AOX loadings. It is also expected that with available river dilution at worst-case flows there would be few sublethal effects beyond the initial dilution zone. Within the initial dilution zone, sublethal responses are expected for organisms that remain constantly exposed within this zone. This presumably would include the non-motile benthos, i.e. freshwater mussels. Fish would more likely move in and out of the zone, thereby decreasing their exposure. With 1 % effluent at low river flow after complete mixing, we might expect the following sublethal responses as reported in the literature (Celgar, 1990, updated from McLeay, 1987): blood chemistry changes and possibly increased hematocrit levels, behavioural change (fish attraction to the effluent), and even some increase in photosynthesis (more related to associated nutrient release).

i) Resin Acids

Total resin acid levels in the Columbia River were found by Dwernychuk (1988) to be highest (34 µg/L) at the first site downstream (500 m) from the Celgar discharge (Table 15). Levels declined downstream to 17 µg/L near the Kootenay River confluence; however, even with Kootenay River dilution (at the Kinnaird site) resin acids were 10 µg/L, which is ten times higher than natural background levels. These levels are consistent with those predicted using effluent dilution calculations in Section 4.3.4g. The distance downstream to the point of return to background levels for total resin acids was not determined. These receiving water levels were measured with a pH of 7.7-8.0, and are within the B.C. working criteria of 45 µg/L for the protection of aquatic life at this pH level (Pommen,1991).

The receiving water concentrations of the nine separate resin acids were each less than 0.05 of the reported 96-h LC50's (Table 15). According to the results of Walden (1976), such levels of resin acids would not by themselves be subjecting Columbia River fish to sublethal stress. With the proposed secondary treatment, future levels of resin acids in the river are expected to be non-detectable (Section 4.3.4g).

The chlorinated resin acid, chlorodehydroabietic acid, was the dominant resin acid found in downstream Columbia River water by Dwernychuk (1988). It was still detectable (5 µg/L) at the furthest downstream site (11 km from the outfall). This is in contrast to its minor presence in the effluent, relative to the unchlorinated resin acids, abietic, dehydroabietic and isopimaric acids. All of the unchlorinated resin acids were reported by Dwernychuk as undetectable at the 11 km site.

Resin acids have been reported from Columbia River fish tissue (see Section 5.1.5) and sediments (see Section 5.1.2).

j) AOX

As mentioned previously (Section 4.3.4g), elevated AOX levels (to 0.28 mg/L) were found downstream from Celgar by the B.C. Ministry of Environment in March, 1989. Such receiving water levels are in agreement with predictions calculated from the effluent AOX loading. Background levels in March, 1989, were undetectable (<0.1 mg/L); however, the detection limits were high. Natural background AOX levels in water can be detectable (0.01 - 0.05 mg/L), depending on the detection limits, and are primarily attributed to naturally-occurring organic acids (humic, fulvic) which can have chlorine concentrations of up to 1 % (Colodey, 1988).

Monthly AOX levels measured with a lower minimum detection limit from October, 1989 to March, 1990 by the B.C. Ministry of Environment show much lower levels downstream from Celgar (34 - 46 µg/L at Castlegar; and 14 - 24 µg/L at Birchbank) (Table29). The reason for such lower than predicted values is unknown; however, the results do show a trend of increasing concentration from background levels (<5 - 13 µg/L) to higher values at Castlegar and declining levels at Birchbank. Kootenay River levels ranged from <10 to 19 µg/L, which may be within the background range. There are no chlorinated discharges in the Kootenay River, downstream from Kootenay Lake.

The full downstream extent of the AOX contamination in the Columbia River has yet to be determined. It is likely to be extensive: Noton (1991) reported that AOX from the Hinton pulp mill persisted over 1250 km in the Athabaska River during winter sampling and subsequent sampling showed persistence even further downstream.

AOX samples of Columbia River water were taken May 29, 1990 by E.V.S. Consultants Ltd. for Celgar. The upstream level was below detection (10 µg/L) and the level at Castlegar was within the range predicted by dilution calculations (121 µg/L). However, their measured AOX was higher downstream at Birchbank (174 µg/L) and Waneta (246 µg/L). The AOX level from the Kootenay River (138 µg/L) was also higher than at Castlegar. Since there are no halogen discharges either on the Kootenay River or the Columbia River downstream from Castlegar, these results could be considered as reflecting contamination or quality control problems until further sampling provides verification.

With secondary treatment and lower chlorine consumption, the future modernized mill is expected to discharge 1.03 kg AOX/ADt, which would result in a receiving water level of 0.1 mg/L (after complete mixing during low flow) (see previous Section 4.3.4g).

k) Chlorinated Phenolics

The only receiving water chlorinated phenolic data available for this report were taken on February 18-21, 1990 and May 29, 1990 (between Celgar and Waneta; as reported in Celgar, 1990). Chlorinated phenolics were not detected in either the upstream control samples or the Kootenay River control samples (Table 30). In the February 1990 sample, 2,3,4,6 tetrachlorophenol (2 ng/L), pentachlorophenol (2 ng/L), both isomers of trichloroguaiacol (10.7 ng/L), and tetra-chloroguaiacol (12 ng/L) were detected in downstream samples. In the May, 1990 samples, dichlorophenols (14 ng/L) and the dichloroguaiacols (14 ng/L), trichloroguaiacols (16-120 ng/L), and tetrachloroguaiacols (16-70 ng/L) were detected in the downstream receiving waters. Levels of total chlorinated phenolics were 48 ng/L at a point 1 km downstream from Celgar, 218 ng/L at Castlegar, 35 ng/L at Birchbank, and 27-36 ng/L at Waneta. No chlorocatechols were detected in Columbia River water samples during either sampling period.

All of the detectable receiving water chlorophenol measurements were less than the interim B.C. criteria (for the protection of aquatic life) by at least an order of magnitude (provided by Dr. P. Warrington, personal communication). At the present time, no jurisdiction has criteria for the chloroguaiacols to put the above data into perspective.

l) Dioxins and Furans in Water

Samples of the domestic water intake at Warfield (7 km downstream from Birchbank) were taken on February 23, 1989, to ascertain whether or not chlorinated dioxin or furan contamination of the drinking water supply was evident downstream from

Celgar. The results are shown in Table 23. All furan congeners were less than the detection limit as were all dioxin congeners, except for heptachlorodibenzo-p-dioxin with a level of 12 pg/L (ppq) compared to the MDC of 11 pg/L. When considered in terms of the international toxicity equivalence scheme, the toxic equivalent of 2, 3, 7, 8 TCDD for the Warfield intake sample was calculated to be 0.12 pg/L. This is considerably lower than the interim guideline for dioxins in drinking water of 15.0 pg/L, which was recently developed by the National Joint Consultative Committee of Senior Health and Environment Officials (M.O.E., 1989).

Celgar (1990) sampled for dioxins and furans in the Columbia River during the period February 18-21, 1990. Dioxins and furans were not detected in any of the three samples taken. The detection limits ranged from <2.3 to <9.0 ppq. Assuming the worst-case of dioxins and furan levels equalling the detection limit, the total 2,3,7,8 TCDD toxic equivalents would be 5.0 ppq for the control site upstream from Celgar, 10.0 ppq for the site 1 km downstream from Celgar, and 6.5 ppq for the downstream site near Waneta. However, these results can also be seen as in agreement with the prediction, based on effluent dioxin levels and river dilution, that dioxin and furan levels in Columbia River water should be well below detection limits of 1-10 ppq (refer to Section 4.3.4 g).

m) Fecal Contamination

Fecal coliform levels in the Columbia River between the Keenleyside Dam and Birchbank have not been examined since 1979. Only one measurement of fecal coliforms has been taken in the intervening 10-year period (<2.0 MPN/100 mL at Keenleyside Dam, site 0200183). Fecal coliform monitoring prior to 1979 indicated that fecal coliform densities were low (<79 MPN/100 mL) (W.I.B., 1979).

Considering that there are five permitted (treated) sewage discharges and eight unpermitted sewage discharges (within Robson) in this reach of the Columbia River, more receiving water monitoring effort must be devoted to this aspect of water quality in the future. The fecal coliform test can give positive results for *Klebsiella* spp. which reach high densities in pulp mill effluent (Warrington, 1988). Since high positive fecal coliform results downstream from a pulp mill may not be related to a fecal origin, a more specific indicator of human fecal contamination such as *Escherichia coli* should be used.

n) Nutrients

The background nutrient regime of this reach of the Columbia River is dominated by the limnology and seasonal nutrient status of Arrow Reservoir. For example, phosphorus levels leaving the reservoir are highest during winter over-turn and decline through the summer as the epilimnion is depleted by reservoir phytoplankton growth.

The Celgar pulp mill accounts for approximately 90 % of the total phosphorus and 92 % of the total nitrogen entering this reach of the Columbia River (Table 32). Few values for nutrient loading from the pulp mill effluent for the recent period (1980 - 1990) were available. However, examination of the available receiving water quality data and observations by Regional staff (R.Crozier, personal communication) indicate that these existing loadings have not contributed to eutrophication or excess algal growth.

Calculations from the known nutrient loadings from Celgar have predicted increases in receiving water nutrient levels (Section 4.3.4.j). The existing receiving water nutrient data, as summarized in Table 33, however, do not show the level of downstream increase compared to upstream background levels as loading calculations would predict. More simultaneous, paired upstream and downstream nutrient measurements are needed to confirm the predictions. At present, there are not enough receiving water nutrient data to make reliable statements on the existing concentrations in the river.

Both ortho- and dissolved phosphorus levels are low in the Columbia River downstream from Keenleyside: orthophosphorus levels have not been detected (<3 µg/L) at a site 500 m downstream from the Celgar discharge. Measured dissolved phosphorus levels have not exceeded 6 ug/L either upstream or downstream from Celgar. Only Dwernychuk noticed an elevation of total phosphorus: from 14 ug/L upstream to 23 ug/L downstream from Celgar (but upstream from Castlegar). At Dwernychuk's site 5, just upstream from the Kootenay River confluence, total phosphorus measured 36 µg/L. The reason for this latter high level is not apparent; however, it is unlikely to represent sewage effluent input from the Robson area and the City of Castlegar discharges given their small loadings.

Nitrite/nitrate-N levels have been about the same at sites upstream and downstream from the pulp mill. Maximum levels upstream and downstream equalled 0.19 mg/L. Ammonia-N levels have shown some difference between upstream and downstream: levels ranged from <5 to 24 µg/L at the downstream Castlegar site 0200200 compared to <5 µg/L at the upstream Keenleyside Dam site 0200183.

The existing receiving water data are not sufficient to calculate reliable nitrogen:phosphorus (N:P) relationships. Recognizing the uncertainty of the data, an approximate N:P ratio could be calculated from the recent MOE data for site 0200183. Combining the maximum ammonia-N and nitrite/nitrate-N concentrations, and dividing this sum by the maximum dissolved phosphorus concentration, gives a nitrogen to phosphorus ratio of 19:1. This suggests that algal growth in this reach of the Columbia River may still be phosphorus-limited. Actual measurements verifying excessive algal growth (standing crop biomass or chlorophyll a data) were not available at the time of writing.

With Celgar's modernization, the predicted increases in receiving water nutrient concentrations (worst-case 60:1 dilution) have been calculated to be:

Kjeldahl Nitrogen	92-107 µg/L
Ammonia-N	27-32 µg/L
Phosphorus, Tot.	17-20 µg/L

Compared to nutrient additions from the existing mill, these data for post-modernization suggest no change over present total phosphorus increases (presently 17 ug/L), but a three-fold increase in Kjeldahl nitrogen (presently 28 µg/L). This indicates that mill modernization could further increase the phosphorus limitation on downstream algal growth.

The Celgar Expansion Review Panel recommended monitoring of attached algae (species composition, biomass, seasonal growth rate) for at least two years prior to and after full-scale operation of the modernized mill at three sites: upstream and downstream from Celgar and one site downstream from Trail. The Panel also concluded that because of the uncertainties regarding the potential for excessive algal growth, Celgar be required to conduct a riverside trough experiment to determine: 1) "which dissolved nutrient (nitrogen or phosphorus) is limiting attached algal biomass and production over the growth seasons evident in the natural system" and 2) "the effects of selected pulp mill effluent loadings on attached algal biomass and production over the growth seasons, using an appropriate control series" (Recommendations 28,29,30)

o) Dissolved Gases

Total dissolved gas levels upstream from the Hugh Keenleyside Dam have been largely below 110 % saturation, with a maximum of 112 % saturation (W.I.B., 1979). The Columbia River downstream from Keenleyside Dam has been reported as having the highest dissolved gas concentrations of the 35 major rivers and lakes monitored in British Columbia by Clark (1977). Dissolved gas measurements downstream from Keenleyside Dam were taken by the Province during the period 1972 - 1977 and were reported in the Kootenay Report (W.I.B., 1979). Of 148 measurements, only 15 % were less than the B.C. working criterion of 110 % saturation. Twenty (13.5 %) of these measurements were within the borderline range of 110-120 % saturation, 51 measurements (34 %) were within the unsatisfactory range of 120-140 % saturation, and 54 measurements (36 %) exceeded the critical level of 140 % saturation at which there is a high probability of extensive fish mortality due to gas bubble disease (Clark, 1977). Data collected by B.C. Hydro in 1985 ranged from 102.6 % to 133 % saturation. Sixty percent (37 of 62) of the 1985 measurements were between 120 and 140 %. Only 21 % of their measurements were less than 110 % saturation. Monitoring by B.C. Hydro in late 1991 has shown maximum levels exceeding 140 % saturation (G. Ash, personal communication).

Dissolved gas supersaturation tends to occur when the sluiceway, as opposed to the low level ports, are used to discharge water. Air is entrained as water plunges into the energy dissipater. These high levels of dissolved gases continue downstream to Roosevelt Reservoir in Washington. Levels exceeding 120 % saturation have been measured in water entering the reservoir and this dissipates only slightly (2-3 %) as the water travels the 225 km to the Grand Coulee Dam (Ash et. at., 1982).

Gas bubble disease is a physically-induced process caused by uncompensated, hyperbaric total dissolved gas pressure, which produces lesions in blood (emboli) and other tissues (emphysema) and subsequent physiological dysfunctions (Bouck, 1980). Behavioural changes of a sub-lethal nature can also occur as a result of physical damage to the lateral line canal. Fish tolerance to elevated gas pressure varies with fish species, life-history stage, water temperature, hardness, depth and length of exposure (Weitkamp and Katz, 1980).

Alderdice and Jensen (1985) modelled the available literature data on total gas pressure (TGP) as it affects salmonids and reported that:

1. there are two forms of gas bubble trauma (GBT): chronic which occurs over a range of 105 - 109.7 % TGP and acute GBT which occurs at TGP levels of >110%.

2. there is no sharp boundary between acute and chronic ranges and the acute threshold varies between 108 and 116%, depending on the levels of ancillary variables which have a sparing effect on GBT response.

3. a general threshold for acute effects occurs at approximately 110 - 112% TGP.

Only a modest amount of study has been focused in the past on the effects of this gas supersaturation upon resident fishes. An examination of 40 fish caught between Keenleyside Dam and Robson in August, 1976, when total dissolved gas levels were approximately 140 % showed only one fish with minor symptoms of gas bubble disease. Whether or not Columbia River fish survive after exposures to supersaturated water sufficient to cause gas emboli is unknown. In his report to the Celgar Expansion Review Panel, the Regional Fisheries Biologist, J. Hammond, reported seeing signs and symptoms of gas bubble disease in fish captured downstream from the Keenleyside Dam. However, this reach continues to support a viable sports fishery for kokanee, rainbow trout, Mountain whitefish and Dolly Varden, and no significant fish kills have been reported. The absence of frequent and severe gas bubble disease observations could suggest some tolerance of Columbia River fish to supersaturation which could be afforded by mitigating factors such as acclimation and the opportunity for the fish to sound to depth and to migrate out of the affected area.

Hydrostatic pressure compensates for approximately 10 % of the supersaturation for each 1 m of water depth. However, there are limits to such compensation. The work by Alderdice and Jensen (1985) showed that the modal depth of fish distribution varies in relation to the level of TGP, i.e., it moves downward as TGP increases above 100%. The modal depth occurs at the compensation depth at 100 - 112% TGP. At higher TGP levels the modal depth rises above the compensation depth and fish show visible signs of gas bubble trauma. The behaviour of fish changes at higher TGP levels so that substantial numbers of fish are found above the compensation depth.

Installation of turbines in the Keenleyside Dam would have the effect of ameliorating dissolved gas supersaturation when the spillway is submerged from May through January each year. Saturation levels would be reduced to 102-110 % (B.C. Hydro, 1984: Celgar, 1990). Dissolved oxygen levels in the water released at this time of the year is predicted to average 13 mg/L. Supersaturation would continue to occur from February to May if the sluiceway continues to be used. Other water release options (i.e., the use of low-level ports) may be available to prevent super-saturation year-round. Since it is not presently known to what extent gas supertsaturation affects the health of aquatic life in the Columbia River, it is not possible to identify the benefits of such amelioration in the future. In general, we could expect more fish utilization of the shallower waters and perhaps greater abundance of benthic invertebrates (hence higher fish productivity), since they too are susceptible to gas bubble trauma. The effects of reduced TGP on the future dissolved oxygen regime of the river has been discussed previously in Section 5.1.1.d.

p) Temperature

Review of the available data indicate that Celgar's discharge of heated effluent (20-39^{o}C) has no effect on receiving water temperatures outside the initial dilution zone. This is as predicted using projections from effluent concentrations (see Section 4.3.4).

5.1.2 SEDIMENTS

The degradation of bottom sediments by log booming debris and contaminated fibre mats in the vicinity of and downstream from Celgar has been described previously in Section 5.1.1 (b). The composition, method of formation, and the areal extent of the fibre deposition require more investigation. This constitutes a serious contamination problem and a significant withdrawal of available fish feeding and spawning habitat.

a) Sediment Dioxin and Furan Levels

Results of sediment dioxin and furan analysis by Environment Canada (Mah et. al., 1989) for sites near the Celgar pulp mill are shown in Table 34. The levels of all dioxin and furan congeners were below detection limits in all three samples from the upstream sites. The concentrations of all tested dioxins were also less than detection in sediments collected at three sites downstream from the mill (i.e., 0.3, 0.8, and 1.3 km downstream). However, these same downstream sites were contaminated with the furans 2, 3, 7, 8-T4CDF (tetrachlorodibenzofuran) and total T4CDF. The latter ranged from 125 to 642 pg/g dry weight and the former from 100 to 642 pg/g dry weight compared to < 10 pg/g upstream. The downstream point of return to non-detectable levels was not determined in this study. The majority of sediments collected downstream from the other nine interior pulp mills in the Government of Canada study also contained these furans (range of <10 - 3168 pg/g). These are the principal furan forms found in bleached kraft pulp mill effluent.

In December, 1989, B.C. Hydro sampled the sediments extensively between Keenleyside Dam and the Kootenay River confluence (Kelly, 1990; Appendix 1). In agreement with the results of Mah et. al., the two samples from the two sites upstream from Celgar showed no detectable dioxins and furans. Twelve of the 20 samples from downstream sites showed detectable levels of 2,3,7,8-T_4CDF and total T_4CDF. The latter ranged from 1.7 to 480 pg/g and the former from 1.7 to 330 pg/g (with detection limits of 0.4 - 3.8 pg/g). The highest TCDF levels were at the boat launch site (7 km downstream from Celgar) and the next highest readings were immediately downstream from the outfall (110 pg/g) and at Tin-cup Rapids (64 pg/g) 9 km downstream from Celgar. The congener P_5CDF was detected (4.4 pg/g) only at the site immediately downstream from the Celgar outfall.

In contrast to the results of Mah et.al., the dioxin congener OCDD, was detected at four of these contaminated sites: immediately downstream from the outfall (57 pg/g); at the boat launch 7 km downstream (14 pg/g); off the Castlegar sewage treatment plant discharge, 8 km downstream (54 pg/g); and at Tin-cup Rapids, 9 km downstream from Celgar (100 pg/g). The congeners H_6CDD (5.2 pg/g) and H_7CDD (3.7 pg/g) were detected at one site: immediately downstream from Celgar's outfall. B.C. Hydro did not sample sediments downstream from the Kootenay River confluence, so the point at which levels return to non-detection is not known. Mah et.al. did not report detectable levels of H_6CDD and H_7CDD downstream from the other interior pulp mills; however, their detection limits (30 and 50 pg/g, respectively) were an order of magnitude higher.

b) Sediment Resin Acid Levels

As hydrophobic substances, resin acids partition from water into non-aqueous phases such as suspended solids and organic particles (e.g., pulp fibres) with eventual accumulation in bottom sediments. The half-life for sediment-bound dehydroabietic acid (DHA) has been computed to be 21 years, in contrast to six weeks in water (Taylor et. al., 1988).

Sediment concentrations of the non-chlorinated resin acids downstream from the Celgar mill were measured by the Waste Management Branch on March 30, 1989 (Table 35) and by B. C. Hydro, December 11 - 13, 1989 (Table 36). Levels of the more persistent chlorinated resin acids were measured by B.C. Hydro (Seakem Analytical Services Ltd.) but not by the Waste Management Branch.

The Waste Management Branch results indicate that the levels of resin acids (e.g., dehydroabietic acid) in the sediments (16 µg/g or ppm) were up to three orders of magnitude greater than that found in water (11 µµg/L or ppb). Sediment-bound resin acids were highest along transect 2, at 1 km downstream from the Celgar effluent. All of the resin acids monitored were detected with the exception of neoabietic acid. Dehydroabietic acid (16 µg/g) and isopimaric acid (11 µg/g) were found to be at the highest concentrations (these were among the major resin acids found in the Celgar effluent). At transect 3 site ii located at Robson ferry 4 km downstream from the Celgar outfall, all resin acids levels were less than detection, except for isopimaric and sandaracopimaric acids. The downstream extent of the sediment contamination for these two resin acids has not been determined. The Waste Management Branch did not sample for resin acids upstream from Celgar, thereby providing no reference against which to interpret the downstream results.

B.C. Hydro collected sediments for resin acid analysis at 13 sites between Keenleyside Dam and the Kootenay River, including 2 sites upstream from Celgar (Table 36). All resin acids were found to be detectable in this reach, except for neoabietic acid, chlorodehydroabietic acid, and dichlorodehydroabietic acid. Interestingly, the upstream levels of pimaric acid (11.3 µg/g) and levopimaric acid (40.1 µg/g) were higher than any downstream sediment levels (<0.1 - 8.4 µg/g for pimaric; and <0.1 - 9.3 µg/g for levopimaric), suggesting some influence of sunken woody debris (see Section 4.1.2). Dehydroabietic acid was highest in the sediments at Tin-cup Rapids (to 48 µg/g) and at the boat launch (43 µg/g) compared to a similarly high level (36 µg/g) at the Keenleyside Dam. The remaining three resin acids were all found to be highest at the boat launch, approximately 7 km downstream from Celgar: sandaracopimaric acid (13.4 µg/g compared to a control level of 5.8 µg/g); abietic acid (12.2 µg/g compared to a control level of 7.4 µg/g); and isoprimaric acid (11.3 µg/g compared to a control level of 3.5 µg/g). Sediment resin acids at the furthest downstream sites (to Tin-cup Rapids) were generally low to below detection, except for abietic and dehydroabietic acids.

The effects of resin acid contamination are difficult to predict. The toxicity of sediment-bound resin acids to benthic invertebrates, periphyton and aquatic vascular plants has not been adequately studied, and although it is known that all resin acids bioaccumulate, their ability to be biomagnified has not been documented. In addition, contaminated sediments, as a result of desorption and resuspension, could have a significant effect on aquatic life in downstream areas where water column concentrations of resin acids are low.

c) Sediment EOX Levels

The most general measure of pulp mill organochlorine compounds in receiving sediments is EOX (extractable organic halides). Although the majority of sediment EOX remains unidentified, the levels of EOX have been correlated with specific compounds such as chloroguaiacols and dioxins/furans (Colodey, 1988). Patterns of EOX sediment contamination downstream from a pulp mill will vary with hydraulic conditions which determine whether sediment is being accumulated or eroded. Areas where sediment EOX has accumulated can act as a continuing source of contamination to the biota, even after the source has been stopped or reduced.

Sediments downstream from the Celgar mill were monitored for EOX by the Waste Management Branch on March 30, 1989, and by B.C. Hydro, in December 1989. EOX levels measured in sediments downstream from Celgar by the Waste Management Branch ranged from 47 to 140 µg/g along transect 2 (1 km downstream) and declined to 34 µg/g at transect 3 (4 km downstream) (Table 35). Background levels were not measured, nor was the downstream extent of EOX contamination determined. Of the 20 sediment samples taken by B.C. Hydro between Keenleyside Dam and Kootenay River (Kelly, 1990) only one sample taken from Tin-cup Rapids (9 km downstream from Celgar) showed detectable EOX (34 µg/g). All other samples, including upstream controls and those taken immediately downstream from the Celgar outfall, were <10 µg/g. The results show high variability at some sites making interpretation difficult and pointing to the need for more replication. By way of comparison, a maximum EOX value of 6270 µg/g was measured in the vicinity of the Norssundet bleached kraft mill in Sweden (Colodey, 1988). Sediment EOX values in the vicinity of the Woodfibre pulp mill in Howe Sound averaged approximately 10 µg/g during January, 1989.

d) Sediment Chlorinated Phenolic Levels

Sediment sampling by the Ministry of Environment on March 30, 1989, and by B.C. Hydro in December, 1989, has indicated the presence of pulp mill-generated chlorinated phenolics between Celgar and the Kootenay River. The range of such contamination beyond this reach, however, is presently unknown.

The Ministry of Environment data are reported in Table 35. Pentachlorophenol was found at the lowest concentration (<0.005 - 0.05 µg/g), whereas the maximum concentrations for the tetrachlorophenols, trichlorophenols, trichloroguaiacols and tetrachloroguaiacols were in the range of 0.12 - 0.14 µg/g at a transect 1 km downstream from the outfall. At a transect 4 km downstream, the levels of all these chlorinated phenolics decreased to below 0.01 µg/g. Tetrachlorocatechol, one of the main chlorophenolics found in sediments downstream from other pulp mills discharging bleached kraft effluent, was not monitored. Upstream (background) levels were not determined, nor was the downstream extent of contamination investigated. The latter is significant since several studies have shown long-range transport of chloroguaiacols (> 500 km) and chlorocatechols (50 km) in the Fraser River (Colodey, 1988).

Results from the 20 B.C. Hydro samples are given in Table 37. These samples were analyzed using far lower detection limits than used by the Ministry of Environment (in the 0.1 ng/g range). The only chlorinated phenolics detected upstream from Celgar were pentachlorophenol (1 ng/g) and 2,3,4,6-tetrachlorophenol (0.6 ng/g), whereas the chlorinated guaiacols, catechols, anisoles, and veratroles were only detected downstream from Celgar. Downstream from Celgar, pentachlorophenol decreased to 0.9 ng/g at 500 m downstream, increased to 2.0 ng/g at the boat launch site (7 km downstream), and decreased at the Tin-cup Rapids sites to <0.2 - 1.0 ng/g. These pentachlorophenol results are far lower than the Ministry of Environment results reported above. The only tetrachlorophenol detected downstream was 2,3,4,6-TeCP. Levels of this isomer were also highest immediately downstream from Celgar (3.0 ng/g) and lowest in the Tin-cup Rapids sediment (<0.4 - 1.0 ng/g).

It is worth noting that these detectable levels of chlorophenols (from both agencies) are considerably lower than the sediment quality objective for chlorophenols of 0.01 ug/g as set for the lower Fraser River (Swain and Holms, 1985). This objective for chorophenols applies to the sum of tri-, tetra-, and penta-chlorophenol and is 0.07 times the lowest AET (apparent effects threshold) for pentachlorophenol alone.

The chlorocatechols were the main chlorophenolic found in the sediments downstream from Celgar: within the initial dilution zone 3,4,5 TCC reached a level of 37 ng/g and TeCC a level of 36 ng/g. Neither of these were detected downstream from the boat launch site. It has been suggested (McLeay, 1987; Colodey, 1988) that higher levels of chlorocatechols can be reached in sediments (relative to their presence in the pulp mill effluent) by conversion of other chlorinated compounds (e.g., chlorolignins) via bacterial action.

The trichloroguaiacols, 3,4,5 TCG and 4,5,6 TCG were both detected downstream from Celgar (but not upstream). The 3,4,5 TCG increased from 3 ng/g in the sediments of the initial dilution zone to 24 ng/g 7 km downstream at the boat launch site. The 4,5,6 TCG increased from 0.1 ng/g within the initial dilution zone to 4 ng/g 500 m downstream.

Trichloroguaiacol levels were several times lower or non-detectable at Tin-cup Rapids. Tetrachloroguaiacol reached 2 ng/g in the sediments at the initial dilution zone and measured up to 20 ng/g at the boat launch site, with lower levels at Tin-cup Rapids (ND to 0.9 ng/g).

It has been shown that under aerobic conditions, O-methylation of chloroguaiacols can occur via microbial action with the synthesis of the more toxic, more bioaccumulative chloroveratroles (Allard et. al. 1988). Both tri- and tetrachloroveratroles were present at high levels in the sediments downstream from Celgar's outfall reaching maximum levels of 29 ng/g and 8 ng/g, respectively, at the boat launch site, 7 km downstream. Both veratroles were detectable at Tin-cup Rapids (up to 13 and 3 ng/g, respectively).

Only the 2,4,6-isomer of trichloroanisole was detected in the sediments downstream from the Celgar outfall with levels of 0.6 - 1.0 ng/g at 500 m downstream, 3 ng/g 7 km downstream, and up to 0.2 ng/g at Tin-cup Rapids. The compounds 2,3,5,6 and 2,3,4,6 tetrachloroanisole were also present at 0.4 ng/g in sediments at the boat launch site, but no where else.

5.1.3 BENTHIC MACROINVERTEBRATES

a) Community Analysis

The benthic macroinvertebrate population of the Columbia River within this reach has been studied by Dwernychuk (1980, 1983, 1984 and 1988) using artificial substrates. The results for this period, in terms of densities, tolerance categories and community analyses are given in Table 38. The results do not show drastic toxic effects, but rather an accommodation of the community structure. This is not unexpected, as a review of work by various researchers has shown that aquatic invertebrates, especially the insect component, are less sensitive to kraft mill effluent than fish (Hutchins, 1979; Sprague, 1988).

Population density values for 1988 indicate a gradual increase from those sites closest to the Celgar outfall downstream to the site at the Columbia/Kootenay confluence.

Invertebrate densities in 1988 at all sites were observed to have increased relative to 1980, suggesting some organic enrichment/accumulation over the years. Dwernychuk has noted similar benthos density responses from the Fraser River near the Prince George pulp mills.

The distribution of benthic faunal tolerance types (sensitive, facultative and tolerant) has remained relatively stable over the period of investigation i.e., conditions have not progressively deteriorated over the years. Tolerant organisms (those adapted to degraded conditions and usually not important as fish food) were most abundant at the site immediately downstream from the Celgar outfall. Nematode worms were especially abundant near the outfall, as has been noted by Dwernychuk near other kraft mill discharges. Progressing downstream there is a shift to facultative organisms (which can tolerate a moderate level of water quality degradation). Sensitive organisms are not a significant component of the benthic community in this reach of the Columbia River.

The pulp mill effluent quality and habitat alterations by fibre deposition have also altered benthic community structure. Richness indices increase with increasing distance from the Celgar outfall. Higher effluent dilution and lower fibre mat impact further downstream allow a more complex community structure. Again, these data point to a stabilization of community structure over the past decade (acclimation by the surviving aquatic community) which can be attributed to the positive aspects of high river flow and periodic flushing of the bottom.

b) Freshwater Mussel Tissue Analysis

Three different species of freshwater mussels were collected from Columbia River sediments upstream and downstream from Celgar on March 30, 1989. Shucked whole body tissues of Anodonta kennerlyi, Gonidea angulata and Margaritiferia falcata were submitted for chlorinated organic contaminant analysis, i.e., EOX, chlorophenols, and dioxin and furans. On November 22, 1990, 24 Anodonta kennerlyi were again collected upstream and downstream from Celgar and submitted for tissue analysis of chlorophenols, chloroguaiacols, chlorocatechols, chloroveratroles, chlorovanillins, chlorosyringols, dioxins/furan, and EOX (Tables 39-42).

Because mussels are large, sedentary, and relatively abundant filter-feeders in close association with the sediments, they are being used increasingly as in situ biological monitors of aquatic contaminants such as metals, pesticides, and industrial organochlorines (Metcalfe and Charlton, 1989). In the Columbia River, mussel biomonitoring can complement traditional water and sediment sampling by defining the biological impact zone. With future process changes at the Celgar mill, biomonitoring with mussels could also be valuable in demonstrating the effectiveness of such changes on the aquatic environment.

The results of the analyses are not strictly comparable and must be used cautiously: the sample size is small, not all species are represented at each site for each date and, for the 1989 dioxin and furan samples, there are no upstream control data. Additionally, the samples were taken during different seasons and nothing is known of the organism parameters which could affect pollutant accumulation such as sex, age or reproductive state. As reviewed by Phillips (1978), these interfering factors may be more important in determining tissue organo-chlorine levels than the actual ambient water levels.

Chlorophenolics

The limited data (wet weight; Tables 39 and 41) indicate that mussels upstream and downstream from Celgar had non-detectable levels of: mono-, di-, and trichlorophenol; 2,3,4,5-tetrachlorophenol; and trichloroguaiacol. Some 2,3,4,6-tetrachlorophenol was detected in one downstream sample (0.07 ug/g) during the March 1989 sampling. Tetrachloroguaiacol was also detected in only one Anodonta kennerlyi sample (5.6 ng/g), 300 m downstream from Celgar. Pentachlorophenol was detected in only one of the 21 mussel tissue samples: 24 ng/g (detection limit of 20 ng/g) from A. kennerlyi 1 km downstream from Celgar. EOX were detectable in mussels captured both upstream and downstream from the pulp mill.

Metcalfe and Hayton (1989) reported that leeches were superior to mussels as biomonitors for chlorophenols. In a comparative test conducted downstream from two kraft mills on Rainy River in Northwest Ontario, concentrations of chlorophenols in the mussel Elliptio complanata (<0.5-3.5 ng/g) were 1-2 orders of magnitude lower than in leeches Nephelopsis obscura (21-121 ng/g). This is related to the rates of elimination, which are slower in leeches (approximately 30-d half-life) than mussels (2 to 3-d half-life). Future biomonitoring work on the Columbia River should investigate the use of leeches.

Tissue EOX levels from March 30, 1989, were detectable upstream (to 2.5 µg/g, mean of 1.4 µg/g, with a detection level of 1.0 µg/g), but lower than levels downstream from the pulp mill: mean of 2.1 µg/g for three A. kennerlyi 1 km downstream from Celgar, and mean of 7.2 µg/g for two Margaritifera falcata from Robson. The EOX increase in downstream animals suggests pulp mill contamination. However, in the samples taken November 22, 1991, mussel tissue EOX (one sample) from upstream from Celgar was higher (21.5 µg/g) than those from two downstream samples (14.6 and 15.5 µg/g). Reasons for the different upstream/downstream trends between the 1989 and 1991 samples are not apparent at this time, but may be resolved with further monitoring.

Dioxins and Furans (Tables 40,42)

In March 1989, only TCDF was detectable (at the ppb level) in the Columbia River mussel samples. Tissue TCDF levels in Anodonta kennerlyi taken 1 km downstream from Celgar ranged from 0.3 to 1.3 ng/g (300 - 1300 parts per trillion), and levels in Margaritifera falcata ranged from 0.04 to 0.15 ng/g. All data are expressed on a wet weight basis.

Mussel tissue (A. kennerlyi) sampled in November, 1990, was subjected to analytical methods capable of lower ppt detection. This revealed:

1) detectable levels of TCDD from both upstream (1.9 ppt) and downstream (3.3 - 3.9 ppt) mussel samples.
2) high levels of TCDF in downstream tissue samples (370 - 400 ppt) compared to upstream samples (9 - 11 ppt), and
3) detectable low levels of 1,2,3,7,8 PCDF (2 - 2.4 ppt) and 2,3,4,7,8 PCDF (3.3 - 3.5 ppt) in downstream mussels (not upstream).

The differences in mussel tissue TCDF maximum levels between 1989 (1300 ppt) and 1990 (400 ppt) more likely reflect variability due to sample size than any real decrease related to external inputs. For the 1989 samples, the number of mussels per composite ranged from 2 to 8, and for 1990, the composites were composed of 6 or 12 animals.

Mussel tissue data from other pulp mill influenced river systems are not presently available for comparison. However, data for marine mussels near coastal B.C. pulp mills are available (Table 43). TCDF levels in marine mussels were lower (50 - 340 ppt) than in the Columbia River and five dioxin congeners were discerned (four of which were not present in the Columbia River samples). Such comparisons, of course, cannot be carried too far because different species, different environments, and different mills are involved.

The implications of these mussel tissue organochlorine levels for the health of the mussel community specifically or the aquatic biota generally cannot be determined at this time. Future bioassay work may elucidate the organismal and community effects of such tissue contamination.

The effects of this dioxin contamination in mussels on wildlife consumers is perhaps less equivocal: all downstream samples have exceeded Newell's (1987) criterion of 3 ppt for the protection of wildlife consumers (if the TEQ concept is applied) (see Section 5.1.4 f for further discussion of wildlife criteria). One 1989 composite sample exceeds this proposed safe level by over 40 times (site 2cii, 1 km downstream from Celgar). The variety of wildlife consuming freshwater mussels, specific to the Columbia River, would include crows, shorebirds, and mammals such as otter, mink, muskrat, and racoon (Fuller, 1974). Food-chain transfer of mussel contaminants has not been studied, but exists as a potential problem.

Human consumption of Columbia River mussels is not likely prevalent or frequent; however, it is a possibility now or in the future. If such consumption was documented as occurring, the Local Medical Health Officer would decide if a consumption advisory was necessary.

EROD Enzyme Activation

The induction of monooxygenase enzymes in fish after exposure to organic contaminants is being used as a direct biochemical indicator of contaminant exposure (Jimenez and Stegeman, 1990). These detoxification enzymes act by decreasing the lipid solubility of the contaminants thereby facilitating their excretion. One of these enzymes, ethoxyresorufin O-deethylase (EROD), appears to be the most distinct biochemical indicator of chlorine bleached kraft mill effluent (Oikari and Lindstrom-Seppa, 1990). Dioxins/furans as well as other planar chlorinated hydrocarbons have been shown to be dramatic EROD inducers, whereas resin acids and chlorinated phenolics are not responsible for induction.

EROD induction in mussels has not been reported in the literature. Given their sedentary nature and relative abundance in the Columbia River, an experiment was conducted at the Ministry of Environment Toxicology Laboratory to determine if these mussels were synthesizing EROD as a response to Celgar's effluent. Live mussels captured on November 22, 1990, at a control site 1.4 km upstream from the pulp mill were transferred to laboratory aquaria containing control water, 1 % Celgar pulp mill effluent and 3.5 % Celgar pulp mill effluent. Samples of the mussel digestive gland tissue were taken at days one, seven and fourteen, and analyzed for EROD. The results of the EROD determinations for all samples in each exposure were less than the most sensitive detection limit achieved (4.0×10^{-9} moles resorufin/mg protein/minute) (CBR International Corp., 1991). The level of effluent exposure used in this experiment was higher than that which has induced EROD in fish, suggesting that mussels do not have the same detoxification biochemistry and are not good candidates for EROD biomonitoring.

5.1.4 FISH TISSUE DIOXIN AND FURAN RESIDUES

Fish collected upstream and downstream from the Celgar mill were subjected to muscle tissue analysis for dioxins and furans by both Environment Canada (August, 1988) and the B.C. Ministry of Environment (November and December, 1989). The Environment Canada study was part of a Province-wide survey of fish and sediments in the vicinity of 10 interior pulp mills (Mah et. al., 1989). Scientists captured 42 individual fish of three different species (largescale sucker, lake whitefish, northern squawfish) (Table 44) and composited seven fish for each analytical sample (Table 45). The Province captured 20 individual fish representing three different sportfish species (yellow walleye, rainbow trout, mountain whitefish). Each of the Province's fish samples was subjected to a separate analysis except for 2 mountain whitefish which were composited. These results are shown in Table 46. All results are expressed on a wet weight basis. The data are presented in sub-sections a)-c) and their implications are discussed in sub-sections d)- g).

a) Tissue Furan Levels

The furan 2,3,7,8 TCDF was the predominant congener contaminating the fish samples of both agencies. Environment Canada found TCDF in samples both upstream from Celgar (2-45 pg/g) and downstream from Celgar (26-908 pg/g). However, the Province's upstream samples had non-detectable levels (<3pg/g), whereas downstream levels ranged from 4 to 170 pg/g. The highest TCDF levels were found in the Environment Canada lake whitefish composite samples (647 and 908 pg/g) and the Province's mountain whitefish individual samples (125 and 170 pg/g). Surprisingly, the lowest TCDF levels were recorded from the bottom-feeding largescale sucker (2 pg/g) and the piscivorous northern squawfish (6 pg/g) (Table 45). The two other piscivorous species, rainbow trout and walleye, also had comparatively low TCDF levels (4-40 and 10-31 pg/g, respectively,Table 46).

These species differences may in part be explained by their different lipid content since dioxins and furans, as organochlorines, are lipophilic. The Environment Canada data show that the highest lipid content was in lake whitefish (to 10.5 % wet weight) and the lowest was in suckers (0.6-3.4 %). However, to confound the picture, squawfish also had a high lipid content (9.2 %). Mah et. al., determined that there was not a significant correlation between the concentrations of furans/dioxins and either fish weight or tissue lipid content. The small sample size in this study, however, does not allow conclusive statements to be made. The Province did not determine the lipid content of its samples.

The highest levels of furans in B.C. fish tissue measured by Environment Canada during its 1988 study (Mah et. al., 1989) were measured in mountain whitefish collected downstream from the pulp mills at Quesnel (1185 pg/g 2,3,7,8 TCDF). The lake whitefish samples collected downstream from Celgar had the second highest TCDF levels (647-908 pg/g) found by Mah et. al., in B.C. In contrast to the Columbia River squawfish (6 pg/g), the squawfish captured downstream from the Weyerhaeuser Ltd. pulp mill at Kamloops had much higher levels of TCDF (704 pg/g 2,3,7,8 TCDF). However, in a North American context, the TCDF levels measured in fish near Celgar are high. Compared to the results of the U.S. EPA National Fish Survey, these Columbia River fish tissue TCDF levels would rank among the most contaminated samples measured to date in the U.S. (the

90th percentile in the U.S. survey is approximately 9 pg/g) (shown in Johnson et. al., 1991).

The 2,3,7,8-TCDF congener was the only furan detected in the samples collected by the Province. In one of the composite lake whitefish samples captured by Environment Canada downstream from Celgar, PCDF was detected (13.4 pg/g). PCDF was the only other furan (besides TCDF) that was detected in fish downstream from the nine other Interior pulp mills samples by Mah et. al., (range 4.0 - 25.1 pg/g).

b) Tissue Dioxin Levels

Dioxins were detected in both lake whitefish (Table 45) and rainbow trout (Table 46) captured downstream from the Celgar mill. The most toxic dioxin congener, 2,3,7,8 TCDD, was detected only in the lake whitefish composite samples (ranging from 6.6 to 10.5 pg/g). In comparison to the samples taken near the other Interior mills (11.7 - 137 pg/g), these levels are low. TCDD was not detected from fish samples upstream from Celgar.

The non-TCDD dioxins that were detectable in the rainbow trout collected by the Province included H_6CDD (94 pg/g), H_7CDD (111 pg/g), and OCDD (121 pg/g). The 2,3,7,8-TCDD congener was not detected in rainbow trout. No other fish samples collected by the Province or Environment Canada from the vicinity of Celgar contained these dioxins. However, these other dioxin congeners were detected in fish downstream from the U.S./Canada border (see next section).

The presence of dioxins and furans in fish tissue is not unexpected since they were detected in the effluent (see Section 4.3.4 g), in the sediments (Section 5.1.2 a), and in unionid mussel tissue (Section 5.1.3 b) downstream from the mill. As hydrophobic compounds, dioxins/furans are largely transported by dissolved organic matter and suspended particulate matter and bound with sediments where they become biologically available. By virtue of their lipophilicity, these compounds can bioaccumulate to measurable levels in fish tissue. According to Cook et. al., (1991), only 2,3,7,8 TCDD bioconcentration factors for fish (relative to water concentrations) have been reported: 39 000 for rainbow trout (Mehrle et. al., 1988) and 7900 - 159 000 for fathead minnows

(Cook et. al.). The most important route for dioxin uptake by fish, however, appears to be through food chain transfer and through contact with contaminated sediments, with water exposure being a less important route (Muir and Yarechewski, 1988; Colodey et.al., 1991).

c) Dioxin/Furan Levels in Roosevelt Reservoir Sportfish

The upper end of Roosevelt Reservoir near Northport, Washington, is approximately 50 km downstream from Celgar. Extending 240 km to the Grand Coulee Dam, this reservoir represents the first downstream catchment for dioxin/furan contaminated water and suspended particulate matter emanating from Celgar. Concerned that reservoir sportfish could show dioxin/furan contamination similar to that of upstream fish, Washington State analyzed reservoir fish muscle tissue in 1989 and 1990.

1989 Sampling

During June and July, 1989, the Washington State Department of Ecology collected two yellow walleye and two white sturgeon for dioxin/furan analysis from the upper reach of Roosevelt Reservoir near Kettle Falls (within 60 km of the U.S./Canada border). This survey constituted an initial screening to determine if these compounds were detectable. The species collected are two of the reservoir's major sportfish species. The results shown in Table 47 confirm that these fish were contaminated with dioxins and furans from the Celgar mill. The results, however, show high within-species variation and the duplicate results are poor in terms of repeatability .

As for the upstream (Canadian) results, the predominant congener was 2,3,7,8-TCDF in both the sturgeon (3.9-321 pg/g) and walleye (8.9-326 pg/g). The tissues of both species were contaminated to the same degree with TCDF; however, the elevated walleye results were approximately 10X higher than the B.C. walleye results (10-31 pg/g), but only one-third to one-half those in the lake and mountain whitefish taken near Celgar.

The Washington State results also revealed detectable levels of four other furan congeners: PCDF, H_6CDF, H_7CDF AND OCDF. Of this list, only PCDF was detected in the B.C. and Environment Canada fish samples. As Johnson (1990) has suggested, this may be due to the higher Canadian detection limits (1-15 pg/g) compared to the lower ones used in the U.S. survey (0.02 - 0.6 pg/g).

All five dioxin congeners tested were found to be detectable in the U.S. fish. None of the walleye analyzed by the Province showed detectable dioxins, whereas the Roosevelt Reservoir walleye showed detectable levels of TCDD (0.2 - 4 pg/g) and PCDD (0.56 pg/g). Again this is likely due to the higher detection limits used by the Province (Zenon Lab; 2-39 pg/g) compared to the U.S. (0.1 - 0.8 pg/g). The highest total dioxin level found in the U.S. fish was 5-20 pg/g for one of the sturgeon, whereas the highest for the Canadian samples was 326 pg/g for one of the rainbow trout caught near Robson (Table 46, sum of H_6CDD, H_7CDD and OCDD).

The U.S. results also revealed substantial within-species differences in TCDD and TCDF levels (Table 47). Re-analysis of the samples confirmed the results of the original analysis (same tissue samples re-analyzed for three fish and duplicate sample analyzed for one sturgeon). Johnson has hypothesized that the disparity could be the natural outcome of different movement patterns (i.e., reservoir versus tributary residence).

1990 Sampling

Because of the small sample size in 1989, the results were deemed inconclusive. To substantiate these preliminary results, the Washington State Department of Ecology conducted an intensive survey between May and October, 1990 (Johnson et. al., 1991). Muscle tissue from Roosevelt Reservoir walleye (12 samples), rainbow trout (12 samples), lake whitefish (12 samples), white sturgeon (4 samples), kokanee (2 samples), and burbot (2 samples) were sampled. Each sample was a composite of five individuals, making a total of 220 individual fish. The results for 2,3,7,8-TCDD and 2,3,7,8-TCDF are shown in Table 48.

2,3,7,8-TCDD was detected in all samples of kokanee (0.7 - 0.9 pg/g), lake whitefish (0.5 - 2.7 pg/g), sturgeon (0.8 - 4.4 pg/g), and in most rainbow trout samples (0.8 - 1.6 pg/g). It was not detected in burbot or in the majority of walleye samples where measured levels (0.2 - 0.3 pg/g) were close to the detection limits.

2,3,7,8-TCDF was again the predominant contaminant found and was detectable in all Roosevelt Reservoir species tested (range of 0.9 - 222 pg/g). As for TCDD, the highest levels were found in lake whitefish (42 - 205 pg/g) and sturgeon (73 - 222 pg/g). TCDF accounted for 76 % of the TEQ, on average. The levels of TCDF in Roosevelt Reservoir fish are lower than those measured in fish closer to Celgar, but are high enough to put the lake whitefish and sturgeon results among the top 10 % of TEQs in the U.S. EPA national fish survey.

Johnson et. al. (1991) also analyzed selected lake whitefish and sturgeon samples for all 2,3,7,8 - substituted PCDD's and PCDF's (see Table 49). The additional congeners detected were: OCDD (3.5 - 40.9 pg/g), PCDD (0.1 pg/g), H_6CDD (0.2 pg/g), H_7CDD (0.3 - 1.5 pg/g), PCDF (0.4 - 1.3 pg/g), H_6CDF (0.4 pg/g), H_7CDF (0.2 pg/g), and OCDF (1.3 - 1.4 pg/g). By employing lower detection limits, Washington has added four more congeners to the list of detectable dioxins/furans downstream from Celgar. However, because of their lower toxicity relative to 2,3,7,8-TCDD, these others do not contribute significantly to the final TEQs (i.e., <5 %).

Lake whitefish eggs and liver tissue were also analyzed for dioxins/furans (Johnson, 1991). As would be expected for samples with high lipid content, both tissues had higher concentrations than found in muscle: eggs, 8.5 pg/g TCDD and 787 pg/g TCDF (87 pg/g TEQ); liver, 3.1 pg/g TCDD and 289 pg/g TCDF (32 pg/g TEQ).

A pattern of fish tissue contamination in Roosevelt Reservoir was apparent for rainbow trout: there was a decrease observed in TCDD and TCDF levels between the upper and lower portions of the reservoir. No such decrease was observed for walleye or lake whitefish. In comparing the Roosevelt Reservoir fish tissue to those from Wenatchee Lake, Washington, an undeveloped lake considered as background, Johnson et. al. concluded that:

1) kokanee, lake whitefish, sturgeon and upper reservoir rainbow trout had TCDD levels 8 - 24 times higher than background, and that

2) TCDF levels were moderately to highly elevated for all species in Roosevelt Reservoir: 12 to 60 times background in burbot, walleye, and lower reservoir rainbow trout: and 190 to 740 times background in lake whitefish, sturgeon, kokanee, and upper reservoir rainbow trout.

d) Levels from Keenleyside to Mouth of Columbia River

Figure 14 from Johnson et. al., (1991) summarizes the available distribution data on dioxin/furan levels (plotted as TEQ's) in Columbia River fish from Keenleyside Dam to the Pacific Ocean. The U.S. Columbia data are from the U.S. EPA National Bioaccumulation Study and from surveys by the Northwest Pulp and Paper Association (from Johnson et. al).

As reviewed by Johnson et. al. (1991), the most contaminated fish species in the Columbia River (TEQs >10 ppt) are lake whitefish, mountain whitefish, and sturgeon between Keenleyside Dam and Rufus Woods Lake (the reservoir immediately downstream from Grand Coulee Dam). Figure 14 also illustrates the greater degree of TCDF contamination in this upper reach compared to the lower river i.e., TCDF contributes a greater portion of the TEQ, whereas TCDD levels are comparable between the Celgar - Roosevelt Reservoir reach and the lower river. Reasons for this have not been advanced; however, Johnson et. al. report that there are four Washington and three Oregon bleached kraft pulp mills located on the lower Columbia River (downstream from Grand Coulee Dam) and that all seven have secondary biological treatment of their effluent.

e) Implications For Fish Populations

Adverse effects on physiology and significant mortality of rainbow trout fry and young carp (+ 1 year) have been observed at whole body TCDD concentrations of approximately 1000 - 2000 pg/g (Mehrle et. al., 1988; Cook et. al., 1991; Spitsbergen, 1988). These levels are 1 to 2 orders of magnitude higher than those of the most contaminated fish in the Columbia River downstream from Celgar (using TCDD TEQs). However, as cautioned by Rabert (1990), TCDD body burdens in fish may not be related strictly to lethality since fish in such tests have been found to die after the TCDD burden has depurated significantly.

Early life stages have been reported to be more susceptible to TCDD body burden-related toxicity than juvenile and adult fish. Walker et. al. (1991) observed reduced hatchability in lake trout eggs at egg TCDD concentrations of $\geq$ 226 pg/g. Lake trout sac fry are even more sensitive to TCDD toxicity when exposed to TCDD as fertilized eggs. Walker et. al. reported that the TCDD concentration in eggs causing 50% mortality (LD_{50}) in swim-up fry was 65 pg/g. The lowest observable effect level was 55 pg/g and the no observable effect level was 34 pg/g. Previous work (Spitsbergen et. al., 1991) has shown that egg TCDD concentrations as low as 40 pg/g cause increased sac fry mortality. Comparing these findings to the one known level of TCDD/TCDF in Columbia River lake whitefish eggs (87 pg/g TEQ) would suggest the possibility of fry mortality and consequent reproductive impairment of the population. Such a comparison between different species is speculative and requires experimental verification; however, it does indicate that further monitoring of Columbia River fish eggs is warranted.

The lowest observed biological effect of exposure to TCDD in fish is the induction of the mixed function oxidase (MFO) enzymes (e.g., EROD). Servizi et. al. (1990) have reported an apparent threshold for EROD induction in the range of 1-10 pg/g 2,3,7,8 TCDD TEQ. While the ecological and physiological significance of such enzyme induction to the health of a fish population requires further investigation, it does provide an early warning of potential adverse effects. All of the fish species monitored downstream from Celgar have tissue TCDD TEQ levels exceeding this early warning stress threshold. MFO induction work has yet to be done on Columbia River fish.

f) Implications for Wildlife

A complete list of birds and mammals that feed on fish and aquatic life in this reach of the Columbia River has not yet been compiled; however, it is expected to be extensive. Aquatic-feeding birds which could potentially be at risk due to pulp mill contamination include osprey, eagles, herons, ducks, geese, gulls and various shore-birds. Piscivorous birds would have higher tissue TCDD levels than those consuming either crustaceans or molluscs (J. Elliot, personal communication). Mammalian species feeding on fish and aquatic organisms include river otters, mink, bears and foxes. Wildlife consumers are more vulnerable to contaminant levels than humans because of their higher dependence on the localized aquatic food chain and because they typically consume the whole organism, especially the soft visceral parts which have higher dioxin/furan concentrations.

Dioxin/furan levels in the birds and mammals from this reach of the Columbia River have yet to be determined. During the winter of 1990-1991, nine mink and five river otter carcasses were sampled from the lower Columbia by the Canadian Wildlife Service (CWS) and the U.S. Fish and Wildlife Service. During May, 1991, CWS also collected osprey eggs downstream from Celgar. These samples were submitted for PCDD/PCDF analyses; however, the results were not available for inclusion in this report (J. Elliott, personal communication).

Dioxin/furan contamination of herring gulls from the Great Lakes has been associated with chick edema disease and a variety of reproductive problems (including embryo mortality and malformation) and adult behavioural changes (Gilbertson, 1983; J. Elliott, personal communication). In British Columbia, birds of Georgia Strait show some contamination with TCDD's and TCDF's although at levels less than that associated with severe reproductive problems elsewhere in the world; however, these birds are showing some sub-lethal effects characteristic of moderate exposure to TCDD-like compounds (J.Elliott).

At the present time, neither B.C. nor Canada have prey-item tissue criteria for the protection of wildlife consumers. Eisler (1986), after reviewing the results of laboratory TCDD studies with birds and mammals, concluded that concentrations of 2,3,7,8 TCDD in food items should not exceed 10 - 12 ppt to protect wildlife consumers. Newell (1987) in his review of the literature for the New York Dept. of Environmental Conservation determined that wildlife feeding primarily on fish with > 3 ppt TCDD would be at risk. Comparison of this 3 ppt threshold value with the TCDD TEQ results from Columbia River and Roosevelt Reservoir fish (Figure 14) indicates that the majority of samples exceed this value.

The extent of harmful effects (especially reproductive) on wildlife requires examination. The Celgar Expansion Review Panel (1991) has recommended that 1) the Canadian Wildlife Service undertake studies of the accumulation of contaminants (including chlorinated organics) in migratory birds in the area affected by the mill, and 2) that

Canadian and U.S. agencies conduct coordinated studies of the accumulation of contaminants (including chlorinated organics) in amphibians and aquatic mammals in the area affected by the mill.

g) Human Health Implications of Contaminated Fish Consumption

Studies of the effects of dioxins on human health have produced equivocal results. Recent evidence indicates that the primary action of 2,3,7,8 TCDD is that of a potent promoter of the tumorigenic potential of other chemicals, but that it is not genotoxic or cocarcinogenic. It also has mammalian reproductive effects thought to be due to the ability of dioxins to modify sex hormone metabolism (NCASI, 1989). Diet appears to be the single largest source of human exposure to dioxins and furans and the ingestion of contaminated fish may be an important pathway for such exposure.

Health and Welfare Canada presently administers a regulatory level (Food and Drug Act) of 20 pg/g 2,3,7,8 TCDD for the commercial sale of fish (however, they usually issue fish advisories if levels exceed 15 pg/g). By the 20 pg/g standard, none of the fish tissue samples from the Columbia River (Tables 45-47) could be considered contaminated and unfit for consumption. However, this regulation is presently under internal review to reflect the current understanding of toxic equivalency and the multi-media approach. In May, 1989, Health and Welfare Canada reviewed the Environment Canada fish tissue dioxin/furan data (Table 45) using the toxic equivalency approach and issued a 40 g/week consumption restriction advisory for lake whitefish in the Celgar area and 7 km downstream (Canada, 1989).

In June, 1990, a mountain whitefish consumption advisory for the Lower Columbia River (in Canada) was issued jointly by the Ministries of Health and Environment. For mountain whitefish, the average TCDD toxic equivalency exceeded the provincial guideline of >15.0 ppt and consumers were advised to restrict their intake to a maximum of 205 g fish/person/week. A Health and Welfare Canada news release dated April 27, 1990, stated that dioxin and furan levels in kokanee, rainbow trout, burbot, and yellow walleye were not of public health significance.

The Washington State Department of Health (DOH) reviewed their 1989 data and concluded that the sample size was too small and the results too equivocal to issue a health advisory on the consumption of Roosevelt Reservoir fish. After a review of the preliminary results from their 1990 sampling, DOH issued a limited health advisory for Roosevelt Reservoir whitefish: children under four years of age, or weighing less than 18 kg, were advised not to eat whitefish. Analysis of the final and complete data set (from 1990) by DOH resulted in their rescinding this health advisory (Marien et. al., 1991). A level of 20 pg/kg body weight/day was used as a human dose level of concern below which no biological effects were believed to occur. Because of the uncertainty inherent in the TEQ for 2,3,7,8 TCDD, and because of the uncertainty about where adverse effects from exposure doses begin, DOH has judged that TEQs in the range 20-80 pg/kg/day do not constitute levels for restricting consumption of lake whitefish and sturgeon by the most sensitive group, infants. Since consumption of Roosevelt Reservoir sport fish at levels approximating those of subsistence fishermen did not produce TEQ daily doses of >80 pg/kg, the earlier cautionary advisory was considered unnecessary.

5.2 KOOTENAY RIVER

The Kootenay River enters the Columbia River approximately 10 km downstream from Keenleyside Dam and 20 km upstream from Birchbank. Water quality data for sites 0200178 and 0200012 upstream from the confluence are summarized in Table 24 (see map for locations). For site 0200178 no data have been collected since 1979; however, for site 0200012 data to 1988 were available. These latter data should be representative of present conditions as there have been no new waste inputs to the Kootenay River between these two sites during the intervening years.

The Water Quality Branch is presently conducting a water quality assessment and objectives-setting exercise for the Kootenay River and west arm of Kootenay Lake (between Balfour and Brilliant) (R. Nordin, Water Quality Branch).

Overall, the water quality of the Kootenay River is very similar to that of the Columbia River. Levels of the dominant ion, calcium, are low (12 - 26 mg/L), and total alkalinity is in the 27-77 mg/L range with pH 7.6 - 8.8. The water is not highly coloured, organic compounds are low in concentration, and levels of total residue vary seasonally but do not exceed 108 mg/L. Fecal coliform levels have been low and for 1984-1988 have not exceeded 33 MPN/100 mL. Total dissolved gases have not been measured recently; however, 12 out of 13 measurements taken during 1972 - 1975 exceeded 110 % saturation. Sublethal effects of this supersaturation on Kootenay River fish have been predicted (W.I.B., 1977). Surface dissolved oxygen levels remain high (>9 mg/L).

Nutrient levels in the Kootenay River are also similar to background levels in the Columbia River: recent orthophosphorus and total phosphorus levels (1984-1988) have ranged from 1 to 5 µg/L, respectively. Total phosphorus levels exceed the approved criteria (lakes) for drinking water (10 µg/L). Ammonia-N levels have ranged up to 15 µg/L in the Kootenay River compared to <5 µg/L at the upstream Columbia River sites. Combining the maximum ammonia-N and nitrite/nitrate-N concentrations, and dividing this sum by the maximum dissolved phosphorus concentration gives a N:P ratio of 16:1, suggesting phosphorus-limited algal growth.

Total copper and total iron may be occasionally high and have exceeded B.C. approved or working criteria. Levels of up to 15 µg/L total copper have been recorded, thus exceeding the aquatic life criterion of 8 µg/L (at total hardness of 70 mg/L). Total iron levels have been recorded at 0.3 mg/L which is equal to the maximum criteria for both drinking water and aquatic life.

5.3 MURPHY CREEK HYDROELECTRIC DAM PROPOSAL

B.C. Hydro has proposed a 270 megawatt (33 m high) hydroelectric dam 3 km upstream from Trail which has the potential to affect both hydrology and water quality in the reach from Keenleyside Dam to Birchbank. As a run-of-the-river project, the dam would provide no additional regulation of the Columbia River, but it would raise upstream water levels and reduce flow velocities. The Murphy Creek Dam project has been on hold for the past decade. A private company, North Pacific Power Corporation, has recently (March, 1989) approached B.C. Hydro with a proposal to revive the dam project with the objective of exporting electricity. The Murphy Creek Dam is the last (in terms of construction priority) of seven dam construction and expansion projects being considered over the next 20 years for the Columbia River system in Canada (G. Ash, personal communication). At the time of writing, the start of construction for the Murphy Creek project would be in the year 2004.

The environmental impact assessment of the original project (IEC, 1981) should still be applicable. This study predicted no significant alteration of the nitrogen, phosphorus, dissolved oxygen or thermal characteristics of the Columbia River by the proposed reservoir. The proposed reservoir is not expected to change the pattern of Celgar's effluent dilution and dispersion (largely because of increased mixing associated with greater water depths). When the proposed reservoir reaches its operating level during summer to early winter, the Keenleyside sluiceway would be submerged, and thus gas supersaturation should not occur. However, supersaturation could continue from February to May during lower operating levels if the present Keenleyside sluiceway remains unmodified. This is unlikely since modifications to the Keenleyside dam and installation of generating capacity is projected to precede the development of Murphy Creek. The most significant effect of the proposed reservoir would be to slow down and accumulate contaminated fibre and suspended solids discharged from the Celgar mill. This effect would assume primary importance in any consideration of the Murphy Creek Dam proposal.

6. PROVISIONAL WATER QUALITY OBJECTIVES

The following provisional objectives are recommended at this time for the protection of aquatic life and other water uses in the lower Columbia River both in the reach between Hugh Keenleyside Dam and Birchbank, and downstream from this reach until other objective levels are set for the downstream reaches. As future receiving water monitoring programs improve the data base and as changes in effluent quality occur (e.g., pulp mill modernization), these objectives will be reviewed and revised as necessary. Objectives for chemical variables only (in three media: water sediment and tissues) are proposed in this report. The need for "ecosystem objectives" or levels of biological properties which can serve as indicators of aquatic ecosystem integrity and health is recognized by the author; however, at this time the required knowledge of the biological properties of this reach of the Columbia River is either unavailable or insufficient. The Columbia River Integrated Environmental Monitoring Program (see Section 7.0) is being designed to provide the needed information on benthic invertebrate community structure and indicator species (including fish) so that ecological objectives can be attempted in the future.

The recommended objectives apply to all parts of this reach of the Columbia River, except for the initial dilution zones of effluents. This is the initial part of the mixing zone where the Province accepts some degree of adverse biological effect i.e., sublethal stress, but not conditions that are acutely toxic or that would cause harmful bioaccumulation, or adverse sludge deposits. These excluded dilution zones are defined arbitrarily as extending up to 100 m downstream from the discharge point from the surface to the bottom and no more than 50 % across the width of the river for a pulp mill discharge or no more than 25 % for a municipal discharge. Initial dilution zones are not to impinge on bathing beaches or fish spawning habitat. This report recommends monitoring at the edge of the Celgar initial dilution zone, i.e. 100 m downstream from the Celgar point of discharge. The purpose of such monitoring is to determine if the recommended water quality objectives are being met at this point in the mixing zone.

Water quality objectives have no legal standing and would not be directly enforced. However, they are issued pursuant to Section 2e of the Environment Management Act, 1981, and as such can be considered as policy guidelines for resource managers to protect water uses in the specified water bodies. They are not directly enforced because of the practical difficulties of: 1) accurately measuring contaminants in receiving waters, 2) discerning between anthropogenic input and natural variability, and 3) attributing contamination which exceeds an objective to particular sources for legal purposes. They will guide the evaluation of water quality, the issuing of permits, licenses, and orders, and the management of the fisheries and of the Province's land base. Before allowing an effluent discharge, the agency responsible for issuing a permit or license must ensure that the water quality objectives will be met under worst-case conditions. They will also provide a reference against which the state of water quality in a particular water body can be checked, and serve to make decisions on whether to initiate basin-wide water quality studies.

Depending on the circumstances, water quality objectives may already be met in a water body, or may describe water quality conditions which can be met in the future. To limit the scope of the work, objectives are only being prepared for waterbodies and for water quality characteristics which may be affected by man's activity, now and in the foreseeable future.

Background levels are taken to mean operational background levels. These refer to ambient levels monitored at a control site immediately upstream or outside the influence of the area of disturbance or discharge. They reflect the existing control levels at any given time, which may not be the same as natural or pre-development levels, and which may change with time as upstream/upcurrent development occurs. They thus provide only a relative frame of reference for assessing change. The control site should be sampled at virtually the same time as the test site.

The following Columbia River water quality objectives are set to protect a number of important designated water uses between the Keenleyside Dam and Birchbank including: aquatic life and their habitats, wildlife consumption of aquatic life, recreational use, aesthetic values, and drinking water.

Dissolved Oxygen

- **an instantaneous minimum of 10 mg/L (derived from EPA,1986)**

This objective provides a high level of protection for the sensitive egg and larval stages of the salmonid species and ensures that there will be no significant impairment of present fish production in this reach of the Columbia River. This water column concentration would maintain an intergravel dissolved oxygen concentration of 7 mg/L. This objective is presently being met all of the time and predictions (Section 5.1.1 (d)) indicate that it can be met in the future, even with the pulp mill expansion and the decrease in gas supersaturation (as a result of changes at Keenleyside Dam).

pH

- **pH range 6.5 - 8.5; Unrestricted change permitted within this range only if free carbon dioxide does not exceed 60 mg/L (Pommen, 1991; McKean and Nagpal, 1991).**

Columbia River pH levels are consistently within this range. Future ambient pH levels are also expected to conform to this objective. This objective is set to protect aquatic life, drinking water, and recreational use from extreme pH changes that could potentially be caused by the pulp mill discharge. Rapid pH changes within this range should be avoided.

Colour

- **a maximum of 15 TCU (Pommen, 1991).**

TCU (true colour unit) is assumed to be roughly equivalent to SWU (single wavelength colour). Columbia River water upstream from the discharges in this reach is clear and colourless year round in its natural state (<10 SWU). There should be no undue increase in colour due to waste input. This objective will protect downstream drinking water and recreation use in terms of aesthetics. This objective will require substantial improvement in the present Celgar effluent colour. Modernization of the pulp mill is predicted to limit the increase in river colour by 16-18 colour units (under worst-case dilution; Section 4.3.4 h), which is close to achieving the above objective. The pulp mill must apply the best available technology and/or practices to control effluent colour and meet the above objective.

Periphytic Algal Growth

- a maximum of 50 mg/m^2 chlorophyll a (Nordin, 1985)

This objective is set for the protection of aquatic life and recreation (aesthetics). The average of at least five samples collected at random from the river bed on one day should be below this maximum. Since this objective is based upon the more stringent criterion to protect recreational use, it would also act to prevent the degradation of available aquatic life habitat. Nitrogen or phosphorus values above which nuisance algal growth would occur cannot be specified at this time with the data presently available.

Suspended Solids and Turbidity

- induced suspended solids (nonfilterable residue) should not exceed 10 mg/L (Singleton, 1985).
- induced turbidity should not exceed 5 NTU (Singleton, 1985).

These objectives are set to protect aquatic life, aquatic habitat and aesthetic values. Background suspended solids levels are less than 100 mg/L and background turbidity is less than 50 NTU. The available data (Section 5.1.1 b) indicate that these objectives are presently being met and predictions of theoretical worst-case increases under modernized mill conditions indicate that these objectives can be met in the future. The proposed treatment system for the modernized pulp mill (Section 4.3.4 c) will ensure that these objectives will be met in the future.

Substrate Sedimentation

- **the organic carbon content of river bottom sediments should not be significantly (95% confidence level) increased over natural background levels.**

This objective is set to protect fish spawning habitat and general aquatic life habitat within this reach of the Columbia River from anthropogenic fibre matting (from wood fibre of pulp mill origin) and woody debris deposition (from log booming activities). Underwater observations indicate that this objective is not being met presently downstream from the Celgar pulp mill. The installation of secondary treatment at the pulp mill is projected to end the fibre matting; however, the objective will not be met in the future with respect to the sunken debris from log booming and handling activities in an area along the south shore from the saw mill to the pulp mill. In this area the objective will therefore be long-term.

Water Temperature

- **no more than a 1°C increase in temperature over background levels.**

This objective applies on a year-round basis to protect aquatic life from the potential effects of heated pulp mill effluent. This objective is presently being met all of the time and predictions indicate that it will be met in the future.

Gas Supersaturation

- **total dissolved gases in any sample should not exceed 110 % saturation (from Alderdice and Jensen, 1985).**

This is a provisional objective set to protect aquatic life, especially salmonid fishes. At present this objective is not always being met (Section 5.1.1 o). This situation will only change in the future if changes are made in water-release from the Keenleyside Dam. The proposed future modifications to the Keenleyside Dam could ensure that this objective can be met most of the time (see Section 5.1.1 o). These structural changes are required to meet this objective and protect downstream fish from acute gas bubble trauma. It is recognized, as reported by Alderdice and Jensen, that a small proportion of the fish population is at risk in relation to the low levels of mortality found in the chronic range of total gas pressure between 105 and 110%. However, it would not be realistic at this time to set a lower objective that clearly cannot be met relative to background levels of up to 112 % measured in the Lower Arrow Reservoir. Further work is necessary to define the background total dissolved gas levels in the Columbia River upstream from the Keenleyside Dam, as well as confirming what levels can be achieved at the Keenleyside Dam if the best available technology is applied to spillway design and water release.

Microbiological Indicators

- **fecal coliforms and Escherichia coli content should not exceed 100/100 mL in 90 % of at least 5 and preferably 10 weekly water samples taken in a period of 30 days at equal time intervals (Warrington, 1988)**

These objectives are set on a year-round basis, to protect downstream drinking water (e.g.Warfield-Trail) for use after filtration (or equivalent) and disinfection. This objective would coincidentally protect irrigation (except for crops eaten raw) and recreation use.

There are insufficient data available at present to determine whether these objectives are being met. Attainment of these objectives in the future should not be a problem given properly operating sewage treatment systems for the City of Castlegar and the elimination of direct discharges of untreated sewage at Robson.

Toxicity

- **the % concentration of pulp mill effluent in the river should not exceed 0.05 of the 96-h LC50 of the pulp mill effluent at any time (Walden, 1976).**

This objective is set to protect aquatic life from sublethality during periods of high effluent discharge and lower river flows. This objective is not met at present under certain conditions (Section 4.3.3 f). However, with pulp mill modernization and effluent treatment in the future, this objective should be attained consistently.

The percent concentration of pulp mill effluent in the river is calculated by dividing 100 by the effluent dilution ratio. The latter may be calculated by dividing the river flow (in the initial dilution zone) by the effluent flow. The dilution ratio can also be calculated by dividing the concentration of a tracer like the sodium ion in the effluent by the increase in sodium between sites upstream and downstream from the outfall, immediately outside the initial dilution zone.

Chlorinated Phenols

- **the total concentration of all tri-, tetra-, and pentachlorophenols should not exceed the following maxima:**
  - **trichlorophenols - 0.05 μg/L**
  - **tetrachlorophenols - 0.1 μg/L**
  - **pentachlorophenols - 0.05 μg/L**

(P. Warrington, personal communication)

These objectives are set to prevent aquatic life toxicity and are based on draft B.C. criteria. Coincidentally they will also protect objectionable tainting of fish flesh and the aesthetic state of downstream drinking water use (Warfield-Trail).

There are insufficient data available to determine whether these objectives are presently being met or whether they can be consistently met in the future.

The recommended levels for trichlorophenols and pentachlorophenols are presently below the available detection limit (0.1 µg/L; Zenon Laboratories Ltd.). Until detection limits are improved, measurements of <0.1 µg/L will be considered acceptable.

Chlorinated Dioxin and Furan Objectives

Chlorinated dioxin/furan objectives are given for three media: water, fish tissue and sediments. These objectives are based on the assumption that these compounds have exposure thresholds, below which no toxic effects would occur. This has been a point of contention (e.g., U.S. EPA, 1986) with some scientists maintaining that zero risk only exists at zero exposure. According to the NCASI (1989) review, the available scientific data support the concept of a threshold-type dose-response relationship for TCDD (at least in the case of liver cancer in rats). Given the evidence, it appears reasonable at this time to derive objectives from reported lowest observed effect levels using appropriate safety factors.

Chlorinated Dioxins and Furans in Fish Tissue

- the maximum concentration of 2,3,7,8 TCDD TEQs in samples of fish muscle tissue should not exceed 1 pg/g (ppt) (wet weight).

B.C. does not at present have criteria for fish tissue dioxin/furan levels on which to base a site-specific objective. The above objective statement was derived by considering the most recent research, as well as established levels for the protection of human and wildlife consumers of fish.

Using Fraser River chinook fry, Servizi (unpublished) found a threshold for EROD induction in the range of 1-10 ppt TCDD TEQ body burden. Hodson (personal communication) also found an induction threshold of 10 ppt for the enzyme, aryl hydrocarbon hydroxylase in white sucker. These induction levels are lower than the lowest observed biological effects reported for lake trout embryos (see Section 5.1.4 e) and thus would be protective of fish health. Although good bioaccumulation data are not presently available, the 1 ppt level has been chosen as the objective because it is below the level of any known effect. Levels for the protection of the benthic invertebrate community are not presently known.

This tissue objective would also be protective of the animals higher in the food chain consuming fish tissues. For the protection of piscivorous mammals and birds feeding primarily on fish, the New York Department of Environmental Conservation arrived at a criterion of 3 ppt TCDD (Newell, 1987). The B.C. Ministry of Environment and the Ministry of Health have agreed that human health advisories be issued when the concentration of 2,3,7,8 TCDD TEQs in the edible portions of fish exceeds 15.0 ppt.

The objective of 1 pg/g is not being met at present in the lower Columbia River: all of the fish species tested to date have exceeded this level. It is hoped, though not established, that this objective can be met in the future after modernization occurs in the Celgar mill. This objective applies to the muscle of any species caught in all parts of this reach of the Columbia River, including the initial dilution zones of effluents.

This objective level is within present detection capabilities. The dioxin/furan minimum detection limits that Zenon Laboratories strive for are 0.7-2.0 pg/g (without high resolution GC/MS). With high resolution GC/MS, Washington State reported detection limits in the range of 0.2-0.6 pg/g.

- the maximum concentration of 2,3,7,8 TCDD TEQ in water should not exceed 0.2 pg/L (ppq).

This objective is set to protect aquatic life and is based on two lines of evidence: 1) the bioassay work by Mehrle et.al. , and 2) bioconcentration from water. At present there is no B.C. criterion on which to base a site-specific objective for water.

A long-term continuous flow 2,3,7,8 TCDD bioconcentration factor (BCF) of 159 000 for fathead minnows (Cook et.al., 1991) is believed to be the most reliable estimate presently available (D. Muir, personal communication). Dividing the no-observable effect level for body burden, 34 pg/g (Walker et.al., 1991), by this BCF gives a concentration of 0.2 pg/L in water. This level should protect fish from excessive bioconcentration of dioxins/furans in their tissues from water (excluding dietary intake).

The chronic (28 d) bioassay work by Mehrle et.al. indicated that the no-observed-effect concentration for rainbow trout survival, growth, and behavioral responses was lower than the lowest exposure concentration of 38 pg/L. Using an application factor of 0.01, which is commonly used for persistent, bioaccumulative contaminants, yields an objective level of about 0.3 pg/L. Using the same reasoning, Kent and Moore (1991) derived an interim draft Canadian water quality guideline of 0.3 pg TCDD/L. This guideline was not expressed in terms of TEQs and is potentially less protective than the objective proposed above for the lower Columbia River. Lupp and McCarty (1989) used the Ontario Ministry of Environment protocol for guidelines development to recommend preliminary water quality guidelines for 2,3,7,8 TCDD (0.1 pg/L) and 2,3,7,8 TCDF (0.2 pg/L). There were insufficient data for the development of guidelines for other congeners. Given the absence of the TEQ approach, these values were not adopted, but they do reinforce the position that objectives for dioxins/furans in water must be < 1 ppq.

The above objective is 75 times lower than the interim national guideline for drinking water (15 pg/L) and thus human consumers of Columbia River water would be further protected by this safety factor. This objective is also 10 times lower than the present detection capability of Zenon Laboratories for water (2 ppq). Thus, whenever TCDD/TCDF are detected in Columbia River water, the objective shall be considered as being exceeded. However, when TCDD/TCDF are found not to be detectable in Columbia River water, fish tissue and sediments shall be considered the appropriate monitoring media. If levels in fish tissue and/or sediment exceed their respective objective, then TCDD/TCDF levels in water shall be considered to be possibly in excess of the water objective as well (because of bioconcentration).

The available fish tissue and sediment data suggest that the objective for water is not being met at this time. As well, the hepta- dioxin congener has been detected in water as far downstream as Trail (Section 5.1.1 l). Modernization of the pulp mill with changes to the pulping/bleaching processes and effluent treatment could have the effect of achieving this objective in the future (Section 4.3.4 g).

Chlorinated Dioxins and Furans in Sediments

- the maximum concentration of 2,3,7,8 TCDD TEQs in bottom sediments should not exceed 0.7 pg/g sediment organic carbon.

B.C. has not yet developed provincial criteria for dioxins/furans in sediments, nor has any other jurisdiction to the knowledge of this author (see PTI, 1991). However, both Canada (CCME) and B.C. are in the early stages of developing such criteria.

Dioxins and furans are very persistent compounds with half-lives in sediment estimated to range to >10-15 years (Rabert, 1990). Such persistence and its potential availability from the sediments will present a continuing contamination problem for the Columbia River into the future, even with no further discharge from the pulp mill. The above objective has been set to protect aquatic life.

One method used to derive sediment quality objectives (SQO) is based on equilibrium partitioning (Ep) from sediment to water/biota and the water quality objective (WQO) as expressed by the following relationship (after EPA, 1989):

$$SQO = (Kow)(WQO),$$

where Kow is the octanol-water partition coefficient, and SQO is expressed as ng TCDD/kg organic carbon. Given that the Kow for 2,3,7,8 TCDD is 6.31×10^6 (log Kow = 6.8, Shio et.al., 1988) and WQO = 0.2 pg/L (as above), the SQO can be calculated to be approximately 1 ngTCDD/g organic carbon or 10 pg/g (ppt) for sediment containing 1 % organic carbon. Assuming that the water quality objective is an appropriate effects concentration for benthic animals, this value of 10 pg/g would protect benthic organisms from the effects of TCDD/TCDF associated with the sediments, but may not address the possible contamination of upper trophic level organisms.

Another approach to deriving a sediment TCDD objective which would provide protection to upper trophic level organisms would be to work back from a safe tissue level to a safe sediment level using bioavailability data. Bioavailability indices (BI=pg/g lipid weight divided by pg/g sediment organic carbon) for TCDD and TCDF were derived from the Mah et. al. (1989) Columbia River sucker and whitefish data by Muir et. al. (1991):

	Mean BI	
	TCDD	TCDF
Suckers	0.32	0.23
Whitefish	0.28	1.41

Muir et. al. point out that, contrary to predictions and laboratory results, their BI's for TCDF in whitefish are higher than those for TCDD. The TCDD BI's are underestimated by the use of the detection limit to estimate non-detectable sediment concentrations, and by a small sample size. For theses reasons the most reliable (conservative) BI available for Columbia River fish is the highest available BI (1.41). Assuming the safe concentration of TCDD TEQs in fish to be the tissue objective (1 pg 2,3,7,8 TCDD TEQs/g), it was calculated that the maximum concentration of TCDD TEQs in the sediment should not exceed (1.0 pg/g divided by 1.41) = 0.7 pg/g. Because this number is protective of upper trophic level organisms such as suckers feeding on detritus at the sediment-water interface and whitefish feeding on filter-feeding insects, it has been adopted for this reach of the Columbia River.

This objective is not being met at present and even with the pulp mill modernization it will not be met in the near-future. The speed with which the sediment levels are reduced depends on a variety of factors including degradation rates, bottom scouring, and downstream transport.

Resin Acids in Water

- the total concentrations of dehydroabietic acid (DHA) and total resin acids in water should not exceed the following concentrations for the given range of receiving water pH values:

Receiving Water pH	DHA µg/L	Total Resin Acids* µg/L
6.5	4	9
7.0	8	25
7.5	12	45
8.0	13	52
8.5	14	60

(after Taylor et.al., 1988)

*** total resin acids are defined as the sum of the individual concentrations of abietic, dehydroabietic, isopimaric, levopimaric, neoabietic, pimaric, and sandaracopimaric acids.**

The M.O.E. method detection limit for these two characteristics is presently 1.0 µg/L. Zenon Laboratories is implementing a new procedure capable of 0.1 µg/L (B.Oliver, personal communication).

There are insufficient data, at present, to establish defensible water quality objectives for each resin acid separately. However, there are sufficient data to establish a separate objective for dehydroabietic acid which is the most persistent non-chlorinated resin acid and the one produced in the largest quantities. These objectives are set to prevent aquatic life toxicity. The few receiving water data that are available have been within these objectives. With modernization of the Celgar mill, these objectives are predicted to continue being met.

Chlorinated Resin Acids in Water

- the maximum concentrations of each of chlorodehydroabietic acid and dichlorodehydroabietic acid in water should not exceed 6.0 ug/L

The Water Quality Branch has not yet established approved water quality criteria for the chlorinated resin acids.

The minimum detectable concentration for these chlorinated resin acids is 1.0-2.0 ug/L. The lowest reported 96-h LC50 for each of these chlorinated resin acids is 600 ug/L (Table 15). Using an application factor of 0.01 (for persistent toxicants) gives the receiving water objective of 6 ug/L. Chronic effect values have not been reported for chlorinated resin acids.

These objectives are set to prevent aquatic life toxicity. Available data indicate that the objective for monochlorodehydroabietic acid is presently being exceeded in the Columbia River between the Celgar discharge and Castlegar. The objectives are expected to be met in the future after mill modernization (see Section 4.3.4 g).

Surface Foams and Floatable Solids

Surface foaming and floatables have been problem characteristics downstream from the existing (pre-modernized) mill. At this time, B.C. has no criteria for these characteristics. Health and Welfare Canada (1983) does have an objective stating that there should be "no visible detectable and aesthetically objectionable solids or foam on the water surface derived from anthropogenic activity". However, because such an objective statement is totally subjective and non-quantitative, it is difficult to monitor and is not proposed here for the Columbia River. Surface foaming and floatables in the receiving waters should not occur in the future with the installation of effluent treatment at Celgar.

Water Odour

Water odour is presently a problem characteristic at times downstream from the existing (pre-modernized) Celgar pulp mill. The Province does not have an approved or working criterion for water odour. Health and Welfare Canada (1983) does have an objective stating that there should be "no objectionable odour attributable to anthropogenic activities". However, as for surface foaming and floatables, objectives for odour are subjective and, although there are standard ways of measuring water odour, these can be complicated and costly. For these reasons, an objective for water odour is not proposed here for the Columbia River. Other objectives that are set in this report (e.g., colour, turbidity, D.O., toxicity, and the organics) will help to ensure that receiving water odour does not exceed threshold levels. Water odour is not projected to be a problem after the biological treatment system is installed with the Celgar expansion and modernization.

7.0 MONITORING RECOMMENDATIONS

The monitoring recommendations for the Columbia River between Keenleyside Dam and Birchbank are made from a technical perspective and the extent to which the recommended objectives monitoring is conducted will depend on the overall priorities and monitoring resources available for the Region and the Province. All monitoring data collected by the permittee and the Ministry of Environment must be placed in the Ministry data bank, SEAM. A SEAM site should be established for each sampling location to ensure data capture and recovery.

7.1 DIFFUSE WASTE SOURCES

Contaminant loading from unpermitted and diffuse waste sources has not been determined to be a major problem for the water quality of the Keenleyside to Birchbank reach (Section 4.1). The one area of concern is at Robson where a few businesses and houses discharge untreated domestic sewage to the river. These discharges require removal in the interest of protecting shoreline recreational use. Until this happens, the receiving waters in these locations should be monitored for microbiological indicators to determine the extent of the contamination.

Westar Ltd. Sawmill

This domestic sewage discharge has been determined (Section 4.2) to have a negligible effect on Columbia River water quality. The effluent characteristics and sampling frequencies given in the existing permit (PE 1273) are appropriate and no modifications or additions are suggested. Effluent flow should be determined at the time of effluent sampling Receiving water monitoring specific to this discharge is not deemed necessary at this time. The overall monitoring program recommended in this report will be sufficient to monitor any effects of this discharge.

Selkirk College

More effluent data are needed to complete an accurate assessment of this discharge. The specified monitoring frequency is quarterly. This is sufficient for assessment purposes and only needs consistent implementation. Microbiological indicators should be added to the list of permit variables. Bacterial contamination is a potential effect (Section 4.5) given that the outfall is shallow and close to shore. Effluent flow should be measured at the time of effluent monitoring.

Receiving water monitoring for this discharge is not deemed necessary at this time. Monitoring conducted at the nearby City of Castlegar discharge (PE 4008) as recommended below should suffice for this discharge as well.

Miscellaneous Discharges

Effluent monitoring of PE 7622 (Robson pub) has not occurred to date. Quarterly sampling of BOD and suspended solids is required by permit. This should be implemented with the addition of microbiological indicators to generate sufficient data to characterize the effluent. Effluent flow should be determined at the time of effluent sampling (so that loadings can be later calculated). Receiving water monitoring for this specific discharge is not deemed necessary at this time.

Quarterly effluent monitoring for BOD, microbiological indicators, and suspended solids should be implemented for PE 7623 (Raspberry Lodge) when the discharge commences. Receiving water monitoring will not be necessary.

City of Castlegar

The two municipal discharges have not been subjected to appropriate levels of effluent or receiving water monitoring in the past. They have been over-shadowed by the larger pollution problems caused by the Celgar pulp mill. Accurate analysis of the effects of such waste loading on the Columbia River has been hampered by the absence of effluent data and the absence of receiving water data from sites proximate to the discharges. It has not been possible to determine accurately the magnitude of water quality deterioration, or the extent of the zones of influence prior to complete dilution. This situation can be corrected in the future with the following recommendations:

1. Effluent monitoring is specified as monthly for PE 4008 and quarterly for PE-80. This sampling frequency is sufficient for assessment purposes. Such data should be gathered for a minimum of three years after which it should be assessed and the need for subsequent increased or decreased monitoring determined by Regional Environmental Protection.

2. Effluent flow, microbiological indicators, and chlorine residual (when chlorinating) should be regularly monitored at the above frequency along with BOD and suspended solids. Effluent nutrient levels (total-P, ortho-P, ammonia-N, nitrite-N, nitrate-N) should be monitored twice yearly for a minimum of three years to establish a minimum data base.

3. The receiving waters at the edge of the initial dilution zones of these two discharges should be monitored once per year (at low flow) for a minimum of three years. This will generate a data base for future assessment. The characteristics recommended include: flow, pH, D.O., temperature, microbiological indicators, suspended solids, total phosphorus, dissolved ortho-phosphorus, and ammonia-N.

Celgar Ltd. Pulp Mill

a) Effluent Sampling

Because of the permit variance at Celgar, there has been only minimal effluent monitoring of a few basic characteristics conducted over the past decade. With the construction of an essentially new mill and with the ending of the permit variance, the existing permit will be amended to include new monitoring requirements. From a water quality assessment perspective, it is recommended that an effluent monitoring program include the following characteristics known to have an effect on the receiving waters, biota and sediments:

Continuous daily monitoring

Flow (m^3/s)
pH
Temperature (°C)

Weekly Monitoring

BOD (mg/L)
Suspended Solids (mg/L)
Colour (SWU)

Monthly Monitoring

Trout bioassay (96-h LC 50)
AOX (mg/L)
Dioxins/furans (pg/L)
Total Resin Acids (mg/L)
Total Fatty Acids (mg/L)
Chlorinated Resin Acids (mg/L)
Chlorophenols (tri-, tetra-, penta-) (mg/L)
Total Phosphorus (mg/L)
Total dissolved phosphorus (mg/L)
Total Kjeldahl Nitrogen (mg/L)
Nitrate-nitrite Nitrogen (mg/L)

The sampling frequency is suggested as an initial start-up frequency (6 months - 1 year) and the need to increase or decrease the frequency beyond this period would be at the discretion of Regional Environmental Protection. Effluent sampling done either by the permittee or the Ministry of Environment should coincide, as closely as possible, with the timing of receiving water monitoring.

b) Receiving water monitoring

A recommended receiving water quality monitoring program is outlined in Table 50. This program was designed to check attainment of the water quality objectives set in this report for the Keenleyside to Birchbank reach of the Columbia River. The monitoring results will also indicate the success or failure of effluent treatment/improvement undertaken by Celgar, and the need for remedial action.

The Water Management Program will fund the laboratory services and the costs associated with sample collection, with the aim of obtaining at least three consecutive years of complete data. Such a data base will give reasonable confidence in the results and may help to predict trends. The results will be summarized each year in a Water Quality Branch report covering all objectives monitoring activities in the Province.

Monitoring is recommended for the period of lowest river flow to examine the worst-case dilution scenario. Four monitoring sites are recommended: a control site upstream from Celgar but below Keenleyside Dam, a site at the edge of Celgar's initial dilution zone but in the mixing zone, a site at Castlegar where mixing is likely complete but upstream from the Kootenay River confluence, and a site at Birchbank to integrate the dilution effects of Kootenay River input. The four monitoring sites should be sampled from upstream to downstream on the same day, and ideally taking time of water travel into account so the same parcel of water is monitored (L. Pommen, personal communication). Sampling should also occur on the same day as effluent sampling during a pulp mill production period.

c) Columbia River Integrated Environmental Monitoring Program (CRIEMP)

The preceding has outlined a minimum monitoring program related to the water quality objectives established in this report. This monitoring program is part of a larger integrated environmental sampling program which will be implemented in 1991-93 with the cooperation of the Ministry of Environment (Environmental Protection and the Water Quality Branch), Environment Canada, Department of Fisheries and Oceans, the City of Castlegar, the City of Trail, and the industrial users (Cominco, Celgar, B.C. Hydro). CRIEMP will integrate all monitoring effort between the Arrow Reservoir and the U.S. border, thus embracing reaches affected by both Celgar and Cominco. Discussing common monitoring requirements and integrating the monitoring efforts will prevent duplication and provide a consolidated information base.

The details of the proposed integrated program have been outlined by Baturin (1992), McDonald (1992), and Sheehan (1992). The media to be monitored are water, fish, sediment, and benthic biota. Apart from the monitoring of water and sediment chemistry which began in 1991, there will be an emphasis on documenting the state of aquatic ecosystem health beginning in 1992:

1) benthic community structure (invertebrates, periphyton, aquatic macrophytes)
2) bioaccumulation study (from chosen sentinel species)
3) sediment toxicity assessment (Microtox, Hyallela, Daphnia, Rainbow Trout)
4) fish health study (mountain whitefish disease incidence, feeding habits, liver enzymes, tissue contaminant levels)

d) Quality Assurance

A quality assurance sampling program will be implemented with the monitoring recommended above, to define the quality of the data objectively in terms of overall or system detection and quantification limits, precision, and accuracy. Such a program will feature sampling protocols, field replicates, field blanks, reference samples submitted from the field, and split samples amongst sampling agencies.

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TABLE 1

MEAN PRE-REGULATION AND POST-REGULATION STEAMFLOWS* FOR COLUMBIA RIVER AT BIRCHBANK

	BIRCHBANK STATION 08NE049		
	MEAN STREAMFLOWS m^3/s		RATIO
	PRE-REGULATION 1952 - 1967	POST-REGULATION 1969 - 1984	POST-REGULATION/ PRE-REGULATION
JANUARY	621	1913	3.1
FEBRUARY	628	1602	2.6
MARCH	659	1332	2.0
APRIL	1015	1276	1.3
MAY	3244	2348	0.7
JUNE	6658	3004	0.5
JULY	5353	2968	0.6
AUGUST	2929	2786	1.0
SEPTEMBER	1654	1787	1.1
OCTOBER	1240	1466	1.2
NOVEMBER	970	1528	1.6
DECEMBER	725	1994	2.8

* DATA FROM WATER SURVEY OF CANADA (1985)

TABLE 2

OCCURRENCES OF LOW DISCHARGE (< 142 m^3/s) FROM ARROW RESERVOIR AT STATION 08NE126 1983 - 1989.

YEAR	NUMBER OF DAYS	MINIMUM FLOW m^3/s	PERIOD
1989	2	141	March 25,26
1988	2	141	June 12,14
1987	14	139 - 141	April 20 - May 15
1986	0	189	April 3
1985	1	141	May 29
1984	14	138 - 141	April 9 - July 12
1983	0	144	July 4

TABLE 3

SUMMARY OF LICENCED CONSUMPTIVE WATER WITHDRAWALS FROM COLUMBIA RIVER BETWEEN HUGH KEENLEYSIDE DAM AND BIRCHBANK

NAME	QUANTITY m^3/d	PURPOSE
CITIC B.C. Inc. and Power. Consolidated (China) Pulp Inc. (at damsite)	146 835.80	Industrial
	136.38	Industrial (fire protection)
Westar Timber Ltd.	4546.00	Industrial
West Brilliant Water User Community (9 licences)	20.43	Domestic
Hunter, R.	5242.29	Irrigation
McInnes, B.V.	2.27	Domestic
Kabatoff, P.P.	7709.26	Irrigation
Palmer, R.J. & A.T.	12 334.81	Irrigation
Kootenay Doukhobor Historical Society (Regional District of Central Kootenay)	20 044.07	Irrigation
Barisenkoff, N.W.	6167.40	Irrigation
Barisenkoff, W.W.	9867.85	Irrigation
Ministry of Forests and Lands	590.98	Industrial
Kinakin, J.M. & E.	777.09	Irrigation
Genelle Recreation Commission	4625.55	Irrigation
	218 900.18 m^3/d (2.53 m^3/s)	

TABLE 4

FISH SPECIES COLLECTED FROM COLUMBIA RIVER

COMMON NAME	SCIENTIFIC NAME
Yellow Walleye	*Stizostedion vitreum vitreum*
Kokanee	*Oncorhynchus nerka*
Rainbow Trout	*Oncorhynchus mykiss*
Lake Whitefish	*Coregonus clupeaformis*
Dolly Varden char	*Salvelinus malma*
Mountain Whitefish	*Prosopium williamsoni*
Suckers (unidentified)	*Catostomus* species
Longnose suckers	*Catostomus catostomus*
Largescale suckers	*Catostomus macrocheilus*
Bridgelip suckers	*Catostomus columbianus*
Northern Squawfish	*Ptychocheilus oregonensis*
Burbot	*Lota lota*
Prickly Sculpin	*Cottus asper*
Torrent Sculpin	*Cottus rhotheus*
Shorthead Sculpin	*Cottus confusus*
Peamouth	*Mylocheilus caurinus*
Redside Shiners	*Richardsonius balteatus*
Carp	*Cyprinus carpio*
Brook Trout	*Salvelinus fontinalis*
Brown Trout	*Salmo trutta*
White Sturgeon	*Acipenser transmontanus*
Chinook Salmon	*Oncorhynchus tshawytscha*
Longnose Dace	*Rhinichthys cataractae*

Sources: - Ash *et al.*, (1982);
- Ministry of Environment inventory data.

TABLE 5

SUMMARY OF EFFLUENT AND REFUSE PERMITS FOR COLUMBIA RIVER BETWEEN HUGH KEENLEYSIDE DAM AND BIRCHBANK

PERMIT HOLDER	PERMIT NUMBER	DISCHARGED TO	WASTE DISCHARGE FLOW (m^3/d)	TYPE OF DISCHARGE	TREATMENT OF DISCHARGE
Power Consolidated (China) Pulp Inc. and CITIC B.C. Inc.	PE1272	Columbia R.	177 000 (maximum)	- industrial effluent	- facilities to contain and recover chemicals and fibre, and to control foam
Power Consolidated (China) Pulp Inc. and CITIC B.C. Inc.	PE1273	Columbia R.	115	- industrial effluent	- secondary treatment plant
Lion's Head Inn	PE7622	Columbia R.	20	- domestic effluent	- secondary treatment package treatment plant
Selkirk College	PE141	Columbia R.	136 (maximum)	- domestic wastes from the college	- silver recovery system, holding tanks, package secondary treatment plant
City of Castlegar	PE80	Columbia R.	2728	- municipal sewage effluent	- aeration ponds, polishing lagoons, chlorination
City of Castlegar	PE4008	Columbia R.	3273 (maximum)	- municipal sewage effluent	- activated sludge treatment plant, chlorination
Power Consolidated (China) Pulp Inc. and CITIC B.C. Inc.	PR1768	Ground	70	- industrial refuse	- leachate collection and infiltration pond
Westar Timber Ltd.	PR1881	Ground	7.6	- sawmill refuse	- open burning

TABLE 6

PREDICTED LOADINGS AND INCREASES IN COLUMBIA RIVER RECEIVING WATER CONCENTRATIONS DOWNSTREAM FROM THE WESTAR AND CELGAR DOMESTIC EFFLUENT DISCHARGE (PE 1273)

CHARACTERISTICS	PERMIT CONDITIONS		MAXIMUM PRESENT LOADING [1]	RECEIVING WATER CONCENTRATION INCREASE AT MAX. LOADINGS	
	Max. Level or Conc.	Loading		Edge of Dilution Zone	After Complete Mixing
Flow	115 m^3/d				
BOD5	45 mg/L	5.2 kg/d	5.7 kg/d	1.9 µg/L	0.5 µg/L
Suspended Solids	60 mg/L	6.9 kg/d	8.6 kg/d	2.8 µg/L	0.7 µg/L
Fecal Coliforms	---	---	1.5×10^{10} MPN/d	0.5 MPN/100mL	0.12 MPN/100mL

1 since flow was not measured on the same day as sampling, the maximum load was calculated using the maximum concentration and the average of the flows from the previous and following days

2 assumptions: - a low river flow of $142 m^3/s$
- at the edge of the initial dilution zone, the effluent mixes with only 25% of the total river flow.

TABLE 7

CELGAR PULP MILL, COMPARISON OF PERMITTED EFFLUENT CHARACTERISTICS BETWEEN THE ORIGINAL PERMIT AND THE AMENDED PERMITS

EFFLUENT CHARACTERISTICS		ORIGINAL PERMIT (ISSUED 1973)		AMENDMENT 1982			AMENDMENT 1984 AFTER E.A.B.[1] APPEAL		
		BLEACHED KRAFT PULP MILL EFFLUENT	WOODROOM HYDRAULIC DEBARKER EFFLUENT	COMBINED PULP MILL AND WOODROOM DEBARKER EFFLUENT		COOLING WATER	COMBINED PULP MILL AND WOODROOM DEBARKER EFFLUENT		COOLING WATER
				Interim Levels	Target Levels by Dec/31, 1984	Target Levels by Dec/31, 1984	Interim Levels	Target Levels by Dec/31, 1984	Target Levels by Dec/31,/84
Flow, Max. Daily	m^3/d	111 000	25 000	177 000	170 000	27 200	177 000	170 000	27 200
Flow, Max. Weekly Avg.	m^3/d	-	-	141 000	132 000	13 600	141 000	132 000	13 600
pH Range		6.5 - 8.5	6.5 - 8.5	6.5 - 8.5	6.0 - 8.0	6.5 - 8.0	2.5 - 8.0[2]	6.0 - 8.0	6.5 - 8.0
Temperature, Max.	°C	35	-	35	35	35	38	35	35
Solids, Suspended		15 kg/t	0.64 kg/m^3	13 900 kg/d	7300 kg/d	-	13 900 kg/d	7450 kg/d	-
Solids, Floatable		Negligible	Negligible	-	-	-	-	-	-
Solids, Settleable		2.5 mL/L	-	-	-	-	-	-	-
Toxicity, 96-h LC50	%	90	17	30	100	-	10	100	-
BOD_5		20 kg/t	0.64 kg/m^3	21 400 kg/d	5500 kg/d	-	40 000 kg/d	5600 kg/d	-
Chlorine Residual	mg/L	<0.1	-	-	-	-	-	-	-
Mercaptans	mg/L	<2.0	-	-	-	-	-	-	-
Dissolved Oxygen,	mg/L	2.0	-	-	2.0	-	-	2.0	-
Sulphides	mg/L	<1.0	-	-	-	-	-	-	-

1 - Environmental Appeal Board
2 - 24-hr. composite

kg/t - kilogram per tonne of air dried pulp
kg/m^3 - kilogram per cubic metre of solid wood input

TABLE 8

WESTAR SAWMILL/CELGAR PULP MILL (PE 1273) SAMPLING OF EFFLUENTS (1981 - 1987)

CHARACTERISTICS		CELGAR DOMESTIC SEWAGE PE 1273		
		Mean	Range of Values	# of Values
BOD_5	mg/L	16	4-59	19
		-	-	-
Coliforms, Fecal	MPN/100/mL	-	13,000	1
Conductance, Specific	µS/cm	-	205	1
Flow	m^3/d	106	60-180	243
pH		-	7.1	1
Solids, Suspended	mg/L	34	10-85	21

TABLE 9

SUMMARY OF CELGAR EFFLUENT QUALITY FOR GENERAL CHARACTERISTICS 1975 - 1990.

CHARACTERISTICS			M.O.E. (W.I.B., 1979) (1) 1975 - 1977		MINISTRY OF ENVIRONMENT 1981 - 1988 (2)		Dwernychuk (1988) (3)	E.V.S. CONSULTANTS April 12-14, 1990 (4)	
			Range	Mean (# of Values)	Range	Mean (# of Values)	June 22, 1988	Range	Mean (# of Values)
AOX		mg/L	–	–	–	–	–	15.6-29.5	22.2 (7)
Alkalinity (as $CaCO_3$)		mg/L	–	–	–	–	95.5	–	74 (7)
Bioassay (96-h LC50)		% effluent	7.5-35	19 (8)	2.4-19	8.8 (39)	–	13-24	16.7 (3)
BOD_5		mg/L	105-536	195 (18)	116-239	182 (11)	111	108-152	127 (7)
Carbon,	Total	mg/L	–	–	–	–	–	200-315	249 (7)
	Inorganic	mg/L	–	–	–	–	–	22-34	28 (7)
	Organic	mg/L	137-621	275 (18)	–	–	–	175-286	220 (7)
Chloride,	Dissolved	mg/L	–	–	–	–	1440	190-288	253 (7)
Chlorine,	Residual	mg/L	–	–	–	–	–	<0.2	<0.2 (7)
Coliforms,	Fecal	MPN/100mL	<200-<2000	(5)	–	–	–	–	–
Colour,	True	TCU	440-4000	94 (1251)	–	–	870	750-1000	964 (7)
Conductance,	Specific	uS/cm	–	–	1200-1780	1490 (10)	1010	1050-1690	1307 (7)
Flow		10^3 m^3/d	41-152	119 (480)	18-204	116 (1695)	–	–	97.9 (7)
Mercaptans		mg/L	0-28.8	3 (71)	–	–	–	–	–
Nitrogen,	Total	mg/L	–	–	–	–	–	1.58-2.25	1.99 (7)
	Kjeldahl	mg/L	1-6	2.3 (17)	–	–	1.31	1.56-1.92	1.7 (7)
	NO_3/NO_2	mg/L	–	0.4 (1)	–	–	–	0.02-0.39	0.28 (7)
Oil and Grease		mg/L	5-205	33 (16)	–	–	–	5-9	7 (7)
Oxygen,	Dissolved	mg/L	0-12.4	2 (598)	0-0.5	0.005 (181)	3.3	–	0 (7)
pH			2.6-11.5	5.4 (499)	1.1-12.5	5.6 (1707)	6.62	3.2-6.7	5.6 (7)
Phenols	mg/L		0.4-3.7	1.3 (18)	–	–	2.5	0.96-1.79	1.37 (7)
Phosphorus,	Total	mg/L	0.3-1.9	1 (18)	–	–	0.5	0.358-0.768	0.51 (7)
	ortho-	mg/L	0.5-1.3	0.7 (17)	–	–	–	0.21-0.405	0.32 (7)
Sodium,	Dissolved	mg/L	–	–	–	–	180	153-219	189 (7)
Solids,	Suspended	mg/L	69-427	180 (17)	51-106	82 (11)	48	37-63	45.1 (7)
	Dissolved	mg/L	979-2316	1340 (14)	–	–	–	826-1140	1011 (7)
	Settleable	mg/L	1.2-650	17 (81)	–	–	–	3-9	5.1 (7)
Sulphide,	Total	mg/L	0-38	2 (82)	–	–	–	<0.5-1.5	0.86 (7)
Tannin & Lignin, Total		mg/L	50-280	135 (18)	–	–	110	325-650	475 (7)
Temperature		°C	13-41	32 (508)	11-39	30 (281)	28	31-36	34 (7)

TABLE 9 (Continued)

CHARACTERISTICS		M.O.E. (W.I.B., 1979) (1) 1975 - 1977		MINISTRY OF ENVIRONMENT 1981 - 1988 (2)		Dwernychuk (1988) (3)	E.V.S. CONSULTANTS April 12-14, 1990 (4)	
		Range	Mean (# of Values)	Range	Mean (# of Values)	June 22, 1988	Range	Mean (# of Values)
Turbidity	NTU	–	–	–	–	8.6	42-75	57 (7)
Resin Acids, Total	mg/L	0.4-14	3 (76)	–	–	2.197	0.464-1.168	0.68 (7)
Abietic acid		–	–	–	–	570	100-280	160 (7)
Dehydroabietic acid	µg/L	–	–	–	–	639	130-380	219 (7)
Isopimaric acid	µg/L	–	–	–	–	437	78-200	120 (7)
Levopimaric acid	µg/L	–	–	–	–	243	57-130	80 (7)
Neoabietic acid	µg/L	–	–	–	–	74	5-27	11 (7)
Pimaric acid	µg/L	–	–	–	–	162	29-110	63 (7)
Sandaracopimaric acid	µg/L	–	–	–	–	54	18-41	28 (7)
Chlorodehydroabietic acid	µg/L	–	–	–	–	74	–	–
Dichlorodehydroabietic acid	µg/L	–	–	–	–	10	–	–

1 For combined pulp mill and woodroom effluent

2 Taken from SEAM (Ministry of Environment (M.O.E.) data bank)

3 Single grab sample

4 As reported by Celgar (1990; Tables 1.8.2, 1.8.3, 1.8.4)

TABLE 10

PREDICTED LOADINGS AND INCREASES IN COLUMBIA RIVER RECEIVING WATER CONCENTRATIONS DOWNSTREAM FROM THE CELGAR PULP MILL EFFLUENT DISCHARGE (PE 1272)

CHARACTERISTICS	PERMIT CONDITIONS			RECEIVING WATER CONCENTRATION[1] INCREASE AT MAXIMUM LOADINGS	
	Target Level[2]	Target Loading	Max. Present Loading or Level	Edge of Dilution Zone	After Complete Mixing
Flow Max. Daily m^3/d	170,000	-	204,000		
BOD_5	-	5,600 kg/d	57,800 kg/d*	18.6 mg/L	4.6 mg/L
Suspended Solids	-	7,450 kg/d	96,000 kg/d	31 mg/L	7.8 mg/L

1 assumes: - a worst-case, low river flow of 142 m^3/s and effluent flow of 170,000 m^3/d
- at the edge of the initial dilution zone, the effluent mixes with only 25 percent of the total river flow.

2 target levels as given in the amended permit (1984).

* highest measurement recorded over the last complete year of sampling.

TABLE 11

WATER QUALITY OF COLUMBIA RIVER UPSTREAM (SITE 0200183) AND DOWNSTREAM (SITE 0200200) FROM THE CELGAR PULP MILL

CHARACTERISTICS		0200183 UPSTREAM FROM PE 1272			0200200 DOWNSTREAM FROM PE 1272		
		Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values
Alkalinity, Total	mg/L	-	53.9	1	-	-	-
Bioassay, Microtox	EC50%	-	-	-	>100	>100	5
Calcium, Dissolved	mg/L	-	18.3	1	-	-	-
Coliform, Fecal	MPN/100mL	-	<2.0	1	-	-	-
Coliform, Total	MPN/100mL	-	5.0	1	-	-	-
Colour	SWU	5	<5-5	11	24.3	11-39	12
	TAC	3	3	3	4.4	4-6	16
	TCU	<5	<5	3	5	<5-5	16
Conductivity, Specific	µS/cm	122	114-128	14	131.5	126-156	28
Hardness, Dissolved	mg/L	-	60.9	1	-	-	-
Magnesium, Dissolved	mg/L	-	3.7	1	-	-	-
Nitrogen, Ammonia, Diss.	µg/L	<5	<5	2	8.3	<5-24	16

TABLE 11 (Continued)

CHARACTERISTICS		0200183 UPSTREAM FROM PE 1272			0200200 DOWNSTREAM FROM PE 1272		
		Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values
Nitrogen, Kjeldahl	mg/L	0.17	0.09-0.24	2	0.08	0.04-0.17	16
Nitrogen, Nitrite/nitrate	mg/L	0.09	0.09	2	0.09	0.09	16
Nitrogen, Organic	mg/L	0.17	0.09-0.24	2	0.08	0.02-0.17	16
Oxygen, Dissolved	mg/L	12.3	11.7-12.7	5	12.7	11-14.2	20
pH		8.0	7.4-8.6	20	7.8	7.3-8.1	49
Phenols, Total	µg/L	2	<2-3	13	5	<2-9	27
Phosphorus, Ortho-	µg/L	<3	<3	2	<3	-	16
Phosphorus, Dissolved	µg/L	5.5	5-6	2	5	4-6	16
Phosphorus, Total	µg/L	11	10-12	2	8.3	7-10	16
Solids, Suspended	mg/L	2.2	1-4	14	1.9	1-7	28
Sodium, Dissolved	mg/L	0.95	0.8-1.1	2	1.4	1.0-2.2	16
Sulphate, Dissolved	mg/L	-	7.9	1	-	-	-
Tannin and Lignin	µg/L	0.1	<0.1-0.1	3	0.3	0.2-0.4	16
Temperature	°C	10.3	9.5-12	5	9.2	7-11.4	20

- Sampled by Ministry of Environment, 1980-1984.

TABLE 12

PREDICTIONS OF SUBLETHAL TOXICITY LEVELS AND RIVER FLOWS REQUIRED TO AVERT SUBLETHAL TOXICITY.

LC50 %(V/V)	SUBLETHAL THRESHOLD % EFFLUENT IN WATER *	DILUTION RATIO	EFFLUENT FLOW RATE m^3/s	FLOW [1] REQUIRED TO AVERT SUBLETHAL CONDITIONS m^3/s	% TIME [2] SUBLETHALITY IS AVOIDED
2.4	0.12	833:1	2.36	1967 4000 (in IDZ)	15 0
13	0.65	154:1	1.35	208	95
40	2.0	50:1	2.36	118	100

[1] For complete mixing conditions, except as noted.
[2] taken from predicted duration of flow graph p.111 of WIB (1979).
* 0.05 of the 96-h LC50 (Walden,1976)

IDZ = Initial Dilution Zone

TABLE 13

LEVELS OF DIOXINS AND FURANS IN THE FINAL EFFLUENT DISCHARGED FROM THE CELGAR PULP MILL, JULY 18, 1989.

COMPOUND (CONGENERS)	INTERNAT'L TOXICITY EQUIVALENCY FACTOR (TEF)	DETECTED CONCENTRATION pg/L (ppq)	TOXIC EQUIVALENTS OF 2,3,7,8 TCDD pg/L (ppq)	DETECT. LIMIT pg/L (ppq)
2,3,7,8 - TCDD	1	ND	ND	14
TCDD (Total)	1	ND	ND	14
PCDD	0.5	ND	ND	37
H_6CDD	0.1	44	4.4	32
1,2,3,4,6,7,8 - H_7CDD	0.01	ND	ND	22
H_7CDD	0.01	ND	ND	22
OCDD	0.001	ND	ND	29
2,3,7,8 - TCDF	0.1	310	-	14
TCDF (Total)	0.1	480	48.0	14
PCDF	0.5	ND	ND	13
H_6CDF	0.1	ND	ND	19
H_7CDF	0.01	ND	ND	29
OCDF	0.001	ND	ND	27

Surrogate	Recovery (%)
$^{13}C_{12}$ - TCDD	79
$^{13}C_{12}$ - PCDD	90
$^{13}C_{12}$ - H6CDD	92
$^{13}C_{12}$ - H7CDD	96
$^{13}C_{12}$ - OCDD	77
$^{13}C_{12}$ - TCDF	84

- ppq is parts per quadrillion which equals picogram per litre ($1x10^{-15}$)
- Effluent flow rate on this day was 88 667 m^3/d
- Bleach plant production on this day was 483 ADt/d
- Toxic equivalents are a means of calculating the toxic effect of combinations of dioxins and furans. The amount of each congener is multiplied by a conversion factor (the International Toxicity Equivalency Factor) to give the amount of 2,3,7,8-T4CDD that would produce the same effect.

TABLE 14

INTERNATIONAL TOXICITY EQUIVALENCY FACTORS (I-TEFs) AND PROPORTION OF CONGENERS OF CONCERN IN A HOMOLOGOUS GROUP.

CONGENER OF CONCERN	I-TEF	CONGENERS OF CONCERN IN A HOMOLOGOUS GROUP
2,3,7,8-TCDD	1	1 out of 22 (5%)
1,2,3,7,8-PeCDD	0.5	1 out of 14 (7%)
1,2,3,4,7,8-HxCDD 1,2,3,7,8,9-HxCDD 1,2,3,6,7,8-HxCDD	0.1	3 out of 10 (30%)
1,2,3,4,6,7,8-HpCDD	0.01	1 out of 2 (50%)
OCDD	0.001	1 out of 1 (100%)
2,3,7,8-TCDF	0.1	1 out of 38 (3%)
2,3,4,7,8-PeCDF	0.5	1 out of 28 (4%)
1,2,3,7,8-PeCDF	0.05	1 out of 28 (4%)
1,2,3,4,7,8-HxCDF 1,2,3,7,8,9-HxCDF 1,2,3,6,7,8-HxCDF 2,3,4,6,7,8-HxCDF	0.1	4 out of 16 (25%)
1,2,3,4,6,7,8-HpCDF 1,2,3,4,7,8,9-HpCDF	0.01	2 out of 4 (50%)
OCDF	0.001	1 out of 1 (100%)

- From Ministry of Environment (1989).

TABLE 15

RESIN ACID LEVELS MEASURED IN CELGAR PULP MILL EFFLUENT AND COLUMBIA RIVER COMPARED TO REPORTED TOXICITY LEVELS

	LOWEST REPORTED 96-h LC50 µg/L		RESIN ACID LEVELS IN EFFLUENT (µg/L)					RESIN ACID LEVELS IN COLUMBIA RIVER (µg/L)						
	McLeay (1)	Ont. (2)	DWERNYCHUK	WASTEWATER TECH. CTR. LAB (3)	E.V.S. CONSULTANTS LTD. (4)			M.O.E. 1985 (5)	DWERNYCHUK 1988 (6) HATFIELD CONSULTANTS LTD.					
					APRIL 12-14, 1990		MAY 29/90		UPSTREAM	DOWNSTREAM FROM OUTFALL				
			JUNE 22, 1988	MAY 16, 1989	RANGE	MEAN (No. of Values)	VALUES	in I.D.Z.	2.75 km	0.5 km	1.6 km	3.5 km	6 km	11 km
Pimaric Acid	700	320	162	743	29-110	63 (7)	21	<1-2	<1	2	<1	1	1	<1
Sandaracopimaric Acid	360	360	54	483	18-41	28 (7)	14	<1-4	<1	2	<1	2	3	<1
Isopimaric Acid	400	220	437	2290	78-200	120 (7)	69	<1-14	<1	6	2	2	<1	<1
Levopimaric Acid	700	600	243	N/A	57-130	80 (7)	10	<1	<1	<1	<1	<1	<1	<1
Dehydroabietic Acid	800	500	639	1920	130-380	219 (7)	120	<1-8	<1	6	2	2	3	<1
Abietic Acid	700	200	570	4190	100-280	160 (7)	85	<1	<1	11	<1	<1	8	5
Neoabietic Acid	610	600	74	1030	5-27	11 (7)	4	<1	<1	<1	<1	<1	<1	<1
Chlorodehydroabietic Acid	600	-	74	N.D.	-	-	-	-	<1	8	2	16	3	5
Dichlorodehydroabietic Acid	600	-	10	N.D.	-	-	-	-	<1	<1	<1	<1	<1	<1
Total Resin Acids			2197	10 660	464-1168	680	323	-	<1	34	6	23	17	10

1 For rainbow trout under static bioassay conditions; from McLeay and Associates Ltd., 1987.
2 From literature review by Taylor <u>et al</u>., 1988. These include flow-through or semi-static tests which show consistently lower LC50 value than from static tests.
3 As reported by EVS/Cirrus (1989).
4 As reported by Celgar (1990).
5 Sampled by Regional Waste Management Branch, June 13, 1985, within the Initial Dilution Zone.
6 Sampled June 22, 1988.

TABLE 16

LEVELS OF CHLORINATED PHENOLICS (μg/L) IN THE CELGAR PULP MILL EFFLUENT

CHARACTERISTICS	B.C. MOE May 16, 1989	E.V.S. CONSULTANTS LTD. May 29, 1990
Monochlorophenols	5.1	0.16
Dichlorophenols	ND	2.8
Trichlorophenols	12.4	4.6
Tetrachlorophenols	ND	1.4
Pentachlorophenol	ND	0.27
TOTAL CHLOROPHENOLS	17.5	9.23
Monochloroguaiacols	3.1	2.1
Dichloroguaiacols	ND	14
Trichloroguaiacols	109.3	19
TOTAL CHLOROGUAIACOLS	112.4	70.1
Monochlorocatechols	ND	<0.05
Dichlorocatechols	ND	<0.05
Trichlorocatechols	ND	5.2
Tetrachlorocatechols	ND	22
TOTAL CHLOROCATECHOLS	ND	27.2

ND = not detected

TABLE 17

SUMMARY OF EFFLUENT MONITORING DATA FOR THE CITY OF CASTLEGAR (PE80, PE4008)

CHARACTERISTIC		PE 80 SEPTEMBER 11, 1984			PE 4008 FEB. 27/86; MAR. 31/87		
		Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values
BOD5	mg/L	–	–	–	<10	<10	2
Conductivity	µS/cm	–	–	–	415	410-420	2
Coliform, Fecal	MPN/100mL	–	27	1	–	33	1
pH		–	–	–	6.2	6.1-6.3	2
Solids, Suspended	mg/L	–	–	–	–	26	1
Dissolved	mg/L	–	–	–	–	310	1
Total	mg/L	–	–	–	–	328	1

TABLE 18

SUMMARY OF PERMITTED AND PRESENT EFFLUENT QUALITY FROM SELKIRK COLLEGE PE 141

CHARACTERISTIC		PERMIT CONDITIONS		PRESENT CONDITIONS January 4, 1982 - January 28, 1988			
		LIMIT	LOADING kg/d	MEAN	RANGE OF VALUES	NUMBER OF VALUES	LOADING[1] kg/d
pH		-	-	6.9	5.9-7.3	4	-
Solids, Suspended	mg/L	60	8.2	23	18-30	4	2.4
Conductivity	µS/cm	-	-	329	255-412	4	-
BOD_5	mg/L	45	6.1	21	14-27	4	2.1
Flow	m^3/d	136	-	53	2.4-597	883	-

1 Maximum present loading calculated using the maximum recorded concentration and the 90th percentile flow (79.3 m^3/d)

TABLE 19

WATER QUALITY OF COLUMBIA RIVER AT CASTLEGAR SITES 1190074 AND 0200604 JULY 1983 AND JUNE 1984

CHARACTERISTICS		AT CASTLEGAR SITE 1190074			AT ROBSON FERRY RAMP NORTH SITE 0200604		
		Mean	Range	Number of Values	Mean	Range	Number of Values
Colour	SWU	36	12-58	12	31	9-44	11
Conductivity	µS/cm	145	137-153	12	140	128-146	12
Oxygen, Dissolved	mg/L	11.4	11.3-11.4	4	11.4	11.1-11.7	4
pH		7.6	7.4-7.8	17	7.6	6.7-7.9	18
Phenols, Total	µg/L	6.4	<2-13	12	5.6	2-10	8
Solids, Dissolved	mg/L	–	–	–	–	82	1
Suspended	mg/L	3.3	2-5	12	4.5	2-11	11
Temperature	°C	11.8	11.2-12.8	4	12.4	11.8-13.2	4

TABLE 20

RESULTS OF RECEIVING WATER SAMPLING BY THE WASTE MANAGEMENT BRANCH BETWEEN THE CELGAR OUTFALL AND CASTLEGAR, JUNE 12, 13, 1985.

CHARACTERISTICS		AT CELGAR OUTFALL WITHIN INITIAL DILUTION ZONE			2 km d/s FROM CELGAR OUTFALL AT LAUNCH RAMP			7 km d/s AT CASTLEGAR FERRY		
		Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values
Colour	SWU	12.3	7-22	6	5.8	<5-8	6	5.8	<5-8	6
Conductivity	µS/cm	126.6	124-132	6	119.2	118-120	6	120	120-121	6
Oxygen, Dissolved	mg/L	12.9	12.7-13	2	12.9	12.6-13.1	2	12.8	12.5-13.0	2
pH		7.8	7.7-7.9	6	7.9	7.9-8.0	6	7.9	7.8-7.9	6
Phenols, Total	µg/L	10.8	5-15	6	3.5	<2-8	6	5.2	2-8	6
Sodium, Dissolved	mg/L	2.8	2-4.2	6	1.3	1-1.5	6	1.5	1.4-1.6	6
Solids, Suspended	mg/L	2.7	2-3	6	1.8	1-2	6	2.0	1-3	6
Temperature	°C	13	12.8-13.2	2	13.3	13.1-13.4	2	13.3	12.9-13.7	2

TABLE 21

COMPARISON OF pH MEASUREMENTS UPSTREAM AND DOWNSTREAM FROM THE CELGAR PULP MILL

Date of Sampling	RECEIVING WATER pH		pH Difference	Effluent pH
	Upstream (0200183)	Downstream (0200200)		
81/06/01	7.9	7.9	0	-
81/06/02	8.2	7.9	-0.3	-
83/07/05	8.2	7.8	-0.4	1.7
83/07/06	8.1	7.7	-0.4	-
83/07/07	8.1	7.7	-0.4	3.0
84/06/12	7.75	7.75	0	5.8
84/06/13	7.9	7.5	-0.4	6.2
84/06/14	7.65	7.65	0	6.4

TABLE 22

COMPARISON OF DISSOLVED OXYGEN MEASUREMENTS UPSTREAM AND DOWNSTREAM FROM THE CELGAR PULP MILL

	Date of Sampling	Receiving Water D.O. (mg/L)		D.O. Difference
		Upstream (0200183)	Downstream (0200200)	
Ministry of Environment	84/06/13 (A.M.)	12.6	12.0	-0.6
	(P.M.)	12.7	12.2	-0.5
	84/06/14 (A.M.)	11.7	11.8	+0.1
	(P.M.)	12.3	11.8	-0.5
B.C. Hydro	83/05/31	11.6	11.5	-0.1
	83/06/14	12.6	11.4	-1.2
	83/06/28	13.8	14.8	+1.0
	83/07/12	12.0	11.8	-0.2
	83/07/26	11.4	12.4	+1.0
	83/08/09	12.0	11.0	-1.0
	83/08/23	10.2	11.2	+1.0
	83/09/07	10.4	11.2	+0.8
	83/09/20	14.0	12.2	-1.8
	83/10/04	13.6	12.8	-0.8
	83/10/12	13.0	13.0	
	83/11/01	14.8	14.0	-0.8
	83/11/16	14.1	13.2	-0.9
	83/11/28	15.6	14.2	-1.4
	83/12/14	12.5	13.2	+0.7
	84/01/03	14.4	14.4	
	84/01/30	14.9	14.9	
	84/02/14	14.8	13.9	-0.9
	84/02/27	13.8	12.2	-1.6
	84/03/13	13.4	12.5	-0.9
	84/03/26	14.0	12.0	-2.0
	84/04/09	14.5	11.5	-3.0
	84/04/25	14.7	13.6	-1.1
	84/05/07	12.1	14.5	+2.4
	84/05/22	12.4	11.9	-0.5
	84/06/06	11.2	10.8	-0.4
	84/06/13	11.8	12.6	+0.8
	84/06/26	13.6	15.1	+1.5
	84/07/10	11.1	10.4	-0.7
	84/07/24	11.8	11.6	-0.2
	84/08/08	10.5	11.9	+1.4
	84/08/22	10.4	10.8	+1.4
	84/09/04	10.8	10.3	-0.5

TABLE 23

DIOXIN AND FURAN LEVELS IN THE WARFIELD DRINKING WATER SUPPLY, FEBRUARY 23, 1989.

COMPOUND	CONCENTRATION[1] pg/L (ppq)	DETECTION LIMIT pg/L (ppq)	METHOD BLANK pg/L (ppq)
2,3,7,8-T_4CDD	<5	5	<5
T_4CDD (total)	<5	5	<5
P_5CDD	<9	9	<9
H_6CDD	<15	15	<15
H_7CDD	12	11	<11
O_8CDD	<13	13	<13
2,3,7,8-T_4CDF	<4	4	<4
T_4CDF (total)	<4	4	<4
P_5CDF	<4	4	<4
H_6CDF	<6	6	<6
H_7CDF	<6	6	<6
O_8CDF	<13	13	<13
	SURROGATE RECOVERY	(%)	
	$^{13}C_{12}$-TCDD	85	
	$^{13}C_{12}$-P_5CDD	93	
	$^{13}C_{12}$-H_6CDD	96	
	$^{13}C_{12}$-H_7CDD	108	
	$^{13}C_{12}$-O_8CDD	94	
	$^{13}C_{12}$-TCDF	83	

[1] Results are corrected for surrogate recovery.

TABLE 24

WATER QUALITY OF KOOTENAY RIVER AT FRASER RAPIDS SITE 0200012 (AUG. 1968 - NOV. 1988) AND AT BRILLIANT SITE 0200178 (FEB. 1974 TO MAR. 1979)

CHARACTERISTICS			SITE 0200178			SITE 0200012		
			MEAN	RANGE	NUMBER OF VALUES	MEAN	RANGE	NUMBER OF VALUES
Alkalinity,	Total	mg/L	59.4	27-70	55	64	49-77	129
Aluminum,	Total	mg/L	-	-	-	0.033	0.03-0.04	4
Arsenic,	Dissolved	µg/L	5.1	<5-7	18	7	7	3
	Total	µg/L	-	<5	1	-	-	-
Boron,	Dissolved	mg/L	<0.1	<0.1	15	-	-	-
Cadmium,	Total	µg/L	-	<0.5	1	-	-	-
	Dissolved	µg/L	<0.5	<0.5	18	1	1	3
Calcium,	Total	mg/L	-	-	-	24	17.5-28.1	38
	Dissolved	mg/L	19.5	15-23	37	20.6	12.8-25.8	48
Carbon,	Total Organic	mg/L	1.9	1-3	24	2.2	1-7	75
	Total Inorganic	mg/L	-	12	1	16	-	1
Chloride,	Dissolved	mg/L	1.0	0.6-1.3	20	0.9	0-3.4	56
Chromium,	Dissolved	µg/L	-	<5	1	-	-	-
Coliforms,	Fecal	MPN/100mL	8.0	<2-79	40	8.0	2-33	50
	Total	MPN/100mL	44.3	<2-540	32	8.1	2-33	24
Colour,	T.A.C.		3.6	<1-15	30	3.1	1-25	66
	True		5.6	5-10	18	5	5	27
Conductivity		µS/cm	131	82-190	76	152	124-180	37
Copper,	Total	µg/L	1.2	<1-3	10	3	1-15	18
	Dissolved	µg/L	1.6	<1-7	18	2	1-7	23

TABLE 24 (Continued)

CHARACTERISTICS			SITE 0200178			SITE 0200012		
			MEAN	RANGE	NUMBER OF VALUES	MEAN	RANGE	NUMBER OF VALUES
Flouride,	Dissolved	mg/L	0.17	0.11-0.27	37	0.16	0.1-0.26	28
Hardness,	Total	mg/L	67	50.6-79.2	37	73	64-86	4
Iron,	Total	mg/L	0.12	<0.1-0.3	22	-	-	-
	Dissolved	mg/L	<0.1	<0.1	27	0.06	0-0.3	35
Lead,	Total	µg/L	1.3	<1-5	17	10	20-40	31
	Dissolved	µg/L	<1	<1	25	3	1-7	21
Magnesium,	Total	mg/L	-	4.6	1	4.7	4-5.1	5
	Dissolved	mg/L	4.3	3.1-5.3	37	4.6	3.3-6.0	42
Manganese,	Total	mg/L	0.02	<0.02-0.03	10	-	-	-
	Dissolved	mg/L	0.02	<0.01-0.02	18	0.01	0.01	21
Mercury,	Total	µg/L	-	<0.05	1	-	-	-
Nitrogen,	Ammonia	mg/L	0.008	<0.005-0.015	48	0.007	0.005-0.1	35
	Nitrate	mg/L	0.07	<0.02-0.14	14	0.1	0.03-0.14	20
	Nitrite	mg/L	0.005	<0.005	16	0.006	0.006	22
	Kjeldahl	mg/L	0.11	0.01-0.25	48	0.08	0.01-0.18	35
	Organic	mg/L	0.1	0.01-0.24	36	0.1	0-0.5	121
	Nitrite/nitrate	mg/L	0.05	<0.02-0.13	37	0.08	<0.02-0.13	35
	Total	mg/L	0.14	0.07-0.2	7	0.19	0.16-0.22	2
Oil and Grease		mg/L	-	<1	1	-	-	-
Oxygen,	Dissolved	mg/L	12.1	9-14.4	41	10.8	9-13	99
	Saturation	%	128	111-139	3	-	-	-
pH			8.1	7.6-8.8	105	8.0	7.7-8.4	35

TABLE 24 (Continued)

CHARACTERISTICS			SITE 0200178			SITE 0200012		
			MEAN	RANGE	NUMBER OF VALUES	MEAN	RANGE	NUMBER OF VALUES
Phenols		µg/L	<2	<2	6	-	-	-
Phosphorus,	Dissolved	µg/L	8	3-22	7	4	3-9	34
	Ortho-P	µg/L	5.8	<3-24	42	2	1-5	35
	Total	µg/L	13.8	6-29	44	6	3-16	35
Potassium,	Dissolved	mg/L	0.6	0.5-0.7	17	0.7	0.2-1.2	58
Resin Acids		mg/L	-	<0.5	1	-	-	-
Silica,	Dissolved	mg/L	4.4	3.7-5.2	17	3.7	2.3-5	37
Solids,	Total	mg/L	89	72-108	50	91	70-108	72
	Dissolved	mg/L	87	70-106	41	89	68-100	19
	Suspended	mg/L	3.5	1-10	8	1.0	1-2	36
	Total Inorganic	mg/L	74	52-90	3	71	52-88	18
Sodium,	Dissolved	mg/L	1.5	1.3-1.8	28	1.6	1.2-2.9	30
Sulphate,	Dissolved	mg/L	10.3	7.6-12.9	27	11.5	6.8-16.5	40
Surfactants		mg/L	-	<0.03	1	-	-	-
Tannin and Lignin		mg/L	0.12	<0.1-0.3	34	0.13	0.1-0.3	35
Temperature		°C	8.7	1-20.5	52	9.4	2-20.1	114
Turbidity		NTU	0.7	0.2-1.5	44	0.4	0.2-0.7	37
Zinc,	Total	µg/L	5.8	<5-16	19	13	6-21	19
	Dissolved	µg/L	5	<5-6	18	18	5-70	16

TABLE 25

B.C. HYDRO WATER QUALITY DATA 1982 - 1984.

			SITE 0200183 KEENLEYSIDE DAM			SITE 0200200 CASTLEGAR			SITE 0200178 KOOTENAY RIVER			SITE 0200003 BIRCHBANK		
			Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range	N
Alkalinity,	Total	mg/L	50	38-63	34	48.8	37-56	34	56	44-80	34	-	-	-
Calcium		mg/L	17	14.3-20	34	16.6	14.3-19.4	33	18.4	15.3-21.9	34	-	-	-
Cadmium,	Total	µg/L	5.6	5-25	29	5.6	5-25	29	5.6	5-25	29	-	-	-
Carbon,	Organic	mg/L	3	1-12	37	2.6	1.0-6.2	32	3.3	1.1-14	37	8.7	3.8-13	3
	Inorganic	mg/L	10.3	5.9-14	33	10.5	6.1-14	32	11.4	7.2-15	33	-	-	-
Chloride		mg/L	0.3	0.1-1.0	34	1.3	0.2-4.9	34	0.8	0.5-1.5	34	-	-	-
Colour		TCU	5	5	33	10	5-25	33	5.7	5-10	34	-	-	-
Copper,	Total	µg/L	10.9	1-77	34	12	5-79	34	14.6	5-97	34	-	-	-
Conductivity		µS/cm	81.6	60-115	38	82	58-100	33	93.4	72-130	37	105	85-128	3
Cyanide,	Total	µg/L	14	10-40	29	28	10-240	32	10	10-20	33	-	-	-
Gases,	Total	%	120	102.6-131	31	118	103-133	31	111.5	100.9-124	32	-	-	-
Hardness,	Total	mg/L	45	47-72	34	57.6	47-67	34	65	52-78	34	-	-	-
Iron,	Total	mg/L	0.03	0.01-0.11	34	0.05	0.01-0.51	34	0.04	0.01-0.43	34	-	-	-
Magnesium,	Total	mg/L	3.4	2.3-4.6	34	3.4	2.5-4.7	33	4.2	3.3-5.1	34	-	-	-
Manganese,	Total	µg/L	5	5-17	34	6.6	5-24	34	5.1	3-14	34	-	-	-
Mercury,	Total	µg/L	0.1	0.05-0.63	29	0.1	0.05-0.75	29	0.06	0.05-0.33	29	-	-	-
Nitrogen,	Ammonia	mg/L	0.005	<0.01-0.009	4	-	-	-	-	-	-	0.01	<0.01-0.021	3
	Kjeldahl	mg/L	0.08	0.01-0.44	102	0.07	0.01-0.18	100	0.08	0.01-0.24	105	0.10	0.04-0.13	3
	NO_2/NO_3	mg/L	0.12	0.03-0.19	106	0.11	0.02-0.19	102	0.05	0.007-0.15	106	0.07	0.03-0.12	3
	Organic	mg/L	0.04	<0.01-0.09	4	-	-	-	-	-	-	0.08	0.04-0.11	3
Oxygen,	Dissolved	mg/L	12.8	10.4-15.6	33	12.5	10.3-15.1	33	11.7	9.2-14.5	33	-	-	-
pH			7.4	6.8-8.4	35	7.2	6.4-8.2	31	7.4	6.7-8.0	35	7.8	7.8-7.9	3
Phenol		µg/L	1.4	1-8	31	2.7	1-12	30	1.4	1-4	31	-	-	-

TABLE 25 (Continued)

			SITE 0200183 KEENLEYSIDE DAM			SITE 0200200 CASTLEGAR			SITE 0200178 KOOTENAY RIVER			SITE 0200003 BIRCHBANK		
			Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range	N
Phosphorus,	Total	mg/L	0.02	<0.01-0.08	106	0.01	0.01-0.03	101	0.01	0.01-0.07	104	<0.01	<0.01	3
	Dissolved	mg/L	<0.01	<0.01	4	-	-	-	-	-	-	<0.01	<0.01	3
	Particulate	mg/L	<0.01	<0.01	4	-	-	-	-	-	-	<0.01	<0.01	3
	Ortho-P	mg/L	<0.01	<0.01	4	-	-	-	-	-	-	<0.01	<0.01	3
Potassium		mg/L	0.71	0.6-1.4	34	0.78	0.6-1.0	33	0.61	0.4-0.8	34	-	-	-
Resin Acids		mg/L	1.0	1.0	29	1.0	1.0	32	1.0	1.0	33	-	-	-
Silica		mg/L	4.1	1.5-6.3	37	4.0	1.3-5.4	33	4.5	2.4-6.4	36	3.2	1.7-4.7	3
Sodium		mg/L	0.85	0.6-1.7	34	1.6	0.8-4.3	33	1.5	0.6-1.8	34	-	-	-
Solids,	Dissolved	mg/L	75	<1-118	36	87	68-143	31	90.4	66-142	36	71	56-87	3
	Suspended	mg/L	-	-	-	-	-	-	-	-	-	1	<1-2	3
	Diss. Inorg.	mg/L	58	N.D.-110	36	59	8-140	31	64.6	28-140	32	-	-	-
Sulphate		mg/L	9.4	5-16	34	9.7	7-21	34	10.5	6-24	34	-	-	-
Tannin/Lignin		mg/L	0.1	0.1	29	0.15	0.1-0.6	32	0.1	0.1	33	-	-	-
Temperature		°C	11	3.5-19.0	34	11.3	3-19.5	34	11	3-18.5	34	-	-	-
Turbidity		NTU	1.5	0.1-3.8	33	1.5	0.8-3.2	32	1.5	0.5-3.0	33	-	-	-
Zinc,	Total	µg/L	6.7	3-17	34	7.5	5-23	34	10	5-25	34	-	-	-

TABLE 26

WATER QUALITY ANALYSES, JUNE 22, 1988; HATFIELD CONSULTANTS FOR CELGAR PULP COMPANY.

PARAMETER			STATION													
			1N	1S	MILL EFFLUENT	2N	2S	3N	3S	4N	4S	5E	5W	KR	6E	6W
<u>Physical Tests</u>																
Water Temp.		(°C)	15.0	15.0	28.0	15.0	15.0	15.0	15.0	15.0	15.0	14.5	15.0	14.0	14.0	14.0
pH			7.73	7.73	6.62	7.92	7.72	7.97	7.88	7.91	7.88	7.91	7.92	7.96	7.96	7.93
Conductivity		µS/cm	112.0	112.0	1010.0	101.0	118.0	101.0	106.0	106.0	101.0	95.2	106.0	112.0	112.0	106.0
Colour		TCU	8.0	8.0	870.0	7.0	19.0	7.0	10.0	7.0	11.0	8.0	9.0	7.0	6.0	8.0
Turbidity		NTU	L1.0	L1.0	8.6	L1.0	L1.0	L1.0	L1.0	L1.0	L1.0	L1.0	L1.0	L1.0	L1.0	L1.0
Suspended Solids		mg/L	L1.0	L1.0	48.0	1.3	1.3	L1.0	3.3	L1.0	L1.0	2.7	L1.0	1.3	4.7	4.6
Dissolved Oxygen		mg/L	12.0	11.9	3.3	11.7	11.2	11.7	11.6	11.6	11.5	11.4	11.4	10.9	10.9	11.0
% Saturation D.O.			124	123	42	121	116	121	120	120	119	117	118	111	111	112
<u>Anions & Nutrients</u>																
Alkalinity	CaCO3	mg/L	53.3	54.3	95.5	53.3	52.1	51.1	52.1	54.3	54.3	51.1	52.1	55.1	55.1	52.1
Chloride	Cl	mg/L	L0.50	L0.50	1440.0	L0.50	2.00	L0.50	L0.50	L0.50	L0.50	L0.50	L0.50	L0.50	L0.50	L0.50
T-Phosphorus	P	mg/L	0.013	0.014	0.50	0.009	0.023	0.009	0.009	0.006	0.010	0.036	0.007	0.009	0.030	0.025
Total Kjeldahl	N	mg/L	0.13	0.21	1.31	0.068	0.11	0.10	0.083	0.15	0.14	0.079	0.10	0.70	0.085	0.087
<u>Other Tests</u>																
BOD-5		mg/L	1.0	1.2	111.0	L1.0	2.3	L1.0	1.6	1.3	1.5	1.3	1.0	1.0	L1.0	L1.0
Phenol		mg/L	-	L0.002	2.48	-	0.005	-	L0.002	-	L0.002	-	L0.002	-	L0.002	L0.002
Tannins & Lignins		mg/L	0.10	0.12	110.0	0.12	0.79	0.13	0.33	0.14	0.39	0.24	0.30	0.10	0.13	0.18
Sodium, Diss.	Na	mg/L	0.92	0.86	180.0	0.76	2.22	0.80	1.27	0.94	1.33	1.02	1.19	1.33	1.31	1.26

Site 1 - Keenleyside Dam (Site 0200183)
2 - 500 m downstream from Celgar
3 - 1.7 km downstream from Celgar (at Robson West)
4 - at Robson ferry
5 - upstream from confluence with Kootenay River
6 - at Kinnaird
KR - Kootenay River

TABLE 27

WATER QUALITY DOWNSTREAM FROM CELGAR DURING LOW FLOW; JUNE, 1984.

COLUMBIA RIVER SITES	CHARACTERISTICS		JUNE 12		JUNE 13		JUNE 14		MEAN
			AM	PM	AM	PM	AM	PM	
0200183	pH		7.7	7.8	7.9	7.9	7.4	7.9	7.8
	Susp. Solids	mg/L	2	2	1	1	4	1	1.8
Between Dam and	Sp. Cond.	µmhos/cm	128	128	126	126	126	125	126.5
Celgar Pulp Mill	Colour	SWU	<5	<5	<5	<5	<5	<5	<5
(Control Station)	Phenol	µg/L	<2	<2	<2	<2	<2	<2	<2
0200604	pH		7.9	6.7	7.6	7.6	7.5	7.6	7.5
	Susp. Solids	mg/L	2	–	6	5	4	2	3.8
At Castlegar Ferry	Sp. Cond.	µmhos/cm	128	132	144	145	144	145	140
North Side	Colour	SWU	<5	9	32	32	35	35	24.6
	Phenol	µg/L	<2	4	2	<2	<2	<2	<2.3
1190074	pH		7.8	7.8	–	7.6	7.5	7.5	7.6
	Susp. Solids	mg/L	2	5	–	2	3	2	2.8
At Castlegar Ferry	Sp. Cond.	µmhos/cm	137	137	–	145	144	142	141
South Side	Colour	SWU	12	14	–	32	41	32	26
	Phenol	µg/L	8	7	–	<2	4	<2	<4.6
0200200	pH		7.7	7.8	7.6	7.3	7.6	7.7	7.6
	Susp. Solids	mg/L	3	3	5	7	2	2	3.7
At Castlegar	Sp. Cond.	µmhos/cm	125	128	123	127	123	127	126
	Colour	SWU	11	15	19	23	19	20	17.8
	Phenol	µg/L	5	6	<2	<2	<2	2	<3.2

	4 km d/s FROM CELGAR OUTFALL		
	June 13		
	1	5	10
)	120	120	121
:	<5	6	<5
:.5	12.5	12.5	12.5
'.9	7.9	7.8	7.9
'	2	3	3
;	2	2	2
..5	1.4	1.5	1.6

TABLE 30

LEVELS OF CHLORINATED PHENOLICS (ppt) IN THE COLUMBIA RIVER, FEBRUARY 18-21, MAY 29, 1990

CHARACTERISTIC	UPSTREAM OF CELGAR SITE 0200183		1 km DOWNSTREAM FROM CELGAR	AT CASTLEGAR	KOOTENAY RIVER CONTROL SITE 0200178	AT BIRCHBANK SITE 0200003	AT WANETA SITE 0200559	
	Feb. 18-21	May 29					Feb. 18-21	May 29
Dichlorophenols	-	<15	-	14	<15	<15	-	<15
Trichlorophenols	<3.0	<20	<15	<20	<20	<20	<8.0	<20
Tetrachlorophenols	<2.0	<20	4.0	<20	<20	<20	2.0	<20
Pentachlorophenol	<1.0	<20	4.0	<20	<20	<20	2.0	<20
Monochloroguaiacols	-	<30	-	<30	<30	<30	-	<30
Dichloroguaiacols	-	<15	-	14	<15	<15	-	<15
Trichloroguaiacols	<0.4	<15	16.0	120	<15	19	10.7	19
Tetrachloroguaiacols	<0.7	<15	24.0	70	<15	16	12.0	17
Total Chlorinated Phenolics	ND	ND	48.0	218	ND	35	26.7	36

- adapted from Celgar, 1990.
- ND = not detected.
- all samples taken on May 29, 1990, unless otherwise indicated.
- chemical analyses by: Seakem Analytical Services Ltd. and Econotech Services Ltd. - Feb. samples; Zenon Environmental Inc. - May samples.
- ppt = parts per trillion.

TABLE 31

CONSTITUENTS IN PULP AND PAPER MILL EFFLUENTS KNOWN TO CAUSE OFF-FLAVOURS IN FISH

CHEMICAL	FISH SPECIES	EXPOSURE TIME (DAYS)	ETTC[a] (µg/L)	NO-EFFECT CONCENTRATION[b] (µg/L)
Chlorophenol	trout, perch, carp	2-7	24-60	20-1,000
2,4-dichlorophenol	trout, perch, bass	2-7	0.4-14	0.01-10
2,4-dichlorophenol	rainbow trout	4	0.1	0.01
2,4,6-trichlorophenol	rainbow trout	2	1-52	10
Benzene	rainbow trout	2	–[c]	5,600
Naphthalene	roach, carp	0.8	1,000-3,400	–
Pentachlorophenol	rainbow trout	2	–	20
Phenol	eel, carp, trout	2-28	20-25,000	5,600-25,000
Toluene	yellow perch	5-7	250-50,000	–

Adapted from McLeay (1987).

[a] Estimated threshold tainting concentration.Lowest concentration at which significant off-flavour fish was noted.
[b] Concentration at which there is no impairment to the flavour of fish.
[c] Not determined.

TABLE 32

AVERAGE NUTRIENT LOADINGS FROM POINT SOURCE DISCHARGES TO THE COLUMBIA RIVER BETWEEN HUGH KEENLEYSIDE DAM AND THE KOOTENAY RIVER*

	TOTAL PHOSPHORUS		TOTAL NITROGEN	
SOURCE	kg/d	% of Total	kg/d	% of Total
Castlegar, PE 80	6	4.5	14	3.7
Castlegar, PE 4008	5	3.8	13	3.4
Selkirk College, PE 141	2	1.5	4	1.0
Celgar Ltd., PE 1272	120	90.2	350	91.9

These loadings were calculated from relatively few data in most cases, and consequently represent order of magnitude values only.

* adapted from the Kootenay Study (W.I.B., 1979).

TABLE 33

Receiving water nitrogen and phosphorus levels (mg/L) upstream and downstream from Celgar**

	UPSTREAM				DOWNSTREAM			
	MOE (1979) 0200183	B.C. HYDRO 1982-1984 RL&L (1984) 0200183	MOE 0200183 TABLE 10	DWERNYCHUK 1988 *	MOE (1979) 0200200	MOE 0200200 TABLE 10	DWERNYCHUK 1988 *	B.C. HYDRO 0200200 1982-1984
Nitrogen								
Ammonia	0.006 <0.005-0.01	0.005 <0.01-0.009	<0.005		0.007 <0.005-0.01	0.008 <0.005-0.024		
Kjeldahl	0.07 <0.01-0.17	0.08 0.01-0.44	0.17 0.09-0.24	0.17 0.13, 0.21	0.1 <0.01-0.23	0.08 0.04-0.17	0.11 0.07-0.15	0.07 0.01-0.18
NO_2NO_3	0.12 0.07-0.18	0.12 0.03-0.19	0.09		0.11 0.05-0.15	0.09		0.11 0.02-0.19
Total	0.19 0.09-0.31				0.21 0.08-0.32			
Organic		0.04 <0.01-0.09	0.17 0.09-0.24			0.08 0.02-0.17		
Phosphorus								
Total	0.007 <0.003-0.026	0.02 <0.01-0.08	0.011 0.01-0.012	0.013, 0.014	0.007 <0.003-0.023	0.008 0.007-0.01	0.01 0.006-0.023	0.01 0.01-0.03
Dissolved	0.003 <0.003-0.003	N.D. (<0.01)	0.006 0.005-0.006		0.003 <0.003-0.005	0.005 0.004-0.008		
Ortho-P		N.D. (<0.01)	N.D. (<0.003)			N.D. (<0.003)		
Particulate		N.D. (<0.01)						

* stations 2,3 and 4, i.e. excluding stations 5 & 6 downstream from Castlegar and Kootenay River

** results are given as mean and range (mg/L)

- blank cells indicate no data.

TABLE 34

DIOXINS AND FURANS IN BED SEDIMENTS COLLECTED UPSTREAM AND DOWNSTREAM FROM THE CELGAR PULP MILL (FROM MAH *ET AL.*, 1989).

SAMPLING LOCATION	MOISTURE CONTENT (%)	ORGANIC C (mg/g)	DIOXIN CONCENTRATION (pg/g dry wt.)						FURAN CONCENTRATION (pg/g dry wt.)					
			2,3,7,8 T4CDD	TOTAL T4CDD	TOTAL P5CDD	TOTAL H6CDD	TOTAL H7CDD	TOTAL O8CDD	2,3,7,8 T4CDF	TOTAL T4CDF	TOTAL P5CDF	TOTAL H6CDF	TOTAL H7CDF	TOTAL O8CDF
Upstream[1]	24.0 26.8 35.9	2.9 1.4 9.2	L15 L15 L15	L15 L15 L15	L20 L20 L20	L30 L30 L30	L50 L50 L50	L75 L75 L75	L10 L10 L10	L10 L10 L10	L15 L15 L15	L25 L25 L25	L40 L40 L40	L75 L75 L75
Downstream[2]	78.1 58.0 39.8	210.0 47.0 11.0	L15 L15 L15	L15 L15 L15	L20 L20 L20	L30 L30 L30	L50 L50 L50	L75 L75 L75	642 298 100	642 330 125	L15 L15 L15	L25 L25 L25	L40 L40 L40	L75 L75 L75

L - Less than

1 - All three upstream samples were taken from lower Arrow Lake at the mouths of Deer Creek, Shield Creek and Syringa Creek

2 - The three downstream sites were:
- 300 m downstream from Celgar's discharge;
- 800 m downstream from Celgar's discharge;
- 1300 m downstream from Celgar's discharge.

TABLE 35

LEVELS OF CHLORINATED PHENOLICS, RESIN ACIDS AND EOX IN COLUMBIA RIVER SEDIMENTS DOWNSTREAM FROM THE CELGAR OUTFALL

SEDIMENT CHARACTERISTICS µg/g	SEDIMENT SAMPLING SITES (DOWNSTREAM FROM THE CELGAR OUTFALL			
	1 KM DOWNSTREAM			4 KM D/S
	2i	2ii	2iii	3ii
Resin Acids:				
Abietic Acid	<0.5	3.0	9.8	<0.5
Dehydroabietic Acid	9.4	16.0	10.0	<0.5
Isopimaric Acid	9.2	11.0	7.5	0.6
Levopimaric Acid	5.0	1.4	1.9	<0.5
Neoabietic Acid	<0.5	<0.5	<0.5	<0.5
Pimaric Acid	0.9	<0.5	<0.5	<0.5
Sandaracopimaric Acid	4.7	3.7	4.3	1.1
EOX (Extractable Organic Halides)	59	140	47	34
Chlorinated Phenolics:				
Pentachlorophenols	<0.005	0.052	0.013	<0.005
Tetrachlorophenols	0.047	0.13	0.068	0.006
Trichlorophenols	0.067	0.14	0.11	0.009
Trichloroguaiacols	0.12	0.05	0.04	<0.01
Tetrachloroguaiacols	0.14	0.10	0.03	<0.01

- Sampled by R. Crozier, Waste Management Branch, Nelson, B.C., on March 30, 1989.

Table 36
B.C. Hydro sediment resin acid analyses

	Upstream Sites		Downstream Sites										
	near Dam #15	near Outfall #11	near Outfall #12	d/s Outfall #20	Boat Launch #18,19	Pass Creek #4	STP #9	Tin-cup Rapids 1	2	3	6	7
Pimaric	11.3	<0.1	1.9	<0.1-1.7	3.4; 8.4	<0.1 (2)	<0.1	<0.1	<0.1-0.8	<0.1;1.6	<0.1;4.4	2.2
Sandaracopimaric	5.8	<0.1	1.2	<0.1 (3)	<0.1; 13	<0.1 (2)	<0.1	<0.1	<0.1	<0.1	<0.1;1.4	<0.1
Isopimaric	3.5	<0.1	2.6	<0.1-3	11.3;2.4	<0.1;4.3	<0.1	<0.1	<0.1	<0.1;0.7	<0.1;4.7	<0.1
Levopimaric	34.9	40.1	1.5	<0.1-3.2	8.1;<0.1	<0.1;9.3	<0.1	3.4	<0.1	1.1; 1.8	1.5; 9	<0.1
DHA	35.8	1.6	1.2	13.5-19.6	43; 11.6	6.6;25.8	<0.1	4.8	3.6-7.4	2.5; 7.6	22.7; 48	9.8
Abietic	7.4	<0.1	3.4	<0.1-8.5	<0.1;12.	<0.1;5.9	<0.1	1.9	<0.1-4.0	<0.1;0.7	3.4;11.6	<0.1
Neoabietic	<0.1	<0.1	<0.1	<0.1 (3)	<0.1 (2)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chloro-DHA	<0.1	<0.1	<0.1	<0.1 (3)	<0.1 (2)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
dichloro-DHA	<0.1	<0.1	<0.1	<0.1 (3)	<0.1 (2)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

- results given as µg/g.
- values in brackets indicates number of samples.

STP = Sewage Treatment Plant (Castlegar).
DHA = Dehydroabietic Acid

TABLE 37

B.C. Hydro sediment organochlorine analyses, December 1989

COMPOUND NAME	UPSTREAM FROM CELGAR				DOWNSTREAM FROM CELGAR											
	SITE #15 at Keenley-side Dam		SITE #11 50 m U/S Outfall		SITE #12 50 m D/S Outfall		SITE #20 0.5 km D/S		SITE #20 OUTFALL		SITE #20		SITE #18 BOAT LAUNCH 7.0 km D/S Outfall		SITE #20	
2,4,6-TRICHLOROPHENOL	ND	(0.5)	ND	(0.2)	ND	(0.5)	NDR	(0.8)	3.0	(0.4)	NDR	(0.7)	4.0	(1.0)	ND	(0.7)
2,3,6-TRICHLOROPHENOL	ND	(0.7)	ND	(0.1)	ND	(0.6)	ND	(1.0)	ND	(0.5)	ND	(0.9)	ND	(1.0)	ND	(0.9)
2,3,5-TRICHLOROPHENOL	ND	(0.5)	ND	(0.3)	ND	(0.4)	ND	(0.7)	ND	(0.3)	ND	(0.6)	ND	(0.9)	ND	(0.6)
2,4,5-TRICHLOROPHENOL	ND	(0.3)	ND	(0.3)	ND	(0.3)	ND	(0.5)	ND	(0.2)	ND	(0.4)	ND	(0.9)	ND	(0.4)
2,3,4-TRICHLOROPHENOL	ND	(0.3)	ND	(0.1)	ND	(0.3)	ND	(0.5)	ND	(0.3)	ND	(0.4)	ND	(0.8)	ND	(0.4)
3,4,5-TRICHLOROPHENOL	ND	(0.3)	ND	(0.1)	ND	(0.3)	ND	(0.5)	ND	(0.3)	ND	(0.4)	ND	(0.6)	ND	(0.4)
2,3,5,6-TETRACHLOROPHENOL	ND	(0.2)	ND	(0.2)	ND	(0.3)	ND	(0.2)	ND	(0.3)	ND	(0.4)	ND	(0.1)	ND	(0.3)
2,3,4,6-TETRACHLOROPHENOL	ND	(0.2)	0.6	(0.2)	ND	(0.2)	1.0	(0.2)	0.5	(0.3)	3.0	(0.3)	3.0	(0.2)	ND	(0.3)
2,3,4,5-TETRACHLOROPHENOL	ND	(0.1)	ND	(0.08)	ND	(0.2)	ND	(0.1)	ND	(0.2)	ND	(0.2)	ND	(0.1)	ND	(0.2)
PENTACHLOROPHENOL	ND	(0.1)	1.0	(0.04)	ND	(0.6)	0.2	(0.2)	0.1	(0.07)	0.9	(0.2)	2.0	(0.1)	0.2	(0.1)
3,4,5-TRICHLOROGUIACOL	ND	(0.08)	ND	(0.1)	3.0	(0.1)	2.0	(0.2)	3.0	(0.1)	13	(0.2)	24	(0.3)	1.0	(0.04)
4,5,6-TRICHLOROGUIACOL	ND	(0.1)	ND	(0.06)	0.1	(0.08)	0.7	(0.2)	0.9	(0.07)	4.0	(0.3)	2.0	(0.1)	0.1	(0.08)
3,4,5-TRICHLOROCATECOL	ND	(3.0)	ND	(0.4)	37	(2.0)	ND	(2.0)	ND	(2.0)	ND	(5.0)	7.0	(1.2)	ND	(2.0)
TETRACHLOROGUIACOL	ND	(0.2)	ND	(0.1)	2.0	(0.1)	2.0	(0.2)	3.0	(0.1)	11	(0.5)	20	(0.2)	1.0	(0.1)
TETRACHLOROCATECOL	ND	(15)	ND	(0.5)	36	(17)	ND	(21)	ND	(11)	ND	(24)	ND	(1.0)	ND	(8.0)
TRICHLOROSYRINGOL	ND	(1.0)	ND	(0.2)	ND	(2.0)	ND	(2.0)	ND	(0.5)	ND	(3.0)	ND	(0.7)	ND	(0.5)
2,4,6-TRICHLOROANISOLE	ND	(0.1)	ND	(0.08)	ND	(0.1)	ND	(0.2)	0.6	(0.4)	1.0	(0.5)	3.0	(0.4)	ND	(0.2)
2,3,6-TRICHLOROANISOLE	ND	(0.1)	ND	(0.08)	ND	(0.1)	ND	(0.2)	ND	(0.4)	ND	(0.5)	ND	(0.4)	ND	(0.2)
2,4,5-TRICHLOROANISOLE	ND	(0.1)	ND	(0.08)	ND	(0.1)	ND	(0.2)	ND	(0.4)	ND	(0.5)	ND	(0.4)	ND	(0.2)
2,4,6 + 2,3,6 + 2,4,5-TCA	ND	(0.1)	ND	(0.08)	ND	(0.1)	ND	(0.2)	ND	(0.4)	ND	(0.5)	ND	(0.4)	ND	(0.2)
2,3,5,6 + 2,3,4,6-TeCA	ND	(0.09)	ND	(0.06)	ND	(0.1)	ND	(0.2)	ND	(0.3)	ND	(0.4)	0.4	(0.3)	ND	(0.2)
2,3,4,5 + 2,3,4,6-TeCA	ND	(0.1)	ND	(0.07)	ND	(0.1)	ND	(0.2)	ND	(0.3)	ND	(0.4)	ND	(0.4)	ND	(0.2)
PENTACHLOROANISOLE	ND	(0.09)	ND	(0.06)	ND	(0.1)	ND	(0.2)	ND	(0.3)	ND	(0.4)	ND	(0.3)	ND	(0.2)
TRICHLOROVERATROLE	ND	(0.4)	ND	(0.3)	0.9	(0.4)	0.8	(0.6)	3.0	(1.0)	6.0	(1.4)	29	(1.3)	1.0	(0.6)
TETRACHLOROVERATROLE	ND	(0.1)	ND	(0.07)	ND	(0.3)	0.3	(0.2)	1.0	(0.3)	2.0	(0.5)	8.0	(0.4)	0.2	(0.1)

ND = Not Dectected
NDR = Peak detected but did not meet quantification criteria
NA = Not Available (insufficient sample to complete analysis)
Detection Limits are given in brackets

TABLE 37 (Continued)

B.C. Hydro sediment organochlorine analyses, December 1989

	near Pass Creek		near STP	Tin-cup Rapids			
COMPOUND NAME	Site 4-2	Site 4-3	Site #9	Site #1	Site #2	Site #2	Site #2
2,4,6-TRICHLOROPHENOL	ND (0.4)	ND (0.6)	ND (0.9)	ND (0.7)	ND (0.6)	ND (0.6)	ND (0.8)
2,3,6-TRICHLOROPHENOL	ND (0.1)	ND (0.4)	ND (0.5)	ND (0.3)	ND (0.9)	ND (0.8)	ND (1.0)
2,3,5-TRICHLOROPHENOL	ND (0.2)	ND (0.4)	ND (0.6)	ND (0.3)	ND (0.6)	ND (0.6)	ND (0.8)
2,4,5-TRICHLOROPHENOL	ND (0.2)	ND (0.4)	ND (0.6)	ND (0.3)	ND (0.4)	ND (0.4)	ND (0.5)
2,3,4-TRICHLOROPHENOL	ND (0.07)	ND (0.2)	ND (0.3)	ND (0.2)	ND (0.4)	ND (0.4)	ND (0.5)
3,4,5-TRICHLOROPHENOL	ND (0.02	ND (0.1)	ND (0.2)	ND (0.2)	ND (0.4)	ND (0.4)	ND (0.5)
2,3,5,6-TETRACHLOROPHENOL	ND (0.09)	ND (0.2)	ND (0.5)	ND (0.2)	ND (0.2)	ND (0.1)	ND (0.9)
2,3,4,6-TETRACHLOROPHENOL	0.7 (0.1)	1.0 (0.2)	1.0 (0.5)	0.7 (0.3)	0.5 (0.1)	0.5 (0.1)	0.5 (0.7)
2,3,4,5-TETRACHLOROPHENOL	ND (0.06)	ND (0.1)	ND (0.3)	ND (0.1)	ND (0.1)	ND (0.08)	ND (0.5)
PENTACHLOROPHENOL	0.8 (0.07)	1.0 (0.07)	2.0 (0.4)	0.5 (0.1)	0.3 (0.06)	0.2 (0.1)	ND (0.4)
3,4,5-TRICHLOROGUIACOL	2.0 (0.1)	NDR (0.1)	5.0 (0.6)	0.9 (0.2)	0.2 (0.05)	ND (0.1)	ND (0.3)
4,5,6-TRICHLOROGUIACOL	ND (0.1)	ND (0.09)	ND (0.6)	ND (0.2)	ND (0.07)	ND (0.1)	ND (0.3)
3,4,5-TRICHLOROCATECOL	ND (0.4)	ND (2.0)	ND (2.0)	ND (2.0)	ND (2.0)	ND (2.0)	ND (5.0)
TETRACHLOROGUIACOL	1.0 (0.1)	ND (0.2)	8.0 (0.8)	0.9 (0.5)	ND (0.1)	ND (0.4)	ND (0.5)
TETRACHLOROCATECOL	ND (0.5)	ND (1.0)	ND (3.0)	ND (1.0)	ND (9.0)	ND (35)	ND (33)
TRICHLOROSYRINGOL	ND (0.4)	ND (0.7)	ND (2.0)	ND (2.0)	ND (1.0)	ND (4.0)	ND (2.0)
2,4,6-TRICHLOROANISOLE	ND (0.2)	ND (1.0)	0.2 (0.1)	ND (0.4)	ND (0.1)	ND (0.1)	ND (0.2)
2,3,6-TRICHLOROANISOLE	ND (0.2)	ND (1.0)	ND (0.2)	ND (0.4)	ND (0.1)	ND (0.1)	ND (0.2)
2,4,5-TRICHLOROANISOLE	ND (0.2)	ND (1.0)	ND (0.2)	ND (0.4)	ND (0.1)	ND (0.1)	ND (0.2)
2,4,6 + 2,3,6 + 2,4,5-TCA	ND (0.2)	ND (1.0)	ND (0.2)	ND (0.4)	ND (0.1)	ND (0.1)	ND (0.2)
2,3,5,6 + 2,3,4,6-TeCA	ND (0.2)	ND (0.7)	ND (0.1)	ND (0.3)	ND (0.1)	ND (0.1)	ND (0.2)
2,3,4,5 + 2,3,4,6-TeCA	ND (0.2)	ND (0.7)	ND (0.1)	ND (0.4)	ND (0.1)	ND (0.1)	ND (0.2)
PENTACHLOROANISOLE	ND (0.2)	ND (0.9)	ND (0.1)	ND (0.3)	ND (0.1)	ND (0.1)	ND (0.2)
TRICHLOROVERATROLE	3.0 (0.9)	ND (4.0)	3.0 (0.5)	2.0 (1.2)	ND (0.4)	ND (0.4)	ND (0.8)
TETRACHLOROVERATROLE	0.5 (0.2)	ND (1.0)	0.9 (0.1)	0.5 (0.4)	ND (0.1)	ND (0.1)	ND (0.2)

TABLE 37 (Continued)

B.C. Hydro sediment organochlorine analyses, December 1989

COMPOUND NAME	Site 3-1	Site 3-2	Site 6-1	Site 6-1	Site #7
2,4,6-TRICHLOROPHENOL	ND (0.4)	ND (0.4)	1.0 (0.4)	ND (0.5)	ND (0.4)
2,3,6-TRICHLOROPHENOL	ND (0.5)	ND (0.8)	ND (0.5)	ND (0.2)	ND (0.5)
2,3,5-TRICHLOROPHENOL	ND (0.6)	ND (0.2)	ND (1.0)	ND (0.9)	ND (0.4)
2,4,5-TRICHLOROPHENOL	ND (0.3)	ND (0.6)	ND (0.7)	ND (0.2)	ND (0.2)
2,3,4-TRICHLOROPHENOL	ND (0.3)	ND (0.2)	ND (0.6)	ND (0.1)	ND (0.2)
3,4,5-TRICHLOROPHENOL	ND (0.2)	ND (0.1)	ND (0.5)	ND (0.09)	ND (0.3)
2,3,5,6-TETRACHLOROPHENOL	ND (0.4)	ND (0.2)	ND (0.1)	ND (0.2)	ND (0.3)
2,3,4,6-TETRACHLOROPHENOL	0.8 (0.6)	ND (0.4)	1.0 (0.09)	ND (1.0)	ND (0.2)
2,3,4,5-TETRACHLOROPHENOL	ND (0.3)	ND (0.1)	ND (0.08)	ND (0.1)	ND (0.2)
PENTACHLOROPHENOL	1.0 (0.6)	0.6 (0.2)	1.0 (0.07)	0.7 (0.09)	ND (0.06)
3,4,5-TRICHLOROGUIACOL	NDR (0.3)	ND (0.3)	6.0 (0.09)	ND (0.7)	0.4 (0.1)
4,5,6-TRICHLOROGUIACOL	ND (0.3)	ND (0.2)	0.6 (0.09)	ND (0.3)	ND (0.2)
3,4,5-TRICHLOROCATECOL	ND (1.0)	ND (1.0)	ND (2.0)	ND (1.0)	ND (1.0)
TETRACHLOROGUIACOL	ND (0.5)	ND (0.4)	ND (0.2)	ND (0.3)	0.3 (0.1)
TETRACHLOROCATECOL	ND (2.0)	ND (1.0)	ND (0.9)	ND (1.0)	ND (17)
TRICHLOROSYRINGOL	ND (0.7)	ND (0.7)	ND (1.0)	ND (0.7)	ND (0.1)
2,4,6-TRICHLOROANISOLE	NA	ND (0.08)	0.2 (0.1)	ND (0.06)	ND (0.1)
2,3,6-TRICHLOROANISOLE	NA	ND (0.08)	ND (0.2)	ND (0.06)	ND (0.1)
2,4,5-TRICHLOROANISOLE	NA	ND (0.08)	ND (0.2)	ND (0.06)	ND (0.1)
2,4,6 + 2,3,6 + 2,4,5-TCA	NA	ND (0.08)	ND (0.2)	ND (0.06)	ND (0.1)
2,3,5,6 + 2,3,4,6-TeCA	NA	ND (0.05)	ND (0.2)	ND (0.04)	ND (0.08)
2,3,4,5 + 2,3,4,6-TeCA	NA	ND (0.06)	ND (0.2)	ND (0.05)	ND (0.1)
PENTACHLOROANISOLE	NA	ND (0.06)	ND (0.2)	ND (0.05)	ND (0.08)
TRICHLOROVERATROLE	NA	ND (0.2)	13 (0.6)	ND (0.2)	ND (0.3)
TETRACHLOROVERATROLE	NA	ND (0.07)	3.0 (0.2)	ND (0.06)	ND (0.1)

TABLE 38

BENTHIC MACROINVERTEBRATE DATA SUMMARY - JUNE 1980, 1983, 1984, 1988

STATION	YEAR	% FAUNA			DENSITY (Number/m^2)	Number ofTAXA	RICHNESS	EQUITABILITY	DOMINANCE	TU DIVERSITY
		SENSITIVE	FACULTATIVE	TOLERANT						
1S & 1N (mean) at dam tailrace	1980	16	76	8	157	18	3.27	0.77	0.62	0.8179
	1983	1.5	97	1.5	12808	29	2.91	0.57	0.21	0.7906
	1984	1	95	4	2104	23	2.83	0.43	0.50	0.5063
	1988	L1	98	L1	13926	31	3.23	0.48	0.32	0.6830
	CV*	152	11	88	98	23	7	27	44	20
2S edge of IDZ	1980	1	27	72	1495	30	3.70	0.74	0.60	0.8815
	1983	L1	31	68	18576	32	3.16	0.63	0.18	0.8218
	1984	L1	34	65	3748	20	2.31	0.61	0.20	0.7994
	1988	0	50	50	15994	29	2.89	0.58	1.20	0.7951
	CV	67	28	15	86	19	19	11	69	5
3S 1.5 km D/S	1980	2	37	61	1186	24	3.25	0.76	0.51	0.8594
	1983	2	58	40	17944	31	3.06	0.72	0.11	0.8865
	1984	2	60	38	3354	28	3.33	0.66	0.15	0.8510
	1988	L1	92	7	18620	35	3.46	0.63	0.14	0.8571
	CV	29	76	61	90	16	5	8	83	2
4S Robson Ferry	1980	1	59	40	4763	26	2.95	0.71	0.51	0.8676
	1983	6	64	30	15710	37	3.73	0.78	0.08	0.9217
	1984	1	49	50	10349	26	2.70	0.62	0.18	0.8168
	1988	L1	95	4	30397	35	3.29	0.47	0.28	0.7157
	CV	111	30	64	72	19	14	21	70	11

TABLE 38 (Continued)

STATION	YEAR	% FAUNA			DENSITY (No. m^{-2})	NO. TAXA	RICHNESS	EQUITABILITY	DOMINANCE	TU DIVERSITY
		SENSITIVE	FACULTATIVE	TOLERANT						
5W U/S of Kootenay R.	1980	10	89	1	2629	26	3.17	0.46	0.80	0.5790
	1983	12	87	L1	15120	22	2.19	0.52	0.31	0.6861
	1984	2	89	9	4275	18	2.03	0.55	0.31	0.6875
	1988	L1	98	2	32712	38	3.56	0.71	0.10	0.8961
	CV	89	5	119	101	33	27	19	78	19
6W at Kinnaird	1980	10	86	5	1581	25	3.26	0.56	0.75	0.6632
	1983	15	84	L1	5029	39	4.47	0.56	0.22	0.7831
	1984	1	99	0	2169	23	2.86	0.57	0.24	0.7640
	1988	2	97	1	20442	47	4.64	0.57	0.22	0.7845
	CV	95	8	127	122	34	23	1	73	8

L = Less than.

* CV = Coefficient of variability (%) = mean/standard deviation X 100

June Columbia River Discharges:
1980 - 162 m^3s^{-1}
1983 - 283 m^3s^{-1}
1984 - 142 m^3s^{-1}
1988 - 420 m^3s^{-1}

TU = Keefe-Bergersen Diversity Index

Table from Dwernychuk (1988).

TABLE 39

LEVELS OF CHLORINATED PHENOLICS AND EXTRACTABLE ORGANIC HALIDES (EOX) IN COLUMBIA RIVER FRESHWATER MUSSEL TISSUE

SAMPLING LOCATION	FRESHWATER MUSSEL SPECIES	TCP[1] µg/g	2,3,4,5 TeCP[2] µg/g	2,3,4,6-TeCP[2] µg/g	PCP[3] µg/g	TCG[4] µg/g	TeCG[5] µg/g	EOX[6] µg/g
2 km Upstream from Celgar Site 1ci	*Anodonta kennerlyi*	<0.05 (8)	<0.05 (8)	<0.05 (8)	<0.02 (8)	<0.05 (2)	<0.05 (8)	<1.0-2.5 (8) Mean=1.35 SD=0.65
1 km D/S Site 2ci	*Anodonta kennerlyi*	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.02 (2)	<0.05 (2)	<0.05 (2)	<1.0 (2)
Site 2cii	*Anodonta kennerlyi*	<0.05 (4)	<0.05 (4)	<0.05 (4)	<0.02 (4)	<0.05 (4)	<0.05 (4)	<1.0 (4)
Site 2ciii	*Gonidea angulata*	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.02 (2)	<0.05 (2)	<0.05 (2)	1.8 (2)
	Anodonta kennerlyi	<0.05 (3)	<0.05 (3)	<0.05-0.07 (3) Mean=0.056 SD=0.012	<0.02-0.024 (3) Mean=0.021 SD=0.002	<0.05 (3)	<0.05 (3)	1.9-2.5(3) Mean=2.1 SD=0.34
Robson Ferry Site 3cii	*Margaritifera falcata*	<0.05 (2)	<0.05 (2)	<0.05 (2)	<0.02 (2)	<0.05 (2)	<0.05 (2)	6.7-7.7 (2) Mean=7.2 SD=0.7

* Mussels collected March 30, 1989.

1 Trichlorophenol
2 Tetrachlorophenol
3 Pentachlorophenol
4 Trichloroguaiacol
5 Tetrachloroguaiacol
6 Extractable Organic Halide

- homogenized whole animal extracts (excluding the shell) were analyzed (ug/g wet weight).
- sample size (number of mussels) is shown in brackets after the sample value.
- mean and standard deviation are shown where necessary and were calculated assuming that non-detectables equalled the detection level.

TABLE 40

LEVELS OF DIOXINS AND FURANS IN FRESHWATER MUSSELS FROM COLUMBIA RIVER SEDIMENTS DOWNSTREAM FROM CELGAR.

SAMPLING LOCATION	FRESHWATER MUSSEL SPECIES	TCDF ng/g	PeCDF ng/g	H_6CDF ng/g	H_7CDF ng/g	OCDF ng/g	TCDD ng/g	PCDD ng/g	H_6CDD ng/g	H_7CDD ng/g	OCDD ng/g
1 km D/S from Celgar Site 2ci	*Anodonta kennerlyi*	0.30	<0.002	<0.005	<0.003	<0.003	<0.002	<0.001	<0.003	<0.002	<0.004
1 km D/S from Celgar Site 2cii	*Anodonta kennerlyi*	1.3	<0.010	<0.09	<0.023	<0.023	<0.01	<0.014	<0.030	<0.014	<0.036
Robson Ferry Site 3ci	*Margaritifera falcata*	0.04	<0.002	<0.011	<0.005	<0.006	<0.004	<0.010	<0.009	<0.007	<0.020
Robson Ferry Site 3cii	*Margaritifera falcata*	0.15	<0.003	<0.009	<0.004	<0.005	<0.003	<0.007	<0.011	<0.004	<0.007

- Sampled March 30, 1989, from homogenized single whole animal extracts (excluding the shell) (n=1).

- ng/g equals ppb or parts per billion (10^{-9}) on a wet weight basis.

TCDF = Tetrachlorodibenzofuran
PCDF = Pentachlorodibenzofuran
H_6CDF = Hexachlorodibenzofuran
H_7CDF = Heptachlorodibenzofuran
OCDF = Octachlorodibenzofuran

TCDD = Tetrachlorodibenzo-p-dioxin
PCDD = Penatchlorodibenzo-p-dioxin
H_6CDD = Hexachlorodibenzo-p-dioxin
H_7CDD = Heptachlorodibenzo-p-dioxin
OCDD = Octachlorodibenzo-p-dioxin

TABLE 41
LEVELS OF CHLORINATED PHENOLICS AND EOX IN COLUMBIA RIVER FRESHWATER MUSSEL TISSUE (SAMPLED NOVEMBER 22, 1990).

Characteristics ng/g (ppb) except EOX	1.4 km U/S[1]	300 m D/S Celgar[2]	1.0 km D/S Celgar[3]
Monochlorophenols	<1.0	<1.0	<1.0
Dichlorophenols	<1.0	<1.0	<1.0
Trichlorophenols	<1.0	<1.0	<1.0
Tetrachlorophenols	<1.0	<1.0	<1.0
Pentachlorophenol	<1.0	<1.0	<1.0
Monochloroguaiacols	<1.0	<1.0	<1.0
Dichloroguaiacols	<1.0	<1.0	<1.0
Trichloroguaiacols	<1.0	<1.0	<1.0
Tetrachloroguaiacol	<1.0	5.6	6.0
Monochlorocatechols	<1.0	<1.0	<1.0
Dichlorocatechols	<1.0	<1.0	<1.0
Trichlorocatechols	<1.0	<1.0	<1.0
Tetrachlorocatechol	<1.0	<1.0	<1.0
Dichloroveratrols	<1.0	<1.0	<1.0
Trichloroveratrols	<1.0	<1.0	<1.0
Tetrachloroveratrol	<1.0	<1.0	<1.0
Monochlorovanillins	<1.0	<1.0	<1.0
Dichlorovanillins	<1.0	<1.0	<1.0
Trichlorosyringol	<1.0	<1.0	<1.0
EOX ug/L (ppb)	21.5	14.6	15.5

-all mussels were Anodonta kennerlyi (Western floater). Analyses done on a wet weight basis.

1. a composite of 12 animals (length 6.4-9.0 cm; weight 12.8-35.3 g).
2. a composite of 6 animals (length 7.1-10.2 cm; weight 17.7-42.5 g).
3. a composite of 6 animals (length 6.8- 8.4 cm; weight 15.2- 23.1 g).

TABLE 42

LEVELS OF DIOXINS AND FURANS IN COLUMBIA RIVER FRESHWATER MUSSELS, SAMPLED NOVEMBER 22, 1990.

SAMPLING SITES			
CHARACTERISTICS pg/g (ppt)	1.4 km Upstream Celgar[1]	300 m Downstream Celgar[2]	1.0 km Downstream Celgar[3]
2,3,7,8 TCDD	1.9	3.3	3.9
Total TCDD	1.9	3.3	3.9
1,2,3,7,8 PCDD	<3.0	<2.9	<2.1
Total PCDD	<3.0	<2.9	<2.1
1,2,3,4,7,8 H6CDD	<2.0	<2.7	<2.5
1,2,3,6,7,8 H6CDD	<2.0	<2.7	<2.5
1,2,3,7,8,9 H6CDD	<2.0	<2.7	<2.5
Total H6CDD	<2.0	<2.7	<2.5
1,2,3,4,6,7,8 H7CDD	<2.6	<1.7	<1.6
Total H7CDD	<2.6	<1.7	<1.6
Total OCDD	<3.4	<2.1	<2.1
2,3,7,8 TCDF	9.0	290.0	280.0
Total TCDF	11.0	370.0	400.0
1,2,3,7,8 PCDF	<1.5	2.4	2.0
2,3,4,7,8 PCDF	<1.5	3.5	3.3
Total PCDF	<1.5	5.9	5.3
1,2,3,4,7,8 H6CDF	<1.7	<2.3	<2.4
1,2,3,6,7,8 H6CDF	<1.7	<2.3	<2.4
2,3,4,6,7,8 H6CDF	<1.7	<2.3	<2.4
1,2,3,7,8,9 H6CDF	<1.7	<2.3	<2.4
Total H6CDF	<1.7	<2.3	<2.4
1,2,3,4,6,7,8 H7CDF	<3.1	<2.0	<1.9
1,2,3,4,7,8,9 H7CDF	<3.1	<2.0	<1.9
Total H7CDF	<3.1	<2.0	<1.9
Total OCDF	<2.6	<1.7	<1.7
Surrogate Recovery (%)			
TCDF	98	108	95
TCDD	82	83	73
PCDD	83	62	79
H6CDD	77	78	90
H7CDD	72	78	78
OCDD	62	72	66
% Moisture	92	95	91
% Lipid	0.5	0.6	1.0

- all mussels were Anodonta kennerlyi (Western floater).

1. a composite of 12 animals (length 6.4 - 9.0 cm; weight 12.8 - 35.3 g).
2. a composite of 6 animals (length 7.1 - 10.2 cm; weight 17.7 - 42.5 g).
3. a composite of 6 animals (length 6.8 - 8.4 cm; weight 15.2 - 23.1 g).

TABLE 43

DIOXIN AND FURAN RESIDUES IN MARINE MUSSELS (*Mytilus adulis*) IN THE VICINITY OF COASTAL B.C. PULP MILLS

LOCATION	TOTALS pg/g (ppt) (wet weight)									
	TCDF	PCDF	H_6CDF	H_7CDF	OCDF	TCDD	PCDD	H_6CDD	H_7CDD	OCDD
Crescent Beach (Control Site)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Howe Sound (Woodfibre)	130	ND	ND	ND	ND	ND	ND	96	ND	ND
Howe Sound (Port Mellon)	48	ND	ND	ND	ND	ND	ND	8	ND	ND
Prince Rupert (Skeena)	240	ND	ND	ND	ND	7.5	ND	290	ND	ND
Gold River (CIP)	341	ND	ND	ND	ND	ND	ND	19	ND	ND
Crofton (BCFP)	82	ND	ND	ND	ND	5	12-14	109-125	9-18	3-15

- ND = Non-detectable
- From Department of Fisheries and Oceans, News Releases May 16, 1988 and June 14, 1989.

TABLE 44

CHARACTERISTICS OF FISH SAMPLED FROM THE COLUMBIA RIVER FOR DIOXIN AND FURAN ANALYSIS

SITE LOCATION	SAMPLING DATE	FISH SPECIES	NO. OF FISH IN COMPOSITE	MEDIAN FORK LENGTH (Range) mm	MEDIAN WEIGHT (Range) g	MEDIAN AGE (Range) years
Upstream from Celgar	16/08/88 17/08/88	Catostomus macrocheilus (largescale sucker)	7	314.0 (281-347)	360.8 (224.7-496.9)	10 (9-13)
	16/08/88 17/08/88 18/08/88	Coregonus clupeaformis (lake whitefish)	7	391.0 (274-508)	1183.2 (228.5-2137.8)	6 (5-8)
	16/08/88 17/08/88	Ptychocheilus oregonensis (northern squawfish)	7	510.0 (484-536)	1999.5 (1660.4-2338.6)	16 (11-24)
Downstream from Celgar	16/08/88 17/08/88 18/08/88 19/08/88	Catostomus macrocheilus (largescale sucker)	7	461.5 (440-483)	1215.3 (1115.8-1314.7)	20 (9-25)
	16/08/88	Coregonus clupeaformis (lake whitefish)	7	469.5 (460-479)	1313.4 (1161.5-1465.3)	6 (5-9)
		Coregonus clupeaformis (lake whitefish)	7	447.5 (440-455)	1198.1 (1057.1-1339.0)	4 (3-7)

- Modified from Mah et al. (1989).

TABLE 45

DIOXIN AND FURAN RESIDUES FOUND IN MUSCLE TISSUE OF FISH COLLECTED BY ENVIRONMENT CANADA, AUG. 16-19, 1989, UPSTREAM AND DOWNSTREAM FROM THE CELGAR PULP MILL.

SITE LOCATION	FISH SPECIES	LIPID CONTENT (% WET WT.)	MOISTURE CONTENT (%)	DIOXIN CONCENTRATION pg/g (ppt)						FURAN CONCENTRATION pg/g (ppt)						
				2,3,7,8 T4CDD	TOTAL T4CDD	TOTAL P5CDD	TOTAL H6CDD	TOTAL H7CDD	TOTAL O8CDD	2,3,7,8 T4CDF	TOTAL T4CDF	TOTAL P5CDF	TOTAL H6CDF	TOTAL H7CDF	TOTAL O8CDF	TCDD TOXIC EQUIVALENTS pg/g
Upstream from Celgar	_Catostomus macrocheilus_ (Largescale Sucker)	0.6	81.5	L2	L2	L3	L5	L10	L15	2.0	2.0	L3	L5	L10	L15	0.2-6.4
	Coregonus clupeaformis (Lake Whitefish)	4.4	74.6	L2	L2	L3	L5	L10	L15	45.4	45.4	L3	L5	L10	L15	4.5-10.8
	Ptychocheilus oregonensis (Northern Squawfish)	9.2	73.1	L2	L2	L3	L5	L10	L15	5.9	5.9	L3	L5	L10	L15	0.6-6.8
Downstream from Celgar	_Catostomus macrocheilus_ (Largescale Sucker)	2.0	78.5	L2	L2	L3	L5	L10	L15	25.8	25.8	L3	L5	L10	L15	2.6-8.8
	Coregonus clupeaformis (a) (Lake Whitefish)	8.9	72.7	10.5	10.5	L3	L5	L10	L15	908	908	13.4	L5	L10	L15	108-111
	Coregonus clupeaformis (b) (Lake Whitefish)	10.5	72.4	6.6	6.6	L3	L5	L10	L15	647	647	L3	L5	L10	L15	71-76

- pg/g equals ppt or parts per trillion (10^{-12}) (on a wet weight basis).
- Modified from Mal et al. (1989)
- TCDD toxic equivalents (TEQ's) are calculated using the International (NATO) Toxicity Equivalency Factors (TEF's). TEQ's are given as a range to express the uncertainty of the measurements. The minimum value assumes that non-detection equals zero; the maximum assumes that non-detection equals the detection limit.

TABLE 46

DIOXIN AND FURAN RESIDUES IN COLUMBIA RIVER FISH COLLECTED BY B.C. MINISTRY OF ENVIRONMENT, 1989

SAMPLING LOCATION & DATE	FISH SAMPLE				DIOXIN & FURAN CONCENTRATIONS pg/g (ppt)												TOTAL TOXIC EQUIVALENTS OF 2,3,7,8 TCDD pg/g (ppt)
	Species	Sex	Length cm	Weight g	2,3,7,8 TCDD	TCDD	PCDD	H_6CDD	H_7CDD	OCDD	2,3,7,8 TCDF	TCDF	PCDF	H_6CDF	H_7CDF	OCDF	
Lower Arrow Reservoir near Keenleyside Dam, Dec. 5/89	MW	M	-	-	<5	<5	<6	<6	<14	<38	<3	<3	<3	<4	<17	<37	0-11
Robson; site 0200604 Nov. 22/89	RT	M	36.5	425	<3	<3	<4	<4	<8	<20	37	37	<2	<3	<9	<15	3.7-10.6
	RT	F	42.2	750	<2	<2	<4	<3	<8	<19	40	40	<2	<3	<9	<15	4.0-9.8
	RT	F	40.1	645	<2	<2	<3	<3	<6	<16	<1	<1	<2	<2	<7	<12	0-5.3
	RT	M	28.8	150	<2	<2	<3	<3	<8	<20	4	4	<2	<2	<9	<15	0.4-5.6
	RT	M	39	570	<1	<1	<3	<2	<6	17	8	8	<1	<2	<8	<12	0.82-4.3
	YW	M	38.4	510	<2	<2	<4	<4	<8	<24	10	10	<2	<3	<11	<23	1.0-6.9
	YW	M	41.6	605	<2	<2	<3	<2	<4	<11	13	13	<2	<2	<5	<10	1.3-6.3
	YW	M	37	430	<2	<2	<3	<2	<4	<12	13	13	<2	<2	<5	<11	1.3-5.3
	YW	M	38	510	<2	<2	<4	<3	<8	<19	31	31	<2	<3	<9	<15	3.1-8.9
	YW	M	35.3	430	<2	<2	<4	<5	<16	<39	16	16	<2	<4	<18	<30	1.6-7.9
	YW	M	33.6	365	<3	<3	<5	<4	<9	<23	26	26	<3	<3	<10	<18	2.6-10.5
	MW	M	31	385	<3	<3	<5	<4	<8	<20	170	170	<3	<13	<10	<16	17.0-25.9
	MW	M	31.9	320	<3	<3	<6	<7	<20	<49	125	125	<3	<6	<23	<38	12.5-21.8
	MW	M	30	285	<2	<2	<4	<3	<8	<19	90	90	<2	<3	<9	<15	9.0-14.8
	MW	F	30.2	260	<2	<2	<3	<4	<10	<26	10	10	<2	<3	<12	<20	1.0-7.0
	MW	M	*	*	<4	<4	<6	<5	<13	<32	170	170	<3	<5	<15	<25	17.0-26.8
	RT	M	36.7	470	<3	<3	<6	94	111	121	34	34	<3	<4	<13	<22	14.0-22.1
	RT	M	43.9	830	<3	<3	<4	<4	<10	<28	16	19	<2	<3	<12	<26	1.9-8.9
Castlegar Ferry, Aug. 24/89	YW	-	36.4	450	-	<8	<8	<17	<17	<25	-	<8	<8	<17	<17	<25	0-20.6
	YW	-	53.4	625	-	<84	<84	<17	<17	<25	-	<8	<8	<17	<17	<25	0-104

TCDD – Toxic Equivalents are given as a range, thus expressing the uncertainty of the measurement. The minimum value assumes that non-detection equals zero; the maximum assumes that non-detection equals the detection limit.
MW – Mountain Whitefish
RT – Rainbow Trout
YW – Yellow Walleye
* – Composite sample of 2 fish (24.5 cm, 185 g; and 25.7 cm, 190 g). See Table 28 for Toxic Equivalence factors.

TABLE 47

DIOXIN AND FURAN RESIDUES IN COLUMBIA RIVER FISH COLLECTED FROM ROOSEVELT RESERVOIR BY WASHINGTON STATE DEPARTMENT OF ECOLOGY, JUNE-JULY, 1989.

SPECIES	White Sturgeon[1]			Yellow Walleye[2]	
LOCATION	Marcus Island			Off Colville River	
DATE	July 3/89	(Duplicate Sample)	June 11/89	July 18/89	July 18/89
LENGTH (cm)	147		163	53.5	45.8
AGE (yrs.)	12-13		12-13		
pg/g (ppt)					
2,3,7,8-TCDD	2.2	2.6	<0.1	0.21	4.0
1,2,3,7,8-PCDD	<0.05	<0.1	<0.1	0.56	<0.2
1,2,3,4,7,8-H_6CDD	<0.03	<0.05	<0.1	<0.08	<0.1
1,2,3,6,7,8-H_6CDD	0.16	0.18	<0.08	<0.07	0.4
1,2,3,7,8,9-H_6CDD	<0.04	<0.06	<0.1	<0.1	<0.1
1,2,3,4,6,7,8-H_7CDD	<0.05	0.44	<0.2	0.61	0.62
OCDD	2.7	17.0	<0.8	8.5	5.7
Total Dioxins	5.1	20	ND	9.9	11
2,3,7,8-TCDF	221	321	3.9	8.9	326
1,2,3,7,8-PCDF	0.72	0.96	<0.08	<0.07	.09
2,3,4,7,8-PCDF	1.3	1.9	<0.09	<0.08	2.4
1,2,3,4,7,8-H_6CDF	<0.02	<0.03	<0.05	<0.05	<0.07
1,2,3,6,7,8-H_6CDF	<0.02	<0.03	<0.05	<0.04	<0.06
2,3,4,6,7,8-H_6CDF	<0.02	<0.04	<0.07	5.0	<0.09
1,2,3,7,8,9-H_6CDF	<0.03	<0.05	<0.10	<0.09	<0.1
1,2,3,4,6,7,8-H_7CDF	<0.03	0.08	<0.09	0.09	<0.08
1,2,3,4,7,8,9-H_7CDF	<0.04	<0.04	2.9	3.7	<0.2
OCDF	<0.07	0.93	<0.6	0.46	<0.3
Total Furans	223	325	6.8	18	329
Total TEQ's	25	36	0.4	1.9	38

ND - Not Detected
TEQ - Toxic Equivalents

1 - Sampled 35 km downstream from U.S./Canada border
2 - Sampled 60 km downstream from U.S./Canada border

From Johnson (1990)

TABLE 48

Dioxin and furan concentrations in Roosevelt Reservoir sportfish collected May-October 1990 (parts per trillion=pg/g, wet weight basis) (from Johnson et.al., 1991)

	Upper Lake Roosevelt					Lower Lake Roosevelt				
Species	Sample Number	Lipid (%)	2,3,7,8-TCDD	2,3,7,8-TCDF	TEQ	Sample Number	Lipid (%)	2,3,7,8-TCDD	2,3,7,8-TCDF	TEQ
Burbot*	448081	0.4	ND(0.1)	2.7	0.3	--	--	--	--	--
	448080	0.4	ND(0.1)	2.9	0.3	--	--	--	--	--
	mean±1SD=	0.4±0	ND	2.8±0.1	0.3±0		No Samples			
Walleye	328084	0.2	ND(0.2)	0.9	0.2	448084	0.3	ND(0.1)	1.1	0.2
	328083	0.2	ND(0.2)	2.1	0.3	448086	0.6	ND(0.2)	1.1	0.2
	188236	0.1	ND(0.2)	2.8	0.4	448085	0.4	ND(0.1)	1.8	0.2
	328085	0.2	ND(0.1)	0.9	0.6	188242	0.1	0.2 EMPC	1.2	0.3
	188235	0.2	0.3	5.1	0.8	188241	0.3	0.2 EMPC	2.2	0.4
	188234	0.4	ND(0.6)	6.0	0.9	188240	0.2	0.3 EMPC	4.9	0.8
	mean±1SD=	0.2±0.1	ND	3.0±2.1	0.5±0.3	mean±1SD=	0.3±0.2	ND	2.0±1.5	0.4±0.2
Rainbow Trout	428105	2.1	0.8	24.2	3.2	328082	1.4	ND(0.1)	3.7	0.4
	328087	3.5	1.5 EMPC	21.9	3.7	188230	2.3	ND(0.2)	6.2	0.7
	428108	4.0	1.3	37.1	5.0	328081	2.8	ND(0.2)	8.0	0.9
	428107	3.7	1.6	44.3	6.0	328080	2.1	ND(1.2)	7.9	1.4
	328086	2.2	0.9	53.2	6.2	188232	2.3	1.1	9.7	2.1
	428106	4.4	1.3	50.3	6.3	188231	3.3	0.7 EMPC	35.6	4.3
	mean±1SD=	3.3±1.0	1.2±0.3	38±13	5.1±1.3	mean±1SD=	2.4±0.6	ND	12±12	1.6±1.4

TABLE 48 (continued)

Species	Upper Lake Roosevelt Sample Number	Lipid (%)	2,3,7,8-TCDD	2,3,7,8-TCDF	TEQ	Lower Lake Roosevelt Sample Number	Lipid (%)	2,3,7,8-TCDD	2,3,7,8-TCDF	TEQ
Kokanee	--	--	--	--	--	448082	16.4	0.7	42.1	4.9
	--	--	--	--	--	188233	4.6	0.9	63.3	7.2
		No Samples				mean±1SD=	10.5±8.3	0.8±0.1	53±15	6.0±1.6
Lake Whitefish	428111	7.6	1.2	77.6	9.0	188239	3.6	0.5	41.6	4.7
	428110	7.7	1.9	118	14	448087	8.0	1.2	122	13
	188245	7.1	1.9	120	14	188238	4.2	1.5	133	15
	188244	1.4	1.9	131	15	188237	1.3	2.3	174	20
	428109	8.5	2.0	157	18	448089	12.1	1.9	196	22
	188243	3.4	2.3	154	18	448088	10.4	2.7	205	23
	mean±1SD=	6.0±2.9	1.9±0.4	126±29	15±3.3	mean±1SD=	6.6±4.2	1.7±0.8	145±61	16±6.9
White Sturgeon	328088	6.0	0.8	72.5	8.0	--	--	--	--	--
	328090	7.8	1.7	117	13	--	--	--	--	--
	448083	10.5	4.4	176	22	--	--	--	--	--
	328089	11.5	2.6	222	25	--	--	--	--	--
	mean±1SD=	9.0±2.5	2.4±1.5	147±66	17±7.9		No Samples			

* four fish composites
ND = not detected; detection limit in parenthesis
SD = standard deviation
EMPC = estimated maximumpossible concentration
Note: 1/2 detection limit used to calculate means and TEQs for non-detected values

TABLE 49

Analysis of selected Roosevelt Reservoir fish samples for 2,3,7,8-substituted PCDD's and PCDF's (parts per trillion= pg/g, wet weight basis) (from Johnson et.al., 1991)

Species:	Lake Whitefish		White Sturgeon	
Location:	Upper Lake	Lower Lake	Upper Lake	
Sample Number:	188243	188237	328089	328090
PCDDs:				
2,3,7,8-TCDD	1.4	1.2	1.9	1.1
1,2,3,7,8-PeCDD	0.1	ND(0.4)	ND(0.2)	ND(0.5)
1,2,3,4,7,8-HxCDD	ND(0.2)	ND(0.4)	ND(0.2)	ND(0.6)
1,2,3,6,7,8-HxCDD	0.2	ND(0.4)	0.2	ND(0.6)
1,2,3,7,8,9-HxCDD	ND(0.2)	ND(0.5)	ND(0.3)	ND(0.7)
1,2,3,4,6,7,8-HpCDD	0.3	ND(0.7)	1.5	ND(1.6)
OCDD	3.7	3.5	40.9	3.5
PCDFs:				
2,3,7,8-TCDF	155	150	261	136
1,2,3,7,8-PeCDF	0.4	ND(0.4)	0.9	0.5
2,3,4,7,8-PeCDF	1.1	0.9	1.3	0.5
1,2,3,4,7,8-HxCDF	ND(0.1)	ND(0.3)	ND(0.2)	ND(0.5)
1,2,3,6,7,8-HxCDF	ND(0.1)	ND(0.3)	ND(0.2)	ND(0.4)
2,3,4,6,7,8-HxCDF	0.4 EMPC	ND(0.4)	ND(0.2)	ND(0.6)
1,2,3,7,8,9-HxCDF	ND(0.2)	ND(0.5)	ND(0.3)	ND(0.8)
1,2,3,4,6,7,8-HpCDF	ND(0.2)	ND(0.2)	0.2 EMPC	ND(0.6)
1,2,3,4,7,8,9-HpCDF	ND(0.4)	ND(0.4)	ND(0.4)	ND(0.9)
OCDF	ND(0.5)	ND(1.3)	1.4 EMPC	ND(4.4)
TEQ =	17.7	16.9	28.3	15.5
% TEQ Contribution:				
2,3,7,8-TCDF	87.5%	88.8%	92.2%	87.7%
2,3,7,8-TCDD	7.9%	7.1%	6.7%	7.1%
other congeners	4.6%	4.1%	1.1%	5.2%

ND = not detected; detection limit shown in parenthesis

EMPC = estimated maximum possible concentration

[1]Note: 1/2 detection limit used to calculate TEQ for non-detected values

TABLE 50

RECOMMENDED RECEIVING WATER MONITORING, KEENLEYSIDE DAM TO BIRCHBANK

SITE LOCATION	SITE NUMBER	SAMPLING FREQUENCY	DATE	No.	CHARACTERISTICS
Upstream from Celgar 100 m Downstream from Celgar At Castlegar	0200183 New Site 0200200	5 weekly samples in 30 days	April	15	Temperature, D.O., pH, suspended solids, turbidity, colour, sodium, total dissolved gases, fecal coliforms, E. coli, Enterococci, foam/floatables/odor observations
		Once	April	3	Resin acids, chlorinated resin acids, chloroguaiacols & chlorophenols, AOX dioxins/furans (latter in sediment and water)
Birchbank	0200003	5 weekly samples in 30 days	April	5	D.O., total dissolved gases, E. coli, Enterococci, foam/floatables/odor observations

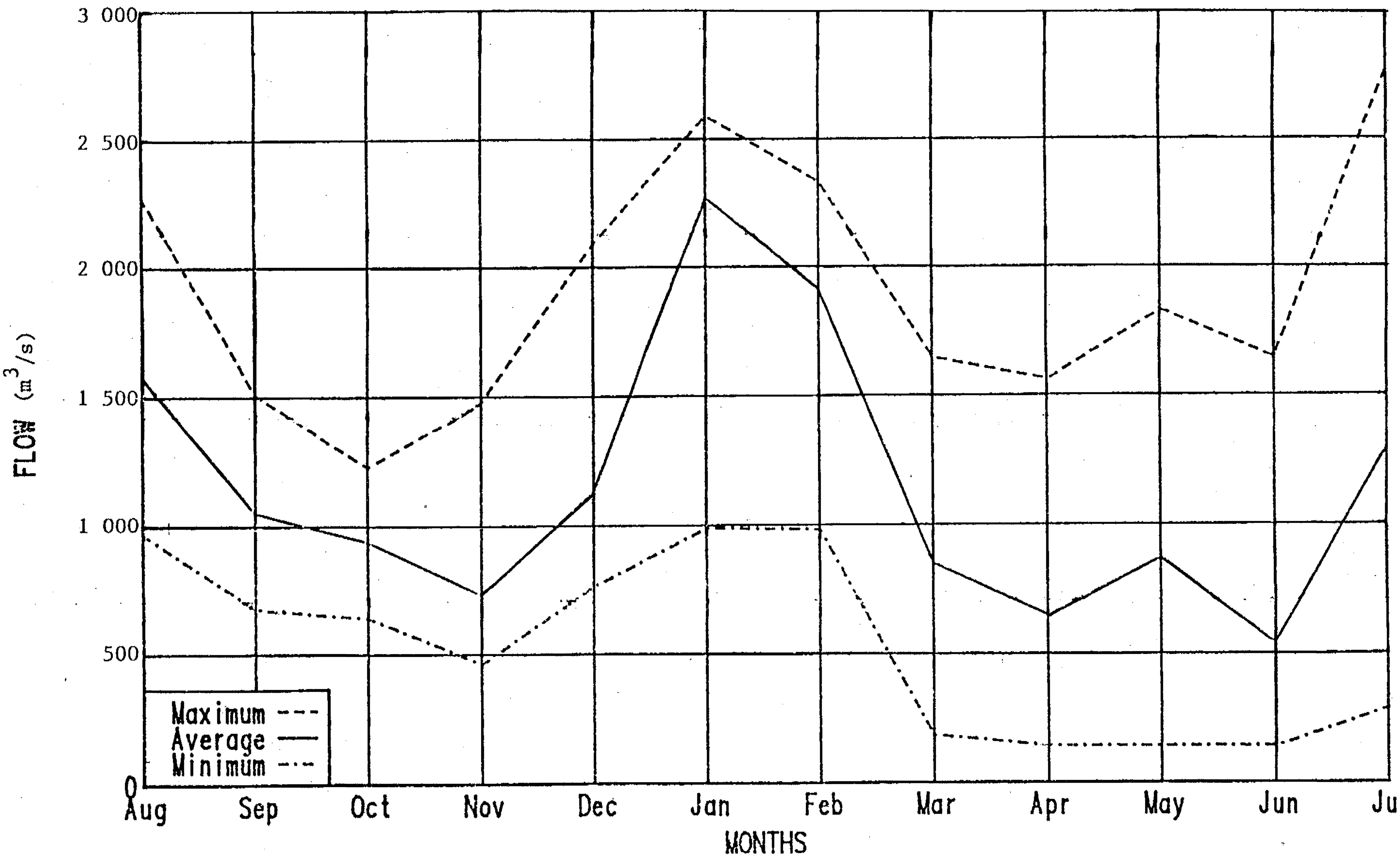


Figure 2 Hydrograph for Columbia River at Keenleyside Dam as predicted by the Assured Operating Plan (1993).

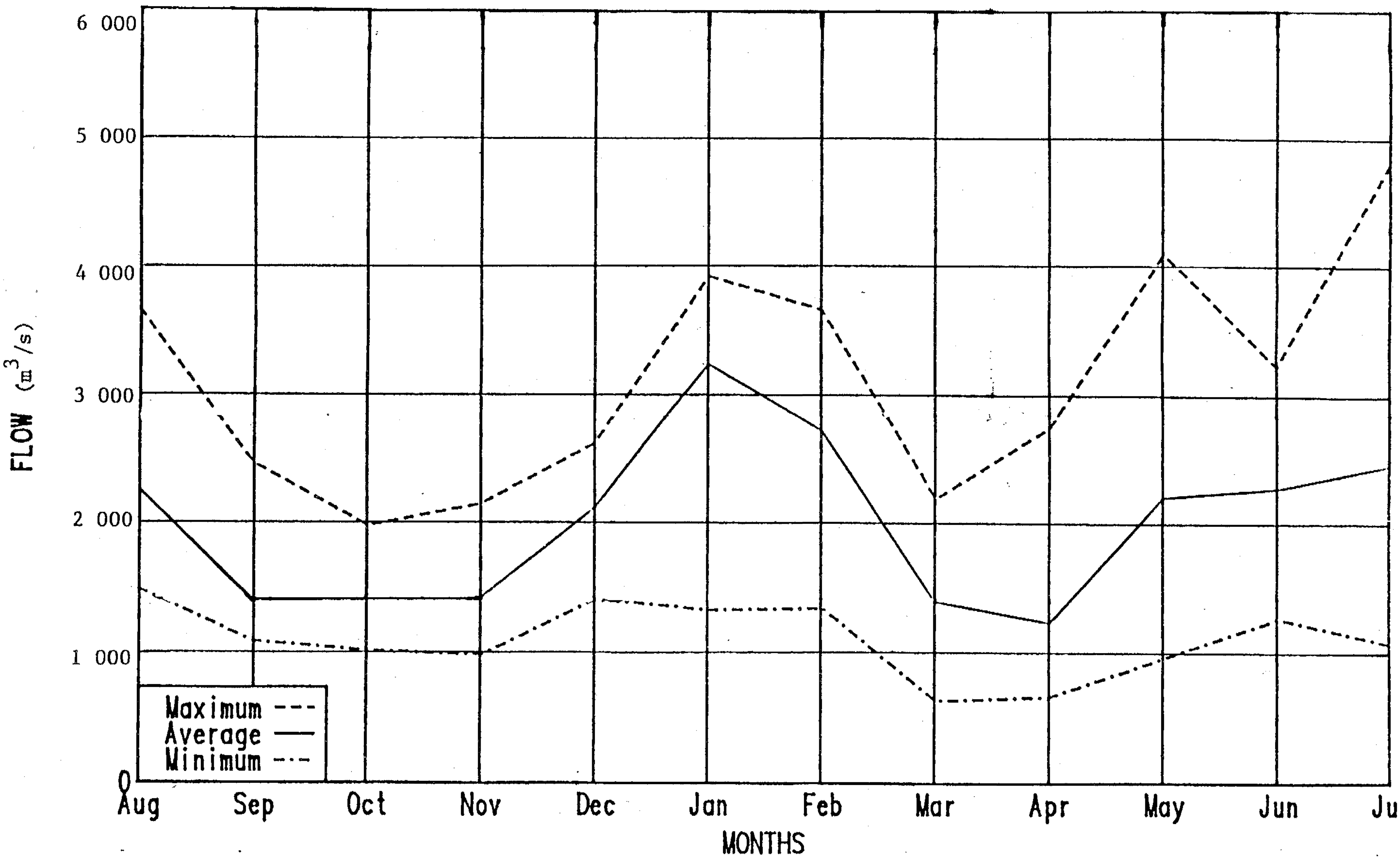


Figure 3 Hydrograph for Columbia River at Birchbank as predicted by the Assured Operating Plan (1993).

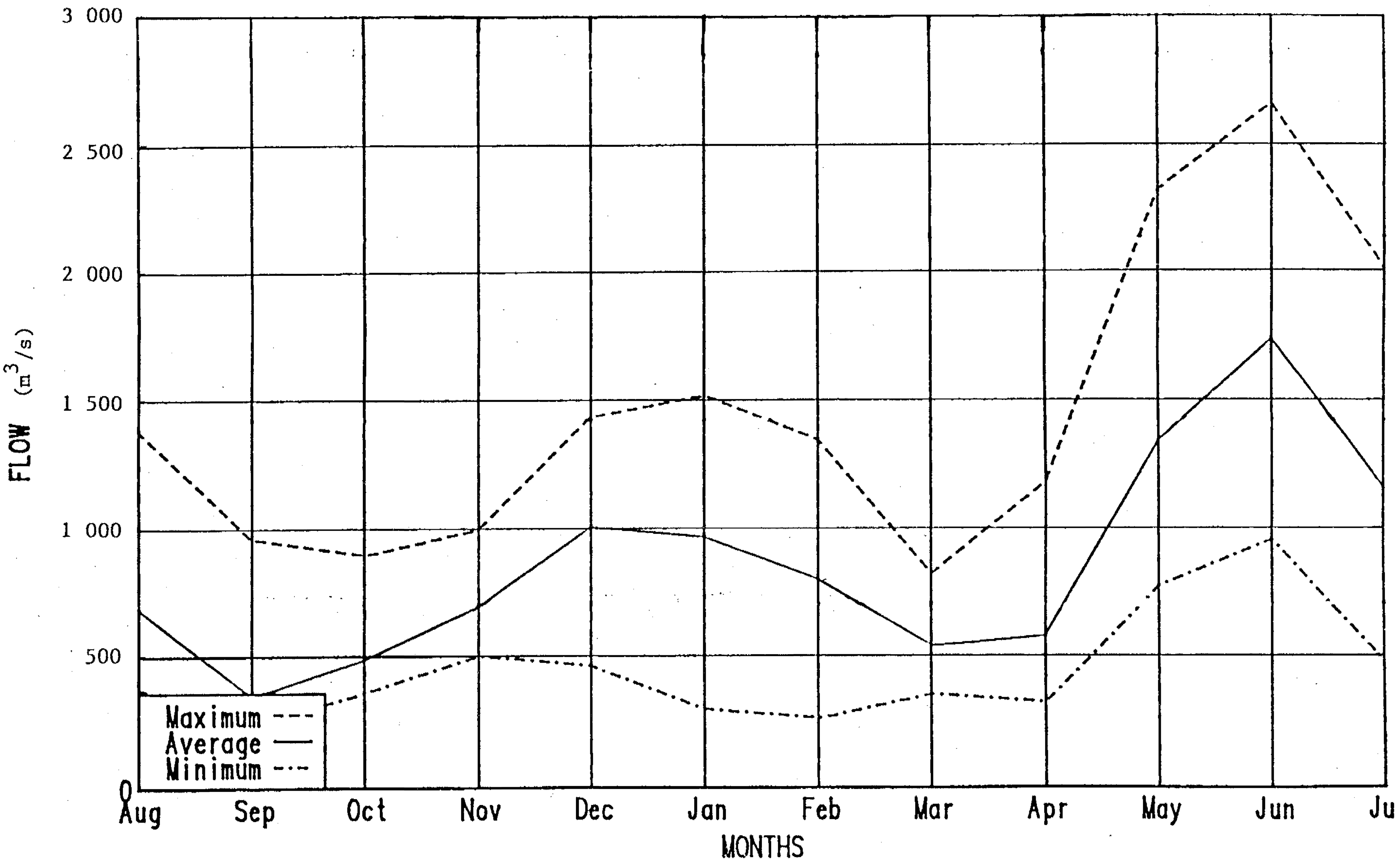


Figure 4 Hydrograph for Kootenay River at Brilliant Dam as predicted by the Assured Operating Plan (1993).

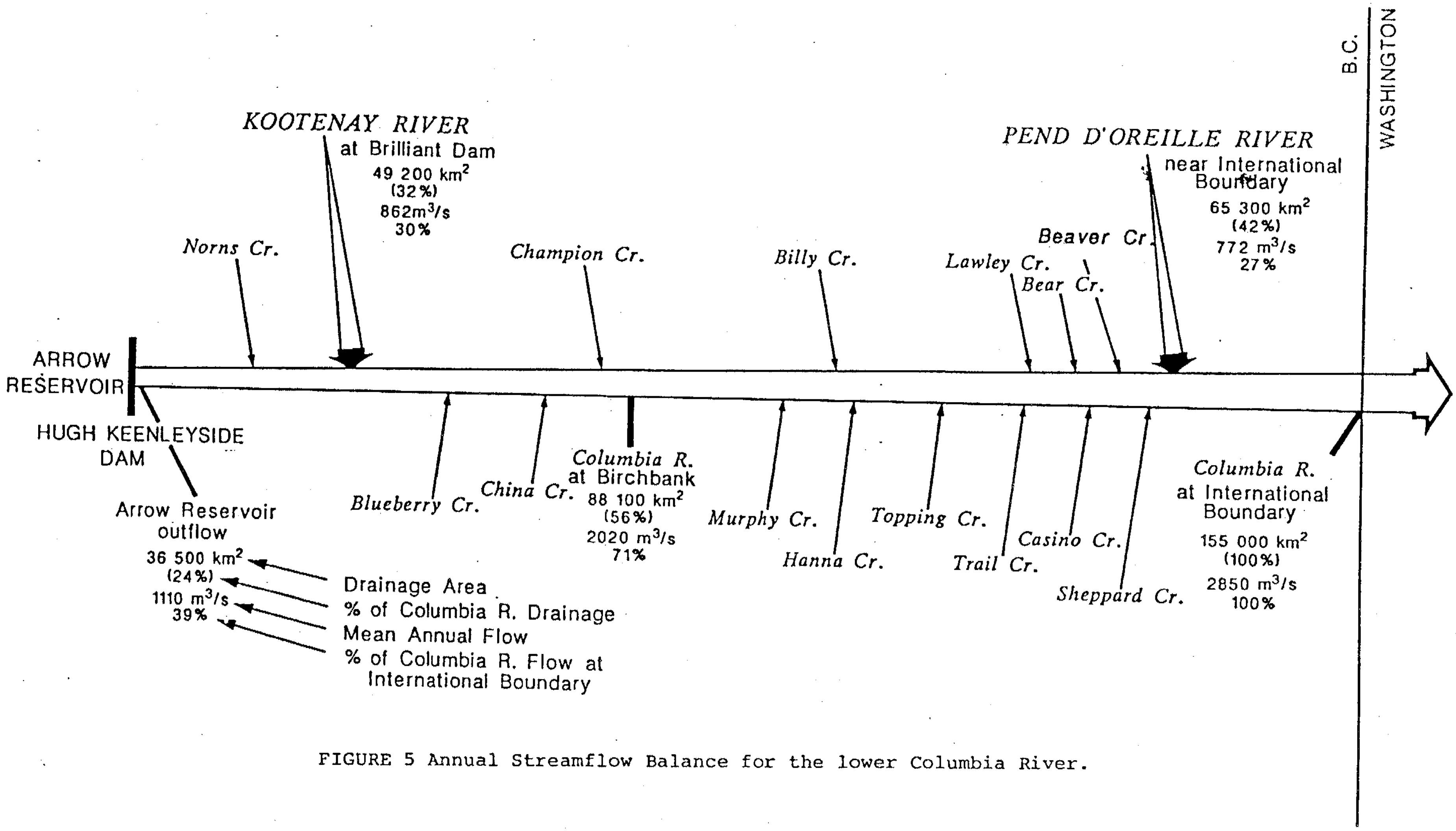
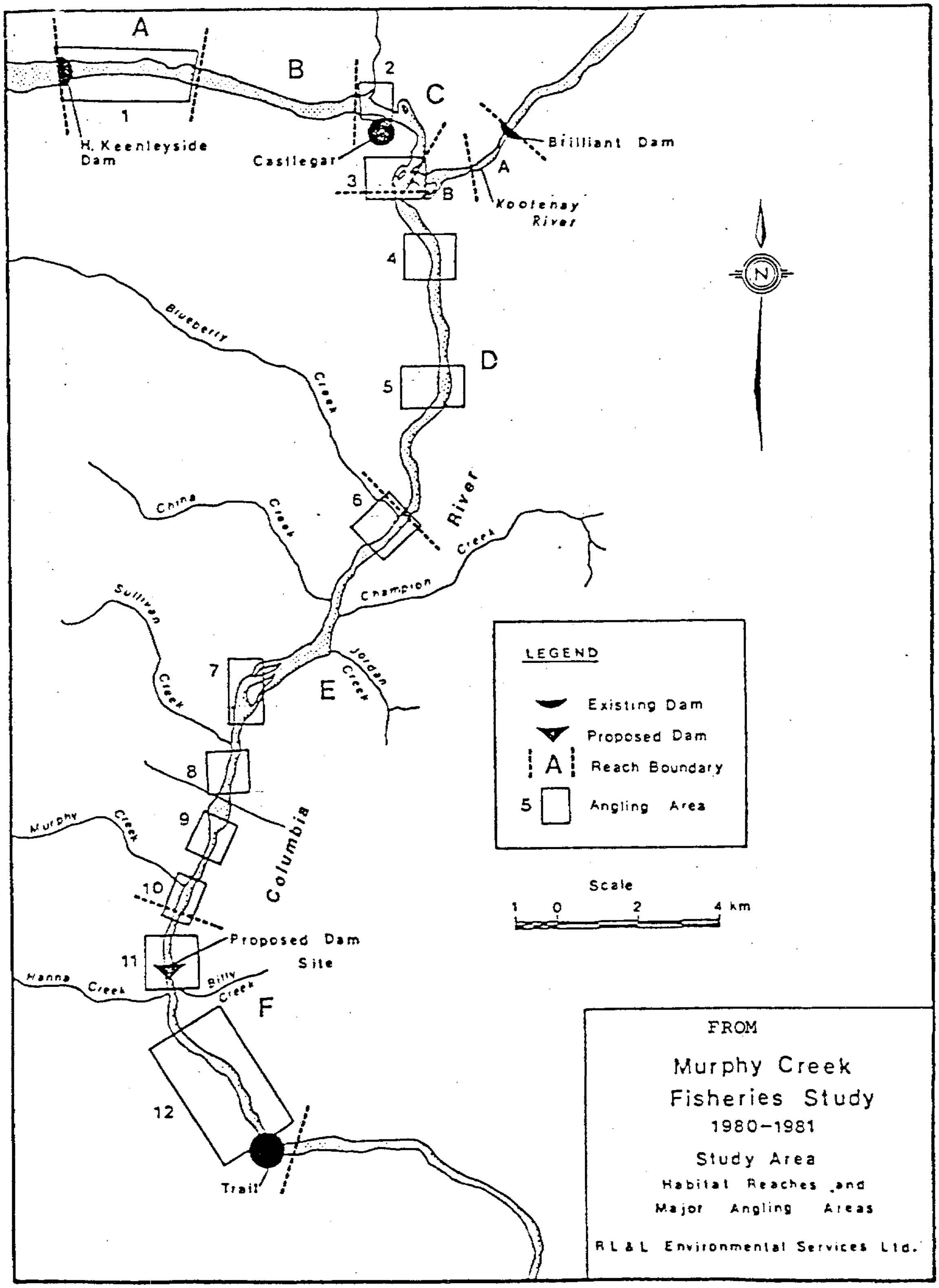


FIGURE 5 Annual Streamflow Balance for the lower Columbia River.

FIGURE 6
Major angling areas in the lower Columbia River



FROM
Murphy Creek Fisheries Study 1980–1981
Study Area
Habitat Reaches and Major Angling Areas
RL&L Environmental Services Ltd.

Figure 7
Distribution of fibre mat and log debris on the bottom of Columbia River associated with the Celgar pulp mill

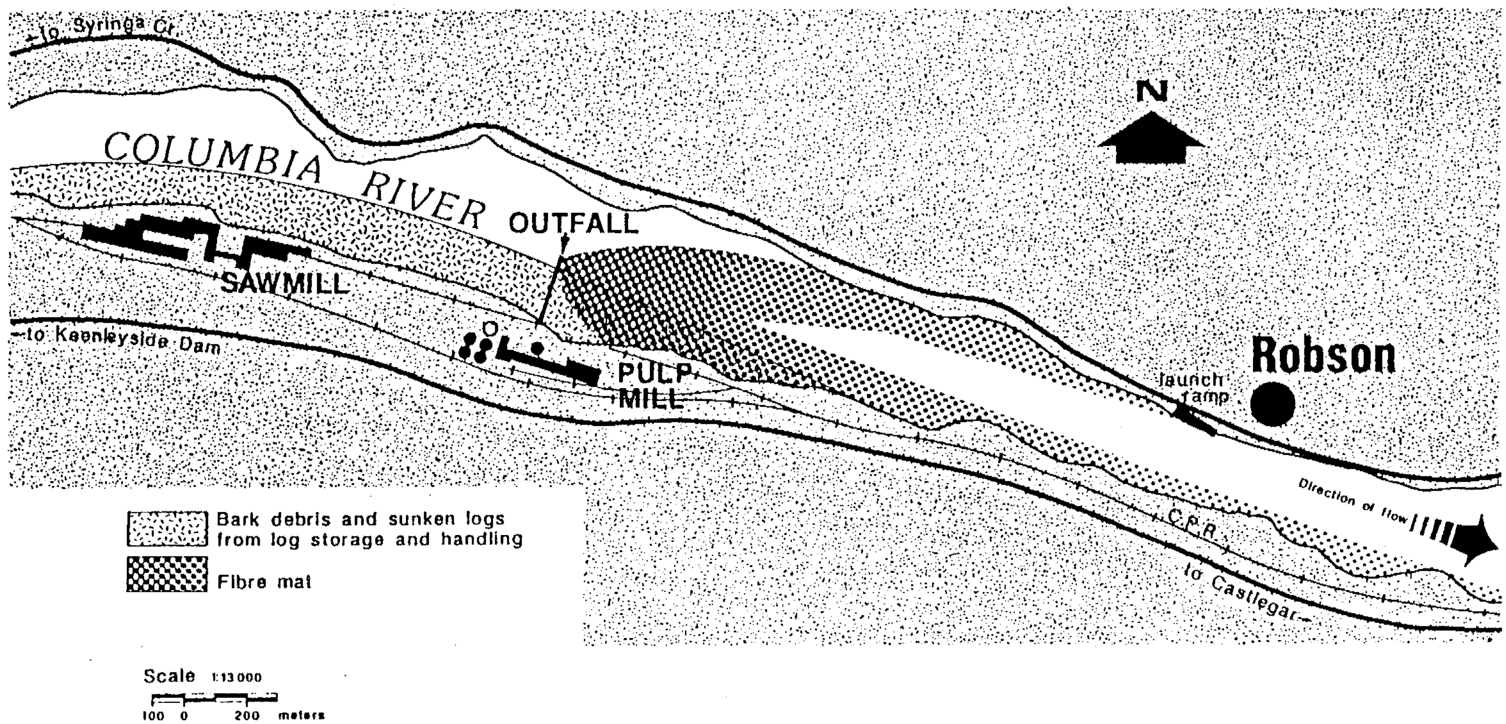


Figure 8
Celgar pulp mill; simplified flow diagram of the pulping and brown stock washing processes

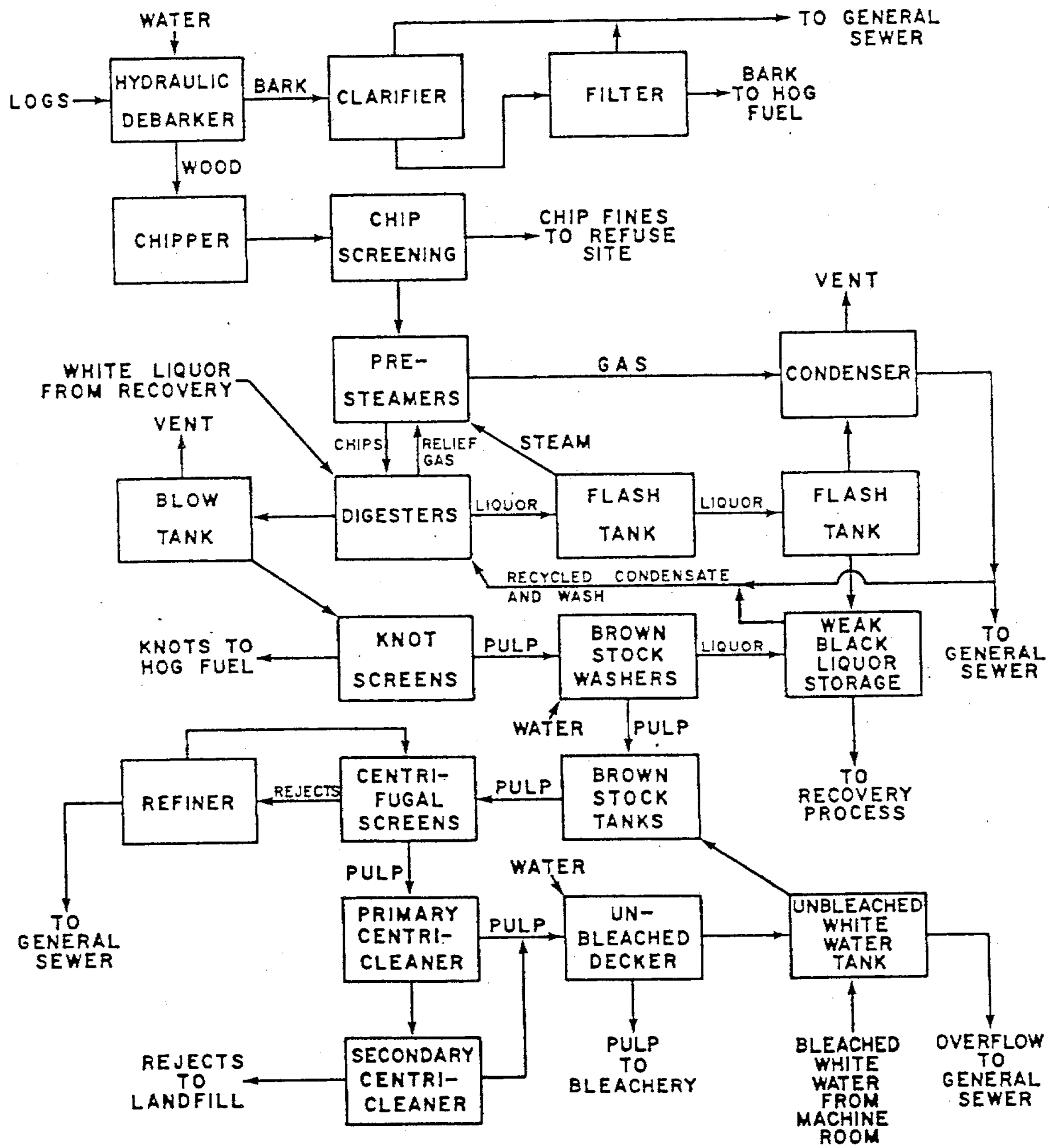


Figure 9
Celgar pulp mill; simplified flow diagram of the recovery process

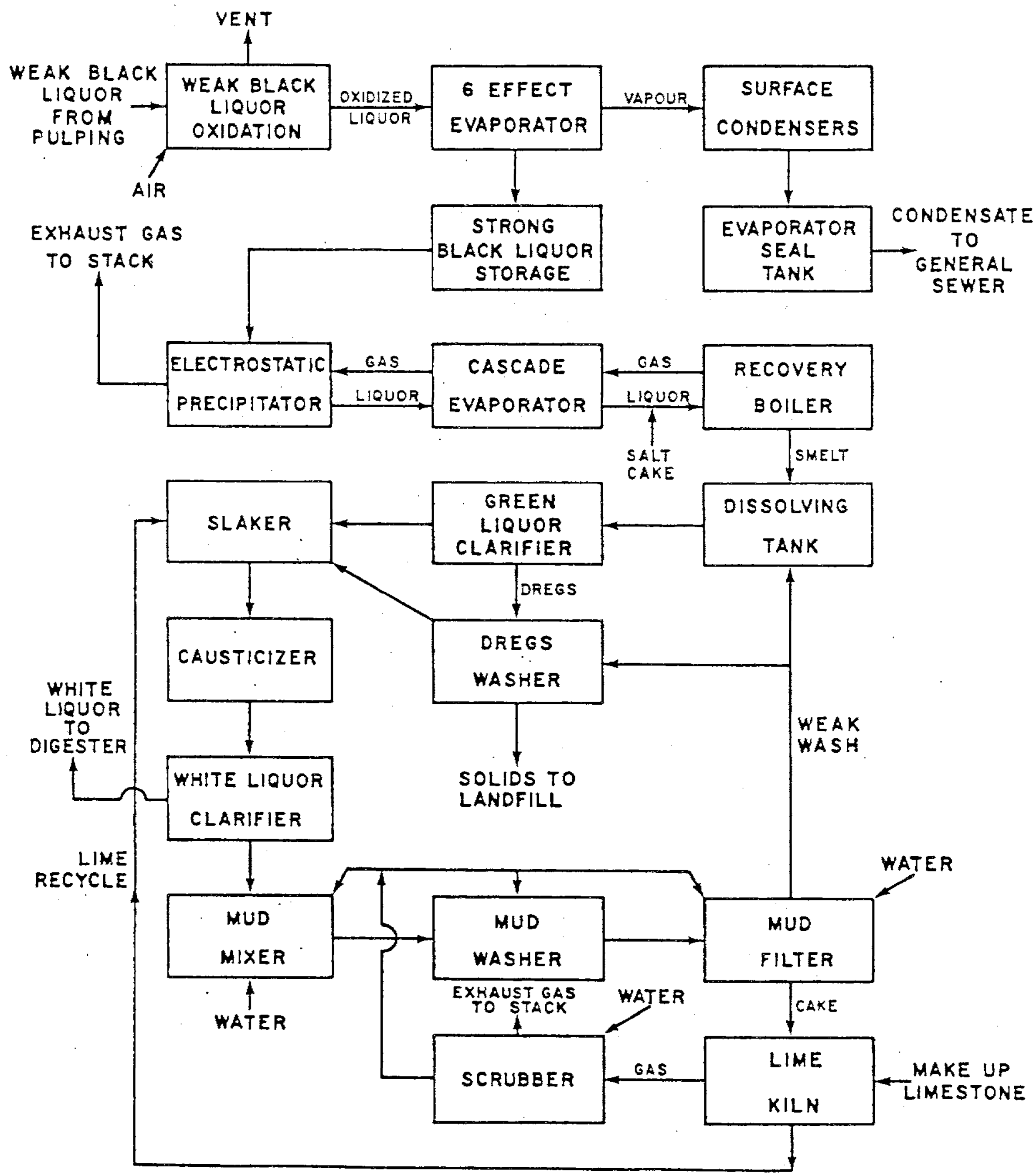


FIGURE 10
Celgar pulp mill; simplified flow diagram of the bleaching, sheet formation and effluent disposal processes.

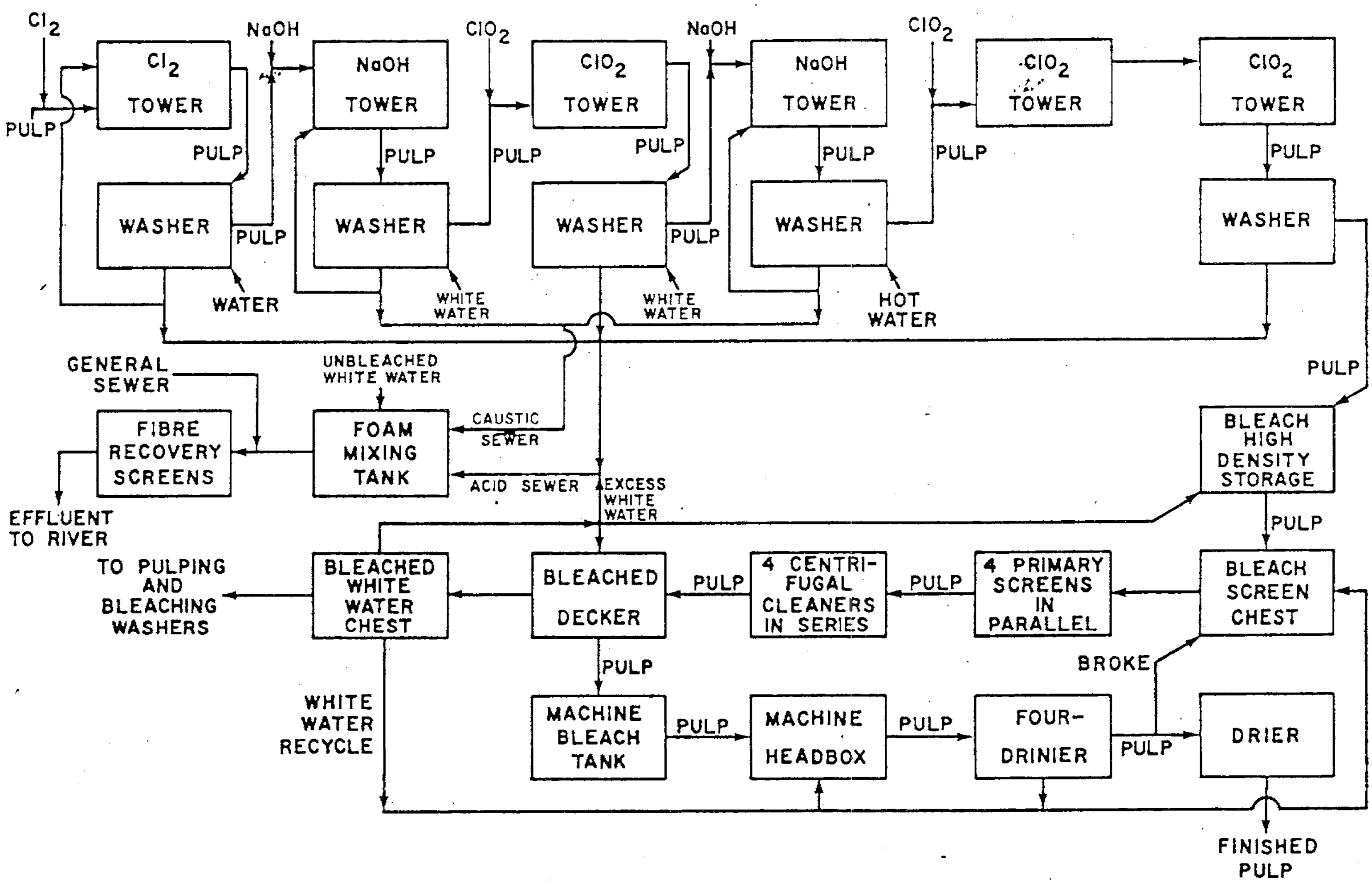
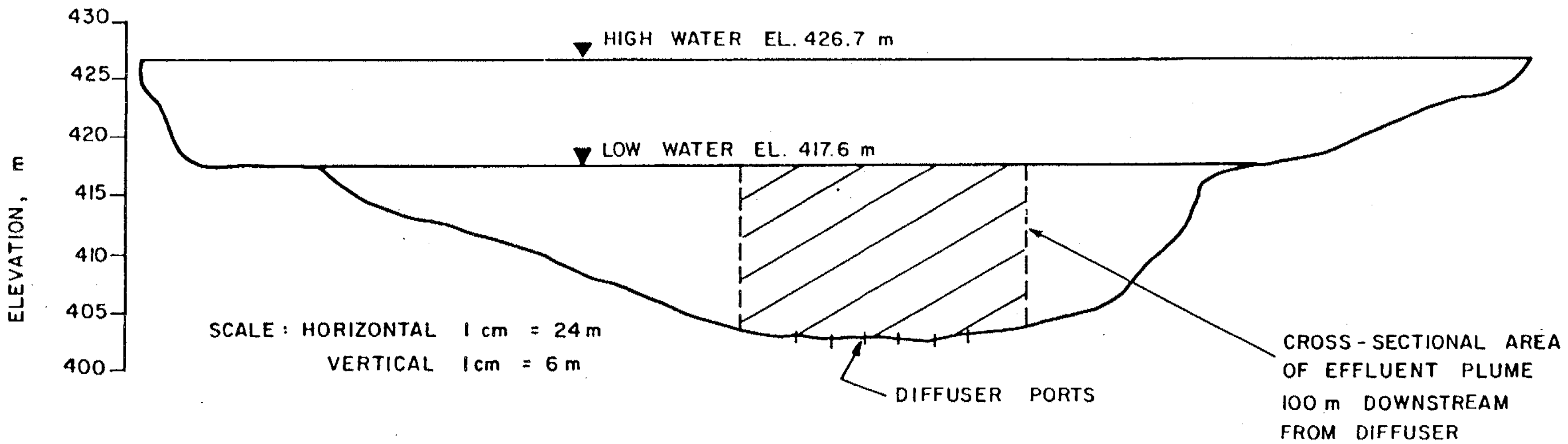


FIGURE 11

CELGAR LTD., EFFLUENT DIFFUSION IN THE COLUMBIA RIVER



CROSS-SECTIONAL AREA OF COLUMBIA RIVER CHANNEL AT EL. 417.6 = 3250 m^2

AVERAGE VELOCITY AT 142 m^3/s = 142 $m^3/s \div 3250\ m^2$ = 0.044 m/s

VELOCITY IN MID CHANNEL = 0.044 m/s $\div$ 0.9 = 0.049 m/s.

CROSS-SECTIONAL AREA OF PLUME 100m DOWNSTREAM FROM DIFFUSER = 100 m x 15 m = 1500 m^2

FLOW THROUGH AREA OCCUPIED BY PLUME = 1500 m^2 x 0.049 m/s = 74 m^3/s

DILUTION AVAILABLE 100m DOWNSTREAM FROM DIFFUSER AT EFFLUENT FLOW OF 1.96 m^3/s = 74 $m^3/s \div 1.4\ m^3/s \simeq$ 38:1

2.36 m^3/s = 74 $m^3/s \div 2.36\ m^3/s \simeq$ 31:1

FIGURE 12
Source, removal and disposition of AOX in Celgar effluent
(from Celgar, 1990)

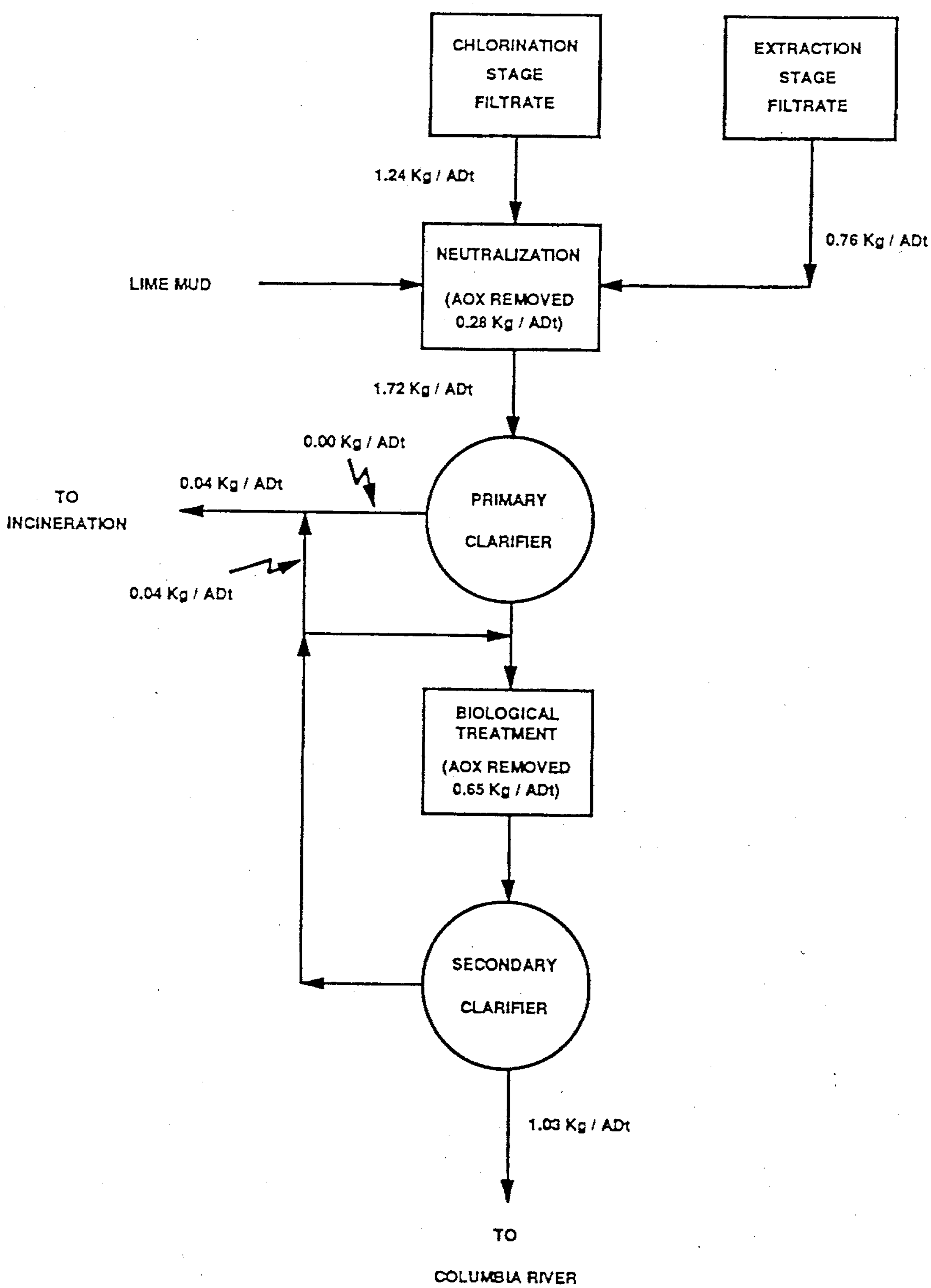


FIGURE 13
Celgar 1990 survey of fibre mat (from Celgar, 1990).

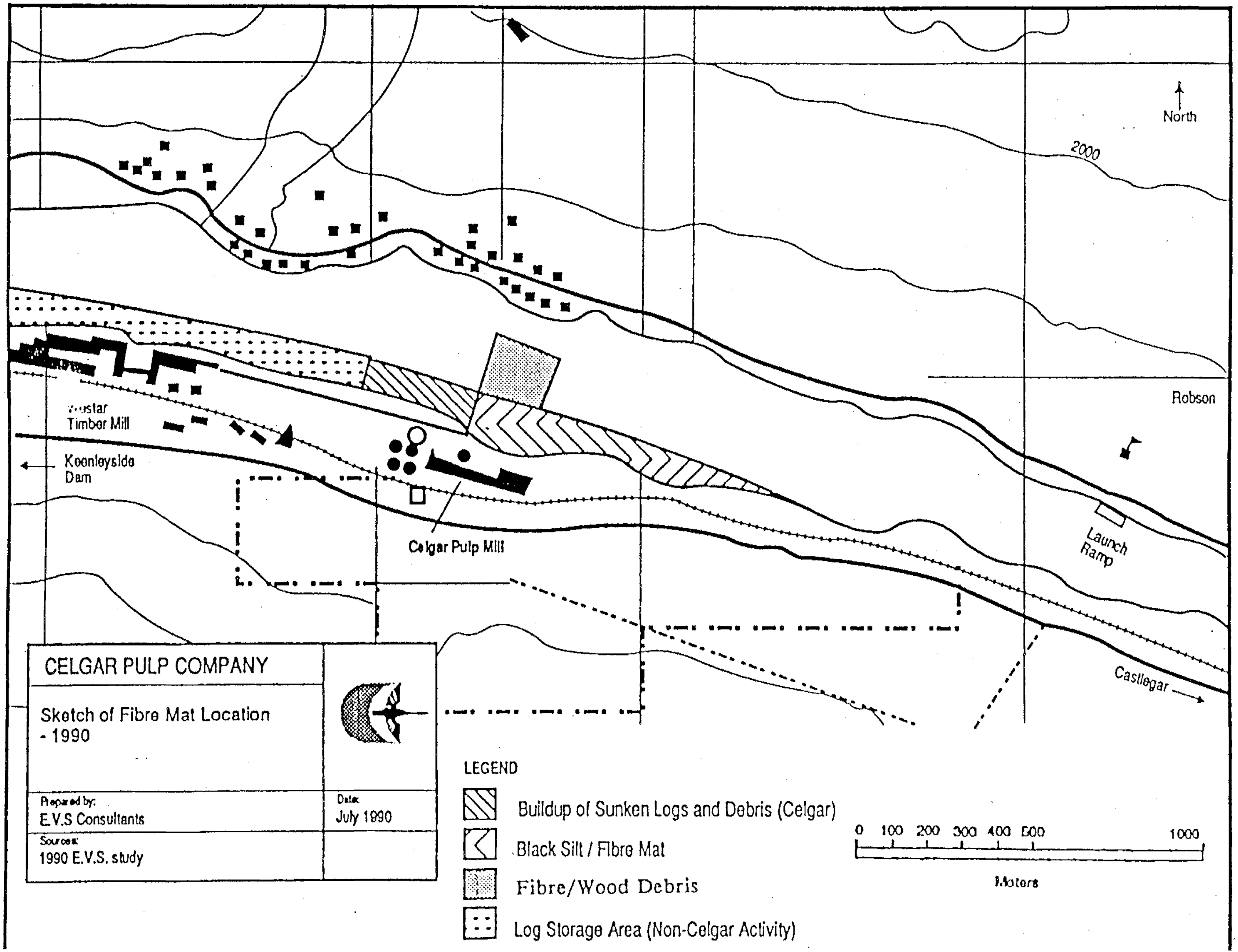
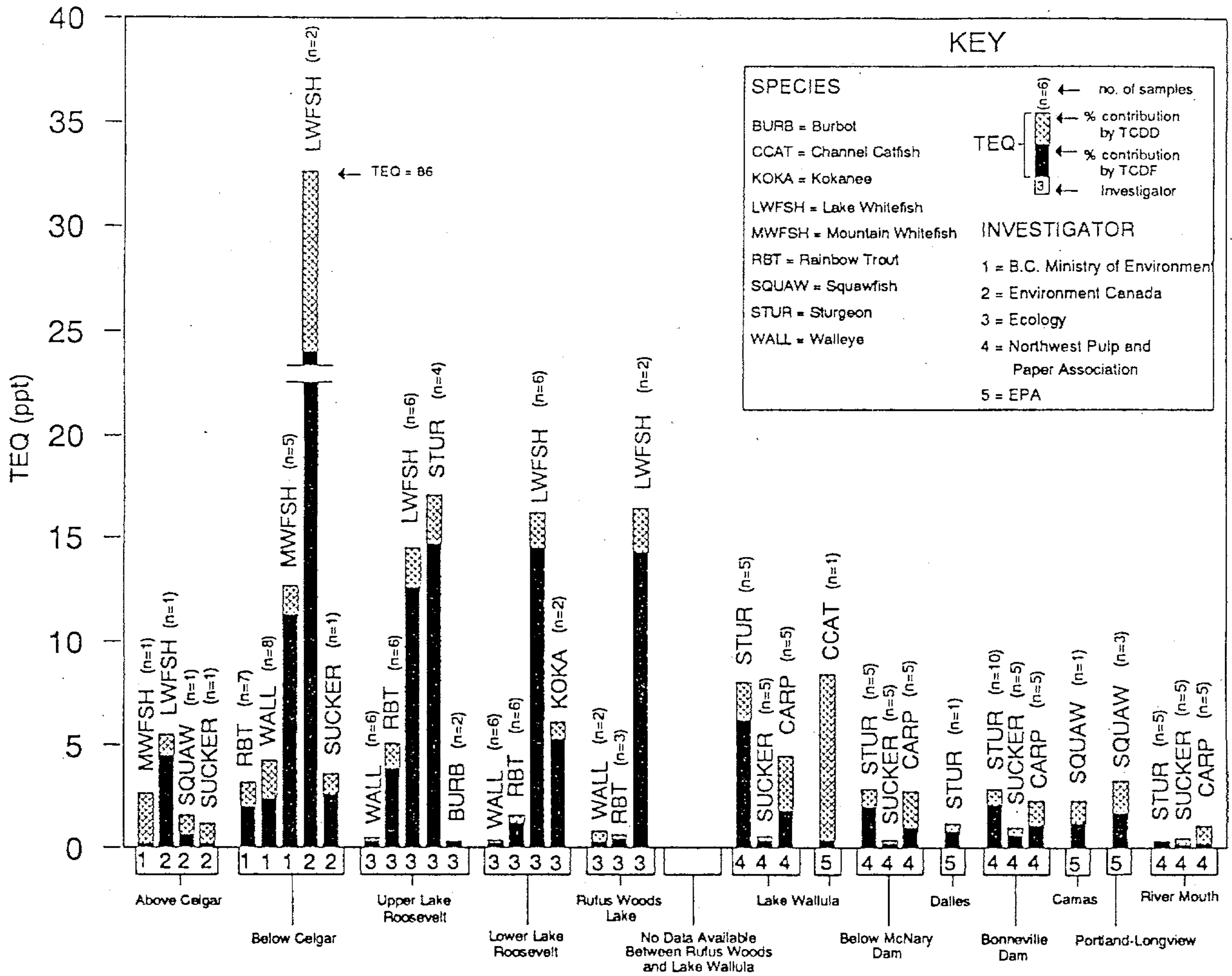


FIGURE 14
TCDD/TCDF TEQs in muscle tissue of resident Columbia River fish, Keenleyside Dam to Pacific Ocean



From: Johnson et.al., (1991).