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EFFECTS OF THE CRESTBROOK FOREST INDUSTRIES PULPMILL AT SKOOKUMCHUCK ON WATER QUALITY OF THE KOOTENAY RIVER BEFORE AND AFTER THE IMPLEMENTATION OF RAPID INFILTRATION OF THE EFFLUENT.

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Vancouver, B.C.

Effects of the Crestbrook Forest Industries Pulpmill at Skookumchuck on water quality of the Kootenay River before and after the implementation of rapid infiltration of the effluent.

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Abstract

Water quality of the Kootenay River above and below the pulpmill at Skookumchuck was studied from June 1980 to June 1982. The direct discharge of the Skookumchuck pulpmill effluent to the Kootenay River resulted in elevated downstream levels of colour, sodium, chloride, tannins and lignins and phenolic materials. There was a poorly defined sag in dissolved oxygen downstream of the effluent disposal site. Additionally there were chlorinated phenols present in samples collected downstream of the pulpmill that were not found upstream of the pulpmill. The change in effluent disposal practice in December 1981 from direct discharge to the river to the rapid infiltration system has eliminated the downstream effects of the pulpmill.

Résume

La qualité des eaux de la rivière Kootenay, en amont et en aval du moulin à papier à Skookumchuck, fut étudiée de juin, 1980 à juin, 1982. Le rejet d'effluent du moulin à papier de Skookumchuck, directement dans la rivière Kootenay, a élévé, en aval, les niveaux de couleur, de sodium, de chlorure, de tannins, de lignines et de materiaux phénoliques. Il y avait une baisse d'oxygène dissout, faiblement déterminée, en aval du lieu du rejet d'effluent. Aussi, il y avait des phenols chlorurés dans les échantillons recueillis en aval du moulin à papier, mais non pas en amount du moulin. Le changement du rejet d'effluent direct à la rivière à un système d'inflitration rapide, en decémbre 1981, a éléminé, l'effet en aval, du moulin à papier.

Introduction

One of the obvious environmental problems in the East Kootenay during the 1970's was the discolouration of the Kootenay River by the effluent disposal practices of the Crestbrook Forest Industries Pulpmill at Skookumchuck. These practices resulted in the Kootenay River being altered to a dark brown colour from its natural glacial blue colour. The Waste Management Branch (Province of B.C.) had issued a permit requiring the colour alteration to be no greater than a 5 unit increase. Although evidence of fish tainting was available (Langford, 1974). The permit did not restrict the discharge of specific materials related to this effect.

Pulpmill effluents contain a wide variety of materials and can exhibit considerable influence on the state of the ecosystem into which they are disposed. Since the Kootenay is an International River, a federal concern exists for the quality of water crossing into the U.S.A. On a local level, prior to construction of the pulpmill and the Libby Reservoir the annual angler use on the Kootenay River south of Skookumchuck, was estimated at 14,000 angler days. In 1976 angler use of the Libby Reservoir/Kootenay River complex was less than 1,000 angler days. This decline has been attributed to both river pollution and limited angling opportunities on the reservoir which the angling public found objectionable.

In the study we looked extensively at colour and other effluent related variables from June 1980, through June 1982. This provided data for one year prior to and six months after the implementation of the new effluent disposal practice. Although asthetically displeasing, colour changes are only an indication of environmental damage. Furthermore, from a fisheries point of view it is important to understand the actively toxic effects (resulting in death) or chronic sub-lethal effects (tainting, impairment to growth, reductions in fish distribution) of pulpmill effluent.

Sodium and chloride are two easily measured variables which are present in the effluent, resulting from their use in the pulping process (Aquatic Studies Branch, 1981). These could be used as effluent tracers since each is conservative (i.e.: not affected by biological activity) (Minns, 1977). Other materials considered were organic and inorganic carbon, tannins and lignins and phenolic material, all are expected to be present in the effluent. During the first year dissolved oxygen concentrations were also measured in the Kootenay River. Oxygen depletions may result from the disposal of effluents with a large oxygen demand into receiving waters.

In addition, pulpmill effluents often contain chlorinated hydrocarbons, particularly chlorinated phenolics. Since precise identificaton of such materials is extremely expensive chose to compare one fraction of the organic material from above the pulpmill to a fraction from below both prior to and subsequent to the implementation of the rapid infiltration system of effluent disposal.

The rapid infiltration system allows the pulpmill effluent to percolate through the bottom of the ponds and through the soil to groundwater. During this process a combination of subsurface chemical action and interactions with soils results in the decolourization of the effluent. The system consists of seven 18.2 hectare basins (plate 1). Each basin is capable of handling a single days effluent on a rotational basis. This system was implemented in December 1981.

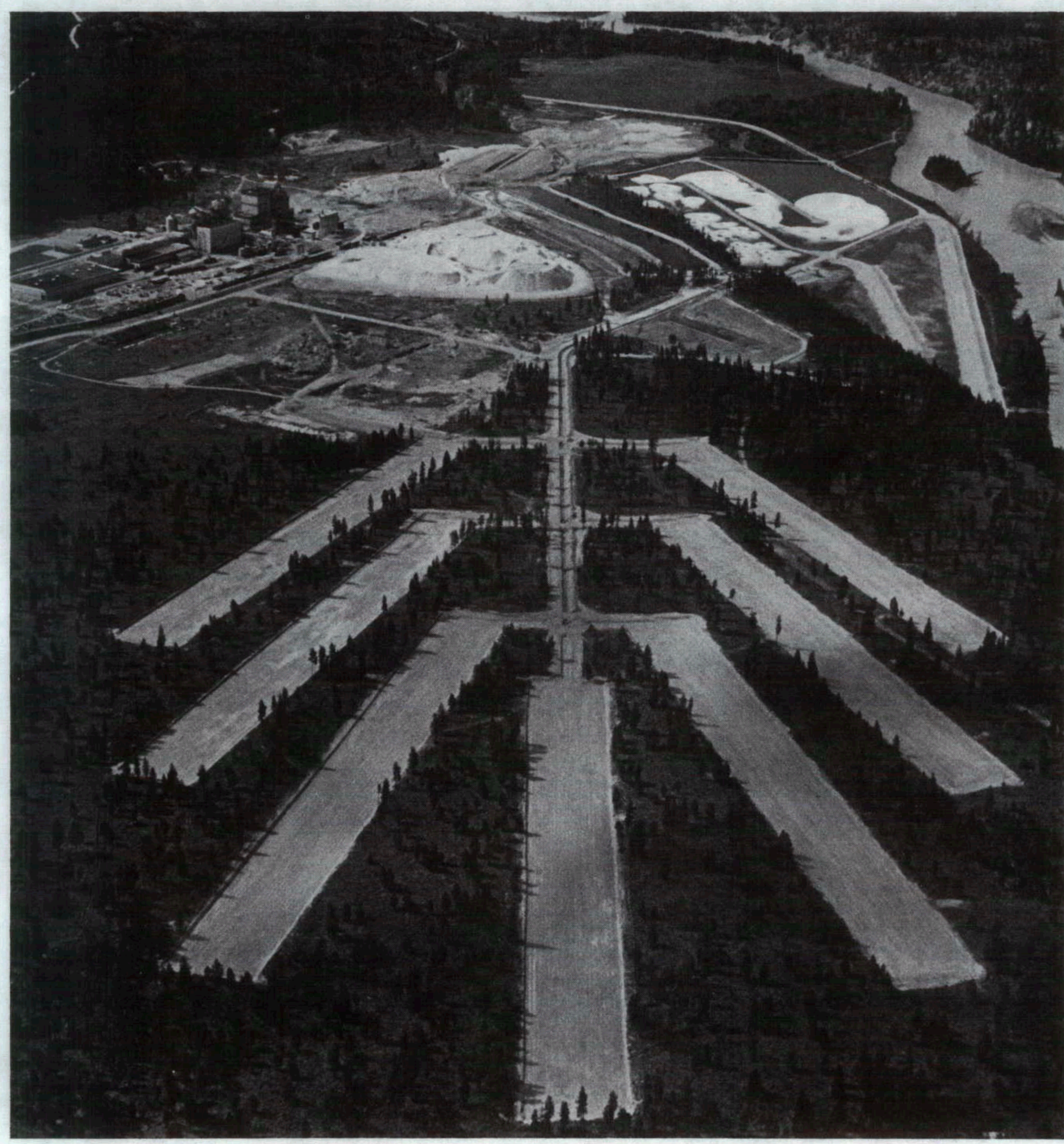


Plate 1. Crestbrook Forest Industries pulpmill showing rapid infiltration ponds in foreground with the Kootenay River in the background. Photo by Brian Kent courtesy of the Vancouver Sun.

Methods

Sampling was performed every other month beginning in June of 1980, at the sites shown in figure 1. These sites are located one kilometre upstream, 1, 2, 5, 10, 15, 20, and 40 km downstream from the location of the pulpmill effluent dispersion system. Samples were collected at the site 1 km downstream only during the initial stages of the study. Collection of samples 40 kilometres downstream commenced in April 1981.

Triplicate samples for analysis of: colour, sodium, chloride, inorganic and organic carbon were collected directly into acid washed 250 mL polyethylene bottles using the IWD replicate sampler. Samples for tannins and lignins were collected similarly. Teflon bottles were substituted for polyethylene for the collection of samples for the determination of phenolics. These samples, also in triplicate, were preserved on site with 1 mL of $CuSO_4$ in sulfuric acid. All analysis was performed by the Water Quality Laboratory of Inland Waters Directorate, Environment Canada using the methods described by Environment Canada (1979).

Samples for determination of dissolved oxygen were collected in triplicate using a D.O. dunker (APHA, 1975). Dissolved oxygen determinations were performed by the azide modification of the Winkler Method (Environment Canada, 1979), with a field portable titration setup. These procedures were only conducted during the first year of the study. Additional dissolved oxygen measurements were made in situ with a

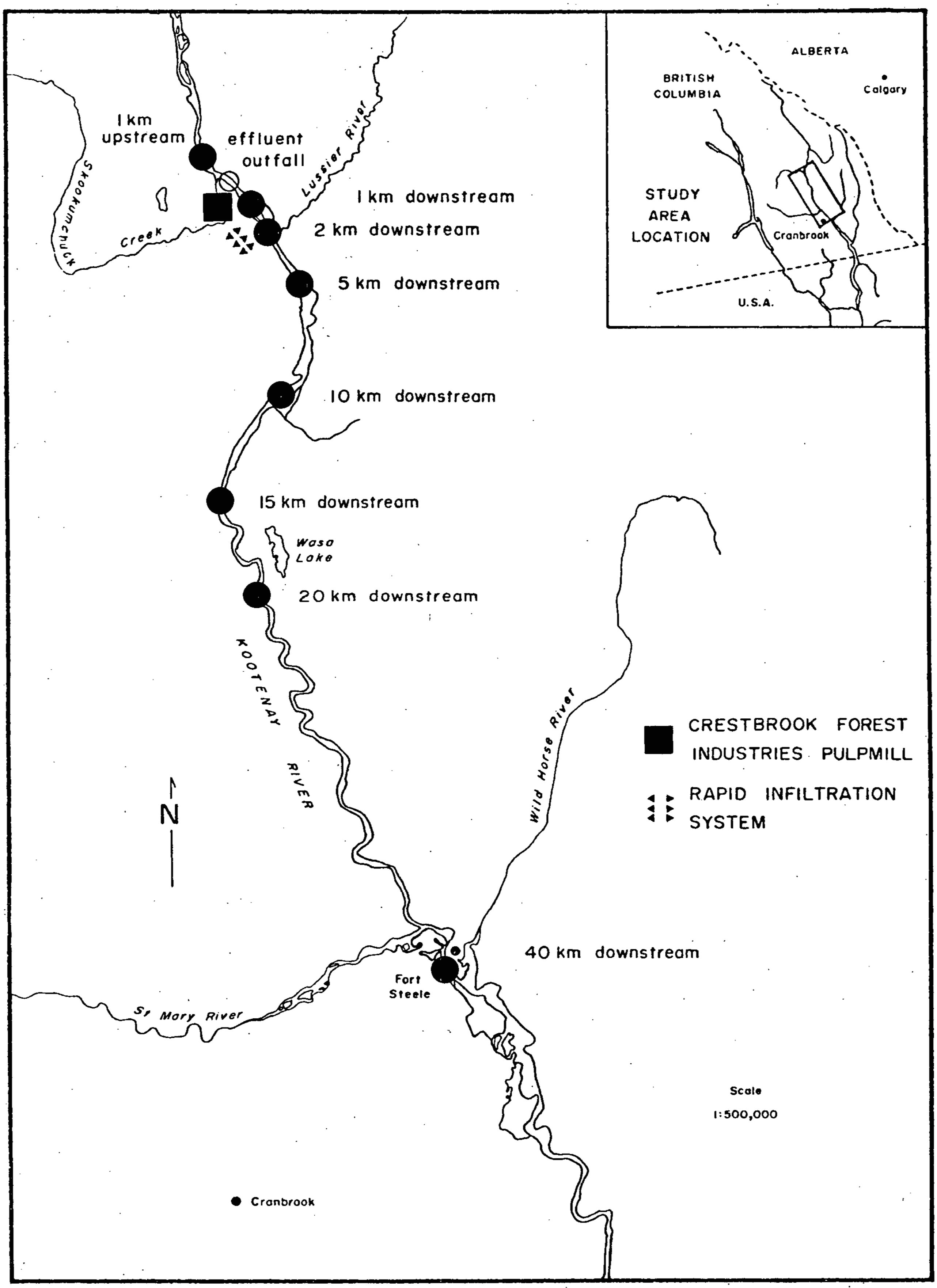


Figure 1. Map of the study area showing sampling locations.

dissolved oxygen electrode.

Samples for more detailed organic analysis were collected on four occasions. These were: February 12, 1981; April 15, 1982; June 10, 1982; and June 22, 1982. The first and last of these were for periods during which direct discharge of the effluent to the river was occurring, whereas the others were during periods when the effluent was being treated in the rapid infiltration system. These samples were collected directly into clean glass containers and returned to the laboratory for analysis.

These samples were extracted with three successive 50 ml aliquots of hexane. The extracts were then evaporated into 5 mls of iso-octane on a Rota-Vap, transferred into a 15 ml calibrated centrifuge tube, and made up to 10 ml with iso-octane. The GC analysis was performed with temperature programming under the following conditions: Initial temperature 150°C, initial hold 2 min, programmed rate 5°C/min, final temperature 220°C, column packing 3% OV 101, detector type-E.C.D., attenuation x 8, injection size 8µl and a carrier gas flow rate of 60 ml/min.

Results

Colour

Geometric mean colour values with their confidence limits determined from samples collected at each site along the Kootenay River over the period of the study are shown in figure 2. In the period prior to February 1982, colour values increased downstream of the pulpmill. These increases were particularly pronounced during December 1980 and February 1981. Observed changes during June and August were substantially less due to the increased dilution of effluent during periods of high riverflow. Subsequent to the change to the rapid infiltration disposal system no downstream increases in colour were observed.

Sodium

Geometric mean sodium concentrations with confidence limits are shown in figure 3. Increases in sodium concentration associated with the pulpmill effluent were observed during the period prior to the change in treatment. These increases were more evident during the winter months when low flow conditions existed. Subsequent to the change in effluent disposal the increases in sodium concentration became negligible.

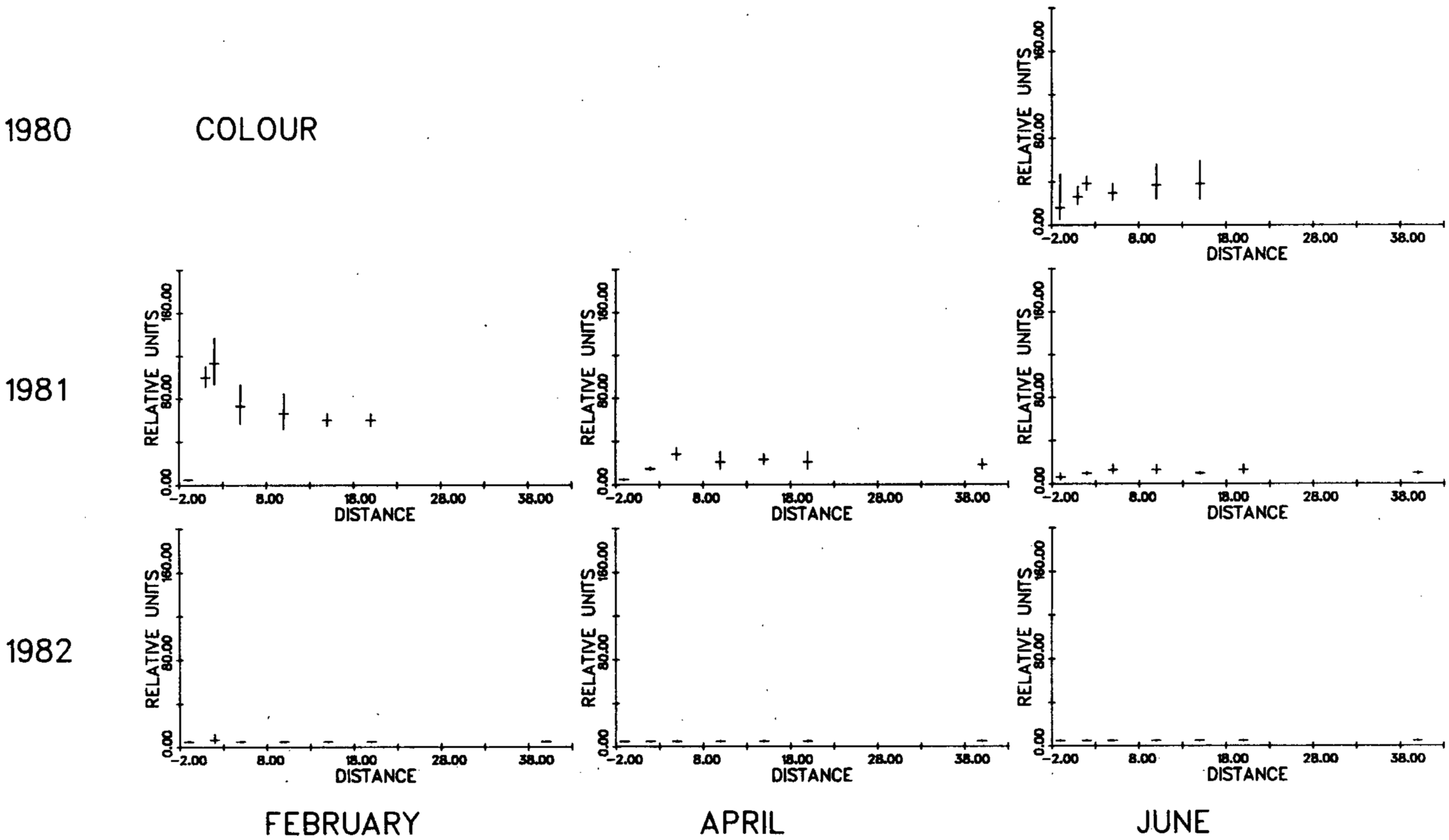
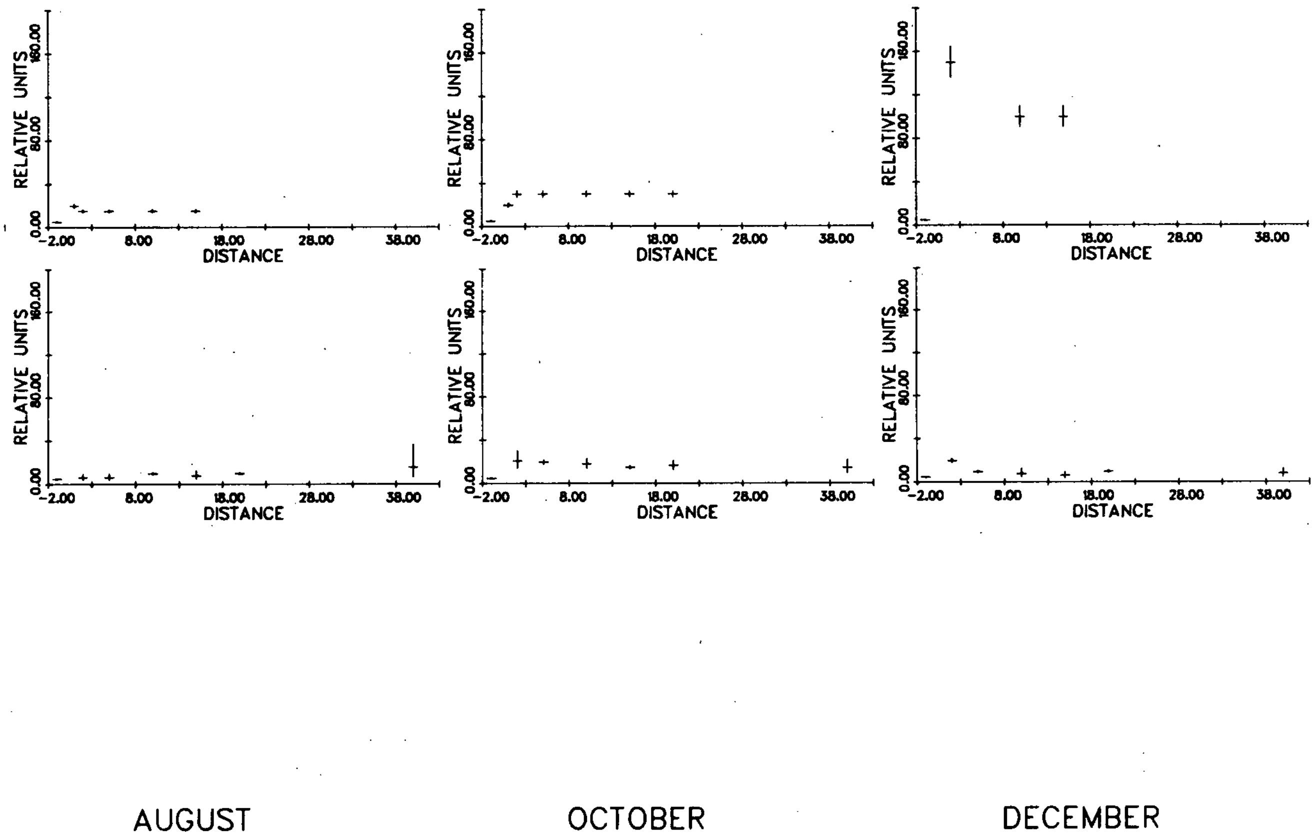


Figure 2. Geometric mean colour measurements with 95% confidence limits along the Kootenay River over the period of study.


RELATIVE UNITS
0.00
80.00
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-2.00
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18.00
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AUGUST
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DECEMBER

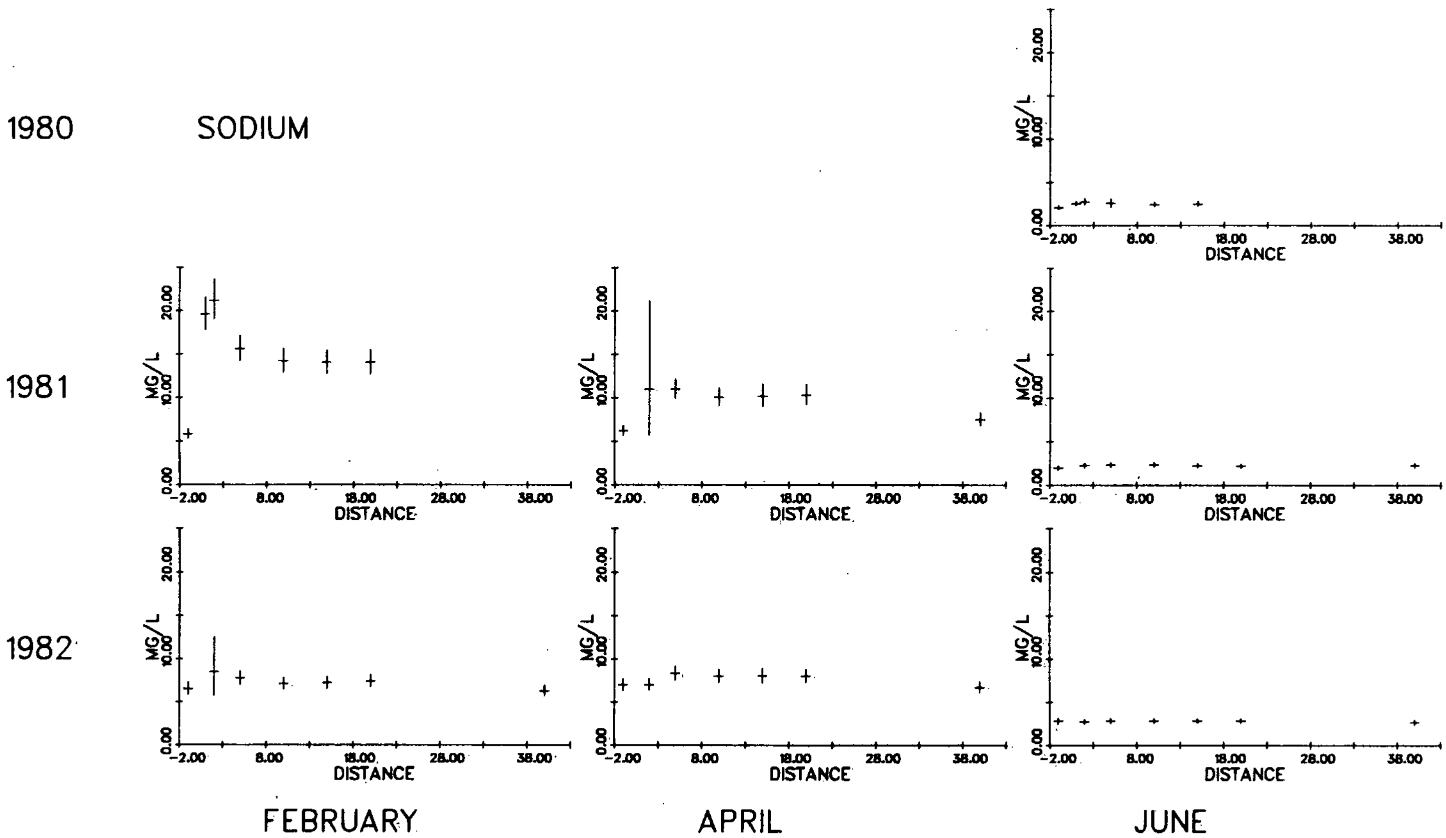
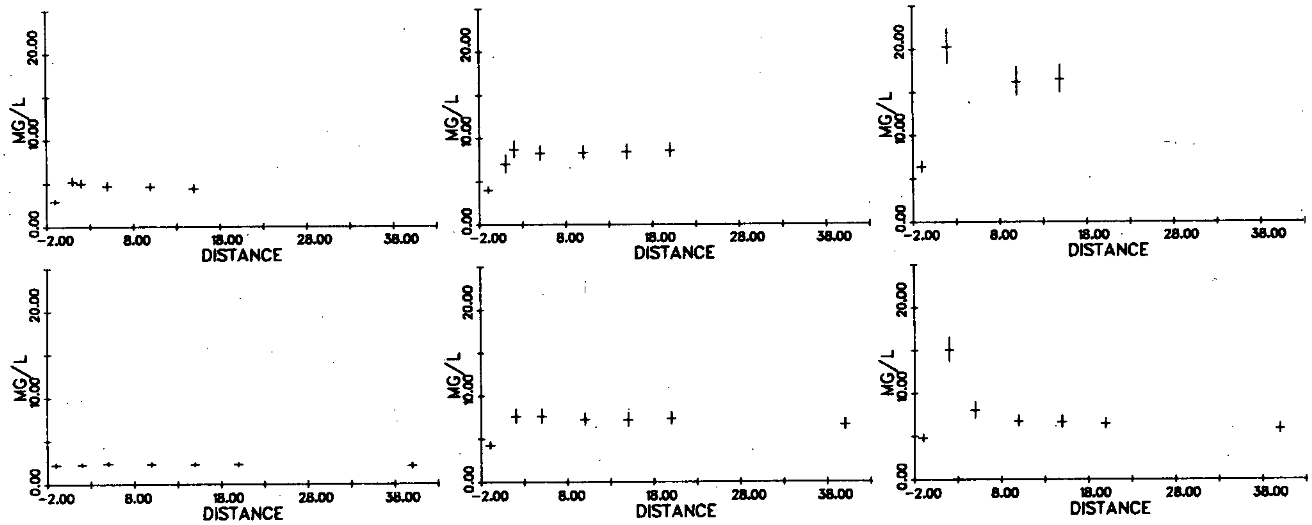


Figure 3. Geometric mean sodium concentrations (mg/l) with 95% confidence limits along the Kootenay River over the period of study.



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Chloride

The Chloride concentrations shown in figure 4 exhibit a pattern similar to sodium. Chloride concentration increases related to the pulpmill effluent were most pronounced during low flow periods prior to effluent disposal by rapid infiltration. Subsequent to the change there is no longer an increase in chloride concentrations downstream from the pulpmill.

Carbon

Total inorganic carbon and total organic carbon concentrations are shown in figures 5 and 6 respectively. The large natural contribution to the level of inorganic carbon masks the smaller contribution from the pulpmill. On the other hand, organic carbon is increased downstream of the pulpmill. These increases were most obvious during the winter of 1980-1981. Subsequent to the implementation of rapid infiltration no changes in organic carbon were observed with downstream distance.

Tannins and Lignins

Tannin and lignin concentrations, figure 7, also reflect the change in effluent disposal practices. Prior to the change to rapid infiltration, the concentrations were much higher downstream of the pulpmill than upstream, while after the start of the new form of treatment concentrations did not change along the reach of river studied.

Phenolic Materials

Concentrations of phenolic materials, figure 8, also demonstrate the pattern observed previously of marked increases in concentrations downstream of the pulpmill prior to the change in effluent treatment. The amount of the increase in concentration appears to be discharge related, with the largest increases occurring during low flow periods. Subsequent to the start up of the rapid infiltration system, phenolic material was no longer observed to increase downstream of the pulpmill.

Dissolved Oxygen

Figure 9 shows dissolved oxygen concentrations for the period during which this variable was measured. There was no sag in dissolved oxygen concentrations downstream of the effluent source when measured by the Winkler method. Table 1 contains the results of parallel measurements by the Winkler method, and by a dissolved oxygen electrode. All readings contained on the table are percent of saturation. At the site upstream of the pulpmill, all measurements were at the fully saturated level with the exception of December, where the readings were somewhat depressed (93%). The electrode readings suggest that there is some downstream sag in dissolved

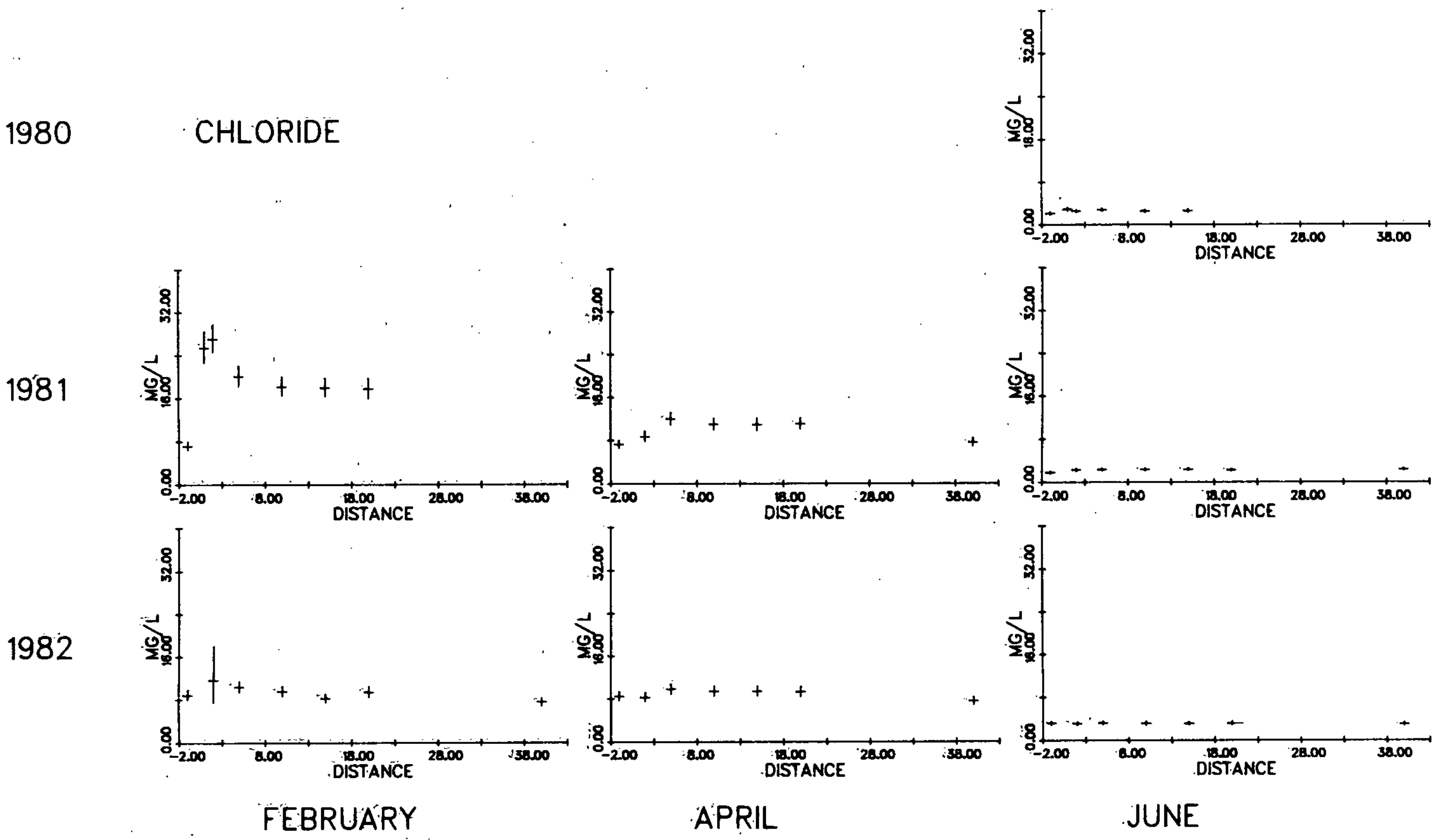
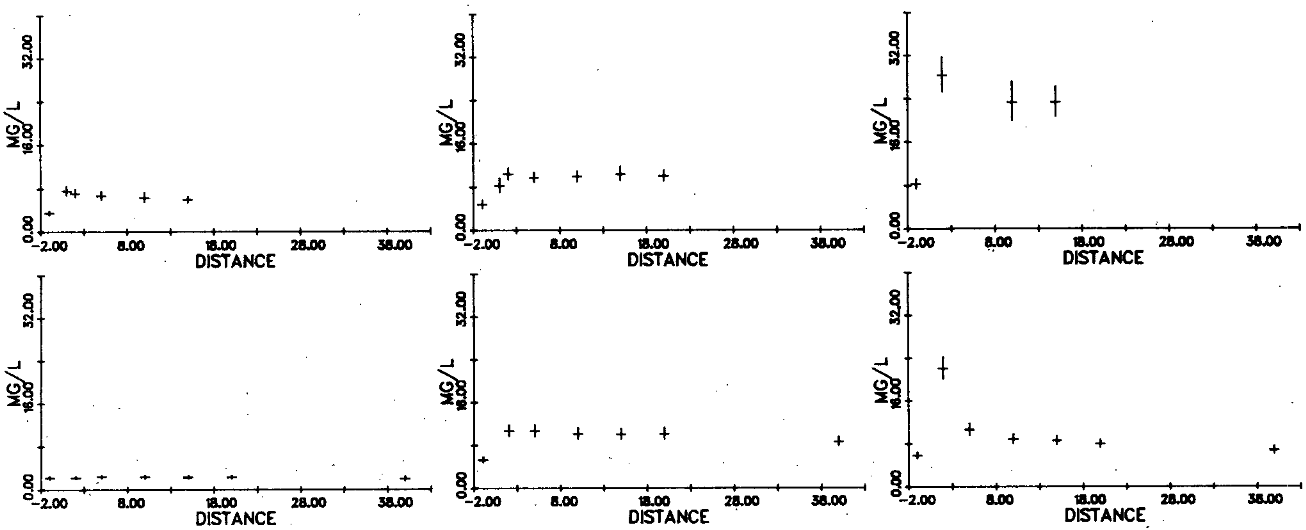


Figure 4. Geometric mean chloride with 95% confidence limits along the Kootenay River over the period of study.



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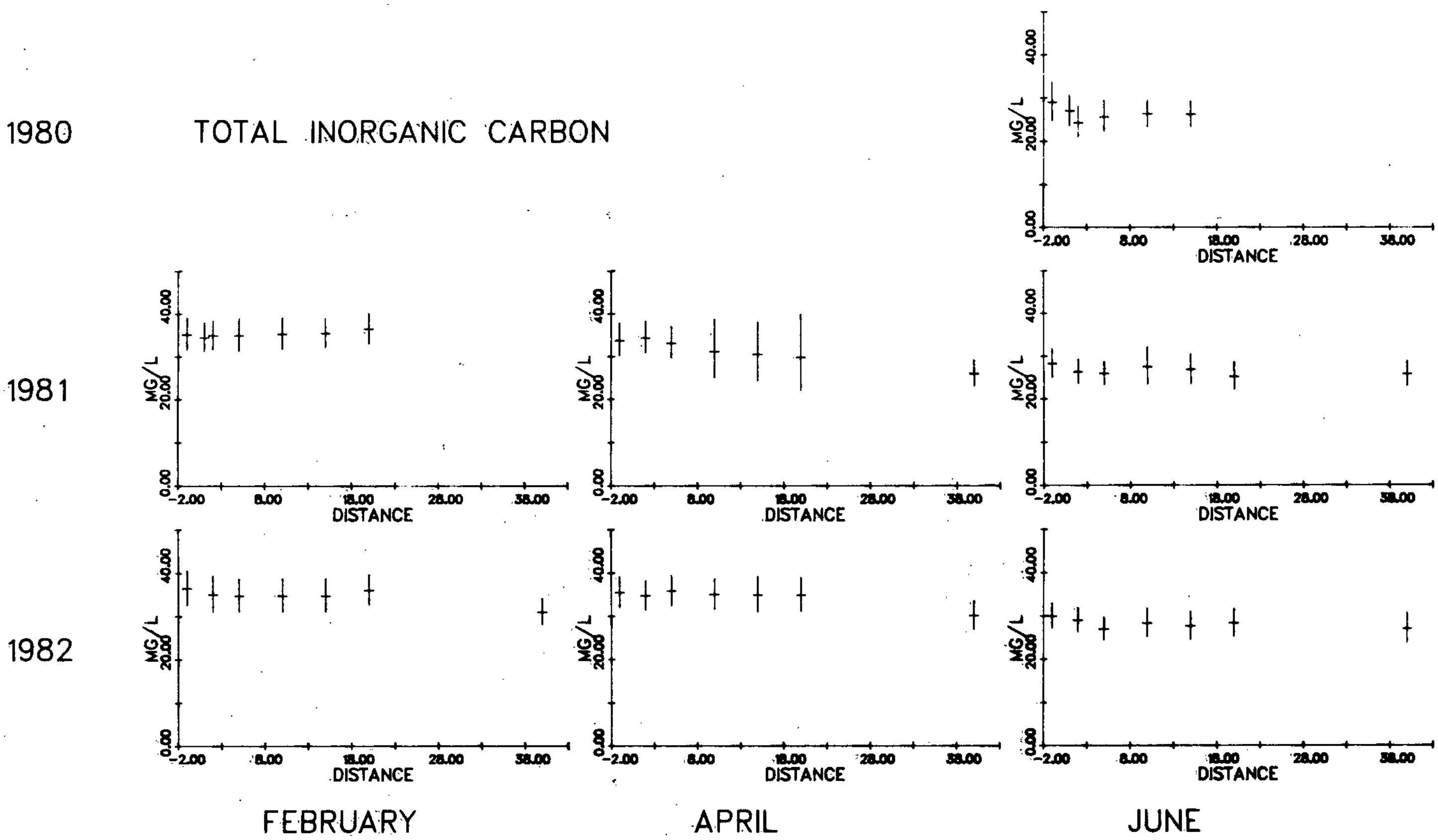
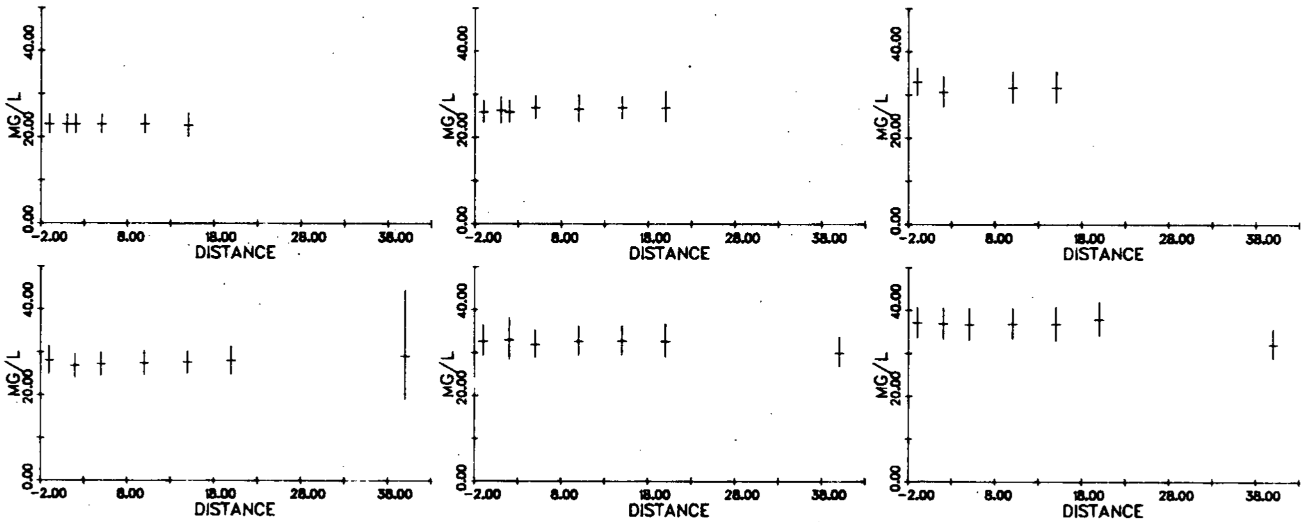


Figure 5. Geometric mean total inorganic carbon with 95% confidence limits along the Kootenay River over the period of study.



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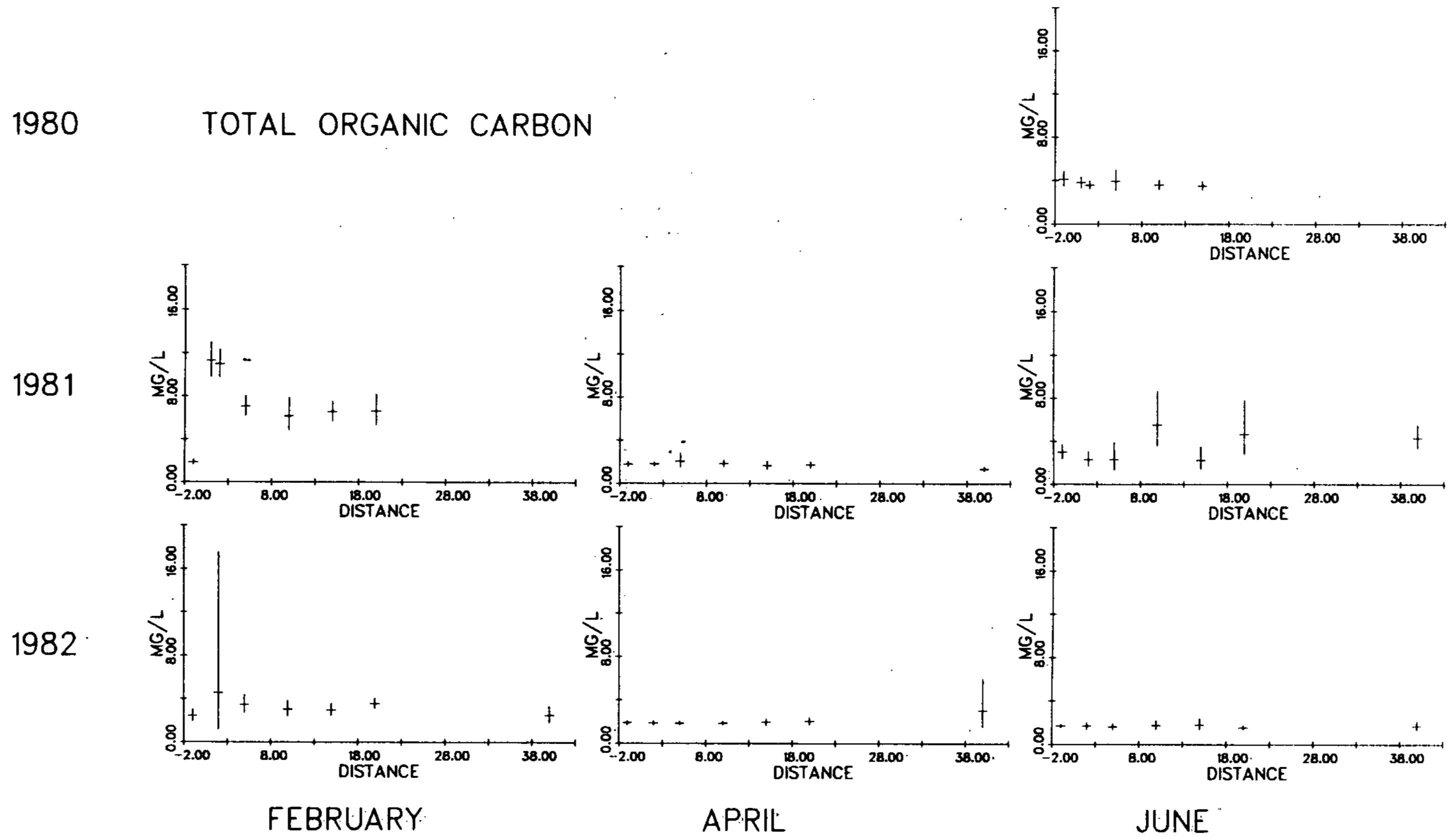
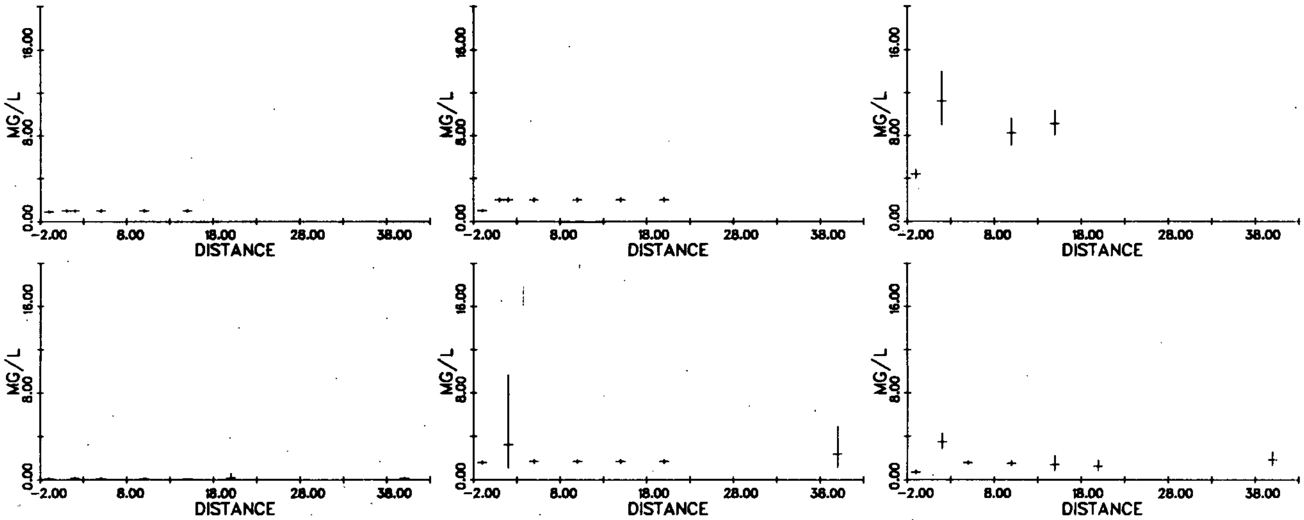


Figure 6. Geometric mean total organic carbon with 95% confidence limits along the Kootenay River over the period of study.



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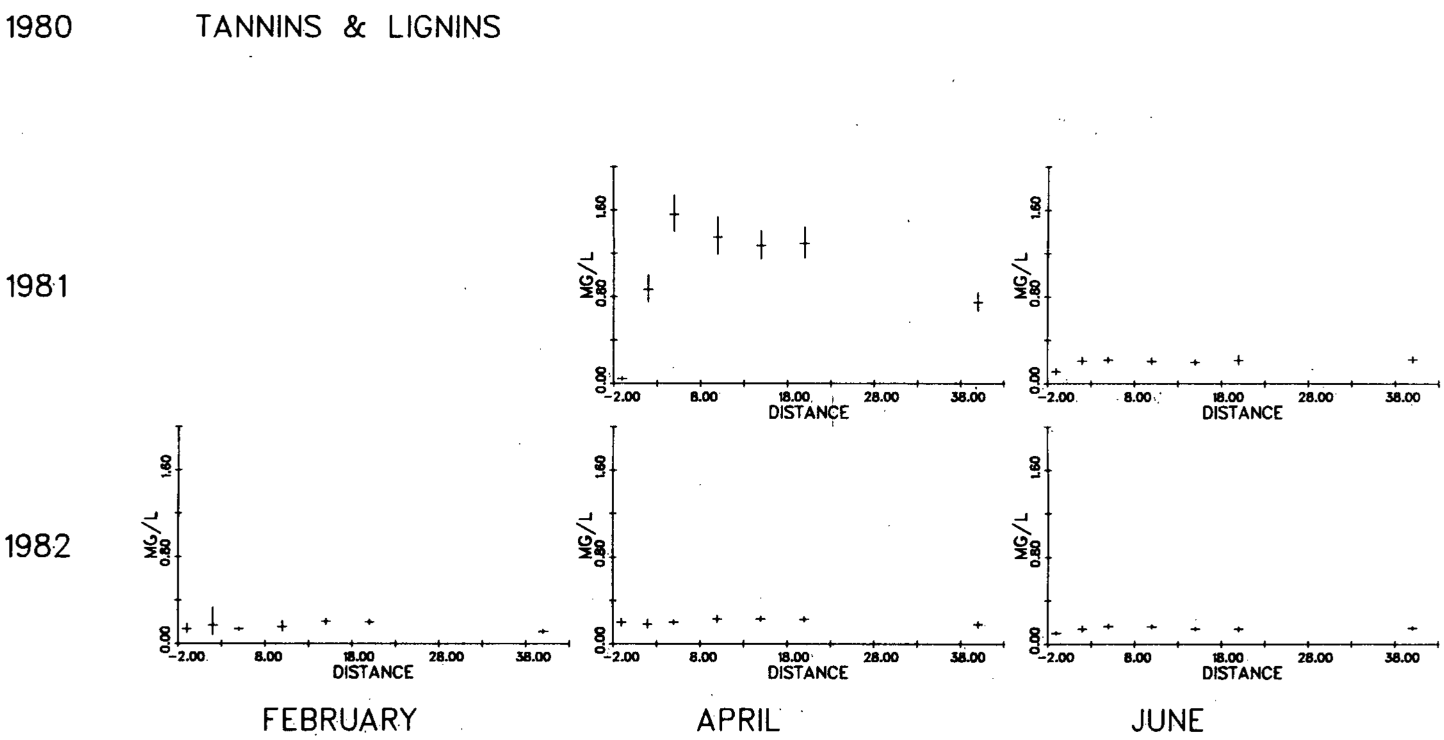
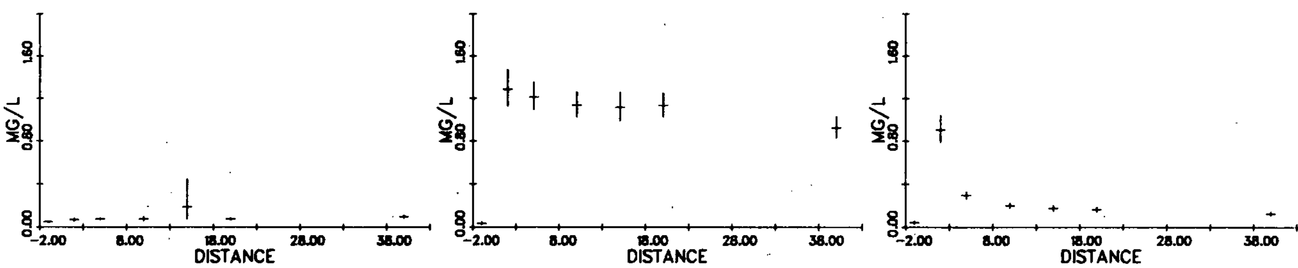


Figure 7. Geometric mean tannin and lignin with 95% confidence limits along the Kootenay River over the period of study.



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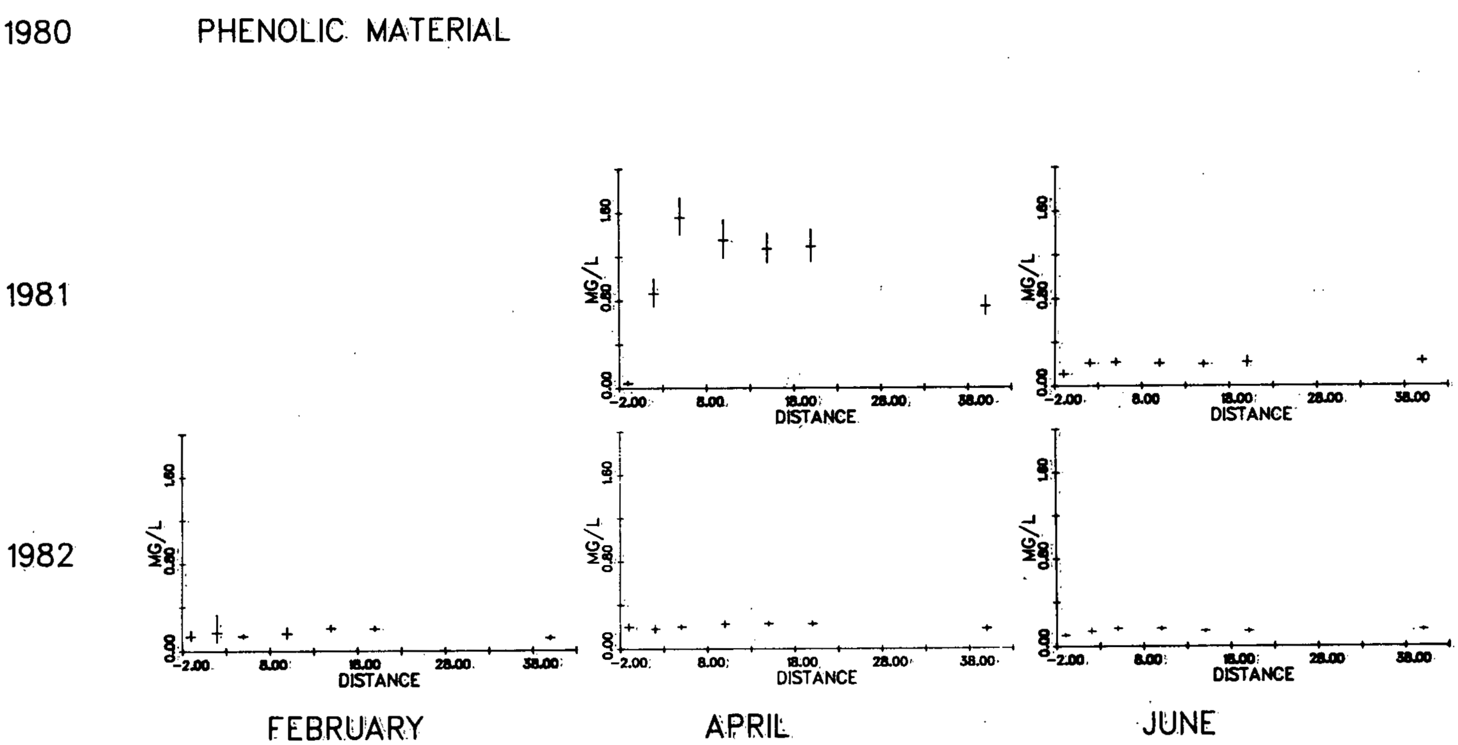
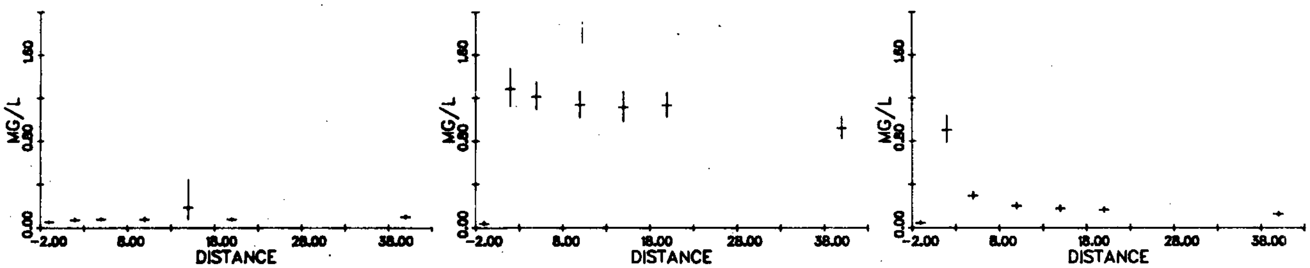


Figure 8. Geometric mean phenolic material with 95% confidence limits along the Kootenay River over the period of study.



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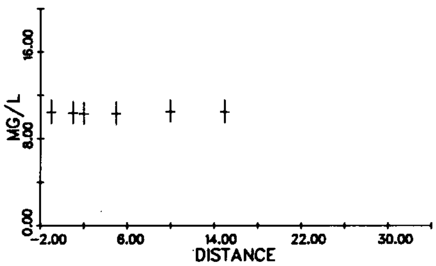
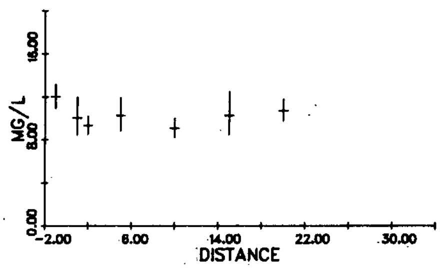
1980 DISSOLVED OXYGEN



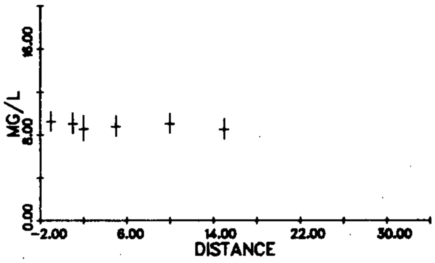
1981



1982

FEBRUARY APRIL JUNE

Figure 9. Geometric mean dissolved oxygen (by Winkler) with 95% confidence limits along the Kootenay River over the period of study.



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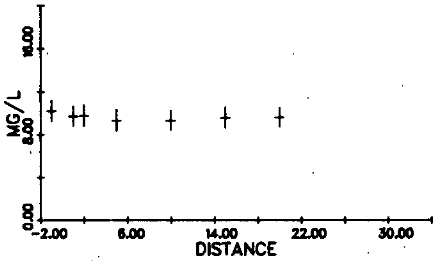

OCTOBER

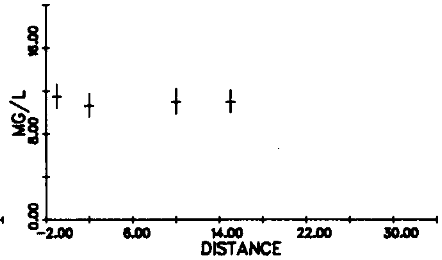

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Table 1. Dissolved Oxygen Saturation by two Methods

METHOD	SATURATION mg/l	PERCENT SATURATION 1 above	1 below	2 below	5 below	10 below	15 below	20 below
June 1980								
Winkler	10.5	100.0	98.8	90.1	98.5	100.0	99.3	
Meter		100.0	84.0	87.7	105.7	89.5	94.2	
August 1980	9.4	98.5	96.2	91.0	93.3	95.9	90.5	
Winkler								
October 1980								
Winkler	10.1	100.5	96.0	96.4	91.9	91.9	94.5	94.9
Meter		98.2	94.9	76.2	73.7	62.2	59.7	82.7
December 1980								
Winkler	12.3	93.2		86.5		89.4	89.4	
Meter		93.2		51.0		91.9	52.8	
February 1981								
Winkler	12.0	100.0	80.4	75.6	82.9	74.4	83.7	87.0
Meter		100.0	83.7	74.8	58.5	97.6	97.5	89.4

oxygen concentrations. These are most pronounced during the winter months, when a partial ice cover existed. Generally, there is poor agreement between the measurements, other than at the upstream site.

Organic Fractions

Figures 10 shows the gas chromatograph scans for samples collected upstream and downstream of the pulpmill on February 12, 1981. In downstream samples a number of unidentified compounds with high electron affinities were present that were not detected in the upstream samples. There were no significant differences between the downstream samples and the upstream samples for the other three samplings.

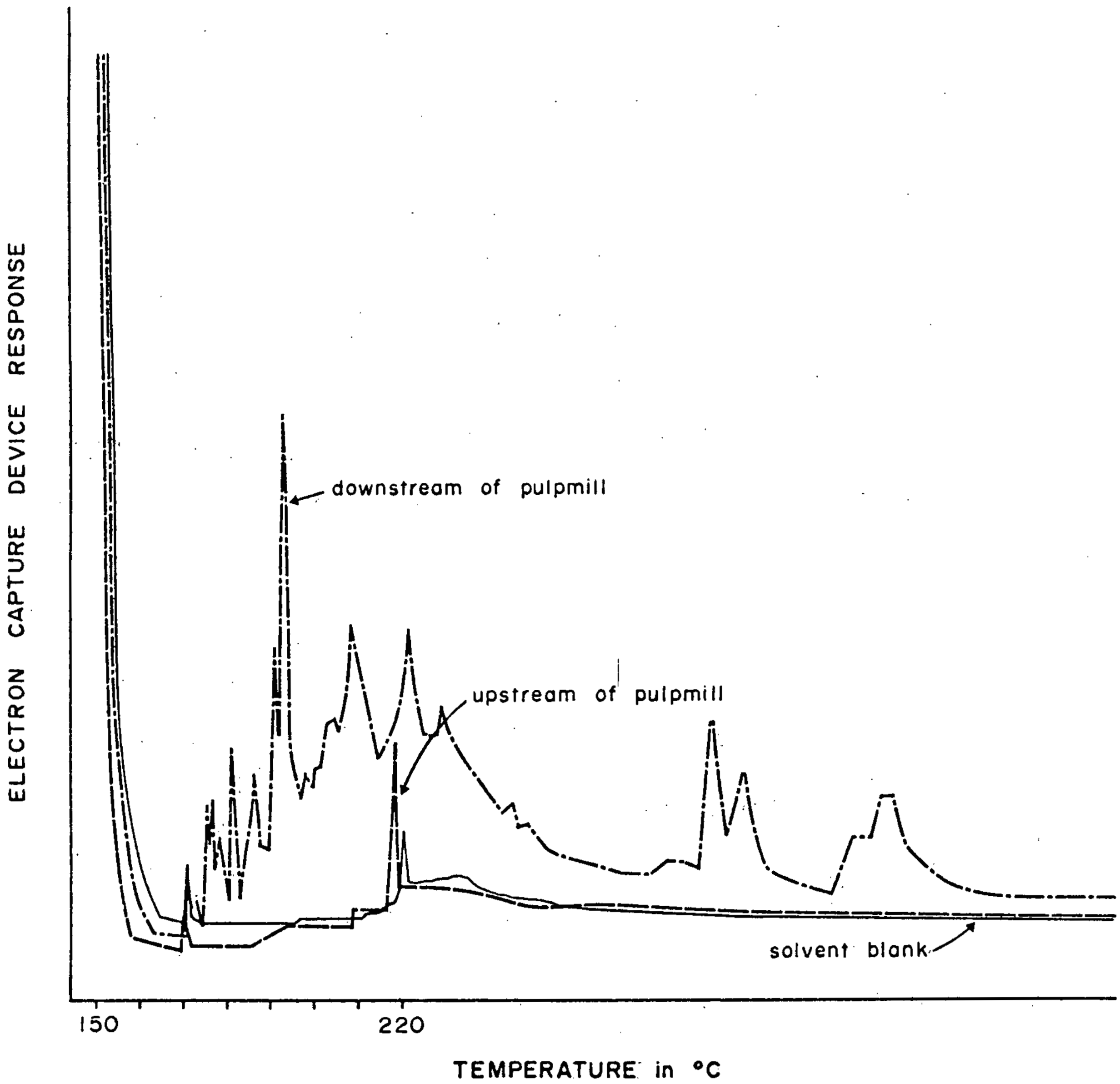

Figure 10. Upstream and downstream gas chromatographs collected February 12, 1982, during direct discharge of the effluent to the Kootenay River.

Discussion

With the exception of total inorganic carbon, all variables considered were found generally to be at higher levels downstream from the pulpmill than were observed upstream. The amount of the increase is related to the discharge of the Kootenay River, the largest increase occurring during the low flow periods and the smallest during freshet. This result occurs because of sample dilution of a stable source. These results are in agreement with the findings of Crozier (1980).

The change in effluent disposal practice from direct discharge to the river to the rapid infiltration system eliminated the downstream increases in colour, sodium, chloride, total organic carbon, tannins and lignins, and phenolic materials. The quality of the Kootenay River downstream of the pulpmill was returned to the natural state, as the result of the change in effluent disposal practice. What the long term effect of the disposal of the pulpmill effluent to the ground water system will be, remains to be seen. It is interesting to note that although the change in effluent disposal was designed primarily for colour removal the other variables examined were also removed from the Kootenay River. This result suggests that recreational use of the Kootenay River may also return to the state which existed prior to the startup of the pulpmill. To date, anglers have been observed returning to historic fishing areas albeit in low numbers.

There is a general lack of agreement between dissolved oxygen determinations by Winkler filtration and membrane electrodes. The discrepancies which exist are all at locations downstream from the pulpmill. It is conceivable that these discrepancies result from the presence of chlorine which is used in waste water treatment. If any residual chlorine exists in the effluent it would result in a positive interference in the Winkler method of determining dissolved oxygen. Since this is the phenomenon generally observed in table 1 it appears that this positive interference exists. Membrane electrodes are an excellent method for dissolved oxygen analyses in waters which are highly coloured or polluted (APHA, 1975).

The organic analysis which was performed on four occasions during the study shows the presence of electro-positive organic compounds downstream of the pulpmill when effluent was discharged directly to the river. There were unidentified compounds present in the samples collected downstream from the pulpmill which did not appear in the upstream samples collected in February 1981. Samples collected subsequent to the change in effluent disposal (April 1982 and June 10, 1982) showed no differences between upstream and downstream. This indicates that the change in effluent disposal practices also served to stop the introduction of these types of compounds into the river. This class of organics contains many of the materials which cause tainting of fish tissue (Fox, 1977), or have lethal or sublethal effects (Walden and Howard, 1971; Whittle and Flood, 1977). Leach and Thakore (1975) and McLean and Brown (1979) implicate resin acid derivatives and chlorinated lignin breakdown products as the materials responsible for tainting and lethal effects.

Under the terms of the permit by which effluent disposal is conducted the pulpmill may, during periods of high flow, discharge directly to the river. A pair of samples were collected on June 22, 1982, during a period of direct discharge to the river. That no difference between the samples was found is likely due to the high dilution rate during freshet.

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