MINISTRY OF ENVIRONMENT AND PARKS
PROVINCE OF BRITISH COLUMBIA

PEACE RIVER AREA

PEACE RIVER MAINSTEM
WATER QUALITY ASSESSMENT AND OBJECTIVES

TECHNICAL APPENDIX

G.A. Butcher
Water Quality Unit
Resource Quality Section
Water Management Branch
Victoria, B.C.

November, 1987

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

LIST OF TABLES (CONTINUED)

Table | Page

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF FIGURES

ACKNOWLEDGEMENTS

The following individuals are acknowledged for their assistance with the preparation and critical review of this report:

Dr. R. J. Buchanan, Mr. R. J. Rocchini, and Mr. L. W. Pommen of the Resource Quality Section, Water Management Branch.

Mr. R. Girard and Mr. B. Carmichael of the Regional Waste Management Branch, Prince George.

Dr. H. M. Richards, Provincial Health Officer, Ministry of Health.

Mr. J. Dick of the Planning and Assessment Branch.

Dr. J. Wiens, Dr. J. Ward, and Dr. M. Clark of the Waste Management Branch.

Mr. J. Hammond and Mr. C. Newcombe of the Recreational Fisheries Branch.

Dr. D. Valiela and Mr. R. Kistritz of the Water Quality Branch, Inland Waters Directorate.

1. INTRODUCTION

The Peace River mainstem is one of five priority sub-basins in the Peace River Planning area for which water quality assessments are being conducted. The location of the general area concerned is shown in Figure 1. Figure 2 shows the priority sub-basins, which include the Pine River, the Pouce Coupe River, Charlie Lake, Bullmoose Creek, and the Peace River mainstem.

The Peace River Sub-basin is comprised of the 167 km of mainstem river between the W.A.C. Bennett Dam and the B.C.-Alberta border (Figure 3). The water quality input from tributary waters is also examined.

The 183 m high W.A.C. Bennett Dam retains Williston Reservoir for hydroelectric generation and provides multi-year regulation of the Peace River. Williston Reservoir is the largest body of inland water in British Columbia with an area of 1 645 km^2. Located 23 km downstream is the Peace Canyon Dam (Site One), a run-of-the-river hydroelectric project, which retains the Peace Canyon Reservoir. There are presently proposals for two more run-of-the-river hydroelectric dams on the Peace River within Britih Columbia: Site C immediately downstream from the Moberly River, and Site E near the Alberta border.

Three physiographic regions straddle this sub-basin: the Rocky Mountain Foothills, the Alberta Plateau Plains, and the Peace River Lowlands (Thurber Consultants Ltd., 1976). The Rocky Mountain Foothills rise abruptly from the Alberta Plateau just west of Hudson's Hope to 1 400 m. The Peace River Lowlands occupy the valleys below 610 m and are dominated by post-glacial river erosion. The Peace River valley is located in a preglacial bedrock channel filled in with gravel. Between elevation 610-760 m are the Alberta Plateau Plains. This flat-to-gently rolling plateau between Hudson Hope and the Alberta border is characterized by glacial drift and glaciolacustrine/ glaciofluvial deposits. Post-glacial river erosion has dissected the plateau and formed pronounced river valleys.

The Peace River valley, especially the north bank, is a significant farming area. Virtually no settlement has taken place on the south side. Within the Peace River Valley, agricultural, wildlife, and recreation uses have been favored by a more desirable microclimate than the surrounding plateau. Floodplain features, wind protection, and solar exposure also distinguish the valley from the surrounding plateau.

This sub-basin contains the towns of Hudson's Hope and Taylor, and the City of Fort St. John. In terms of land-use impact, the major economic activities in the sub-basin are concerned with the resource sector: agriculture, forestry, and petroleum exploration and production.

The agricultural capability of the Peace River Valley is generally described as Class 1, making it an important agricultural area. Crops include grain, forage, seed, and vegetables. Pasturage and beef production are also important in the Peace River Valley. The logging and sawmill industries are significant employers in this sub-basin, although there is little logging done in the valley, apart from accessible areas on the north bank. Sawmills in Taylor and Fort St. John service other logging areas within the Peace River Unit (Thurber Consultants Ltd., 1976).

Natural gas and oil exploration has occurred in the past and the most significant production within the Peace River Valley is in the Wilder Gas field at the confluence of the Moberly and Peace Rivers (Canadian Resourcecon Ltd., 1978). The Village of Taylor is the centre of petroleum processing with an oil refinery, a natural gas processing/extraction plant, a sulphur recovery plant, and an oil pumping station (Thurber Consultants Ltd., 1976).

The main point-source effluents in the Peace River sub-basin are process and cooling waters from the Taylor refinery and natural gas processing/extraction plant, and treated municipal sewage from the City of Fort St. John.

2. HYDROLOGY

2.1 PRE-REGULATION

Streamflow regulation of the Peace River began in 1967 with the completion of the W.A.C. Bennett Dam. Prior to 1967, flow in the Peace River followed a seasonal pattern common to large northern rivers fed by seasonal snowmelt. The natural flow regime at Hudson's Hope was characterized by:

- low flows (139-256 m^3/s) and ice-cover during the winter.
- peak flows (5010-8810 m^3/s) in late spring due to snowmelt. (Water Survey of Canada, 1983)
- a gradual flow reduction during late summer and fall with occasional rain-derived peaks.

Flows at Taylor showed a similar pattern to those at Hudson's Hope, but averaged about 10 percent higher (Thurber Consultants Ltd., 1979).

2.2 POST-REGULATION

(a) Flow Regime

The years 1968 and 1969 saw the greatest withdrawal from the natural flow regime to provide storage in Williston Reservoir. Since 1970, water has been released from the W.A.C. Bennett Dam at a relatively uniform rate throughout the year in keeping with the demands of electrical power production. Construction of the Peace Canyon Dam began in 1974 and was completed by 1980. This is a run-of-the-river hydroelectric facility with very little storage, and thus it has little effect on the streamflow regulation caused by the W.A.C. Bennett Dam.

Table 1 shows the mean monthly streamflows for the Peace River at Hudson's Hope and Taylor for the years 1955-1967 (pre-regulation) and 1970-1982 (post- regulation). At Hudson's Hope mean flows during the winter months (November-April) are now 2.1-4.8 times greater than those before regulation. The formerly high flows of May to July have been eliminated (from May to July flows are only 0.2 to 0.4 pre-regulated flows) and during the period August to October, the mean flows are roughly equal to pre-regulated levels.

Further downstream, near Taylor, the effects of streamflow regulation by the W.A.C. Bennett Dam are similar to those at Hudson's Hope (Table 1). Mean monthly winter flows are now relatively uniform, ranging from 1.8 to 4.2 times their former values. The spring and summer streamflow peak has been suppressed, and only during August-October do the mean streamflows reach pre-regulation conditons. The contribution of an additional 27 000 km^2 of unregulated drainage area on the east slopes of the Rocky Mountains to the Peace River near Taylor, does not significantly alter the pattern of streamflow regulation caused by the W.A.C. Bennett Dam (Table 1; Schaefer, 1976). However, inflow from the unregulated rivers (the Pine, Moberly, and Halfway Rivers) can produce occasional minor peaks in the Peace River flows near Taylor during snowmelt and summer rainstorm events.

Since regulation, the larger tributaries to the Peace River likely have a greater effect on Peace River water quality during spring when their flows are high and Peace River flows are low (relative to pre-regulation conditions). During the winter, the tributaries would have less effect than they did under the natural regime because of the increased Peace River flows.

An annual hydrograph showing maximum, minimum, and average flows for the Peace River near the Alberta border (at Site E) is shown in Figure 4. This is an estimated hydrograph projected for 1985-1986 using probable hydroelectric load data for the W.A.C. Bennett Dam (Woodley, 1983). A summary of the minimum flows to be released from the W.A.C. Bennett Dam throughout the year, as required by B.C. Hydro's water licence, is shown in Table 2. The minimum flow to be released during the open-water season is 283 m^3/s (as measured at Hudson's Hope).

Only once since construction of the W.A.C. Bennett Dam have flows at Hudson's Hope been lower than this value. For 35 days during the period June 17-July 23, 1980, flows ranged from 188 m^3/s to 282 m^3/s. On several other occasions, minimum actual flows have approximated the minimum release flow, e.g.:

- 292 m^3/s on July 24, 1975.
- 292 m^3/s on October 13, 1979.
- 294 m^3/s on July 18, 1981.

b) Sediment Regime

Prior to regulation, the Peace River was a stable gravel-bed river carrying a small bedload and a moderate suspended sediment load, and neither aggrading nor degrading (Thurber Consultants Ltd., 1979). Since regulation, there has been no spring flood, which in turn has resulted in a lower suspended sediment load and the following changes in channel morphology and capacity:

- gravel deposits are accumulating in the main channel of the Peace downstream from tributary river mouths. In addition, the input of flood flows from the tributaries at times when the flow in the Peace River is lower than pre-regulation times has initiated bed and bank erosion near the mouths of the tributaries. These effects are most apparent in the reach from Hudson's Hope to Taylor.

- the channel capacity of the Peace River is being reduced by the encroachment of vegetation-stabilized gravel bars.

c) Ice Regime

Since regulation by the W.A.C. Bennett Dam, the Peace River freeze-up occurs later than it would under a natural flow regime (Thurber Consultants Ltd., 1979). This results from the higher post-regulation winter discharges and the residual heat stored in the Williston Reservoir.

The tributaries to the Peace River generally all develop ice-cover by mid-November and retain it until late April. The Peace River does not develop continuous ice-cover for many miles downstream from the Bennett Dam. The maximum extent of the ice-free reach depends on the severity of the winter, and has varied from 100 km to over 320 km downstream from the dam. Associated with the development of a continuous ice-cover is a rise in river level in the order of 3-5 m.

d) Low Flow Estimates

The seven-day average winter low flows (mean and 10-year return period) estimated for the October-April period are 686 and 505 m^3 s at Hudson's Hope, 734 and 556 m^3/s at Fort St. John, and 832 and 614 m^3/s at Taylor (Barr, 1984). The late summer low flows are smaller: the seven-day low flow (mean and 10-year return period) in August expected for the Peace River near Hudson's Hope, Fort St. John, and Taylor are 786 and 343 m^3/s, 881 and 436 m^3/s, and 1080 and 564 m^3/s, respectively. These low flow values were estimated for post-regulation conditions (1977-1985).

For the Beatton River at Fort St. John, the winter low flow is smaller than the late summer low flow. The seven-day average low flows (mean and 10 year return period) are 0.68 and 0.17 m^3/s for the October-April period, and 32 and 2.8 m^3/s for August (Obedkoff, 1982). The 7-day average low flows (mean and 10-year return) for the effluent discharge period from the City of Fort St. John, April 1 - June 30, are 37.2 and 11.1 m^3/s (Barr, 1984). This is an "end-of-freshet" low flow.

e) Annual Streamflow Balance

An annual streamflow balance for the Peace River from the W.A.C. Bennett Dam to Dunvegan, Alberta, is summarized in Figure 5. The major tributaries to the Peace River contribute up to 24.2% of the mean annual flow (M.A.F.) of the Peace River above the confluence with the Alces River (i.e. near the B.C.-Alberta border). As a result, the Peace River M.A.F.

increases from 1 050 m^3/s at Hudson's Hope to 1 454 m^3/s at the Alces River.

In terms of streamflow, the Pine River is the largest tributary (14 percent of Peace River M.A.F. at Alces R.), followed by the Halfway River (5 percent) and the Beatton River (3.6 percent). The Moberly River and the Kiskatinaw River each contribute 0.8 percent of the Peace River M.A.F.

3. WATER USES

3.1 WITHDRAWALS

A summary of licensed consumptive water withdrawals from the Peace River mainstem is given in Table 3, and their locations are shown in Figure 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 is conservative. The licensed withdrawals (2.53 m^3/s) represent roughly one percent of the minimum flow permitted in the Peace River under the terms of B.C. Hydro's water license.

The largest withdrawal (99 percent) of Peace River water is for industrial purposes. Only 0.75 percent of the licensed water usage is for domestic and water works purposes.

The Village of Hudson's Hope, about 35 km downstream from the Bennett dam, draws part of its water supply directly from the Peace River on a year-round basis (the rest is supplied by three springs). The water is settled and chlorinated prior to distribution. Chlorination provides protection fromm upstream domestic effluent discharges. These include the unpermitted sewage discharges from the G.M. Shrum Generating Station (30 km upstream) and the chlorinated domestic effluent discharge (PE 5240) from the tourist facilities at the Peace Canyon Dam (6 km upstream). Hudson's Hope discharges its domestic effluent to the ground, thus eliminating any negative effect on downstream water users.

D. Peck Holdings Ltd. withdraws a small amount of water (13.6 m^3/d) from the Peace River for livestock watering. This withdrawal is 75 km downstream from the effluent discharges at the Peace Canyon Dam, and 16 km upstream from the City of Fort St. John effluent discharge (PE 389).

The Village of Taylor, about 120 km downstream from the Bennett dam, withdraws it water from the Peace River through an infiltration gallery.

The water is chlorinated at the pump house and then pumped to a reservoir where it is settled before distribution. The reservoir provides water for Taylor's population and for part of the domestic water supply of the Petro-Canada refinery. The City of Fort St. John (PE 389) discharges treated sewage effluent into the Peace River 12.5 km upstream from the Taylor intake. Taylor discharges its domestic effluent to the ground, thereby eliminating downstream problems with effluent discharge to the Peace River.

The Petro-Canada refinery at Taylor accounts for 81.3 percent of the licensed water usage from the Peace River mainstem. Roughly two-thirds is used in the gas plant and one-third in the oil refinery. Less than 2 800 m^3/d, on the average, is used as plant process water for purposes such as boiler makeup, desalting, etc. (Canadian Bio Resources Consultants Ltd., 1979). Most of the water consumed by Petro-Canada (88 percent) is used as cooling water on a once-through basis. A small portion of the water withdrawal (272.5 m^3/d) is for the refinery water works. This water use could be negatively affected by the City of Fort St. John effluent discharge, 12.5 km upstream.

At present, there are no licensed withdrawals from the Peace River for the purpose of crop irrigation. However, according to Canadian Bio Resources Consultants Ltd. (1979), there is a total of 101 ha of vegetable production under irrigation using Peace River water. Of this, 40.5 ha is at Bear Flats and the other 60.7 ha is at Taylor on the south bank. This estimate was based upon producer interviews carried out by the agriculture assessment component of the Site C environmental and socio-economic studies. The amount of water withdrawn is not known, but is not likely large (e.g., an application of 1 m of water on 101 ha would amount to only 11 200 m^3/year which is negligible compared to the licensed withdrawal of ~ 219 000 m^3/d).

Three run-of-the-river hydroelectric dams have been proposed for the Peace River downstream from the Peace Canyon Dam: Site C upstream from the Moberly River and about 100 km downstream from the Bennett dam; Site E 5 km upstream from the B.C./Alberta border; and a dam at Dunvegan, Alberta, 120 km downstream from the B.C./Alberta border. Site C and the Dunvegan Dam are presently on indefinite hold, and Site E is no longer being actively considered. The proposed Dunvegan Reservoir would not flood any land or watercourse in British Columbia. Since Site C would be a run-of-the-river facility, it would maintain an outflow equivalent to the minimum release from the W.A.C. Bennett and Peace Canyon Dams. For this reason, if the Site C Dam were to be developed, there would be no effect on the downstream dilution of the waste discharges from the City of Fort St. John and the Petro-Canada refinery at Taylor once the reservoir was filled.

3.2 FISH RESOURCE

Within a regional context, fisheries values are high in the Peace River mainstem. A total of 21 species of fish were collected from the Peace River by consultants to B.C. Hydro (Table 4; Thurber Consultants Ltd., 1976). Two additional species, goldeye and kokanee, are known from the Peace River (J. Hammond, personal communication). Of these, nine species can be considered as sport fish: Arctic grayling, Mountain whitefish, yellow walleye, burbot, Dolly Varden char, rainbow trout, goldeye, kokanee, and northern pike.

The most abundant* fish species captured between the Peace Canyon Dam and Site C were mountain whitefish (48 percent), suckers (19 percent), Arctic grayling (18 percent), and rainbow trout (7 percent) (M.O.E., 1982). Most of the sampled fish (70 percent) were captured within 10 km of the Peace Canyon Dam . This concentration in fish productivity is believed to be the result of lower turbidity, the presence of suitable spawning substrates, and the availability of zooplankton near the outlet of the Peace Canyon Dam.

---

*sampling methods selected the larger fish and underestimated the abundance of smaller species (e.g. cyprinids).

The distribution and movement of fish in the Peace River is still poorly understood. However, some elements of a pattern have emerged from consultant data (Thurber Consultants Ltd., 1976; Renewable Resources Consulting Services Ltd., 1979). In general, rainbow trout, Arctic grayling, and Dolly Varden char are relatively more abundant in the upper reaches of the Peace River mainstem, upstream from the Moberly River, and suckers are proportionately more numerous in the lower reaches, downstream from the Moberly River. All four species are generally headwater spawners; rainbow trout may spawn in the mainstem, while the other three species are not believed to spawn in the Peace River mainstem. Mountain whitefish are common throughout the B.C. portion of the Peace River, and there is evidence that the mainstem is the major spawning area. Walleye are abundant in the heated effluent plume from the Taylor refinery dicharge, as well as at the mouths of the Beatton, Moberly, and Kiskatinaw Rivers. Walleye spawning sites have not been identified in the Peace River system. Goldeye are uncommon in the Peace River in British Columbia, but have been sampled at the mouth of the Beatton River and near the Alberta border. Goldeye spawning has not been confirmed, but is likely occurring in the Peace River mainstem. Northern pike and burbot are found throughout the Peace River. Pike probably spawn in side channels and burbot are believed to spawn in the mainstem (J. Hammond, personal communication).

Fish productivity in the Peace River is limited by low water temperatures, high levels of suspended solids, and recently by hydroelectric dams which have inundated spawning areas and blocked migration routes. To date, water quality degradation resulting from waste discharges has not been identified as a factor constraining fish production.

3.3 RECREATION

The Peace River plays an important role with respect to outdoor recreation for residents of the Peace region (M.O.E., 1982). Area residents appear to use the Peace River extensively, and more than all other rivers of the region combined. Sports fishing is the most significant of the water-associated activities on the Peace River, comprising an estimated 45 percent of the total recreation days. Boating, swimming, and canoeing combined account for only 10 percent of total recreation days; camping accounts for 14 percent; and sightseeing accounts for 31 percent. The demand for water-associated recreation and fishing is expected to increase in step with the population of the Peace region and tourism.

The major fisheries locations in the Peace region, in order of importance, are the Peace River, Williston Reservoir, and Charlie Lake (M.O.E., 1982). Approximately 30 percent of the regional total of angling days are provided by the Peace River mainstem. Sport fishing occurs at the tail-race of the Peace Canyon Dam, and on the Peace River where there is access and at the confluences of the major tributaries, such as Farrell Creek, Halfway River, Cache Creek, Pine River, Moberly River, Kiskatinaw River, and Beatton River. The area upstream from the Halfway River received most of the fishing effort and contained 59% of the anglers interviewed by Renewable Resource Consultants Ltd. (1979).

The entire length of the Peace River mainstem in British Columbia is used by boaters (canoeists, river-boaters) during the open-water season. Islands in the main channel and remote shore areas are used by the boaters for camping. Low water temperatures do not permit comfortable swimming, although back channels can be sufficiently warm for wading. There are no organized swimming areas in the Peace River, but there are swimming/wading areas used by local families and neighborhoods (Thurber Consultants Ltd., 1976). There has been no inventory of such areas valued as swimming holes. Swimming is known to occur at Peace Island Provincial Park near Taylor (B. Keilo, personal communication).

4. WASTE DISCHARGES

The most important waste discharges in this sub-basin are the treated sewage effluent from the City of Fort St. John (PE 388, PE 389) and the process and cooling water effluent from the Petro-Canada refinery at Taylor (PE 1379). Also assessed in this report are several smaller discharges which are not considered to be priority problems by the regional Waste Management Branch. These include the proposed Peace Canyon Coal Project (currently on hold), the treated sewage discharges from the B.C. Hydro facilities at the G.M. Shrum Generating Station (unpermitted) and the Peace Canyon Dam (PE 5240), and the Recreational Fisheries Branch Hatchery at the Peace Canyon Dam (PE 6372). A chemi-thermomechanical pulp mill is under construction at Taylor by Fibreco Export Inc. for completion in 1988. The mill's impact on the river is not assessed in this report. Details of the waste discharge permits issued by the Waste Management Branch for the Peace River mainstem are summarized in Table 5. The locations of these waste discharges are shown in Figure 3. Waste discharges to land are included where impact on surface water quality is possible. However, full assessment of groundwater quality is outside the scope of this study.

The term "initial dilution zone" used in this report is taken as defined by the Pollution Control Objectives (Province of British Columbia; 1974, 1975), i.e. as extending 100 m downstream from the point of discharge, but not exceeding 25 percent of the width of the water body. The term "mixing zone" is defined as extending downstream from the point of discharge to a point where complete mixing occurs. The latter zone may be shorter or longer than the former zone.

4.1 DIFFUSE (NON-POINT SOURCE) WASTE DISCHARGES

A large portion of the lands in the Peace River drainage are used for agriculture (especially, lands adjacent to the north bank). Grain, vegetable, and hay crops are the main agricultural activity, and are accompanied by heavy use of fertilizers and herbicides (primarily the phenoxy group).

Fertilizers and pesticides probably contribute the most significant non-point source waste loading to the Peace River mainstem (Girard, 1982). Data are unavailable as to the size of this non-point source contribution.

Diffuse suspended solids loading to the Peace River are also thought to be important by the regional Waste Management Branch. Logging, which is primarily conducted to the north of the Peace River, likely affects the nutrient and sediment regimes of the larger tributaries, such as the Beatton River and the Halfway River. Storm sewer discharges from the City of Fort St. John and the Villages of Hudson's Hope and Taylor also contribute to the suspended solids loading. Additionally, these storm sewers likely discharge hydrocarbons derived from the oils used as a road dust suppressant (Girard, 1982).

Oil has been spilled accidentally into tributary rivers and streams, and have travelled down the Peace River into Alberta (Girard, 1982; Keilo, 1984, personal communication). Oil spills are intermittent and unpredictable, and represent a continuing threat to the aquatic environment of the Peace River mainstem. Two examples of significant oil spills which have reached the Peace River follow:

- an oil battery (Norcen Pipeline Ltd.) overflow in July, 1979, sent oil down the Alces River and into the Peace River.
- a broken oil pipeline (Westcoast Pipeline Co., Ltd.) sent oil into Stewart Creek, a tributary to the Pine River, in May, 1977. The oil travelled the 65 km distance down the Pine River and into the Peace River.

Measurements of non-point source contributions to the Peace River sub-basin have not been made. Given the demonstrated importance of these sources in other areas, a future study of these in the Peace River is justifiable.

4.2 G.M. SHRUM HYDROELECTRIC GENERATING STATION (W.A.C. BENNETT DAM)

a) Description of Discharge

There are two treated sewage discharges to the Peace River from the G.M. Shrum Generating Station (both are unpermitted). One of these discharges is from the B. C. Hydro maintenance personnel washroom facilities at the powerhouse. The other discharge originates from tourist and staff washroom facilities at the control room. The two effluent streams each receive secondary treatment in separate aeration plants and are chlorinated prior to discharge into the tail-race below the W.A.C. Bennett Dam (Putsep, 1984).

Neither of these discharges is exempt under the Class A exemptions for municipal type discharges under the Waste Management Regulation since they discharge to surface waters. Both discharges should be placed under permit.

b) Present Waste Loads

B.C. Hydro effluent monitoring data for the period, October, 1979 to October, 1983, are summarized in Table 6. There are no data available for earlier periods of discharge. In addition, there are no Ministry of Environment effluent monitoring data for these discharges.

The results show that both treatment systems produced effluent of highly variable quality; however, these are very small discharges receiving high dilution in the tail-race of the W.A.C. Bennett Dam. Loading estimates are given in Table 6. These may be low since they were calculated using mean effluent flows, not maximum flow values (which are not available).

Flow. B.C. Hydro has only average flow data for the two discharges. Individual flow data have not been recorded. Average effluent flows are 0.91 m^3/d for the powerhouse discharge and 5.5 m^3/d for the control room discharge (Table 6). Effluent dilution at the minimum release flow (283 m^3/s) and average effluent flow would be $3.8x10^6$:1 for the combined discharges, after complete mixing.

$\underline{BOD_5}$. Six out of 10 BOD measurements for the powerhouse discharge and 3 out of 11 measurements for the control room discharge are greater than 45 mg/L. The powerhouse discharge is the lower quality discharge: average BOD values equalled 103 mg/L compared to 40 mg/L for the control room discharge. The maximum daily BOD_5 load for both discharges is estimated to be 1.3 kg/d (Table 6).

The high dilution and oxygenation available in the tail-race (the point of discharge) ensure that there will be no effect on the dissolved oxygen (D.O.) of the receiving waters. The maximum increase in receiving water BOD_5 is predicted to be $5.3x10^{-5}$ mg/L, after complete mixing:

$$\frac{1.3 \text{ kg/d}}{283 \text{ m}^3/\text{s} \times 86.4} = 5.3 \times 10^{-5} \text{ mg/L}$$

Suspended Solids. The powerhouse discharge is also the lower quality discharge with regard to suspended solids: all measurements have exceeded 60 mg/L, compared to 3 out of 11 measurements for the control room discharge. The maximum daily suspended solids load for both discharges is estimated to be 2.7 kg/d (Table 6). Under conditions of this loading and a minimum reservoir release flow of 283 m^3/s, the increase in receiving water suspended solids is estimated to be $1.1x10^{-4}$ mg/L, i.e., a non-measurable effect on receiving water quality.

Fecal coliform bacteria concentrations ranged from <10 to $5.4x10^5$ MPN/100 mL for the powerhouse discharge and from <10 to $5.6x10^4$ MPN/100 mL for the control room discharge. Using maximum theoretical loadings and assuming a minimum reservoir release flow of 283 m^3/s, the total increase in fecal coliform levels in the receiving waters (from both discharges) is predicted to be 0.03 MPN/100 mL (Table 6), a non-measurable effect on receiving water quality.

Chlorine residual levels have not been measured. This omission should be corrected in the future.

c) Future Waste Loads

No increase in the capacity of the waste discharge facilities at the G.M. Shrum Generating Station is expected in the near future. Thus, future waste loads would be equivalent to present waste loads.

4.3 PEACE CANYON COAL PROJECT

Cinnabar Peak Mines Ltd. has proposed to develop an open-pit coal mine in the Johnson Creek drainage which is on the south side of the Peace Canyon Reservoir, 17 km southwest of Hudson's Hope (see Figure 3). The proposed mine has a life expectancy of 15 years at a production rate of 0.9 million tonnes of thermal and metallurgical coal per year. The coal has been described as being of low sulphur content. Construction of the mine, which was to have started in 1983, has been delayed indefinitely as a result of infrastructure problems and depressed market conditions. No permits from either the Waste Management Branch or the Water Management Branch have been issued for any aspect of this proposed development.

A preliminary environmental impact assessment has been reported in a Stage I submission (Cinnabar Peak Mine Ltd., 1981). In keeping with the requirements of a Stage I report, many of the design and siting details have not been specified. However, the information provided does indicate potential detrimental effects on the lower reaches of Johnson Creek.

The potential sources of wastewater are as follows:

- excavation of the pit and construction of the surface facilities and waste dumps would alter local flow regimes and could increase suspended solids loading in the runoff to Johnson Creek.
- maintenance activities at the minesite and in the workshops could

contribute elevated levels of oil and grease to the runoff.

- the fugitive loss of nitrogen from explosives use in the pit could elevate nitrogen levels in the runoff. High levels of nitrate, nitrite, and ammonia could exceed toxic levels for aquatic life, and high levels of nitrate could reach the drinking water standard of 10 mg/L. It is possible, but unlikely that very high levels of nitrogen could contribute to nuisance algal growth since Johnson Creek is probably P-limited.
- disposal of domestic sewage (depending on the method chosen) could elevate phosphorus in the receiving waters to levels causing nuisance algal growth. Strict control of this element would have to be instituted to prevent excessive algal growth.
- acid generation from the coal and overburden, and the potential mobilization of toxic metals are significant issues which have not yet been addressed by the proponent.

A surface water management plan has not yet been submitted for this proposed mine, making it difficult to project the effects on water quality in downstream reaches of Johnson Creek or the Peace Canyon Reservoir. It is known that the lower 0.9 km of Johnson Creek contains the best sport fish spawning and rearing habitat within the confines of the Peace Canyon Reservoir (Cinnabar Peak Mines Ltd., 1981). Sportfish, such as rainbow trout, Dolly Varden char, Arctic grayling, mountain whitefish, and burbot, have been captured in lower Johnson Creek. The water quality of the Johnson Creek drainage and the Peace River receiving waters must be protected if this use is to be maintained.

Several aspects of the minesite development plan outlined in the Stage I report do indicate some degree of water quality mitigation:

- coal wash water from the preparation plan will be centrifuged and recycled, so that waste water from the coal treatment will not enter the surface water. Centrifuged fines will be land disposed, thereby eliminating tailings ponds.

- domestic sewage will not be associated with other plant water and will likely be discharged to a tile field.
- pit water will be pumped to the processing plant water-clarification system and will supply make-up water for the processing plants.
- minesite roads will be sprayed with water, not oil, for the purpose of dust abatement.
- there will be no surface stockpiling of clean or raw coal, thus eliminating problems with coal-storage-pile runoff.
- drainage from the waste rock dumps will probably be free of heavy metals contamination as the rock and coal are low in sulphur (averaging 0.72 percent S).

Although this mining project has been delayed for the forseeable future, water quality protection for Johnson Creek (in the form of water quality objectives) should be implemented in advance of construction. Water quality objectives would best be established for Johnson Creek during the environmental review process for the coal project, but prior to the issuance of Ministry of Environment permits and licenses. At that time, considerably more will be known about the water quality and water uses in Johnson Creek, and the potential for water quality impacts. This will permit the establishment of realistic water quality objectives.

4.4 RECREATIONAL FISHERIES BRANCH HATCHERY (PE 6372)

a) Description of Discharge

The Recreational Fisheries Branch (B.C. Ministry of Environment and Parks) operates a rainbow trout hatchery on the north bank of the Peace River at the site of the Peace Canyon Hydroelectric Generating Station (Figure 3). The hatchery has a production capacity of 70-80 000 trout fry annually for stocking in the Peace Canyon Reservoir (Dinosaur Lake), to compensate for the loss of natural production upstream from the dam.

The hatchery began operating and discharging on April 11, 1981. Waste Management Branch effluent permit PE 6372 was issued on July 16, 1982. The permit authorizes a year-round discharge of hatchery effluent to an unnamed creek which flows 300 m to the Peace River. This unnamed creek does not support a fish population, nor is it used for water supply or recreation. The effluent consists of fish excretory products, uneaten fish meal, and wastes from the cleaning of holding pens. The authorized limits of permitted effluent quality characteristics are as follows: BOD_5, 10 mg/L; total suspended solids, 5 mg/L; ammonia-N, 0.5 mg/L; nitrate-N, 1.2 mg/L; and total phosphorus, 0.2 mg/L.

b) Present Waste Loads

Effluent monitoring data, for the period June-September, 1982, are summarized in Table 7. Monitored characteristics have all been lower than the permitted levels, although the number of samples was small.

Hatchery outflow has not been recorded at the time of effluent sampling by regional Waste Management Branch personnel. One outflow value (846 m^3/d) was provided by N. Todd, Supervisor of Hatcheries, Recreational Fisheries Branch. This value is significantly lower than the permitted maximum of 1 310 m^3/d. Effluent dilution in the Peace River during the August seven-day average 10-year low flow (343 m^3/s; see Section 2.2c) for the present maximum hatchery outflow (1 310 m^3/d) would be approximately 23 000:1, after complete mixing.

All monitored effluent characteristics were less than or equivalent to the permitted maximum levels (Table 7). Estimates of maximum present loadings and predicted increases in receiving water (Peace River) concentrations are given in Table 7. With the large dilution available in the Peace River, even during low flows, there are not expected to be measurable increases in the receiving water concentrations of any of the permitted effluent characteristics.

c) Future Waste Loads

Future waste load projections have not been made for this discharge because it is not known, at this time, if the hatchery will undergo expansion. The fate of the hatchery will be determined by joint review between the Recreational Fisheries Branch and B.C. Hydro in 1986, at the end of the five-year pilot period. It is apparent, from the data presented in Table 7 that doubling or even trebling the discharge from the hatchery would have a negligible effect on Peace River water quality, outside of the initial dilution zone.

4.5 PEACE CANYON HYDROELECTRIC GENERATING STATION (PE 5240)

a) Description of Discharge

Waste Management Branch effluent permit PE 5240 authorizes B.C. Hydro to discharge treated domestic sewage from tourist and employee washroom facilities at the Peace Canyon Dam to the Peace River. This discharge is located 8 km upstream from the Village of Hudson's Hope. The effluent is treated in an extended-aeration sewage treatment plant and is chlorinated prior to discharge to the tailrace (where rapid mixing is assured). The permit allows a year-round maximum discharge of 13 m^3/d with BOD_5 of 100 mg/L and total suspended solids of 100 mg/L.

b) Present Waste Loads

Effluent monitoring data, available for the period November, 1978 to November, 1983, are summarized in Table 8. The maximum recorded effluent flow was 5.9 m^3/d (mean = 5.1 m^3/d), approximately half of the permitted daily maximum (13 m^3/d). Dilution of this small discharge in the Peace River under low flow condition (August 7-day, 10-year low flow = 343 m^3/s; see Section 2.2c) would be greater than $5x10^6$:1. No effects on downstream water quality are conceivable outside of the initial dilution zone.*

---

* defined as extending 100 m downstream from the discharge but not exceeding 25 percent of the river width.

Of the 10 BOD_5 values recorded, only one value (216 mg/L) exceeded the permit level of 100 mg/L. The maximum present BOD_5 load (1.3 kg/d) was estimated to be equal to the permitted load (Table 8). Ten measurements of suspended solids were taken (9-180 mg/L), and three of these measurements exceeded the permitted maximum of 100 mg/L. The maximum present suspended solids load was estimated to be 1.1 kg/d, less than the permitted load of 1.3 kg/d (Table 8). Neither BOD_5 loading nor suspended solids loading are predicted to result in measurable increases in receiving water concentrations (Table 8).

Chlorine residual levels reached a maximum of 0.3 mg/L (of 7 values). The maximum chlorine residual loading is not predicted to produce a measurable level in the receiving waters (Table 8).

Nitrogen and phosphorus levels in the effluent are also given in Table 8. Under conditions of maximum present loading for these characteristics and minimum Peace River flows, it is expected that there will be no measurable increase in receiving water concentrations, after complete mixing has occurred (Table 8).

Total and fecal coliform levels in the effluent are given in Table 8. Under conditions of maximum present loading and minimum Peace River flows, the increase in receiving water level for both total and fecal coliform bacteria is expected to be less than 0.1 MPN/100 mL (Table 8). From these data, it is apparent that this discharge does not present a health hazard to the community water supply for the Village of Hudson's Hope, 8 km downstream.

c) Future Waste Loads

There is not expected to be an increase in the discharge quantity authorized by permit PE 5240 in the near future. Future waste loads can be presumed to be equal to present waste loads.

4.6 THE VILLAGE OF HUDSON'S HOPE

There is no discharge of domestic sewage into the Peace River from the Village of Hudson's Hope. Sewage treatment is provided by two 2.2 ha oxidation ponds plus a single 0.4 ha exfiltration pond. The ponds are located approximately 900 m north of the Peace River. This discharge to ground is authorized by Waste Management Branch effluent permit PE 411.

Use of only one of the oxidation ponds was designed to service a population of 1 500 to 2 000, while bringing the other oxidation pond on-line would double the service capacity (Waste Management Branch permit file, Victoria; Cinnabar Peak Mines Ltd., 1981). Hudson's Hope had an estimated 1982 population of 1 405. The population is projected to increase to 1 715 in 1987 and to 2 094 in 1992 (Table 9; Stone, 1982). Thus, the present lagoon and exfiltration system has abundant capacity to service the projected population to 1992 and well after that. The discharge of sewage from Hudson's Hope to the Peace River is not imminent. Sludge has not been removed from the ponds in the past and removal is not forseen for the near future (R. Porter, personal communication).

4.7 THE CITY OF FORT ST. JOHN (PE 389; PEACE RIVER DISCHARGE)

The City of Fort St. John had an estimated 1982 population of 14 184. The population was projected to increase to 18 522 in 1987 and 22 565 in 1992 by Stone, Table 9; 1982). Agriculture, forestry, transportation, and the oil and natural gas industry are the dominant sectors in the economy of Fort St. John. However, in the past few years the population has actually declined due to inactivity in the oil and gas industry. The 1985 population was estimated to be 13 493. By 1990, the population is projected to be 14 897 assuming a two percent growth rate over the 1985 estimate (Table 9).

Two separate sewage treatment systems serve the City of Fort St. John. The north system (see Section 4.8) discharges treated effluent to the Beatton River during the period, April 1-June 30, under Waste Management

Branch Permit PE 388. The south system (covered in this section), treats and discharges 65 percent of the City's effluent to the Peace River on a year-round basis.

a) Description of Discharge

The south sewage treatment system was authorized initially by provisional permit PE 244 (issued in August, 1968), which specified primary treatment. This was superseded by the present permit (PE 389) issued in March, 1971. The permit, at that time, required installation of secondary treatment works by December, 1972. These were installed as required and produced reasonable effluent quality (Waste Management Branch permit file, Victoria). The treatment facility consisted of four anaerobic and four aerobic lagoons which had sufficient capacity to retain all effluent generated between October 31 and May 1 each year. Discharge to an unnamed tributary to the Peace River occurred during the balance of the year. However, because of infiltration problems and rapid population growth, the system's capacity to retain six months effluent flow was exceeded. A lagoon berm failure occurred in August, 1976 and continuous discharge was deemed necessary.

Permit PE 389 was amended on March 14, 1980, allowing year-round discharge directly to the Peace River through an enclosed pipe ending with a diffuser in mid-channel. The outfall is located 12 km upstream from the community water supply intake for the Village of Taylor. Permitted BOD_5 levels were upgraded to 45 mg/L from 50 mg/L and suspended solids were downgraded from 25 mg/L to 60 mg/L on the amended permit. The new effluent pipeline and outfall eliminated open discharge of sewage to an ephemeral tributary stream, and resulted in improved effluent dispersion in the Peace River. The amended permit required the installation of continuous flow recording equipment and the upgrading of facilities for year-round chlorination. The lagoon system operated on a continuous discharge basis, and provided a minimum of eight days of anaerobic treatment and 120 days of aerobic treatment at a permitted flow of 5 180 m^3/d.

Permit PE 389 was again amended on July 18, 1985. In an attempt to improve effluent quality, the lagoon system was redesigned in October, 1983. The permit amendment was to reflect the increased treatment aeration due to the installation of six aerators in three anaerobic lagoons, and to reflect the short circuiting of the storage lagoons in the winter. The works authorized are one aerobic cell, three anaerobic/aerated cells, two facultative lagoons, chlorination facilities, continuous flow recording equipment, and the outfall with diffuser to mid-channel of the Peace River. The permitted flow, BOD, and suspended solids levels remained unchanged. The operation of the treatment system now varies seasonally:

Winter:

a) anaerobic cell, retention 2 1/2 days
b) 3 aereated cells, retention 7 1/2 days
c) aerobic cell, short circuit across
d) aeration and chlorination

Summer:

a) anaerobic cell, retention 2 1/2 days
b) 3 aerated cells/anaerobic cells, may operate either way, retention 7 1/2 days
c) aerobic cell, surface area 35 acres, retention 42 days
d) aerobic cell, surface area 16 acres, retention 23 days
e) chlorination

b) Present Waste Loads

Ministry of Environment and Parks effluent monitoring data for the period April, 1973, to June 1985, are summarized in Table 10. The data are presented for three time intervals: prior to March, 1980, when the effluent was discharged to the unnamed stream; after March, 1980, when the effluent was discharged directly to the Peace River; and after October, 1983, the time of lagoon redesign. The results demonstrate that effluent quality deteriorated when the treatment system switched from lagoon storage to continuous year-round discharge, but has improved since 1983.

Flow. Daily effluent flow data for this discharge are not available in a tabulated form. The City of Fort St. John monitors the discharge on a daily basis, but has not removed the data from the flow-meter charts. The City of Fort St. John does provide the Waste Management Branch with a total lagoon outflow value for each year (Table 11).

For the period prior to 1980, the Waste Management Branch recorded one flow measurement: on July 4, 1973, effluent flow was 5 500 m^3/d. For the years 1981 to 1983, the mean daily discharge (calculated from the annual total lagoon outflow) ranged from 3 234 m^3/d to 4 745 m^3/d (Table 11). A review of the flow-meter chart for the year 1982, showed that the maximum daily discharge was 11 365 m^3/d recorded on August 26 (more than twice the permitted level).

Flow-meter charts were analyzed for the periods, January 4-December 31, 1983 and January 4-April 10, 1984. The maximum daily discharge recorded in 1983 was 11 252 m^3/d (August 19, 1983). The mean daily discharge for 1983 was 3 466 m^3/d. The maximum daily discharge recorded in 1984 (January-April) was 6 365 m^3/d (April 3), and the mean daily discharge was 4 773 m^3/d (Table 11). Eighteen percent (51 out of 278) of the effluent flow measurements recorded in 1983 exceeded the permitted maximum level of 5 180 m^3/d. Of the effluent flow measurements available for 1984, 38 percent (34 out of 90) exceeded the permitted maximum level.

At the maximum effluent flow recorded (11 365 m^3/d), effluent dilution in the Peace River, after complete mixing, would be 3 315:1 during the 1-in-10 seven-day average August low flow and 6 698:1 during the mean seven-day average August low flow (see Section 2.2d for low flows).

At the permitted effluent flow (5 180m^3/d), effluent dilution in the Peace River, after complete mixing, would be 7 272:1 during the 1-in-10 seven-day average August low flow and 14 700:1 during the mean seven-day average August low flow.

<u>BOD_5</u>. While only 21 percent (7 out of 33) of the BOD_5 values exceeded the permit level (50 mg/ L) before 1980, 51 percent (22 out of 42) of the BOD_5 values exceeded the upgraded permit level (45 mg/L) between system modification in 1980 and 1983. BOD_5 values averaged 33 mg/L for pre-modification effluent and 63 mg/L for the post-modification effluent. The BOD_5 concentrations before and after outfall construction in 1980 (up to 1984) are significantly different ($t = 3.2$, $t_{.05(74)} = 1.9$). These data suggest that the lower retention time inherent in the continuous discharge pattern may have been responsible for the decreased effluent quality. Seasonality does not appear to be involved. Thirteen of the BOD_5 values that exceeded permitted levels between 1980 and 1983 occurred in the winter (December to March) when the lagoons would be ice-covered and less oxygenated and 12 of the values occurred during the spring (April to June) when ice-cover would not be a problem. After the 1983 lagoon redesign, BOD_5 values averaged 17 mg/L. Only one value (53 mg/L) was in excess of the permit requirement of 45 mg/L.

The maximum 1980-1983 daily BOD_5 load (1 419 kg/d) was six times higher than the permitted loading level of 233 kg/d (Table 12). The 1980-1983 average daily BOD_5 load (298 kg/d; calculated from an average concentration of 63 mg/L) also exceeded the permitted loading level. The maximum BOD_5 load calculated for the present period (after lagoon redesign) was 292 kg/d. However, given the large dilution available in the river, the effect of three BOD_5 loadings on dissolved oxygen (D.O.) in the river was minimal. Assuming that a maximum BOD_5 loading (1 419 kg/d) occurred during the August low flow period, the theoretical increase in the receiving water BOD_5 concentration was calculated to be 18 µg/L (Table 13). During the winter low flow (October-April), the predicted maximum increase in receiving water BOD_5 concentration was calculated to be 20 µg/L. With a maximum BOD_5 load of 292 kd/g for the present period (after lagoon redesign in 1983), the predicted increase in receiving water BOD_5 concentrations would be only 5 µg/L. Assuming that there is complete mixing of effluent and river water outside of the initial dilution zone, this discharge (PE 389) should have no effect on the dissolved oxygen regime of the Peace River. This is borne out by actual receiving water BOD_5 measurements: during September-October, 1980, after construction of the diffuser outfall, BOD_5 levels downstream from the outfall were <10 mg/L (Table 14).

Suspended Solids. Prior to 1980, 40 percent (11 out of 32) of the monitored suspended solids values exceeded the permit limit of 25 mg/L. After the permit value was downgraded to 60 mg/L in 1980, only one of 39 measurements exceeded the limit (Table 10). The 1980 modification of the treatment system had no effect on suspended solids concentrations. Although average concentrations decreased from 32 mg/L (pre-1980) to 26 mg/L (1980-1983), there is no statistically significant difference between the two data sets ($t=1.0$, $t_{.05}$ $(66) = 2.0$).

A maximum suspended solids load of 232 kg/d for the 1980-1983 period was recorded on March 3, 1982. This loading was 75 percent of the permitted loading of 310 kg/d (Table 12). Under conditions of such a loading, the theoretical maximum increase in receiving water suspended solids was calculated to be 0.006 mg/L during the August low flow and 0.005 mg/L during the October-April low flow (Table 13). For present conditions (post 1983) with a maximum suspended solids loading of 324 kg/d (Table 12), the theoretical maximum increase in suspended solids levels would be 0.005 mg/L during the August low flow and 0.004 mg/L during the October-April low flow. This discharge is not predicted to have any effect on the suspended solids regime of the Peace River (outside the initial dilution zone). Redesign of the lagoons in 1983 has improved the suspended solids levels in the effluent (none of the 20 measurements post-1983 exceeded the permitted level of 60 mg/L).

Nitrogen values suggest that the effluent may have been undergoing less nitrification between 1980 and 1983 (after installation of the new outfall and the change to a continuous discharge regime). Although the number of samples is small, it appears that ammonia-N levels increased from a pre-1980 mean of 11.7 mg/L (n=5) to a 1980-1983 mean of 23.5 mg/L (n=3) Whether the lower nitrification is a result of a shorter lagoon retention time or due to seasonality (the three 1980-1983 BOD_5 values were from late March when ice-cover may be present) is unknown at this time. After 1983, ammonia-N returned to lower levels with a mean of 15.6 mg/L (Table 10). Nitrite/-nitrate levels have concomitantly decreased from a pre-1980 mean of 0.15 mg/L (n=2) to a 1980-1983 mean of 0.025 mg/L (n=4). There are no nitrite/-nitrate data available for the present (post-1983).

A maximum actual ammonia-N load of 220 kg/d was recorded on March 11, 1981 (Table 12). At this loading under conditions of winter (October-April) and mid-summer (August) 7-day average low flows, the maximum increase in receiving water concentration is predicted to be 3-3.5 µg/L (Table 13). For present conditions (post-1983) with a maximum ammonia-N loading of 121 kg/d (Table 12), the theoretical maximum increase in the concentration of ammonia-N would be 1.5 µg/L during the August low flow and 2 µg/L during the October-April low flow. A maximum actual nitrite/nitrate load of 0.3 kg/d was recorded on March 11, 1981 (Table 12). The predicted increase in receiving water nitrite/nitrate levels at low flows was calculated to be in the range of 0.003-0.004 µg/L (Table 13). These predicted increases of receiving water nitrogen levels would not impair Peace River water quality for downstream uses.

There are presently insufficient water quality data to verify the prediction of negligible nitrogen level increases. Ammonia-N levels upstream from discharge PE 389 have ranged from <0.005 to 0.023 mg/L (n=7) for the period 1971-1974 at sites 0400134-0400136, while levels downstream at sites 0400492-0400492 have ranged up to 0.07 mg/L (n=3) for the period 1974-1980 (Tables 14 and 15). The low number of samples and the absence of paired data make upstream/downstream comparisons difficult in this case. Additionally, these data were recorded before the installation of the diffuser outfall, which would act to increase effluent dispersion.

<u>Phosphorus</u>. Total phosphorus levels in the effluent averaged 4.2 mg/L (range 3.0-5.1 mg/L) before the treatment system alterations in 1980, and 6.3 mg/L (5.7-7.0 mg/L) after the treatment system alterations for the

period 1980-1983 (Table 10). Dissolved (ortho-) phosphorus levels also showed an increase: from an average of 4.8 mg/L (n=4) before treatment system changes to an average of 5.6 mg/L (n=3) after treatment system alterations for the period 1980-1983 (Table 10). Total dissolved phosphorus has decreased from a 1980-1983 mean of 5.8 mg/L (n=3) to 4.0 mg/L (n=3) after 1983.

A maximum actual dissolved ortho-phosphorus loading of 50 kg/d occurred on March 11, 1981 (Table 12). At this loading, receiving water concentrations are predicted to increase by only 0.7-0.8 µg/L during both the mid-summer (August) and winter (October-April) low flow periods (Table 13). This predicted level of increase would not have a measurable effect on downstream water quality. Paired upstream/downstream receiving water phosphorus data are needed to verify the predicted increase.

Fecal Coliform bacteria concentrations in the effluent were high until changes were made to the treatment system in 1983. Fecal coliform levels averaged 48 MPN/100 mL and ranged up to 24 000 MPN/100 mL before treatment system modification in 1980. After the modification in 1980 (up to 1983), fecal coliforms averaged 2 982 MPN/100 mL and ranged up to 920 000 MPN/100 mL (Table 10). After 1983, the redesigned treatment system showed marked reductions in fecal coliform levels. Fecal coliform counts have been consistently below detection (<2 MPN/100 mL, n=17) in the effluent (personal communication, B. Carmichael).

A maximum actual fecal coliform loading of 3.1×10^{13} MPN/d occurred on December 14, 1981 (Table 12). With this loading, the theoretical maximum increase in receiving water fecal coliform level would be 41 MPN/100 mL during the August low flow and 49 MPN/100 mL during the October-April low flow (Table 13). These levels presume complete mixing of effluent with river water and no die-off or increase of fecal coliforms (which may not be realistic). Increases in fecal coliforms could impair the downstream use of Peace River water by the Village of Taylor for its domestic water supply 12 km downstream. Since Taylor's water supply is filtered by an infiltration gallery (Section 3.1) and then chlorinated, ambient fecal coliform levels of <100 MPN/100 mL (30 day, 90th percentile) should protect this water use (M.O.E., 1980; p. 24).

There are presently insufficient data to verify the predicted increases in fecal coliform level downstream from discharge PE 389. Fecal coliforms have ranged up to 130 MPN/100 mL for the period 1971-1974 upstream from the discharge, and 200 MPN/100 mL for the period 1974-1980 downstream from the discharge (Tables 14, 15). The latter suggest that the Peace River outside the initial dilution zone would be safe for swimming (i.e. <200-400 MPN/100 mL; Richards, 1983). More paired upstream/downstream data are necessary to verify these predictions and to evaluate the new outfall and redesigned lagoons.

<u>Chlorine Residual</u> levels in the effluent are not specified by permit, although the permit does specify that the effluent shall contain no toxic chemicals. Chlorine residual levels in the effluent have ranged from <0.1 to 1.8 mg/L. There was one anomalous value of 20 mg/L. Receiving water chlorine residual levels have not been measured.

If the effluent permit specified a maximum effluent chlorine concentration of 3 mg/L, as recommended by the Pollution Control Objectives for municipal-type waste discharges (M.O.E. 1975), chlorine loading to the Peace River, under conditions of maximum effluent flow, would be in the order of 34 kg/d (Table 13). This loading would translate to a receiving water concentration of <1 µg/L after complete mixing during both the August and October-April low flows (Table 13). Thus, the recommended effluent objective limit of 3 mg/L effluent chlorine residual provides more than sufficient protection for downstream water uses.

<u>Metals</u> levels (chromium, copper, lead, and zinc) were monitored only twice, on April 13 and 22, 1981, after construction of the Peace River outfall. Maximum metals levels are not specified in the permit, although there is a specification that the effluent contain no toxic chemicals.

Total chromium levels were <5 and 6 μg/L. Total copper levels were 0.04 and 0.05 mg/L. Total lead values were 8 and 10 μg/L, and total zinc was 0.05 and 0.07 mg/L (Table 10). Maximum actual loadings for these metals are shown in Table 12.

Predicted increases in receiving water metals concentrations after complete mixing are given for two low flow periods in Table 13. Receiving water total chromium levels could be elevated only by <0.001 μg/L. If added to background levels which are in the range of 0.005-0.007 mg/L, the resultant level would not be high enough to impair the most sensitive water use (aquatic life criterion of 20 μg/L).

Receiving water total copper concentrations are presently less than 10 μg/L. An additional 0.005 μg/L increase as predicted in Table 13, would not be a significant increase nor would it impair downstream water quality. Receiving water total lead levels could increase by <0.001 μg/L during low flow conditions (Table 13). This would not constitute a significant increase nor would it impair water quality since ambient total lead levels are low (<4 μg/L) (Table 15).

Receiving water zinc levels could be increased by 0.008 μg/L after complete mixing during low flow conditions (Table 13). Background zinc levels in the Peace River reach 30μg/L (Table 15), and such a theoretical increase would be insignificant.

c) Future Waste Loads

Projected future waste loadings for the key characteristics of discharge PE 389 are presented in Table 12. The future loadings for 1990 were estimated using 2 percent annual increases in maximum present loadings equal to the estimated percentage increase in the population of Fort St. John. The future waste loads given in Table 12 are based on the assumption that the trend of maximum present actual loadings continues into the future.

Future increases in Peace River receiving water concentrations during the August low flow are given in Table 13. Future increases in receiving water concentrations for all key characteristics except fecal coliform bacteria are predicted to be negligble. There should be no discernable impairment of Peace River water quality due to effluent BOD_5, suspended solids, chlorine residual, ammonia-N, nutrients, or metals (outside the mixing zone). However, if future fecal coliform loading is predicted from past maximum loads, then effluent fecal coliform levels could impair downstream water quality. Once complete mixing has occurred, receiving water fecal coliform concentrations could increase by 141 MPN/100 mL (Table 13). This is within the 200/400 MPN/100 mL guideline for swimming (Richards, 1983), but is too high for the downstream Taylor intake (100 MPN/100 mL, 90th percentile). More recent post-1983 data supplied by the Region (B. Carmichael, personal communication) indicate that fecal coliforms cannot be detected in the effluent, and thus there would be no impairment of Peace River water quality. The contradictory evidence indicates that further monitoring should be undertaken to verify predicted increases. If the predictions made from pre 1983 data are accurate, there is the need for improved and consistent chlorination of the effluent in the near future to protect downstream domestic use by the Village of Taylor. Additional protection of Taylor's drinking water will be provided by filtration and chlorination at the pumphouse intake.

4.8 THE CITY OF FORT ST. JOHN (PE 388; BEATTON RIVER DISCHARGE)

The City of Fort St. John is split by a ridge which effectively divides the city into two drainage areas for the purpose of municipal effluent discharge. The southern portion of the city discharges effluent to the Peace River (Section 4.7). The northern portion (covered here) discharges approximately 35 percent of Fort St. John's sewage effluent to the Beatton River under Waste Management Branch permit PE 388.

a) Description of Discharge

Permit PE 388 was issued on March 18, 1971, and authorized a maximum discharge of 16 818 m^3/d for the period May 1 to June 30. The effluent quality was specified as BOD_5 of 50 mg/L and suspended solids of 25 mg/L.

On May 26, 1982, the permit was amended to increase the discharge period by one month (April 1 to June 30). Maximum effluent flow was reduced to 11 000 m^3/d, and effluent characteristics were changed to BOD_5 of 45 mg/L and suspended solids of 60 mg/L. The treatment system consists of four anaerobic and four aerobic lagoons discharging through a 2.5 km long pipeline to the Beatton River. The outfall is located 2.5 km upstream from the Beatton River highway bridge, and 36 km upstream from the Peace River. The effluent is not chlorinated.

b) Present Waste Loads

Ministry of Environment and Parks effluent monitoring data for the period June, 1974 to May, 1983, are summarized in Table 16.

Flow. Daily effluent flow data are not available for this discharge. Recurrent vandalism of the effluent flow metering facility has prevented the City from submitting daily flow records, according to R. Harcombe (personal communication). Total effluent outflow for the discharge period has been estimated from the lagoon storage volume for 1981 and 1982. In 1981, there was a total effluent discharge of 810 000 m^3 and an average daily discharge of 13 300 m^3/d, assuming a constant effluent flow over the 61 day discharge period (May 1-June 30). In 1982, there was a total discharge of 756 000 m^3 and an average daily discharge of 8 307 m^3/d, assuming a constant effluent flow over the 91 day discharge period (April 1-June 30). Both of these estimated average daily discharge values were less than the permitted flows for 1981 and 1982.

At the present maximum permitted effluent flow of 11 000 m^3/d, effluent dilution would be 87:1 during the 1-in-10 year 7-day average low flow and 292:1 during the mean 7-day average low flow for the Beatton River during the spring discharge period (see section 2.2d), after complete mixing.

It appears that effluent discharge has proceeded past the June 30 cut-off date. Review of the effluent quality data has shown that, in the past, samples of the discharge have been taken in mid-summer (e.g., July 9, 1979 and August 18, 1977).

$\underline{BOD_5}$. Only one out of 14 BOD_5 values recorded since 1974 exceeded the permit maximum of 45 mg/L: on July 9, 1979, BOD_5 equalled 185 mg/L. This value is suspect because it deviates excessively from the mean (23.6 mg/L). However, it is retained here for the purpose of constructing a worst-case projection.

More recent data (March, 1984 - June, 1985) supplied by the Region (B. Carmichael, personal communication) have also been low (1-12 mg/L; n=7). The maximum daily BOD_5 load is estimated to be 2 035 kg/d using the value of 185 mg/L (Table 16), more than four times the permitted loading. Since this loading value was calculated from an outlying maximum concentration and the maximum permitted effluent flow, it is likely an overestimate of actual loadings.

Under the extreme theoretical conditions of such a maximum loading during an "end-of-freshet" mean low flow (37.2 m^3/s; see definition p.6), the maximum receiving water BOD_5 increase is predicted to be 0.63 mg/L (Table 17). This is not a significant increase, and would not be expected to reduce Beatton River dissolved oxygen (D.O.) to levels toxic to fish or other aquatic life. The predicted value assumes that 1) water temperature = 20°C, 2) no re-aeration occurs, and 3) travel time to the river mouth = 5 days. If the variable effects of re-aeration, lower temperatures, and BOD exertion during the travel time from the waste source are considered, the predicted D.O. depletion would be even less than 0.6 mg/L. The lowest D.O.

value recorded in the Beatton River at site 0400145 downstream from the discharge during the discharge period was 8.2 mg/L (Table 18). Water quality samples (including D.O.) have not been taken at this site since 1974.

Suspended Solids. Prior to May, 1982, 5 out of 10 of the suspended solids values exceeded the original permit level of 25 mg/L. Since permit downgrading to 60 mg/L of suspended solids, none of the measurements taken have exceeded the new limit. Between 1974 and 1983, suspended solids ranged from 6 to 222 mg/L, and averaged 44 mg/L (Table 16). Recent data (1984-1985) not included in Table 16 indicates that suspended solids ranged from 4-11 mg/L (B. Carmichael, personal communication).

The maximum daily suspended solids load has been estimated to be 2 442 kg/d, nearly four times the permitted loading of 660 kg/d (Table 16). Under extreme conditions of this maximum loading during an "end-of-freshet" mean low flow, the maximum increase in receiving water suspended solids concentration is predicted to be 0.76 mg/L after complete mixing (Table 17). Since ambient levels of suspended solids in the Beatton River can be high during the effluent discharge period (measured up to 2 229 mg/L), this theoretical increase would not impair downstream Beatton River water quality.

Fecal Coliform bacteria concentrations in the effluent ranged from 5 to 4 000 MPN/100 mL over the period, 1974-1983 (Table 16). Prior to May, 1982, when the new permit was issued, effluent fecal coliform densities ranged from 5 to 20 MPN/100 mL (n=4). Between May 1982 and May 1983, fecal coliform densities ranged from <200 to 4 000 MPN/100 mL (n=3). These high coliform levels were measured during periods of ice-cover (B. Carmichael, personal communication).

The maximum fecal coliform load is predicted to be 4.4×10^{11} MPN/d (Table 16). Under conditions of a mean low river flow during the discharge period, such a loading would translate to a theoretical increase in receiving water fecal coliform concentration of 14 MPN/100 mL (Table 17).

This increase, if confirmed, may necessitate filtration or equivalent treatment plus disinfection necessary prior to the use of downstream Beatton River water for domestic drinking water (B.C. Ministry of Health, 1982). The Beatton River is naturally turbid during the April-June effluent discharge period, and thus filtration would be necessary prior to drinking the water in any case. There are no plans to use the Beatton River as a source of domestic water supply. The predicted worst-case fecal coliform level is well within the 200-400 MPN/100 mL guidelines for swimming (Richards, 1983).

Nitrogen. Ammonia-N levels in the effluent averaged 1.7 mg/L, and ranged from 0.9 to 3.0 mg/L during the period June, 1974 to June, 1975 (Table 16). More recent data for the period March, 1984 to June 1985, show that ammonia-N levels ranged from 1.6 to 13.6 mg/L (n=3) (B. Carmichael, personal communication). The maximum daily ammonia-N load has been calculated to be 150 kg/d using the recent maximum value of 13.6 mg/L. The theoretical maximum increase in receiving water ammonia-N levels has been calculated to be 0.05 mg/L for the mean 7-day average low flow during the spring discharge period (Table 17). The maximum level of un-ionized ammonia-N would be much lower (i.e. <0.003 mg/L) and could not be considered toxic to aquatic life.

Nitrite/nitrate-N levels in the effluent ranged from 0.14 to 0.9 mg/L (n=3) over the period 1974-1975, and from 0.03 to 0.09 mg/L (n=2) during 1985. There are no nitrite/nitrate data for the interim period 1975-1983. Using the maximum concentration recorded (0.9 mg/L), the maximum theoretical nitrite/nitrate-N load is estimated to be 10 kg/d (Table 16). Under conditions of this loading during an "end-of-freshet" low flow, the maximum increase in receiving water nitrite/nitrate-N concentration is predicted to be 3 µg/L (Table 17). Such an increase would not impair downstream water quality. Nitrite/nitrate-N levels at site 0400145 ranged from <0.02 to 0.04 mg/L for the period 1973-1974 (Table 18).

Phosphorus. Total phosphorus levels in the effluent ranged from 0.5 to 5.7 mg/L, and averaged 2.3 mg/L for the period 1971-1974 (Table 16). A more recent measurement of 5.1 mg/L (June 26, 1985) was provided by Region (B. Carmichael, personal communication). The maximum daily total phosphorus load has been calculated to be 63 kg/d. Under mean low flow conditions during the spring discharge period, this total phosphorus loading would result in a maximum receiving water increase of 20 µg/L (Table 17).

Receiving water total phosphorus levels for the Beatton River near its mouth have reached up to 1.9 mg/L (Tables 18,19). These high levels are likely related to the high suspended solids concentrations in the Beatton River. Dissolved phosphorus levels are more biologically meaningful. Dissolved phosphorus has ranged from 21 to 79 µg/L. Under the right conditions, these levels of available (dissolved) phosphorus could cause a problem with algal growth. Light is probably a limiting factor in spring due to high turbidity (see Tables 18,19). There have been no observations of downstream algal growth to indicate whether it has reached the proportions of a visible problem.

c) Future Waste Loads

Projected future waste loads for key characteristics of discharge PE 388 are presented in Table 16. The future waste loads for 1990 were estimated from two percent annual increases in maximum present loadings equal to the estimated percentage increase in the population of Fort St. John. These waste load estimates are tenuous, since they were not derived from actual present loadings using recent data, and may not reflect realistic increases in population growth.

Future increases in Beatton River receiving water concentrations during the spring discharge period low flows are given in Table 17. Two scenarios are presented: one assumes that effluent characteristics comply with permitted levels; and the other assumes a trend continuing from present maximum loadings. In the first case, assuming permit compliance for the discharge in 1992, there will be negligible increases in receiving water BOD_5 (0.15 mg/L) and suspended solids (0.2 mg/L). In the second case, if present extreme loadings continue to 1992, we might expect:

- an effluent flow of 12 100 m^3/d. During an "end-of-freshet" (April 1 - June 30) low flow, effluent dilution would be 256:1 in 1990.
- a slight increase in receiving water BOD_5, but not sufficient to lower ambient D.O. to levels toxic to aquatic life. The requirements for the complete exertion of the small predicted 1990 BOD_5 increase (0.7 mg/L) would not be realized.
- a theoretical maximum increase in receiving water suspended solids of only 0.8 mg/L - insufficient to degrade downstream water quality.
- an increase in receiving water fecal coliforms of 15 MPN/100 mL, a level which would permit swimming, although domestic use would require filtration and disinfection.
- an increase in receiving water ammonia-N levels of 0.05 mg/L: too low to cause toxicity problems with un-ionized ammonia-N.
- a theoretical increase in total phosphorus (21 µg/L) but limiting factors such as light would prevent the growth of downstream nuisance algae.
- a negligible increase in nitrite/nitrate-N concentrations (3 µg/L).

4.9 THE VILLAGE OF TAYLOR

The Village of Taylor no longer discharges municipal sewage effluent to the Peace River. Since 1973, the Village has discharged its effluent to a 2-cell exfiltration and evaporation lagoon system, located on the north boundary of the Petro-Canada refinery. The lagoon is 1.5 km north of the Peace River and 150 m west of an unnamed tributary to the Peace River. This discharge to the ground is authorized by Waste Management Branch permit PE 1836, issued on December 19, 1973. The permit specifies a BOD_5 of 45 mg/L and suspended solids of 60 mg/L within the ponds. In addition to sewage from the Village, the Petro-Canada refinery contributes its settled domestic sewage to the lagoons.

Before the installation of the exfiltration basins, sewage from the Village flowed into a septic tank (constructed in 1959) and was discharged into an unnamed tributary to the Peace River at a point 2 km upstream from the confluence. The tributary could not provide 20:1 dilution and the septic tank provided poor treatment (PE 1836 permit file, Waste Management Branch, Victoria). The septic tank has since been removed from the treatment system.

At present, the Village of Taylor with a 1984 population of 1 081 (Stone, 1982) uses only one lagoon or approximately 50 percent of the capacity of the treatment system (B. Keilo, 1984; personal communication). The full capacity of the system would be reached upon doubling of the population which is not projected to occur until the mid-1990's. If required, there is room to expand the exfiltration basins. There should be no need in the near future to resume a direct discharge to surface waters.

4.10 PETRO-CANADA INC. (TAYLOR REFINERY)

The Petro-Canada operates a refinery, a natural gas processing plant and a natural gas liquids extraction plant located approximately 15 km southeast of Fort St. John on the north bank of the Peace River and east of Highway 97 across from the Village of Taylor. Petro-Canada Inc. purchased the refinery from Pacific Petroleums Ltd. in 1980, and also operates the natural gas processing plant which is owned by Westcoast Transmission Co. Ltd. The natural gas plant went into production in 1957, and the refinery started in 1958.

The refinery process used by the Petro-Canada refinery can be classified as topping and catalytic reforming and cracking (Cote, 1976). The marketed products include gasoline, diesel fuel, and residual (bunker oil). The refinery has a maximum throughput capacity of $<4\ 500\ m^3/d$ (liquid petroleum gas, crude charge, and condensate products) (PE 1379 permit file, Reports Library, Waste Management Branch, Victoria).

a) Description of Discharge

All effluent from the refinery and natural gas processing plant is discharged to the Peace River through a 1 m diameter submerged pipe placed The discharge pipe does not have a diffuser. The effluent includes:

i) Storm Run-off from roofs, roads, and undeveloped and developed areas. Refinery run-off is usually uncontaminated, except for low amounts of oil and grease (Cote, 1976). Various surface drainage ditches send the run-off to a settling bay to remove suspended solids and then to a retention pond before being discharged in combination with the cooling water and process effluent (see Figure 6).

ii) Cooling Water used on a once-through basis. Refinery cooling water is elevated in temperature, but usually oil-free, although traces of oil can enter the cooling water from occasional leaks in the heat exchangers until repairs are made. Cooling water may also be contaminated with treatment chemicals (chlorine, biocides, chromate solutions, polyphosphates, zinc, sulphates) and heavy metals from corrosion inhibitors (if added) or as products of corrosion (Cote, 1976).

The cooling water at the Petro-Canada refinery is intercepted by oil skimming bays before being discharged in combination with the surface run-off and process effluent (Figure 5). Petroleum hydrocarbons, which may have been introduced into the cooling water, are removed by the skimming bays. Suspended solids in the cooling water (from the Peace River) tend to settle out in these bays.

iii) Process Effluent originates from a number of sources, including: crude oil desalting, distillation, and catalytic cracking; caustic soda washing of products; boiler blowdown which may contain biocides; and drainage from the cleaning and flushing of product tanks and lines.

Desalter water may contain sodium chloride, naphthenic acids and other soluble organics, ammonia, sulphide, and traces of phenol. Distillation wastewater may contain substantial quantities of oil, ammonia, and sulphide. Water from catalytic cracking may contain ammonia, sulphide, phenols, and cyanide. Drainage from tank and line flushing are usually contaminated only by oil. Boiler blowdown may contain high levels of suspended and dissolved solids and treatment chemicals such as chelating agents, inorganic polyphosphates, or organic phosphorus (Cote, 1976).

Refinery process effluent may also include catalysts. The catalyst used at the Petro-Canada refinery is hydrofluoric acid. Losses from the HF alkylation system contribute fluoride to the wastewaters of this refinery (PE 1379, permit file, Waste Management Branch, Victoria).

The process effluent at the Petro-Canada refinery receives intermediate and biological treatment, as defined by Cote (1976), before it is mixed with the cooling water and storm run-off and discharged to the Peace River. Treatment consists of a sour water stripper, gravity separation of oil and settleable solids using API (American Petroleum Institute) separators, an equalization basin, an activated aeration cell with integral clarifier and charged with mutant bacteria, and a final aeration pond (see Figure 6). The mutant bacteria additive is purported by the manufacturer to be capable of biologically degrading benzenes, phenols, creosols, amines, alcohols, detergents, and cyanides from refinery wastewaters (no assessment of its efficacy has been made to date).

iv) Natural Gas Processing Plant Effluent. A diethanolamine solution is used to strip CO_2 and H_2S from the natural gas. Small amounts of diethanolamine and sulphide may enter the plant wastewaters as a result of spillage, pump leaks, and maintenance. (W.H. Weldon, Waste Management Branch; personal communication, 1984).

The gas plant effluent enters the refinery treatment system at the A.P.I. separator stage (Figure 6), and flows through the equalization basin, the activated aeration cell, and the final aeration pond prior to discharge in combination with the cooling water and storm runoff.

v) <u>Natural Gas Liquids Extraction Plant Effluent</u> is made up of a continuous discharge from the methanol dehydration system, washwater, and intermittent discharges from the fuel and regeneration knock-out drums. This effluent enters the sour water stream as it leaves the API separator.

Waste Management Branch permit PE 1379 was issued to Pacific Petroleums Ltd. on July 3, 1973, for the Taylor refinery and gas plant. The permit authorized a maximum effluent discharge of 144 000 m^3/d of cooling water and 2 050 m^3/d of process effluent. Permitted effluent characteristics for the original permit are given in Table 20. Permitted levels for certain effluent characteristics (e.g. BOD_5, phenol, ammonia-N, oil and grease, and sulphide and mercaptans) are expressed as grams per m^3 of refinery throughput. For these characteristics, waste loading, and hence receiving water concentrations vary in relation to refinery production.

On August 19, 1981, the permit was amended to reflect an upgrading of the effluent treatment system, a change in the discharge point to the Peace River, an increase in the cooling water discharge to 205 000 m^3/d, and changes in permitted levels of effluent characteristics. Table 20 presents a comparison of amended permit levels to the original permit levels. For the cooling water effluent, in addition to the increased allowable discharge, the suspended solids requirement was dropped and oil and grease levels were downgraded from 1.0 mg/L to 2.0 mg/L above background. For the process effluent, flow remained the same (2 050 m^3/d), but permitted levels were relaxed for suspended solids (from 20 mg/L to 60 mg/L) and for sulphides and mercaptans (from 0.3 mg/L to 1.0 mg/L). Permitted levels for the heavy metals (chromium, copper, lead, nickel, zinc) were deleted from the amended permit. Permitted levels for the remaining effluent characteristics were upgraded (i.e. amended levels are lower). Stormwater run-off effluent standards were specified in the amended permit for the first time first time (Table 20). The above amendments were issued subject to monthly bioassays of the process effluent. The permittee was also required to conduct annual biological studies of the receiving water quality. The results of these studies were reported by Noton (1981).

On May 24, 1985, the permit was amended (Table 20) to incorporate the following:

- inclusion of the discharge from the natural gas liquids extraction plant
- expression of process effluent BOD_5 phenol, ammonia-N, and oil and grease as maximum daily loads in terms of kg/d. These limits were derived from the 90 percentile of 1984 operational data.
- expression storm runoff effluent phenol and oil and grease as maximum daily loads (kg/d) rather than throughput charge (g/m^3)
- amendment of suspended solids permitted levels in the storm runoff to increases over background.
- an increase in process effluent flow to 2060 m^3/d.

b) Present Waste Loads

Effluent monitoring data collected by the permittee and the Ministry of Environment and Parks for the period 1972 to 1983 are summarized in Table 21. Permitted and maximum actual waste loads for the cooling water and process effluent are given in Tables 22 and 23. Since the discharger improved effluent treatment facilities over the period 1972-1983, the maximum waste loads that have been calculated represent the worst-case.

i) Storm Run-off

Stormwater flow data for the period July, 1976 to January, 1982 varied from 0 to 1,530 m^3/d and averaged 348 m^3/d (n-912). More recent data (May to September, 1985) ranged from 0 to 135 m^3/d and averaged 60 m^3/d. The permit has allowed stormwater volume to be variable.

Run-off water quality was not monitored prior to 1984. Monitoring data for the period January, 1984 to April, 1985 was examined. Oil and grease levels (<0.1-0.3 g/m^3 remained far below the permitted level (2.9 g/m^3). Phenol levels ranged from <0.001 to 0.5 g/m^3 and averaged 0.10 g/m^3. Only 2 out of 10 phenol measurements exceeded the permitted level of 0.17 g/m^3. Suspended solids ranged from 9-370 mg/L and 7 out of the 11 measurements exceeded the 1981 permit level of 60 mg/L. No paired flow data are available to calculate actual loadings for high suspended solids concentrations. Run-off is added to the wastewater stream and is diluted by the process effluent and cooling water.

ii Cooling Water

It is not possible at this time to determine from Provincial data whether there are any contaminant additions to the cooling water as it passes through the refinery. Data are available for the cooling water before it enters the refinery complex (site 0400157) but not after it has passed through at a point before it is added to the process effluent and discharged. A new cooling water sampling site is required to determine the cooling water load attributable to refinery input prior to the mixing with effluent. With sufficient paired cooling water inflow/outflow data it would be possible to separate the ambient load from refinery load i.e. outflow load minus inflow load equals refinery load.

Limited sampling of the cooling inlet and return water by Cross and Nix (1986) indicated no difference in pH values or concentrations of oil between inlet and return water.

Flow

All measurements of cooling water flow (n=2 070) have been less than the permitted level of 205 000 m^3/d. The maximum flow level of 198 000 m^3/d (2.3 m^3/s) (Table 21) recorded in June, 1980, exceeded the previous permit maximum of 144 000 m^3/d. For the period, 1972-1983, cooling water flow averaged 164 000 m^3/d (1.9 m^3/s). More recent flow data provided by the Region indicates that cooling water flow ranged from 83 000 m^3/d to 155 000 m^3/d over the period, May-September, 1985.

The Peace River provides greater than 300:1 dilution for the cooling water during minimum flow periods (Table 24). At the maximum permitted cooling water discharge of 205 000 m^3/d, the dilution would be greater than 350:1 during both the winter and August low flow periods. This is the dilution that would be achieved after complete mixing in the Peace River without the addition of process effluent or storm run-off. Initial dilution before complete mixing is expected to be considerably lower since the outfall has no diffuser. Complete mixing may not occur for a long distance downstream from the outfall since the river is quite wide (approximately 420 m at the outfall). The extent of this mixing zone has not yet been determined and this should be a priority for future work.

Temperature. Temperatures of the cooling water/process effluent mixture (site 0410136) averaged 23°C and ranged up to 50°C (Table 21) for the period 1972-1983. Only 7 percent (15 out of 229) of the measurements exceeded the maximum permitted temperature of 32°C. However, temperature measurements were measured consistently only during the period 1971-1975, and sporadically during 1981-1982. Temperature was not monitored between 1975 and 1981. The newest data (post-1982) available for assessment were from Cross and Nix (1986). Weekly sampling from May to October, 1985, showed that the temperature of the combined return water discharge ranged from 16.7 to 29.4°C.

The impact of adding heated effluent to the Peace River would be negligible outside the mixing zone (i.e. after complete mixing). Assuming a cooling water discharge of 50°C at the maximum permitted flow of 2.37 m^3/s, during the August low flow (564 m^3/s) with an ambient temperature of 16.5°C, the elevation in ambient temperature after complete mixing would be 0.1°C (and estimated to be 0.2°C in the initial dilution zone). If the same temperature and volume of cooling water were discharged during the winter low flow (614 m^3/s), an ambient temperature of 2°C would be increased by 0.2°C after complete mixing (0.4°C in the initial dilution zone). The point of complete mixing is unknown, but may be in the order of several kilometers downstream as shown by Noton (1981).

Noton found the temperature at the outfall to be elevated by 5-6.5°C. At a point 70 m downstream from the outfall, the temperature elevation had decreased to 1-1.5°C above ambient. The same temperature elevation was recorded up to 1.5 km downstream from the discharge. Using these data, it appears that outside the prescribed initial dilution zone (i.e. 100 m downstream), the temperature increase may be equal to or greater than the 1°C increase recommended by the Pollution Control Objectives for Chemical and Petroleum Industries (M.O.E., 1974).

During sampling in 1985, Cross and Nix (1986) measured a temperature elevation of approximately 1°C at a point 50 m downstream from the discharge. River temperature returned to ambient levels within 200 m of the outfall.

iii Process Effluent

The following analysis includes all process effluent characteristics specified in the permit (PE 1379). Both old permits (issued in 1973 and 1981) specified that effluent BOD_5, phenols, ammonia-nitrogen, and oil and grease were to be reported in terms of refinery throughput (i.e. g/m^3 of production). However, data for these characteristics were reported as concentrations in the effluent (i.e. mg/L) for the period, 1972-1981, and as g/m^3 of production, up to (but not including) 1984. Compliance of these characteristics relative to permitted levels is discussed only for the period after the permit amendment in 1981.

Flow was generally within permitted levels over the period 1973 to 1982: of 2 072 effluent flow measurements, 255 (12 percent) were greater than the permitted discharge of 2 050 m^3/d. A maximum effluent flow of 4 706 m^3/d was recorded January 20, 1976. Flow averaged 3 697 m^3/d for the period 1972 to 1982 (Table 21). The overall monthly mean effluent flows for 1983 and 1984 were 2 585 and 2 772 m^3/d respectively. The average monthly flows over this period ranged from 332 to 3 345 m^3/d. For the first nine months of 1985 (the latest period for which flow data were available), the overall monthly mean flow was 1 243 m^3/d (range: 773-1 692 m^3/d).

The Peace River provides a potentially large amount of dilution for the process effluent, even during minimum flow periods (Table 24). At the maximum effluent discharge rate recorded (4 706 m^3/d), the Peace River would provide greater than 15 000:1 dilution during both the winter and August low flow periods. The cooling water, coming directly from the Peace River, provides initial dilution (approximately 70:1 on average) for the process effluent prior to discharge. The dilution ratios shown in Table 24 are those that would be achieved after complete mixing in the Peace River. The distance from the outfall to the point of complete mixing (the mixing zone) is presently unknown. Complete mixing may not occur for a long distance downstream from the outfall since the outfall does not have a diffuser and since the Peace River is wide at the point of discharge. Projected increases in contaminant concentrations downstream from the discharge have been calculated both for the edge of the initial dilution zone and also further downstream assuming complete mixing. The determination of the size of this mixing zone and the actual contaminant levels within this zone must be a priority for future work.

<u>BOD_5</u> levels in the process effluent exceeded the permit level of 22.8 g/m^3, for 50 percent (48 out of 96) of the measurements during the period of December, 1981 to September, 1983. Process effluent BOD_5 in terms of refinery production ranged from 1.4 to 244 g/m^3, and averaged 32 g/m^3 (Table 21). The concentration of BOD_5 in the process effluent has ranged from <5 to 1 091 mg/L, and has averaged 135 mg/L, for the period 1972-1983 (Table 21). For the period, October 1983 to April 1985, the overall monthly average of process effluent BOD_5 was 15.8 g/m^3 (range: <2.3-88.2 g/m^3).

The effect of present maximum BOD_5 loadings from the process effluent on dissolved oxygen (D.O.) in the Peace River does not appear to be serious. During the August low flow period (2-year return), the predicted maximum increase in receiving water BOD_5 concentration was calculated to be 0.008 mg/L (Table 25). At the edge of the initial dilution zone we would expect a BOD_5 concentration of <0.1 mg/L assuming a factor of 2 as reported by Pommen (1986).

This would not reduce Peace River D.O. to levels harmful to aquatic life: ambient D.O. levels are high (9.5-13 mg/L; Table 27).

Total Cyanide levels in the process effluent have ranged from 0 to 3.5 mg/L and have averaged 0.21 mg/L (Table 21) over the period 1972-1983. Between 1981 and 1983, approximately 92 percent (108 out of 117) of the cyanide measurements were less than the upgraded permit level of 0.1 mg/L. In 1984 and 1985, there was further improvement: all cyanide measurements in the process effluent were less than 0.1 mg/L. This compares to only 60 percent compliance with the earlier (1973) permit limit of 0.2 mg/L.

A maximum total cyanide concentration of 3.5 mg/L was recorded on December 13, 1977. This translates to a maximum, actual load of 5.8 kg/d which is 39 times higher than the permitted load of 0.2 kg/d. A more recent loading of 1.6 kg/d was recorded on May 5, 1980 (Table 23).

Under conditions of a maximum worst-case cyanide loading (5.8 kg/d), the maximum increase in receiving water cyanide levels was calculated to be 0.08 µg/L during the most severe annual low flow. This increase by itself would not represent impairment of Peace River water quality. At the edge of the initial dilution zone, we might expect a level of 0.16 µg/L (assuming a two-fold increase over complete mixing levels as per Pommen, 1986). This level is less than the criteria for weak-acid dissociable cyanide (5 µg/L, 30 day average; 10 µg/L, maximum). Cyanide levels downstream from the refinery have not been measured at elevated or toxic levels (refer to Section 4.10b ii).

Fluoride levels in the process effluent ranged from 0.4 to 113 mg/L and averaged 10.4 mg/L over the period, 1972-1983 (Table 21). Between 1981 and 1983, approximately 37 percent (41 out of 110) of the measurements exceeded the upgraded permit limit of 10 mg/L. Only 18 percent (49 out of 279) of total fluoride measurements from 1972 to 1981 exceeded the previous permit limit of 15 mg/L. However, recent data for 1984, 1985 (provided by Region) indicate significant improvement: the overall monthly average for fluoride was 4.8 mg/L (range: 1-11 mg/L).

A maximum actual fluoride load of 189 kg/d was recorded on March 30, 1982. This is approximately nine times higher than the permitted loading of 20.5 kg/d (Table 23). However, even at this worst-case loading, the predicted maximum increase in receiving water concentration at low flow (0.002 mg/L; Table 25) would not impair Peace River water quality. Within the initial dilution zone, we would not expect worst-case fluoride levels to exceed 0.004 mg/L (assuming a two-fold increase over levels after complete mixing). These projected maximum increases are less than the maximum ambient concentration recorded (0.13 mg/L) and would not raise downstream levels above the 1 mg/L working criterion for the protection of aquatic life.

Ammonia-nitrogen. Total ammonia-N levels in the process effluent have been high. Expressed in terms of refinery production, ammonia-N levels have ranged up to 92 g/m^3 and have averaged 19 g/m^3 over the period from December, 1981 to September, 1983 (Table 21). Approximately 80 percent (80 out of 96) of the ammonia-N measurements for this period exceeded the upgraded 1981 permit level of 5.3 g/m^3. The actual concentration of total ammonia-N in the process effluent has ranged from 0.05 to 249 mg/L, and has averaged 41.4 mg/L, over the period 1972-1983 (Table 21). More recently there has been a significant improvement in ammonia-N: average monthly values ranged from <0.05 to 23 g/m^3 (overall mean of 3.6 g/m^3). High ammonia-nitrogen levels are characteristic of gas plant waste waters, as a result of amine treatment. Monenco Consultants Pacific Ltd. (1984) recorded a maximum ammonia-N concentration of 204 mg/L in gas plant effluent before mixing with the refinery process effluent.

A maximum total ammonia-N level of 92 g/m^3 was recorded on August 17, 1982, resulting in an actual loading of 86 kg/d (Table 23). This is approximately eight times higher than the permitted load of 10.9 kg/d. However, no effect on Peace River water quality is expected even at such worst-case loading: under the condition of an August low flow, receiving water ammonia-N concentrations should rise by only 0.001 mg/L (Table 25) after complete mixing (0.002 at the edge of the initial dilution zone).

The maximum total ammonia-N level measured downstream from the refinery by the Ministry of Environment and Parks was 0.011 mg/L as N (Section 5.3). Further receiving water sampling is needed to confirm these predictions.

Oil and grease levels in the process effluent have been low relative to the 1981 permit level of 8.0 g/m^3 of refinery production, ranging from 0.2 to 10.5 g/m^3 and averaging 2.0 g/m^3 over the period of December, 1981 to September, 1983 (Table 21). Seventeen percent (16 out of 94) of the oil and grease values for this period exceeded the upgraded permit level of 8.0 g/m^3. For the period 1972-1983 the actual concentration of oil and grease in the process effluent ranged from 0 to 612 mg/L and averaged 7.1 mg/L (Table 21). More recent data (1984, 1985) provided by the Region indicates further effluent improvement: average monthly oil and grease values ranged from 0.2 to 1.9 g/m^3 (overall mean of 0.7 g/m^3).

A recent maximum oil and grease load of 13.6 kg/d occurred on May 25, 1983 (Table 23). This is less than the permitted loading of 16.4 kg/d. This process effluent loading could result in an increase in the receiving water oil and grease concentration of <0.2 µg/L during both summer and winter low flow periods, assuming complete mixing (Table 25). Within the initial dilution zone we would not expect worst-case oil and grease levels to exceed 0.4 µg/L (assuming a two-fold increase over levels after complete mixing).

Complete mixing of oil and grease contaminants with the receiving water is unlikely to happen. Oil and grease would more likely separate from the effluent after discharge and float to the surface forming a hydrocarbon sheen or film. Noton (1981) noticed such an oily film on the water surface at downstream sampling sites. Oil and grease concentrations in these films would be localized and higher than those predicted above. To date, there has been no analysis of the hydrocarbon content in the surface films downstream from the Taylor discharge. Future water quality sampling should correct this omission.

pH. The pH of the process effluent has improved over the years, pointing to better pH control and the efficiency of the sour water strippers (Figure 5). From 1972 to September 1981, 35 percent (154 out of 445) of the pH measurements exceeded the original permit limits of pH 6.5-9.0. Most of the non-compliant values (88 percent) were recorded before 1978, and the majority were overly basic (i.e., greater than pH 9.0, only 5 pH values were less than pH 6.5). For the period 1981-1983 following issuance of the 1981 amended permit, all pH measurements (n=102) were within the upgraded permit limits of 6.5- 8.5, except for one (pH 8.7), recorded on June 7, 1983. More recent data (1984, 1985) provided by the Region shows continued compliance: average monthly pH values ranged from 6.5 to 8.9 (overall monthly mean of pH 7.9).

Phenols. For the period, 1981 to 1983, process effluent phenols have occasionally been high, ranging from 0.001 to 28.6 g/m^3 and averaging 0.5 g/m^3 (Table 21). Most of the phenols measurements (90 percent, n=99) for this period have been less than the 1981 upgraded permit limit of 0.17 g/m^3. The actual concentration of phenols in the process effluent ranged from 0.002 to 17.6 mg/L, and averaged 1.3 mg/L, for the period 1972-1983 (Table 21). More recent data (1984, 1985) provided by Region indicate that monthly average levels ranged from <0.001 to 0.09 g/m^3; all values being lower than the permitted level. Gas plant effluent phenols levels have been recorded up to 10.4 mg/L (Monenco Consultants Pacific Ltd., 1984).

There have been occasional high loadings of phenols: on April 12, 1983, an actual phenols load of 6 kg/d occurred. This is approximately 18 times higher than the permitted load of 0.3 kg/d. An even higher load likely occurred on May 10, 1983, when phenols reached a level of 28.6 g/m^3, although there are no production flow data available to calculate an actual load (Table 23).

Under the worst-case conditions of a 6 kg/d phenols loading during low flow, the receiving water phenols concentration is expected to increase by 0.08 μg/L (Table 25). This increase by itself would have no discernible effect on Peace River quality. Concentrations would be higher within the initial dilution zone (0.16 μg/L), assuming levels twice as high compared to those after complete mixing. This level is less than the 0.001 mg/L working criterion for aquatic life (fish tainting). However, phenol is a non-specific analysis and may include a mixture of phenolic materials (e.g. non-chlorinated phenols) that do not contribute to the environmental effects on which the criterion was based. Analysis of the different phenolic classes present in the effuent, is required. Actual levels of phenols downstream from the discharge have reached 0.027 mg/L according to Noton (1981).

Dissolved Phosphorus levels in the process effluent ranged from 0 to 28.3 mg/L, and have averaged 0.6 mg/L over the period, 1973-1983 (Table 21). More recently (1984, 1985) average monthly values have ranged from 0.22 to 0.8 mg/L. From 1973 to September, 1981, all dissolved phosphorus measurements were less than the original permit limit of 3.0 mg/L. The maximum concentration recorded for this period was 1.6 mg/L (on November 29, 1977). After the permit limit was upgraded in September, 1981, to 1.0 mg/L, compliance fell to 71 percent (i.e. 64 out of 94 values were less than 1.0 mg/L).

A maximum, actual loading of 37 kg/d occurred on April 27, 1982. This is 18 times higher than the permitted loading of 2.1 kg/d (Table 23). Even with such a maximum worse-case loading, receiving water concentrations would increase by less than 0.5 μg/L during minimum Peace River flows (Table 25). No impairment of Peace River water quality would result from the process effluent phosphorus loading. The projected increase would not be large enough be itself to stimulate excessive algal growth (see Section 5.3 Phosphorus).

<u>Suspended Solids</u> levels in the process effluent have ranged from 2 to 2 240 mg/L, and have averaged 69 mg/L over the period, 1972-1983 (Table 21). Prior to downgrading the permitted suspended solids level from 20 mg/L to 60 mg/L in the amended permit, compliance was low: 87 percent (346 out of 399) of suspended solids measurements exceeded 20 mg/L. After permit amendment in 1981, only 15 percent (17 out of 113) of suspended solids values exceeded 60 mg/L. For the recent period 1984, 1985, the overall monthly average level of suspended solids was 35 mg/L (range: 11.6-78.4 mg/L). The maximum suspended solids load was 172 kg/d recorded on December 21, 1982. This loading is 40 percent higher than the permitted loading of 123 kg/d (Table 23). The expected increase in receiving water suspended solids loading as a result of this worst-case loading during minimum flows is less than 0.002 mg/L (Table 25) after complete mixing.

<u>Total and dissolved solids</u>. Total solids are specified in the permit, although it is an uninterpretable variable because it represents a summation of dissolved solids and suspended solids.

Total solids levels in the process effluent have been high occasionally: over the period 1972-1983 total solids have averaged 672 mg/L and ranged from 66 to 4 920 mg/L (Table 21). Between 1972 and September, 1981, when the maximum permitted total solids level was 2 000 mg/L, approximately 98 percent (392 out of 401) of the total solids measurements were less than the permitted value. After permit amendment in September, 1981, 86 percent (19 out of 22) of the total solids measurements were less than the upgraded permit limit of 1 500 mg/L. A maximum actual load of 2 064 kg/d was recorded on June 8, 1982 (Table 23).

Review of actual data showed that approximately 90 percent of the total solids concentration was comprised of dissolved solids. Dissolved solids over the sampling period 1983-1984 averaged 1 215 mg/L (range 796-1990 mg/L; Table 21). A maximum actual dissolved solids load of 2 035 kg/d was recorded on January 25, 1983. The effect of such loading on the Peace River after complete mixing would not be significant: the increase in receiving water dissolved solids level is expected to be approximately 0.03 mg/L during both the winter and August low flows (Table 25). Ambient dissolved solids levels upstream from the refinery (sites 0400138-0400140) range from 100 to 124 mg/L. Elevated levels of dissolved solids have not been recorded downstream from the refinery.

Sulphide levels have been high in the process effluent over the period of record 1972-1983: ranging up to 1 326 mg/L and averaging 35 mg/L (Table 21). The gas plant waste water makes a significant contribution to these process effluent sulphide levels. The maximum sulphide level (of four samples) taken by Monenco Consultants Pacific Ltd. (1984) was 292 mg/L.

The original permit specified a maximum of 0.3 g/m^3 (Table 12); however, sulphide levels were reported as mg/L. The amended 1981 permit specified a maximum of 1.0 mg/L. For the period September, 1981 to September, 1983, approximately 73 percent (76 out of 104) of the total sulphide values have been less than the permit limit of 1.0 mg/L. For the more recent period 1984, 1985 all monthly mean sulphide values have been lower than the permitted level.

The highest actual loading was 20 kg/d which occurred on January 5, 1982 (Table 23). This loading is approximately 10 times higher than the permitted load of 2.1 kg/d. However, no impairment of Peace River water quality is expected from such loading. The expected increase in the receiving water total sulphide concentration would be less than 1 µg/L (Table 25). The increase in receiving water levels of H_2S (the toxic portion of total sulphide) would be even less: using the data from Broderius and Smith (1976) and assuming Peace River pH=7.8, T=5°C, 19.5 percent of the sulphide concentration increase (or 0.06 µg/L) would be present in the un-ionized H_2S form (after complete mixing during the extreme low flow periods, Table 25). At higher pH or temperature, the concentration of un-ionized H_2S would be lower.

Metals levels (chromium, copper, lead, nickel, zinc) were specified in the original permit, but deleted from the amended 1981 permit (Table 20). The majority of values for each metal that was monitored between 1972 and 1981 were lower than the permitted maxima.

Dissolved chromium ranged from <0.005 to 0.22 mg/L and averaged 0.02 mg/L (Table 21). Ninety-nine percent (91 out of 92) of the dissolved chromium values were less than the permitted limit of 0.2 mg/L. Dissolved copper ranged from <0.001 to 3.2 mg/L and averaged 0.08 mg/L. Approximately 93 percent (97 out of 104) of the dissolved copper values were less than the permit maximum of 0.1 mg/L. Dissolved lead ranged up to 0.6 mg/L and averaged 0.07 mg/L. Ninety-two percent (85 out of 92) of the dissolved lead values were less than the permitted level of 0.2 mg/L. Dissolved nickel ranged up to 0.16 mg/L and averaged 0.04 mg/L. Ninety-one percent (84 out of 92) of the dissolved nickel values were less than the permitted level of 0.1 mg/L. Dissolved zinc ranged up to 0.47 mg/L and averaged 0.06 mg/L. Ninety-seven percent (84 out of 87) of the dissolved zinc measurements were less than the permitted level of 0.2 mg/L. Maximum, actual loadings for these metals are shown in Table 23. Even under conditions of maximum loadings during minimum streamflows, there would be no increase in receiving water metals concentrations that could constitute an impairment of Peace River water quality (Table 25).

Bioassay. Static bioassays using rainbow trout (96 h LC50) were conducted on the process effluent intermittently between April, 1974 and August, 1981. Since September, 1981, bioassays have been conducted on a monthly basis as required by the amended permit (Table 21).

For the period of record (April, 1974 to September, 1983) the average trout bioassay 96-h LC50 was 72.2 percent (of process effluent). The LC50 ranged from very toxic (3.8 percent) to non-toxic (greater than 100 percent process effluent). There has been a recent improvement in effluent quality as evidenced by the bioassay data. Before 1981, the bioassay 96 h LC50 averaged 56 percent (range of 3.8->100 percent); after the amended permit was issued, the bioassay 96 h LC50 averaged 84 percent (range of 40->100 percent). According to Cross and Nix (1986) all bioassay results for the period May-October 1985 were non-toxic (both acute and chronic tests). The effluent produced a stimulatory effect on the life cycle of *Daphnia magna*. It is possible to extrapolate a flow proportioned relationship between the process effluent toxicity and the potential toxicity in the Peace River using the method of Esvelt *et al.*, (1973). A toxicity concentration for the effluent diluted by the river (TCr) can be calculated as follows:

$$TCr = \frac{TCe}{\text{dilution ratio}}$$

, where TCe equals the reciprocal of the 96 h LC50,

$$\text{i.e. } TCe = \frac{100}{96\text{ h LC50}}$$

The value of TCr, in toxic units (T.U.), is an estimate of potential toxicity in the river at a point where effluent mixing is complete. A TCr of 1.0 T.U. would indicate 50 percent mortality of the fish in the river.

Extrapolation of the process effluent toxicity data to the river is based on the maximum acute toxicity value of the effluent since permit amendment in 1981 (96 h LC50 of 40 percent). Under conditions of the maximum permitted effluent discharge during the October-April low flow (dilution ratio of 15 300:1), the TCr in the Peace River would be 0.0002 T.U. This is 50 to 500 times lower than the safe levels of 0.01 to 0.1 T.U. for persistent toxicants recommended by the U.S. National Technical Advisory Committee (cited from Singleton, 1980) and the safe level of 0.01 T.U. for cumulative toxicants recommended by the National Academy of Sciences and the National Academy of Engineering (cited from Singleton, 1980). The potential toxicity of the effluent in the river during the August low flow period would be even lower since the higher flows provide greater dilution. The calculated TCr value assumes complete effluent mixing with the river. Concentrations, hence toxicity, would be greater in the initial dilution zone before complete mixing has occurred. If we assume a two-fold increase in concentration in the initial dilution zone compared to concentrations after complete mixing (Pommen, 1986) the potential toxicity (0.0004 T.U.) would still be far lower than the recommended safe levels.

Organic Contaminants. Recent analysis (Cross and Nix, 1986) of the process effluent for the following volatile organic compounds did not yield detectable concentrations (R. Girard, personal communication) (Cross and Nix, 1986).

1,1-Dichloroethane	cis or trans-1,3-Dichloropropene
Methylene chloride	Toluene
trans-1,2-Dichloroethene	cis or trans-1,3-Dichloropropene
1,1-Dichlorethene	1,1,2-Trichloroethane
Chloroform	Dibromochloromethane
1,1,1-Trichloroethane	Tetrachloroethene
1,2-Dichloroethane	Chlorobenzene
Benzene	Ethyl benzene
Carbon tetrachloride	Bromoform
Trichloroethene	1,1,2,2-Tetrachloroethane
1,2-Dichloropropane	1,3-Dichlorobenzene
Bromodichloromethane	1,2-Dichlorobenzene
2-Chloroethylvinyl ether	1,4-Dichlorobenzene

None of the following polycyclic aromatic hydrocarbons tested for at the same time were detectable. Only benzene was detectable (5 µg/L).

Acenaphthene	Benzo(a)pyrene
Acenaphthylene	Fluoranthene
Anthracene	Fluorene
Benzo(a)anthracene or Chrysene	Naphthalene
Benzo(k)fluoranthene or Benzo(b)fluoranthene	Phenanthrene
	Pyrene

Benzene (10 µg/L) was also detected in ground seepage springs discharging on the river bank below the refinery/gas plant complex. Neither aliphatic hydrocarbons nor polycyclic aromatic hydrocarbons were detected. This seepage water was shown not to be acutely toxic to rainbow trout; however, it did have an adverse chronic/sublethal effect on *Daphnia magna* (Cross and Nix, 1986).

For benzene, the U.S. EPA (1980) reported an acute toxicity level for freshwater aquatic life of 5.3 mg/L. For marine life, the available data indicated an acute toxicity level of 5.1 mg/L. Definitive chronic toxicity data were not available. For the maximum protection of human health from the carcinogenic effects of benzene in drinking water and contaminated organisms, the U.S. EPA recommended a zero concentration based on the non-threshold assumption. Since a zero level may not be attainable, levels of 6.6, 0.66, and 0.066 µg/L were given corresponding to incremental increases of cancer risk over a lifetime estimated at one in 100 000, one in 1 000 000 and one 10 000 000, respectively.

iv) Natural Gas Processing Plant Effluent

The gas plant effluent enters the refinery treatment system at the A.P.I. separator stage, and is mixed with the refinery process effluent before the latter is sampled (Figure 5). Thus, the above analysis of process effluent quality included the gas plant effluent.

There is no separate sampling of gas plant effluent. However, Monenco Consultants Pacific Ltd. took four samples of gas plant waste water for analysis in 1984. Some of the results of this work have been previously mentioned under process effluent (Section 4.10 b iii). Analysis of these samples for organic contaminants indicated the presence of two polycyclic aromatic hydrocarbons (PAH), methyl phenanthrene (5µg/L), and phenanthrene (7 µg/L), and one bicyclic aromatic hydrocarbon, naphthalene (5 µg/L). Aromatic hydrocarbons are of concern in the aquatic environment because many of them are well documented carcinogens (E.P.A., 1980). PAH adsorb strongly onto suspended particulates. Benthic organisms have also been shown to extensively bioaccumulate PAH from sediments. Although fish and mammals do not bioaccumulate PAH, they can metabolize it and these metabolites are also known to be carcinogens and cytotoxins.

The aromatic hydrocarbons found in the effluent have shorter half lives (due to volatilization and photolysis) and are less potent as carcinogens compared to other PAH (e.g. benzo(a)pyrene). The more potent PAH were not found to be present. However, both naphthalene and phenanthrene are on the EPA list of "Priority Pollutants" because of their potential carcinogenicity, and until further data show otherwise, they should be regarded with concern.

The total concentration for the three aromatic hydrocarbons in the effluent was 17 µg/L. However, these samples were for untreated effluent prior to biological treatment and prior to dilution with cooling water (up to 100:1) in the discharge line. With an additional minimum 10 000:1 dilution available in the Peace River, the receiving water level would be expected to be <1 ng/L, after complete mixing. The Aquatic Ecosystem Objectives Committee (A.E.O.C., 1983) chose benzo(a) pyrene (BaP) as its indicator PAH, and recommended a maximum level of 0.01 µg/L BaP in water to protect aquatic life. The World Health Organization has proposed a maximum limit for drinking water of 0.01 µg/L for BaP, and a maximum limit of 0.02 µg/L PAH (based on a composite analysis of six PAH; none of which were found in the effluent). The projected level of aromatic hydrocarbons in the Peace River after complete mixing is far lower than these guidelines.

The U.S. EPA (1980a) could not find sufficient freshwater aquatic life data for PAH to permit a statement concerning the actue or chronic toxicity. For marine life, the available data for PAH indicated an acute toxicity level of ≤300 µg/L. For the maximum protection of human health from the potential carcinogenic effects due to exposure to PAH in drinking water, the U.S. EPA recommended a zero concentration based on the non-threshold assumption. Since, the zero level may not be attainable, levels of 28, 2.8, and 0.28 ng/L were given corresponding to incremental increases of cancer risk over a lifetime estimated at one in 10,000, one in 100,000 and one in 1,000,000 respectively. It should be noted that these levels for the protection of human health are based on data for BaP (benzo (a) pyrene) as an indicator PAH and may not reflect the actual toxicity of phenanthrene.

The U.S. EPA (1980b) could not derive a naphthalene criterion for the protection of human health because of the insufficiency of the available data. Because of its potential carcinogenicity, the EPA called for the generation of more data. For freshwater aquatic life, the available data for naphthalene indicated an acute toxicity level of 2300 ng/L and a chronic toxicity level of 620 ng/L.

The remaining organic compounds identified from the gas plant effluent included:

- long chained alkanes (C_{15}-C_{33})(0.82 mg/L; base/neutral fraction)
- ethyl hexanol (12 µg/L)
- N, N dimethyl cyclohexanamine (12 µg/L)
- methyl dibenzothiophene (20 µg/L)
- benzene diamine (22 µg/L)
- unidentified aromatic nitrogen (13 µg/L)
- unidentified aliphatic nitrite (33 µg/L)

The first four organics are low toxicity compounds and would be below detection in the receiving waters. Benzene diamine is of environmental concern, since the aromatic amines have long been recognized as carcinogens. The unidentified aromatic nitrogen and aliphatic nitrite require identification before comment can be made on their environmental safety (Monenco Consultants Pacific Ltd., 1984).

c) FUTURE WASTE LOADS

Projected future waste loadings for key characteristics are presented in Table 23 for the process effluent. The future loadings for 1992 assume a 50 percent increase in refinery production. Petro-Canada is now (1984) in the early stages of an expansion of the natural gas processing plant for the purpose of extracting natural gas liquids. No firm commitments to proceed have been made, but a 33-50 percent increase in production is believed to be realistic (B. Keilo, 1984; personal communication). While a 50 percent increase in gas plant production would not necessarily equate to a 50 percent increase in waste loads, it is used here as a reasonable assumption for the purpose of examining future effects on the Peace River.

Future loadings have been projected assuming that present worst-case waste loading trends continue (i.e., 50 percent increase over maximum present loading). Future increases in Peace River receiving water concentrations (after complete mixing) as a result of process effluent discharge at maximum contaminant concentration and during minimum streamflow periods are presented in Table 25. The results indicate:

- that the future maximum increase in receiving water BOD_5 concentration could be 15 µg/L after complete mixing. This would have no effect on Peace River dissolved oxygen (D.O.) levels. Ambient D.O. levels are high (9-13 mg/L) and river conditions are not appropriate for rapid BOD exertion (i.e., T <20°C, re-aeration).

- a maximum phenol level of only 0.12 µg/L after complete mixing. This is lower than both the 1 µg/L working criterion for aquatic life (fish tainting) and the 0.002 mg/L working criterion for drinking water (tainting).

- a maximum un-ionized H_2S level of 0.08 µg/L, after complete mixing. This is 25 times lower than the 0.002 mg/L working criterion for aquatic life.

- future maximum increases in the levels of cyanide and fluoride would not increase receiving water levels beyond the working criteria levels once complete mixing occurs; future levels are also not expected to exceed criteria in the mixing zone.

- a future maximum increase in total ammonia-N of 1.8 µg/L, which would not be in excess of the criteria for aquatic life (0.42 mg/L; 30 day average; 0.03 mg/L, maximum) (assuming a worst-case situation of pH=8.4, T=16°C). Future levels would also not exceed criteria in the mixing zone.

Maximum receiving water concentrations of these contaminants in the mixing zone are assumed to be twice as high as those after complete mixing (Pommen, 1986). These projections describe a worst-case situation. They are based on maximum contaminant loads which may be several times higher than the normal loads and which are discharged only infrequently for short periods during low flow.

5. WATER QUALITY ASSESSMENT

The water quality of the Peace River mainstem was analyzed for five separate reaches:

1) between the W.A.C. Bennett Dam and the City of Fort St. John discharge (PE 389),
2) between the City of Fort St. John discharge (PE 389) and the Petro-Canada refinery/gas plant discharge at Taylor (PE 1379).
3) downstream from Taylor to the Alberta border, and
4) the lower Beatton River, from the City of Fort St. John discharge (PE 388) to the confluence with the Peace River (see Figure 3).
5) at Dunvegan, Alberta (120 km downstream from the border).

Projected or theoretical receiving water concentrations due to waste discharges have been calculated for some important variables, and were used to supplement actual water quality data in order to predict the worst-case conditions. Projections are especially useful for sites with a small number of samples or a limited sampling period.

The Ministry of Environment and Parks does not yet (at the time of writing) have approved water quality criteria for all the important characteristics. For characteristics without approved criteria, temporary working criteria have been adopted on a provisional basis from other jurisdictions and the literature for the purposes of this assessment. The final criteria to be adopted as provincial policy may be different from these working criteria.

5.1 PEACE RIVER, W.A.C. BENNETT DAM TO FORT ST. JOHN

The Halfway River and the Moberly River are the major tributaries in this reach of the Peace River. The mean annual flow (MAF) of the Peace River at Hudson's Hope (1 050 m^3/s) is increased by 76 m^3/s from the Halfway River and by 12 m^3/s from the Moberly River (Figure 5). The influence of these two tributaries on the water quality of the Peace River is discussed below.

a) Halfway River

Water quality data for the Halfway River upstream from the confluence with the Peace River are available for only one sampling date (July 30, 1975) (Table 28). A comparison of these limited data with the data for the Peace River upstream from the Halfway River (Section 5.1c) does not show any major differences which would suggest effects on downstream water quality.

The Halfway River was alkaline (pH 8.3, total alkalinity 168 mg/L), hard (188 mg/L), slightly colored (5 T.C.U.), low in nutrients (<3 µg/L dissolved phosphorus, <0.02 mg/L nitrite/nitrate), and turbid (27 N.T.U.). Total metal concentrations for cadmium, iron, and copper exceeded the working criteria for aquatic life; however, these are likely due to high levels of suspended solids (not measured) as indicated by the high turbidity. Dissolved concentrations for these metals have not been measured. Mercury, zinc and fecal coliform levels have not been measured. Additional sampling is required to determine the concentration of these unmeasured variables and to establish the full variability of the Halfway River water quality.

b) Moberly River

The Moberly River enters the Peace River approximately 6 km upstream from the Fort St. John discharge (Figure 3). Water quality data for the period April, 1973 to October, 1974 are available for one site upstream from the confluence with the Peace River (Table 28). A comparison of these data with those for the Peace River (Table 15) shows that on occasion the Moberly River had high levels of dissolved mercury, nutrients, and suspended solids comparable to the Peace River, but that the high dilution available in the Peace River (88:1, MAF data) would preclude significant downstream effects.

The Moberly River was moderately buffered and hard (total alkalinity 103-157 mg/L, pH 7.2, dissolved hardness 99-165 mg/L), colored (3-34 T.C.U.) and turbid (8.2-550 N.T.U.). Suspended solids levels ranged up to 1 249 mg/L on April 25, 1973. On the same date, at Peace River site 0400134, 4 km downstream from the Moberly River, suspended solids were 299 mg/L (no suspended solids data are available for the Peace River upstream from the Moberly on this date).

Dissolved metal levels in the Moberly River, for copper, mercury, and zinc exceeded the working criteria for aquatic life. The maximum level of dissolved iron (0.3 mg/L) equalled the working criteria for aquatic life and public water supplies. The maximum concentration of dissolved mercury (0.6 µg/L) is greater than the maximum concentration recorded in the Peace River (0.4 µg/L)(Section 5.3). On the date that this maximum dissolved mercury concentration occurred in the Moberly River (April; 25, 1973), dissolved mercury in the Peace River at site 0400135 (4 km downstream from the Moberly River) reached a maximum of 0.14 µg/L (Section 5.1c). Dissolved mercury was not measured in the Peace River upstream from the Moberly River. Further sampling is needed to determine the significance of Moberly River mercury contribution to the Peace River.

Total nutrient levels have also been measured at high levels in the Moberly River (Table 28). A maximum total phosphorus level of 1.3 mg/L was recorded on April 25, 1973. On the same date, total phosphorus levels in the Peace River 11 km downstream from the Moberly River (site 0400138) reached 0.3 mg/L, compared to a maximum concentration of 0.111 mg/L (site 0400138) recorded on April 25, 1973. On the same date at the downstream Peace River site 0400140 (11 km downstream from the Moberly River) nitrate-N measured 0.12 mg/L. Phosphorus levels in the Peace River upstream from the Moberly River were not measured on the same date, but have not exceeded 0.02 mg/L. Fecal coliform levels have been low (Table 28), ranging from 2 to 23 MPN/100 mL, compared to 200 MPN/100 mL in the Peace River at site 0410017 (7 km downstream from the Moberly River, upstream from Fort St. John).

c) Peace River Mainstem

There are water quality data for 16 Ministry of Environment and Parks water quality sites on the Peace River, upstream from Fort St. John. The map locations of these sites are shown in Figure 3. More precise site descriptions are given in Table 29.

The water quality data for these sites are summarized in Tables 15 and 30-33, inclusive. Collectively, the data for these sites span the period of November, 1971, to October, 1980, while individually each site was sampled over a much shorter period. There are presently insufficient data to distinguish trends between upstream and downstream sites.

The present water quality of the Peace River upstream from Fort St. John is a function of the quality of water released by the W.A.C. Bennett Dam, and to a lesser extent, the quality of tributary inflows. Anthropogenic waste sources in this reach are small and effluent dilution is great (Sections 4.2-4.6, inclusive).

<u>General Characteristics</u>

The available water quality data show that the water in this reach of the Peace River was alkaline (pH 7.8-8.3, total alkalinity 80-505 mg/L), well oxygenated (D.O. 9.4-13.4 mg/L during open-water), moderately hard (81-181 mg/L), slightly colored (1-23 T.C.U.), and variably turbid (1.3-160 NTU). From a drinking water perspective, water of this hardness and alkalinity would be considered of good quality. The water color exceeded at times the 15 T.C.U. maximum acceptable level for drinking water (relative to aesthetics). Turbidity values frequently exceeded the 5 N.T.U. maximum acceptable limit for drinking water. The high turbidity values would necessitate filtration (or equivalent treatment) to eliminate turbidity prior to drinking water use. High turbidity is related to high concentrations of suspended sediment (up to 770 mg/L) and colored organic and inorganic compounds (tannin and lignins <0.1-2.2 mg/L; total iron

<0.02-1.1 mg/L), occurring during periods of high run-off (e.g., snowmelt and rainstorms). Analysis of B.C. Hydro sediment data indicated that over 90 percent of the present sediment load is carried by flows which occur on a statistical basis only 20 percent of the time in an average year (Canadian Bio Resources Consultants Ltd., 1979).

Metals

Dissolved metal concentrations in the upstream reach of the Peace River have exceeded the working criteria for the protection of aquatic life (Tables 15, 32). These dissolved metals include:

	Maximum Level Recorded	No. of Values Exceeding/Equal to Criteria	Working Criteria for Aquatic Life	Site
Copper	9 µg/L	3 of 8	2 µg/L	0400134
Lead	15 µg/L	1 of 8	5-10 µg/L	0400134
Mercury	0.14 µg/L	1 of 8	0.1-0.2 µg/L	0400135
Zinc	0.1 mg/L	1 of 7	0.05 mg/L	0400135

None of these maximum metal levels exceeded the working criteria for public water supplies. The dissolved metals would not be due to suspended sediment levels, but rather reflect the upstream contribution from the Williston Reservoir and tributary streams. There are no pre-impoundment water quality data to determine whether metal concentrations have increased since the filling of Williston Reservoir.

Mercury levels in Southern Indian Lake reservoir in northern Manitoba were observed to increase significantly after impoundment (Bodaly and Hecky, 1979). It has been postulated by these authors that inundation and erosion of boreal soils can increase the supply of mercury to reservoir waters through leaching of humic-rich soils and suspension of clay particles. Increases in fish-tissue mercury concentrations occurred along with impoundment and increases in reservoir-water mercury levels.

Little is known about the present mercury levels in fish in the Peace River downstream from the W.A.C. Bennett Dam. Two northern pike specimens taken in 1971 near Fort St. John had low muscle mercury concentrations of 0.08 and 0.09 µg/g wet weight (Barret et al., 1980). Data are not available for other food fish species. Health and Welfare Canada has identified high mercury levels in some fish species taken from several locations in the Williston Reservoir watershed (Truelson, 1984). Dolly Varden char (2 samples) in the Finlay River had muscle tissue mercury levels that were three times the acceptable commercial fishing limit of 0.5 µg/g wet weight. Bodaly and Hecky (1982) stated that if the Site C Reservoir were constructed, piscivorous fishes would exhibit total mercury concentrations in muscle tissue of greater than 0.5 µg/g soon after river impoundment. Whether such high tissue mercury levels are already present downstream from Williston Reservoir is not known and requires investigation.

Nutrients. Total phosphorus levels upstream from Fort St. John have been high, ranging up to 0.3 mg/L at station 0400134 (Table 15). Review of the data showed that high total phosphorus values occurred on dates of high levels of suspended solids, signifying that the total phosphorus was likely of the particulate form which is not used in plant nutrition. Levels of the more biologically available dissolved phosphorus have been low (less than 0.003 mg/L), although only three samples have been taken (Table 32).

Nitrate-N and nitrite/nitrate-N levels have ranged up to 0.12 mg/L (mean=0.05 mg/L). Ammonia-N levels have ranged up to 0.023 mg/L (mean=0.01 mg/L) at sites 0400134-0400136 (Table 15). When the average dissolved inorganic nitrogen concentrations (0.06 mg/L NH_3+nitrite/nitrate) are compared to dissolved phosphorus (0.003 mg/L), the nitrogen to phosphorus ratio becomes 20:1. This indicates that algal growth in the Peace River upstream from Fort St. John is phosphorus-limited.

Nutrient concentration increases resulting from point-source waste loading is not a significant factor upstream from Fort St. John. Nitrogen and phosphorus level increases, as a result of the domestic sewage discharge from facilities at the Peace Canyon Dam are predicted to be nil outside the mixing zone. Nutrient loading from the other upstream discharges (e.g. the Shrum Generating Station and the Recreational Fisheries Branch Hatchery) has not been measured, but is thought to be equally negligible.

Fecal Coliform bacteria have reached levels of 130 MPN/100 mL, 3 km upstream from the Fort St. John discharge (sites 0400134-0400136; Table 15) and 200 MPN/100 mL 200 m upstream from the discharge (site 0410017; Table 33). These concentrations exceed the B.C. Ministry of Health criteria for drinking water that will receive only disinfection or disinfection plus filtration (or equivalent) prior to use, but not for primary contact recreational waters. There are presently insufficient data to prove which level of treatment is necessary prior to drinking use; however, the data do suggest that filtration (or equivalent) and disinfection may be needed.

The source of the fecal coliforms is presently unknown. The predicted worst-case increases of fecal coliforms in downstream receiving waters from upstream point sources are negligible outside the mixing zones: 0.03 MPN/100 mL from the facilities at the Shrum Generating Station and 0.1 MPN/100 mL from the Peace Canyon Dam facilities. Fecal coliform levels have not been measured upstream from sites 0400134-0400136, making it difficult to determine the source of the receiving water fecal coliform levels. It is likely that agricultural run-off (e.g. feedlots, grazing cattle) may be responsible for these concentrations, but at present there are no data specific to this area that would confirm this suspicion. Further study of the diffuse sources is required to determine the extent and location of these fecal coliform loadings.

A first step to pinpoint the source of the bacterial contamination would be to differentiate between human and animal feces. The ratio of fecal coliforms (FC) to fecal streptococci (FS) is generally greater than 4 in human sewage and less than 0.7 in animal wastes (Geldreich, 1972). Salmonella infection is also high in livestock (10 - 20%) as opposed to in people (1%). Thus, predominantly livestock-contaminated water can be distinguished from human sewage contamination by a low FC/FS ratio and a high *Salmonella* level.

Dissolved Gases. Exposure to hyperbaric gas pressure can be lethal to aquatic invertebrates and fish. Gas bubble disease refers to a physically induced process caused by uncompensated, hyperbaric total dissolved gas pressure, which produces primary lesions in blood (emboli) and in other tissues (emphysema) and subsequent physiological dysfunctions (Bouck, 1980). Behavioral changes in fish can also occur as a result of damage to the lateral line canal, e.g. feeding behavior, with consequent sub-lethal effects (M. Clark, personal communication). Fish tolerance to gas supersaturation (a measure of uncompensated hyperbaric gas pressure) can vary with fish species, life-history stage, water temperature, hardness and depth, and length of exposure (Weitkamp and Katz, 1980). Alderdice and Jensen (1985) recommended that total gas pressure in the Nechako River should be less than 110% to prevent acute problems, although as much 5% mortality (chronic) would occur between 105% and 110%. A safe upper limit for supersaturation of 110 percent has been established by the U.S. Environmental Protection Agency (E.P.A., 1977), although Bouck contends that 115 percent saturation would be safe for wild salmonids in large, deep rivers. *In situ* studies have shown even higher tolerance to gas supersaturation where fish are able to sound to depth. In the Columbia River, high levels of dissolved gas supersaturation (to 144 percent) were observed downstream from the Hugh Keenleyside Dam, but only one of 40 captured fish exhibited minor symptoms of gas bubble disease (W.I.B. 1979).

Spillways of hydroelectric projects can cause supersaturation if the spillwater is dropped to great depths in a plunge basin where the hydrostatic pressure is sufficient to increase the solubilities of atmospheric gases. The spillway at the W.A.C. Bennett Dam was designed to minimize the chances of dissolved gas supersaturation. The spillway has a spoon-shaped spill basin which dissipates the energy of the cascading water over a wide area, upward and outward (Renewable Resources Consulting Services Ltd., 1979). According to Abelson (1974) the spillway design results in little entrapment of gases compared to the old style dam with a straight vertical plunge of water into a deep receiving basin. Clark (1977) reported that levels of <100-110 percent saturation would be satisfactory for fish below dams (although sub-lethal effects are possible), and that levels of 120-140 percent saturation would be unsatisfactory below dams with the likelihood of significant mortality in water shallower than 3 m.

Total dissolved gas levels measured during the period 1974-1978 downstream from the W.A.C. Bennett Dam (Tables 30, 31) were generally less than 110 percent saturation, i.e., within the satisfactory range as recommended by the E.P.A. (1977). One sample at site 0900192 (near the spillway) reached 114 percent saturation, which is within the borderline range (110-120 percent saturation). However, this value occurred during spillway tests which would be atypical for the discharge regime and thus represents a worse-case situation (M. Clark, personal communication). Dissolved nitrogen levels were all less than 110 percent saturation during the same time period (Tables 30, 31). Total dissolved gas levels have not been monitored since 1978.

Fish reared in shallow troughs in hatcheries are inherently more susceptible to gas bubble disease than are wild fish (Bouck, 1980). The Recreational Fisheries Branch Hatchery at Hudson's Hope draws its water supply downstream from the Peace Canyon Dam, but does not experience problems with gas bubble disease. (N. Todd, personal communication). The hatchery water is aerated and tumbled over baffles prior to distribution, ensuring the elimination of gas supersaturation.

5.2 PEACE RIVER: FORT ST. JOHN TO TAYLOR

The Pine River enters this reach of the Peace River approximately 1.8 km upstream from the Alaska Highway bridge (Figure 3). The mean annual flow (M.A.F.) of the Peace River upstream from the Pine River (1 190 m^3/s) is increased by 199 m^3/s from the Pine River (Figure 5). The ratio of Peace River mean annual flow to Pine River mean annual flow, assuming uniform mixing, is 6:1. The Pine River is the largest tributary of the Peace River in British Columbia, contributing 14 percent of the Peace River flow at the B.C.-Alberta border.

a) Pine River

Upper Watershed

The water quality of the upper Pine River (i.e. upstream from the Murray River) near the Village of Chetwynd was reviewed by Butcher (1985). Most of the Pine River watershed is in a pristine natural state with minimal land disturbance. The resulting water quality was determined to be good with the exception of seasonally high suspended sediment loads. This is accompanied by levels of turbidity, total iron, and total manganese in excess of B.C.'s drinking water quality standards.

The major influence on water quality in the upper Pine River is year-round discharge of treated sewage from the Village of Chetwynd. Available water quality data for sites downstream from Chetwynd did not show any serious impairment of water quality, although the data base was not sufficient for a thorough analysis. Two trends were evident from receiving water data projected from waste loads: first, phosphorus levels during the August low flow are projected to be double ambient concentrations, thereby reducing the N:P ratio to 5:1 and stimulating nuisance algal growth; and secondly, fecal coliform concentrations are projected to be up to 40 MPN/100 mL during the August low flow and 4 000 MPN/100 mL during the winter low flow.

Chetwynd is well upstream from the Peace River and there is substantial dilution of the upper Pine River by the Sukunka and Murray Rivers, and thus it is not expected that Chetwynd would have any effect on the Peace River. The Northeast Coal Project is located in the upper Murray River drainage and is also not expected to have any adverse impact on the Peace River water quality.

At Mouth of Pine River

Water quality data for the Pine River upstream from the confluence with the Peace River for the period 1971-1977 are presented in Table 34. Comparison of these data to those from the Peace River upstream from the Pine River confluence (Table 27) shows that:

1) the Pine River was similarly alkaline (total alkalinity 87-177 mg/L, pH 7.5-8.4), moderately hard (91-187 mg/L), colored (<1-39 TAC), and variably turbid (turbidity 3-460 NTU, suspended solids 4-643 mg/L);
2) the Pine River had higher maximum levels of dissolved phosphorus (44 µg/L compared to 24 µg/L at Peace River site 0400491), total phosphorus (1.4 mg/L compared to 0.3 mg/L at Peace River site 0400138), and ammonia-N (34 µg/L compared to 15 µg/L at Peace River site 0400139);
3) the maximum levels of dissolved lead (5 µg/L), dissolved mercury (0.17 µg/L), dissolved zinc (60 µg/L), and dissolved copper (4 µg/L) in the Pine River were similar to or less than levels measured in the Peace River (Table 38), while the maximum levels of total manganese (0.4 mg/L) and total iron (34 mg/L) were higher than the levels in the Peace River; and
4) the maximum level of fecal coliform bacteria (920 MPN/100 mL) in the Pine River was higher than the maximum level recorded in the Peace River upstream from the Pine River (490 MPN/100 mL).

Available data for Peace River sites downstream from the Pine River do not show discernible increases which could be related to Pine River input.

Given the dilution available for Pine River water and the general similarity of Pine River water quality to that of the Peace River, it is apparent that the Pine River would not produce major effects on downstream Peace River water quality.

b) Peace River Mainstem

There are eight Ministry of Environment and Parks water quality sites and one Inland Waters Directorate water quality site on this Peace River reach between Fort St. John (downstream from PE 389) and Taylor (upstream from PE 1379). The map locations of these sites are shown in Figure 3 and site descriptions are given in Table 29. The water quality data for these sites are summarized in Tables 14 (0400491-0400492), 26 (0400157), 27 (0400138- 0400140), 33 (0410018), 35 (07FA003), and 36 (0410053). Collectively, these data span the period 1971-1980.

Several problems with the available data detract from its usefulness for this analysis. First, sampling was not done systematically on the same day at all stations for the same water quality variables; and therefore upstream/downstream trends cannot be established conclusively. Secondly, there are only a few samples (n=1-3) for most characteristics at the two sites nearest to discharge PE 389. Thirdly, the distances between sites are too great for the purpose of delineating a zone of influence for the Fort St. John discharge; and fourthly, much of the data were recorded prior to the installation of the new Fort St. John outfall to the Peace River.

General Characteristics. Given the above qualifications, the available data do not suggest that discharge PE 389 from Fort St. John has negatively altered downstream receiving water levels of alkalinity, pH, dissolved oxygen, hardness, color, turbidity, or suspended solids (see Table 37 for a comparison of values, upstream/downstream from PE 389). Although the sample size is small, there are no apparent signs of sewage-related impacts 25 m downstream from the outfall. Further sampling is needed to define the zone of influence.

Metals. The available data show no obvious increase in metals concentrations downstream from PE 389 which could be attributed to the discharge. This follows the predictions of no significant increases in metals concentrations made in Table 13. As shown in Table 38, there is no apparent increase in total cadmium, total chromium, dissolved copper, total mercury, or total zinc levels downstream from PE 389 when compared to upstream levels. Downstream increases are noted for total copper, total nickel, and for total and dissolved lead. High concentrations of total copper, total lead, total mercury, and total nickel occurred at site 0400157, the cooling water intake embayment for the Petro-Canada refinery. These high levels could have resulted from pump maintenance activities as noted for increases in oil and grease levels (Section 5.10b ii).

Metals concentrations in this reach of the Peace River exceeded working water quality criteria for aquatic life for these metals: total and dissolved copper, total cadmium, total and dissolved lead, total mercury, and total zinc, as shown below.

	Maximum Level Recorded µg/L	No. of Values Exceeding/Equal to Criteria	Working Criteria for Aquatic Life µg/L
Copper , Total	100	7 of 9	2
, Dissolved	10	2 of 2	2
Cadmium, Total	0.5	2 of 2	0.2-4
Lead , Total	35	3 of 9	5-30*
, Dissolved	29	3 of 24	5-30*
Mercury, Total	0.7	1 of 2	0.1
Zinc , Dissolved	90	3 of 23	50

It should be emphasized that the sample sizes for these characteristics have been small and that further sampling is needed.

* depending on hardness and species present.

<u>Nutrients</u>. Total phosphorus levels downstream from the Fort St. John discharge have ranged from 0.003 to 0.3 mg/L, the same range of values recorded for sites upstream from Fort St. John. The maximum concentration of 0.3 mg/L occurred on the same date (April 25, 1973) as the maximum concentration (0.3 mg/L) for upstream sites, indicating that this high level was unrelated to the discharge of sewage, and more likely related to the high suspended sediment level recorded on this date (288 mg/L).

Only four dissolved phosphorus samples have been taken from the reach between PE 389 and PE 1379. The values range from less than the detection limits (<0.003 mg/L) to 0.024 mg/L. All dissolved phosphorus values for sites upstream from Fort St. John were less than the detection limits (Table 38). One set of paired upstream/downstream values was taken, and these indicate a significant increase in dissolved phosphorus downstream from discharge PE 389. On July 30, 1975, dissolved phosphorus was 0.003 mg/L at site 0400495 (35 km upstream from PE 389) and 0.024 mg/L at site 0400491 (0.2 km downstream from PE 389). This represents an eight-fold increase over ambient conditions. However, the maximum increase in receiving water dissolved phosphorus was predicted to be 0.7-0.8 µg/L during extreme low flows (Section 4.7 b). The high phosphorus value of 0.024 mg/L suggests that the effluent was not completely diluted with river water at site 0400491, 200 m downstream from the discharge. This is not an unexpected result, since these measurements were taken before the new diffuser outfall was installed in 1980. It is likely that the new outfall provides better dilution. Clearly, more dissolved phosphorus data are needed to evaluate the effectiveness of the outfall.

The maximum receiving water nitrogen levels in this reach downstream from Fort St. John were recorded as follows: nitrate-N, 0.1 mg/L; nitrite/-nitrate-N, 0.54 mg/L; and ammonia-N, 0.015 mg/L (Table 38). Combining the average ammonia and nitrite/nitrate concentrations, and comparing this sum (0.054 mg/L) to the average dissolved phosphorus concentration (0.01 mg/L) gives a nitrogen to phosphorus ratio of 5.4:1. This shows a reduction in the N:P ratio calculated for the reach upstream from Fort St. John (20:1), to a situation where algal growth downstream from Fort St. John could be nitrogen-limited. Given this information, algal growth should have reached nuisance proportions downstream from PE 389. However, because few data are available to calculate these ratios, their reliabililty is suspect. To date, casual observations of algal growth have not indicated a problem. Light is probably a limiting factor for algal growth as a result of high levels of turbidity and suspended solids. In the future, systematic observations of algal growth should be recorded.

Fecal Coliform bacteria have not been extensively sampled immediately downstream from the Fort St. John discharge. Only four samples have been taken from the three sites at 25 m (0400492), 200 m (0400491), and 500 m (0410018) downstream from PE 389. Fecal coliform levels at these sites ranged from 50 to 200 MPN/100 mL. The maximum fecal coliform level in this reach of the Peace River was 490 MPN/100 mL, at site 0400138, 6 km downstream from discharge PE 389. Fecal coliform levels have not been measured immediately upstream from Taylor (12 km downstream from PE 389). Fecal coliform levels in the Fort St. John discharge have improved markedly since institution of the redesigned treatment system in 1983: counts have been consistently below detection. Thus, even with maximum background (i.e. upstream) levels of up to 130 MPN/100 mL, we would not expect downstream levels of greater than 200 MPN/100 mL, as have been measured in the past. Fecal coliform concentrations now would not exceed working criteria for contact recreation (200-400 MPN/100 mL; Richards, 1983); however complete water treatment plus disinfection may be necessary prior to drinking water use in Taylor (i.e. >100 MPN/100 mL; B.C. Ministry of Health, 1982). These conclusions are tentative because of the sparse data, and more sampling for fecal coliforms is required within this reach to define the situation.

Dissolved Gases have been measured only at one site (0400492) within this reach. Total dissolved gases ranged from 101.5 to 104.6 percent saturation and dissolved nitrogen ranged from 101.3-107 percent saturation (Table 14). These values are within the safe range for fish species.

5.3 PEACE RIVER, TAYLOR TO THE BEATTON RIVER

a) Water Quality

There are five Ministry of Environment and Parks water quality sites and seven Chemical and Geological Laboratories Ltd. water quality sites on the Peace River between the Village of Taylor and the confluence with the Beatton River. The map locations of the Ministry of Environment sites are shown in Figure 3 and site descriptions for all sites are given in Tables 29 and 39.

The water quality data for these sites are summarized in Tables 36, 39, 40 and 41. The Ministry of Environment data span the periods November, 1971 to October, 1974 and April 1978. The Chemical and Geological Laboratories Ltd. (Noton, 1981) data are from June and September, 1980.

These water quality data are not representative of the worst-case conditions which are possible when peak waste loadings coincide with minimum river flows. Waste loadings from the refinery on the dates of the most recent water quality sampling were low to average and the actual dilution ranged up to two times greater than the minimum theoretical dilution (Table 42). Thus, the following analysis of actual water quality data in this reach of the Peace River is qualified with predicted, worst-case values.

General Characteristics. The available water quality data for alkalinity, pH, and hardness downstream from discharge PE 1379 do not indicate significant change relative to upstream water quality. The pH of the refinery process effluent since 1981 has been consistenly less than 8.5 (Section 4.10b).

Dissolved oxygen data for the Peace River downstream from discharge PE 1379 does not show any change relative to upstream sites which could be attributed to the Petro-Canada effluent. This is in agreement with the predictions made from effluent data (Section 4.10b).

Turbidity and suspended solids data for sites downstream from the refinery also show no change relative to upstream sites. This is in agreement with predictions of downstream suspended solids increase of less than 1 mg/L (Section 4.10 b).

Elevated temperatures were recorded downstream from the discharge and extended at least 2 km downstream. The temperature of the effluent leaving the end of the outfall has been measured at up to 6.5°C over ambient temperatures. Downstream temperatures remained up to 1-1.5°C above ambient for a distance of 2 km downstream. These temperatures were recorded during the spring and late summer when ambient temperatures are at their highest. During the winter, a much larger temperature differential might be expected. These data indicate that the refinery discharge may increase the receiving water temperature (outside the 100 m initial dilution zone) by more than the 1°C increase allowed by the Pollution Control Objectives. Once complete mixing has been achieved, it has been predicted that the Peace River temperature would increase by 0.1°C during the low flow.

Phenols

Noton (1981) found elevated levels of phenols (0.011 mg/L and 0.027 mg/L) in the end-of-pipe turbulence (i.e. approximately 10 m downstream from the outfall) compared to the upstream control site in June and September, 1980 (Tables 39 and 41). All downstream sites (70 m, 400 m, 1 km downstream from the outfall) had phenol levels equivalent to background levels (<0.002-0.006 mg/L). The Ministry of Environment and Parks has sampled phenols only once at two sites (0410054 from the Petro-Canada outfall. Both phenol levels (0.002 mg/L) equalled the upstream value (Table 34). The prediction of a 0.08 µg/L increase in receiving water phenols (made in Section 4.10 b) was for a worst-case situation. The working criteria for phenols are 0.001 mg/L for aquatic life (fish tainting) and 0.002 mg/L for public water supplies, although it is not yet known whether the phenol levels determined here include those phenolic materials that are responsible for the environmental effects on which the criteria are based.

Oil and Grease

Oil and grease levels have been elevated downstream from the Petro-Canada outfall. The Ministry of Environment and Parks recorded a concentration of 24.4 mg/L in a surface sample at site 0410054 100 m downstream from the outfall (Table 36). The concentration 400 m downstream on the same day was 1.0 mg/L (Site 0410055, Table 36). The maximum level of oil and grease recorded by the Ministry upstream from the outfall was 2.9 mg/L at site 0400157 (Table 26). Noton (1981) found detectable levels of oil and grease (3 mg/L) only at a site 400 m downstream from the outfall in June, 1980 (Table 39). In September, 1980, an elevated level (9 mg/L) was found only in the turbulent receiving water at the end of the outfall.

Noton described varying amounts of oil on the surface water at downstream sites which were not evident at control sites. The source of the oil has not been positively identified, although Noton suspected that it may originate from refinery-contaminated groundwater seeping into the river immediately downstream from the outfall.

It was predicted in Section 4.10 b that effluent loading could increase receiving water oil and grease levels by 0.2 µg/L. However, this assumes complete mixing with the receiving waters which is unrealistic since oil and grease would tend to separate from the water as a surface film. Surface concentrations as shown above, are much higher than this prediction.

Metals. Elevations in the concentrations of total copper, total lead, and dissolved mercury have been recorded downstream from the Petro-Canada outfall relative to upstream levels. Total copper reached a maximum concentration of 20 µg/L downstream from the outfall (Table 40), compared to maximum upstream levels of <10 µg/L (Table 27) (excluding the suspicious total copper level of 10 µg/L from site 0400157, for reasons given in Section 5.2). Total lead reached a maximum of 10 µg/L downstream from the outfall (Table 40) compared to a maximum upstream concentration of 5 µg/L (Table 27) (excluding results from site 0400157). Downstream dissolved mercury levels reached a maximum of 0.4 μg/L (Table 40) compared to a maximum upstream level of 0.14 μg/L (Table 15). All of these maximum metals concentrations downstream from the outfall exceeded working criteria for the protection of aquatic life. Downstream total zinc levels reached a maximum of 70 μg/L (Table 40) compared to an upstream maximum dissolved level of 9 μg/L (Table 27).

Concentrations of receiving water cadmium, chromium, and nickel downstream from the outfall showed no change relative to matching upstream concentrations. Dissolved copper, dissolved lead, and dissolved zinc levels were lower at sites downstream from the Petro-Canada outfall, compared to upstream levels. Downstream dissolved copper was 2 μg/L (Table 40) compared to an upstream maximum of 150 μg/L (Table 27). Downstream dissolved lead was 3 μg/L (Table 40) compared to an upstream maximum of 29 μg/L (Table 27) and downstream dissolved zinc was 50 μg/L (Table 40) compared to an upstream maximum of 100 μg/L (Table 15). These dissolved metals levels may be lower than upstream levels, but they still equal or exceed their respective criteria for aquatic life. However, they are lower than the respective safe limits for drinking water.

Metals concentrations in the receiving water were not predicted to increase as a result of waste loading from the refinery discharge (Section 4.10 b). The above reported increases/decreases in metals concentrations may not reflect actual trends since paired upstream/downstream data taken on the same day were not available for comparison. Future sampling of this type is needed to verify the patterns of metals concentrations discussed above.

Cyanide was measured on only one occasion in 1978 by the Ministry of Environment and Parks at three sites (Table 36). The three measurements were less than the detection limit (<0.01 mg/L). Noton (1981) also recorded levels below the detection limit (<0.02 mg/L) at seven downstream sites in June and September, 1980.

The worst-case increase in receiving water cyanide concentrations (after complete mixing) was predicted to be 0.08 µg/L (Section 4.10 b). This concentration is lower than the working criteria for both aquatic life (4-10 µg/L and public water supplies (200 µg/L). Concentrations within the initial dilution zone are also not expected to exceed these criteria. Additional monitoring for weak-acid dissociable cyanide (minimum detectable concentration ≦5 µg/L) is needed.

Nutrients. Total phosphorus levels downstream from the Petro-Canada outfall have ranged from <0.003 to 0.9 mg/L (at sites 0400142-0400144, Table 40). The maximum concentration of 0.9 mg/L occurred at site 0400144 on April 24, 1973. The maximum upstream concentration (0.3 mg/L) occurred at site 0400138 on April 25, 1973. No other paired data for total phosphorus are available. These data suggest a sizeable elevation of total phosphorus downstream from the refinery outfall, although it may be due to background variation between two days.

The Ministry of Environment and Parks has measured dissolved phosphorus downstream from the refinery outfall only once at two sites (0410054-0410055). At both sites in April, 1978, dissolved phosphorus was 0.004 mg/L compared to 0.009 mg/L at the paired upstream site (0410053) (Table 36). In September, 1980, Noton (1981) found that total and dissolved phosphorus levels at both control and downstream sites were less than their detection limit of 0.016 mg/L. It was predicted from waste load data (Section 4.10b), that the maximum increase in receiving water dissolved phosphorus would be 0.5 µg/L.

The maximum receiving water nitrogen levels downstream from the Petro-Canada refinery were as follows: nitrate-N, 0.13 mg/L; nitrite/nitrate-N, 0.11 mg/L; and ammonia-N, 0.011 mg/L (Table 40). These are not elevated relative to upstream levels (Tables 14, 27, 35 and 36). Combining the average ammonia (0.02 mg/L) and nitrite/nitrate (0.06 mg/L), gives a nitrogen: phosphorus ratio of 20:1, indicating phosphorus limitation. This shows an increase over the N:P ratio (5.4:1) calculated for the Peace River reach between Fort St. John and Taylor, although the ratios were calculated using very few data.

Fecal Coliform bacteria have been sampled downstream from the Petro-Canada outfall at sites 0400142-0400144 on five occasions during the period 1971-1974 (more recent data are not available). Fecal coliform levels ranged from <2 to 350 MPN/100 mL (geometric mean of 26 MPN/100 mL). This is similar to the maximum of 490 MPN/100 mL recorded upstream at site 0400138, during the same period. Fecal coliforms are not discharged from the Petro-Canada refinery. The source of the contamination was upstream, possibly from the City of Fort St. John and from diffuse sources both upstream and downstream from the City.

These data suggest that coliform levels were safe for contact recreation (200 MPN/100 mL geometric mean), and that drinking water would have to receive more treatment than disinfection prior to use. There are presently too few data to be conclusive. More fecal coliform samples are required to verify the magnitude and downstream extent of the contamination.

Sulphide. Total sulphide levels measured by the Province in 1978 (Table 36) were not detectable (<0.05 mg/L) downstream from the refinery discharge. Noton (1981) also reported that all of the downstream sulphide measurements were not detectable (<0.01 mg/L, <0.05 mg/L; Tables 39 and 41) in 1980.

Un-ionized H_2S is the more toxic portion of total sulphide. If un-ionized H_2S is taken to be 20 percent of total sulphides (assuming pH = 7.8, Temp. = 5°C; Broderius and Smith, 1976), the above results would translate to a maximum downstream un-ionized H_2S concentration of <0.01 mg/L (<0.002 to <0.10 mg/L). The worst-case increase in receiving water total sulphide (as un-ionized H_2S) was predicted to be <0.001 mg/L during the low flow (Section 4.10 b). This is less than the working criteria for aquatic life (0.002 mg/L), and the public water supply criterion of 0.05 mg/L. Presently, there are insufficient receiving water sulphide data from which to draw unambiguous conclusions.

Fluoride. The Province has measured receiving water fluoride levels on only one occasion (April, 1978) at two downstream sites. Both measurements were <0.1 mg/L. Noton, (1981) found no difference in fluoride levels between upstream sites (<0.10-0.13 mg/L) and downstream sites (<0.10-0.14 mg/L).

The maximum increase in receiving water fluoride levels as a result of the refinery discharge was predicted to be 0.002 mg/L (Section 4.10 b). Both the actual concentrations and the predicted concentration increases are less than the working criteria for aquatic life and public water supplies (1.0 and 1.5 mg/L, respectively).

b) Benthic Macroinvertebrates

The benthic macroinvertebrate population of the Peace River between the W.A.C. Bennett Dam and the Alberta border has been studied only near the Petro-Canada refinery at Taylor. Noton (1981) of Chemical and Geological Laboratories Ltd. (C+G) sampled natural and artificial substrates, both upstream and downstream from the refinery effluent discharge during June and September, 1980. The sampling results, in terms of mean numbers and percent species composition, are given in Tables 44-47.

The benthic invertebrate communities sampled downstream from the refinery discharge in 1980 were generally different in taxonomic composition, and lower in density and diversity than those upstream. In addition, downstream samples were ranked closer to the origin in the species-density ordination, indicating that they were stressed relative to upstream (control) samples. Changes in species composition were not always consistent. However, oligochaetes and nematodes (pollution-tolerant organisms) were generally more abundant at downstream sites, while plecopterans, trichopterans, and blackfly larvae (in general, pollution-sensitive organisms) were more abundant upstream from the effluent. Benthic faunal changes in 1980 were noted 1.5 km downstream from the discharge. The full downstream extent of effects was not determined.

The mode of action of the refinery effluent on the benthic invertebrate community is not known. The water quality sampling conducted by C&G on June 11 and September 11, 1980, did not reveal which variables would have affected the benthos. The present analysis of water quality has found significant increases in temperature, metals (copper, lead, zinc, and mercury), and oil and grease downstream from the refinery outfall. These variables singly or in combination, could be implicated in the observed faunal change. Alternatively, the effects could have been produced by nutrient changes or by unknown organic compounds which have yet to be measured. Chemical synergism or sub-lethal behavioral changes could also be responsible for the observed changes in the benthos. The possibility that unknown organic contaminants may be entering the river raises concern for the contamination of downstream water uses and deleterious effects on the downstream fish community. A study of the combined refinery effluent is needed to determine the types and amounts of organic contaminants present.

The standing crop of benthic invertebrates up to 1.5 km downstream from the refinery showed responses (in 1980) ranging from an increase to an order of magnitude decline. Although this does not represent a serious decline in the overall aquatic productivity of the Peace River, it could mean a significant reduction in the types and amount of food available for fish for a minimum distance of 1.5 km downstream from the refinery. The downstream invertebrate community may also be more vulnerable to further contaminant stress.

The improvement in effluent quality since 1983 was reflected in the 1985 study of the benthic community by E.V.S. Consultants (Cross and Nix, 1986). The benthos associated with both natural and artificial substrates showed no evidence of adverse impact related to Petro-Canada effluent or groundwater seepage. Statistical analysis showed no distinction between sites located upstream and downstream from the effluent discharge. Comparison of the benthic community between 1982 (Noton, 1982) and 1985 showed: 1) an increase in both the number of taxa and number of individuals at the majority of stations sampled in 1985; and 2) species richness was higher than in 1982 and relatively constant at all downstream stations suggesting minimal effects of the discharge. Cross and Nix (1986) concluded that the increase in species richness since improvement in effluent quality indicated improving water quality.

c) Sediments

Results of sediment hydrocarbon analysis by E.V.S. Consultants Ltd. (Cross and Nix, 1986) indicated that there was no trend of increasing aliphatic hydrocarbon concentrations downstream from the effluent discharge. Levels were 5-8 μg/g at all stations except for one station upstream from the discharge (29 μg/g). The source of this anomolous value was not identified.

5.4 PEACE RIVER, BEATTON RIVER TO THE ALBERTA BORDER

The Beatton River and the Kiskatinaw River are the major tributaries in this reach of the Peace River. The mean annual flow (M.A.F.) of the Peace River downstream from Taylor (1 390 m^3/s) is increased by 53 m^3/s from the Beatton River and by 11 m^3/s from the Kiskatinaw River (Figure 5). The ratios of Peace River M.A.F. to Beatton River and Kiskatinaw River M.A.F. are 26:1 and 126:1, respectively.

a) Beatton River

The Beatton River enters the Peace River approximately 18 km downstream from Taylor and 25 km upstream from the B.C./Alberta border (Figure 3). On the Beatton River immediately upstream from the confluence with the Peace River, there is one Ministry of Environment and Parks water quality site (0400145) and one Inland Waters Directorate water quality site (07FC0002). The map locations of these sites are shown in Figure 3 and site descriptions are given in Table 29. There are no other water quality sites between the Fort St. John discharge (PE 388) and the Peace River.

The water quality data are summarized in Table 18 for site 0400145 and in Table 19 for site 07FC0002. The Ministry of Environment and Parks data span the period November, 1971, to October, 1974. The Inland Waters Directorate data are for March to September, 1976.

The water quality assessment for this downstream reach is hampered by an absence of water quality data both upstream (i.e. a control) and immediately downstream from discharge PE 388. This prevents an accurate analysis of the impact of the Fort St. John discharge relative to upstream conditions. Additionally, it is not possible to define the downstream extent of the zone of influence from discharge PE 388. More recent data are also needed.

General characteristics. The available data for alkalinity, pH, hardness, color, dissolved oxygen, turbidity, and suspended solids at the mouth of theBeatton River do not suggest degradation from expected natural conditions. The Beatton River is variably alkaline (28-276 mg/L; pH 7.2-8.2) and hard (48-257 mg/L), highly colored (144-205 TAC units), well oxygenated (8.2-13.4 mg/L), and turbid (13-680 NTU; suspended solids 6.4-2229 mg/L). The sites from which these data were taken are too far downstream to show the small increases in BOD and suspended solids predicted in Section 4.8 b due to the Fort St. John discharge (PE 388).

The high levels of color in the Beatton River water make it undesirable for public water supplies (working criteria, 15-75 TCU) and recreation (working criteria 15 TCU). Turbidity and suspended solids also exceed working criteria for public water supplies, and treatment would be needed to remove the suspended solids prior to drinking use.

Metals. As shown in Tables 18 and 19, the following metals have been measured at concentrations higher than working criteria for public water supplies, aquatic life, or recreation:

		Maximum Level Recorded	No. of Values Exceeding/Equal to Criteria	Working Criteria	Site
Arsenic	, Extractable	440 µg/L	2 of 6	R,A,P 50 µg/L	07FC0002
Cadmium	, Extractable	1.1 µg/L	4 of 8	A 0.2-4.0 µg/L	07FC0002
Copper	, Total	30 µg/L	2 of 2	A 2 µg/L	0400145
	, Extractable	25 µg/L	8 of 8	A 2 µg/L	07FC0002
	, Dissolved	50 µg/L	6 of 7	A 2 µg/L	0400145
Iron	, Total	1.7 mg/L	1 of 1	P 0.3 mg/L A 0.3-1 mg/L	0400145
	, Extractable	8.4 mg/L	8 of 8	P 0.3 mg/L A 0.3-1 mg/L	07FC0002
	, Dissolved	2.6 mg/L	1 of 7	P 0.3 mg/L A 0.3-1 mg/L	07FC0002
Lead	, Total	14 µg/L	2 of 2	A 5 µg/L	0400145
	, Dissolved	6 µg/L	1 of 7	A 5 µg/L	0400145
Manganese	, Total	0.09 mg/L	1 of 1	P 0.05 mg/L	0400145
	, Extractable	0.33 mg/L	8 of 8	P 0.05 mg/L A 0.1-1 mg/L	07FC0002
	, Dissolved	0.08 mg/L	1 of 7	P 0.05 mg/L	0400145
Mercury	, Extractable	0.13 µg/L	2 of 6	A 0.1 µg/L	07FC0002
	, Dissolved	0.83 µg/L	2 of 7	A 0.1 µg/L	0400145
Nickel	, Extractable	30 µg/L	1 of 8	A 25 µg/L	07FC0002
Selenium	, Extractable	3.4 µg/L	2 of 7	A 1 µg/L	07FC0002
Zinc	, Total	0.11 mg/L	2 of 2	A 0.05 mg/L	0400145
	, Extractable	60 µg/L	1 of 7	A 50 µg/L	07FC0002

A - working criteria for aquatic life

P - working criteria for public water supplies

R - working criteria for recreation

Metal concentrations exceeding the working criteria for public water supplies include arsenic, iron, and manganese. The maximum concentrations recorded for dissolved mercury (0.83 μg/L), extractable arsenic (440 μg/L), and dissolved iron (2.6 mg/L) are particularly high compared to levels recorded for other reaches in the Peace River sub-basin. It should be noted that the Ministry of Environment and Parks dissolved mercury data are substantially higher than the extractable mercury data recorded by Environment Canada. More monitoring of these variables is needed to resolve this difference (extractable data are expected to be greater than dissolved data). It should be noted that these apparent differences may also reflect the wide fluctuations for the parameters measured on different days. For more valid comparisons between sites, future sampling should be conducted on the same dates.

The high metal levels would preclude the use of the lower reach of the Beatton River for drinking water, without appropriate treatment. Future studies should attempt to identify the source of these high metal levels, which cannot be attributed solely to high levels of suspended solids. Fish tissue mercury levels have not been recorded for the Beatton River. However, high levels are to be expected and fish tissue sampling should be a future priority. This could include metallothionein analyses from fish livers. Additionally, the loss of metal sensitive planktonic algal species could be checked (M. Clark, personal communication).

Without comparative upstream data, it is difficult to assess the exact contribution to these levels from discharge PE 388. In addition, without effluent metal-loading values (Table 16), it is impossible to calculate predicted increases in receiving water metal levels. However, no obvious increase in metal concentrations was observed downstream from the Peace River, Fort St. John discharge (Section 5.2). Since both PE 388 and PE 389 arise from the same source and are of similar magnitude discharging to large rivers, we might expect similar effects on the receiving waters. Such a conclusion requires confirmation from an adequately designed sampling program. The effluent from PE 388 should be checked for metals as a first step.

Nutrients. Total phosphorus levels at the mouth of the Beatton River have been very high, ranging up to 1.9 mg/L (Table 19). These high levels were coincident with high suspended solids levels. It has been predicted (Section 4.8 b) that Beatton River receiving water total phosphorus levels would increase by 0.06 mg/L, downstream from the Fort St. John discharge. Whether the high total phosphorus values recorded at the mouth reflect such effluent contribution will require paired upstream/downstream data.

Dissolved phosphorus levels have been high, ranging from 0.02 to 0.08 mg/L. Further study is required to determine the extent of the contribution of effluent phosphorus loading to this receiving water level.

The maximum concentrations of nitrogen recorded at the mouth of the Beatton River were: nitrate-N, 0.18 mg/L; nitrite/nitrate-N, 0.7 mg/L; and ammonia-N, 0.5 mg/L (Tables 18, 19). Combining the average ammonia (0.1 mg/L) and nitrite/nitrate concentrations (0.2 mg/L), and dividing this sum by the average dissolved phosphorus concentration (0.038 mg/L) gives a nitrogen to phosphorus ratio of 8:1. This is a low N:P ratio for the Peace River sub-basin. It potentially indicates no limitation or co-limitation of nutrients in the lower Beatton River. Admittedly, this calculation of N:P ratios using average values derived from sporadic measurements is less valid than concurrent N, P measurements taken during the active growing period: however, it provides a rough approximation until more valid measurements are available. In the future, a better indication of nutrient limitations would be provided by an examination of N:P in algal tissue (Nordin, 1985).

Reliable observations of algal growth downstream from PE 389 are not presently available, although algal growth is not believed to be a significant problem by regional Waste Management Branch staff. Light is probably the immediate limiting factor for algal growth during the spring effluent discharge period as a result of the high levels of turbidity and suspended solids. Observations of algal growth and paired upstream/downstream nitrogen and phosphorus data from the same date are needed to evaluate the effect of nutrient loading by PE 388 on the receiving waters.

Fecal Coliform bacteria were sampled at the mouth of the Beatton River during the period, 1972-1974, by the Ministry of Environment and Parks (Table 18). Of a total of six samples, only one (170 MPN/100 mL) was taken during the effluent discharge period on June 15, 1972. The remaining samples ranged from 20 to 130 MPN/100 mL, for periods when effluent was not being discharged.

This suggests that the Beatton River fecal coliform levels would be safe for contact recreation (200 MPN/100 mL geometric mean; 400 MPN/100 mL 90th percentile). Predicted increases in fecal coliform levels (45 MPN/100 mL) are also within this guideline for contact recreation (Section 4.8 b). These coliform levels would make filtration or equivalent treatment plus disinfection necessary, prior to drinking use. At present, there are no plans to use the Beatton River downstream from PE 388 as a source of domestic water supply. More sampling is required for sites both upstream (control) and immediately downstream from discharge PE 388 to confirm whether the working criteria are being met.

b) Kiskatinaw River

The Kiskatinaw River enters the Peace River approximately 11 km upstream from the B.C./Alberta border (Figure 3). Water quality data for the Kiskatinaw River are available for 3 sites including: 2 sites (0400544, and 07FD0007) 40 km upstream from the Peace River at the Alaska Highway crossing; and 1 site (0400149) immediately upstream from the Peace River confluence (Table 48). These data span the period 1972-1976. The map locations of these sites are shown in Figure 3, and site descriptions are given in Table 31.

The City of Dawson Creek draws its water supply from the Kiskatinaw River. At present, there are no licenced waste discharges impinging on the natural water quality of the Kiskatinaw River. The river traverses the agricultural area of the Alberta Plateau physiographic region and may receive diffuse loads of suspended solids, fertilizers, and phenoxy herbicides related to farming practices.

<u>General Characteristics</u>. The Kiskatinaw River is very hard with total alkalinity ranging from 103 to 249 mg/L, dissolved hardness ranging from 102 to 260 mg/L, and pH ranging from 7.5-8.6 for all three sites (Table 48). In comparison, the Peace River has reached a maximum dissolved hardness concentration of 130 mg/L at site 0400144. The Kiskatinaw River is as variably colored as the Beatton River, well oxygenated (D.O. 8.6-13.2 mg/L), and extremely turbid (26-3400 NTU; suspended solids 29-5726 mg/L) during high flows. Since turbidity exceeded the working criterion for public water supplies, treatment (settling, filtration) would be necessary prior to domestic consumption.

<u>Metals</u>. As shown in Table 48, the following metals have been measured at concentrations higher than working criteria for aquatic life and for public water supplies.

		Maximum Level Recorded	No. of Values Exceeding/Equal to Criteria	Working Criteria	Site
Aluminum	, Total	8.7 mg/L	2 of 5	A 0.05-0.1 mg/L	0400544
Cadmium	, Total	1.1 μg/L	5 of 5	A 0.2-4 μg/L	0400544
Chromium	, Total	50 μg/L	1 of 6	A 30 μg/L	0400544
Copper	, Dissolved	10 μg/L	6 of 7	A 2 μg/L	0400149
	, Extractable	20 μg/L	7 of 7	A 2 μg/L	07FD0007
Iron	, Total	40.3 mg/L	6 of 6	P, A 0.3-1.0 mg/L	0400544
	, Extractable	4.5 mg/L	7 of 7	P, A 0.3-1.0 mg/L	07FD0007
Lead	, Total	100 μg/L	2 of 6	A 5-10 μg/L	0400544
	, Extractable	10 μg/L	1 of 7	A 5-10 μg/L	07FD0007
Manganese	, Total	0.56 mg/L	5 of 6	P 0.05 mg/L	0400544
	, Extractable	0.45 mg/L	3 of 7	P 0.05 mg/L	07FD0007
Mercury	, Total	0.1 μg/L	1 of 5	A 0.1 μg/L	0400544
Nickel	, Total	60 μg/L	1 of 6	A 25 μg/L	0400544
Selenium	, Extractable	1.4 μg/L	6 of 6	A 1 μg/L	07FD0007
Zinc	, Total	0.34 mg/L	3 of 6	A 0.05-0.3 mg/L	0400544
	, Dissolved	0.09 mg/L	1 of 7	A 0.05-0.3 mg/L	0400149

A - working criteria for aquatic life
P - working criteria for public water supplies

Metal concentrations exceeding the working criteria for public water supplies include total and extractable iron and manganese. These high concentrations are related to the high suspended solids, and treatment (i.e. settling) prior to domestic use should eliminate the problem. The maximum concentrations for total aluminum, total cadmium, total chromium, total iron, total manganese, total nickel, and total zinc from the Kiskatinaw River are higher than maximum concentrations recorded for any upstream reaches of the Peace River or its large tributaries.

Nutrients. Nutrients have been measured at high levels in the Kiskatinaw River. A maximum total phosphorus concentration of 2.4 mg/L was recorded on April 24, 1973. On the same date, total phosphorus levels in the Peace River upstream from the Kiskatinaw River (site 0400146) reached 1.1 mg/L Comparable downstream data are not available for this date.

High dissolved phosphorus levels have also been recorded: up to 0.108 mg/L. This is four times higher than the maximum dissolved phosphorus level recorded downstream from the Fort St. John discharge PE 389 (0.024 mg/L). On the Peace River downstream from the Kiskatinaw River (site 07FD005), dissolved phosphorus reached a maximum of 0.018 mg/L (not on same date as the maximum level recorded for the Kiskatinaw River).

The maximum concentrations of nitrogen recorded at the mouth of the Kiskatinaw River were: nitrite/nitrate, 0.17 mg/L; and ammonia-N, 0.132 mg/L (Table 48). The sum of the average ammonia-N and nitrite-nitrate concentrations when divided by the average dissolved phosphorus concentration gives a nitrogen to phosphorus ratio of 3:1. This indicates that algal growth in the Kiskatinaw River is potentially nitrogen-limited, although light is probably the most important limiting factor as the Kiskatinaw River experiences high levels of turbidity and suspended solids. The high ammonia-N levels (0.132 mg/L) under summer conditions (assume pH = 8.6, T = 18°C) could produce un-ionized ammonia-N levels of 0.016 mg/L. This concentration could cause sub-lethal toxicity in fish in the Kiskatinaw River if it occurred over a prolonged period (greater than 10 days).

The source of this nutrient loading may be from diffuse agricultural practices. The effect on the Peace River after complete mixing would be negligible as a result of the high available dilution (126:1). However, there may be local effects downstream from the confluence before complete mixing is achieved.

Fecal Coliform levels at the mouth of the Kiskatinaw River have ranged from 6 to 220 MPN/100 mL (geometric mean of 29 MPN/100 mL). This suggests that these waters would be appropriate for contact recreation, although water treatment in addition to disinfection may be required for drinking water purposes. The effect of these fecal coliform levels on the Peace River downstream from the Kiskatinaw River would be negligible after complete mixing.

c) Peace River Mainstem

There are four water quality sites on this reach of the Peace River upstream from the Alberta border: the Ministry of Environment and Parks has monitored three sites (0400146-0400148) at a transect 8 km downstream from the Beatton River; and the Inland Waters Directorate has monitored one site (07FD0005) 20 km downstream from the Beatton River and 3 km upstream from the border. The locations of these sites are shown in Figure 3, and described in Table 29. The water quality data for these sites are given in Tables 35 and 49, and span the period November 1971 to September, 1976.

General Characteristics. Alkalinity, pH, and hardness levels downstream from the Beatton River were within the range of those at upstream sites and were less variable: total alkalinity ranged from 70 to 104 mg/L downstream compared to 76-505 mg/L upstream; total hardness ranged from 83 to 106 mg/L downstream compared to 81 to 181 mg/L upstream; and pH ranged from 7.7 to 8.2 downstream compared to 7.6-8.9 upstream.

Turbidity ranged to higher values (1.3-410 NTU) at the sites downstream from the Beatton River than those upstream (1.3-170 NTU). This appears to be due to the influence of the Beatton River which was highly turbid (13-680 NTU). This trend was reflected in maximum suspended solids values. Suspended solids downstream from the Beatton River ranged up to 2 098 mg/L; those upstream ranged up to 822 mg/L during the same time period (1971-1974). The contribution of suspended solids from the Beatton River (maximum concentration, 2 229 mg/L) affected downstream Peace River suspended solids loads. The Kiskatinaw River plays a smaller role in contributing suspended solids although data for the Peace River both upstream and downstream from the Kiskatinaw River are not available.

Color levels were also higher downstream from the Beatton River (9-77 TAC; 5-120 apparent) compared to levels upstream from the Beatton River (1-25 TAC; 5-50 apparent). Again, high color levels in the Beatton River (144-205 TAC) were responsible for the high values at downstream Peace River sites. The Kiskatinaw River may also play a role in contributing to the high color levels at Peace River site 07FD0005. The color values recorded within this reach exceeded the maximum acceptable limit for drinking water of 15 true color units (based on aesthetic considerations) and color removal prior to use would be desirable.

Metals. As shown in Tables 35 and 49, the following metals have been measured at concentrations exceeding the working criteria for aquatic life and public water supplies:

		Maximum Level Recorded	No. of Values Exceeding/Equal to Criteria	Working Criteria	Site
Cadmium	, Extractable	0.4 µg/L	3 of 25	A 0.2 µg/L	07FD0005
Copper	, Dissolved	10 µg/L	5 of 6	A 2.0 µg/L	0400148
	, Extractable	10 µg/L	18 of 25	A 2.0 µg/L	07FD0005
	, Total	20 µg/L	1 of 2	A 2.0 µg/L	0400148
Iron	, Dissolved	1.0 mg/L	4 of 6	P,A 0.3 mg/L	0400146
	, Extractable	3.4 mg/L	16 of 31	P,A 0.3 mg/L	07FD0005
Lead	, Extractable	7 µg/L	2 of 25	A 5 µg/L	07FD0005
	, Total	32 µg/L	2 of 2	A 5 µg/L	0400146
Manganese	, Extractable	1.2 mg/L	12 of 25	P 0.05, A 0.1 mg/L	07FD0005
Mercury	, Dissolved	1.0 µg/L	1 of 6	A 0.1; R,P 1.0 µg/L	0400147
Selenium	, Extractable	1.1 µg/L	1 of 15	A 1.0 µg/L	07FD0005
Zinc	, Dissolved	50 µg/L	1 of 5	A 50 µg/L	0400147

A - working criteria for aquatic life
P - working criteria for public water supplies

Metal concentrations which were most frequently and most severely in excess of the criteria include copper, iron, and manganese. It should be noted that the Inland Waters Directorate manganese data (site 07FD0005) exceeded the criteria for public water supplies, although the Ministry of Environment data did not.

Figure 7 compares the metals sampled from this reach which are in excess of the working criteria for aquatic life to those in the upstream reaches of the Peace River. The list of metals in excess of the aquatic life criteria for the Peace River downstream from the Beatton River includes three metals (iron, manganese, and selenium) which are not found to be in excess of the criteria, upstream from the Beatton River. The source of these metals appears to be tributary input from the Beatton River and the Kiskatinaw River.

Figure 8 shows the same kind of comparison for the working criteria for public water supplies. The metals, iron, manganese, and mercury have been measured in this reach of the Peace River in excess of or equal to their respective drinking water criteria. In comparison, no metals have been measured in excess of the criteria upstream from the Beatton River. The Beatton River and the Kiskatinaw River appear to be the likely source. Evidence supporting this hypothesis is that the highest dissolved iron measurement recorded in this reach of the Peace River occurred on the Beatton River side of the Peace River (i.e. site 0400146). Additionally, comparison of the metals data with those from upstream sites does suggest that high levels of dissolved iron and dissolved mercury were coincident with high levels of these metals in the Beatton River (e.g. upstream from the Beatton River dissolved mercury did not exceed 0.4 µg/L, while levels at the mouth of the Beatton River reached 0.83 µg/L and levels on the Peace River downstream reached 1.0 µg/L).

The mercury data recorded by the Ministry of Environment and Parks are not in agreement with those recorded by the Inland Waters Directorate. While the Ministry measurements of maximum dissolved mercury ranged from 0.4 to 1.0 µg/L, the Inland Waters Directorate did not detect (<0.05 µg/L) extractable mercury in any of 19 samples. The two sampling programs occurred during different years and natural fluctuations could account for the differences. Further monitoring is needed to determine whether in fact the Beatton River and the downstream Peace River experience these high mercury levels.

Nutrients. Total phosphorus levels downstream from the Beatton River ranged from 0.01 to 1.1 mg/L (Tables 35 and 49). The maximum concentrations occurred on April 24, 1973, during a period of high suspended solids loading (1560 mg/L). This indicates that much of the total phosphorus was in the particulate form. On this same date, total phosphorus was 0.9 mg/L upstream from the Beatton River at site 0400144 and 1.6 mg/L at the mouth of the Beatton River (site 0400145). These data indicate that the Beatton River increases downstream Peace River total phosphorus levels. Such paired upstream/downstream data for dissolved phosphorus are not available. Dissolved phosphorus levels downstream from the Beatton River have reached up to 0.018 mg/L (site 07FD0005). This maximum concentration is considerably higher than dissolved phosphorus values upstream from Fort St. John (<0.003 mg/L), but less than the maximum level of 0.024 mg/L recorded 200 m downstream from the Fort St. John discharge (PE 389).

Nitrogen levels in the Peace River downstream from the Beatton River ranged as follows: nitrate-N , <0.02-0.11 mg/L; nitrite/nitrate, 0.008-0.24 mg/L; and ammonia-N, 0.001-0.04 mg/L. Combining the maximum ammonia and nitrite/nitrate concentrations, and dividing this sum by the maximum dissolved phosphorus concentration, gives a nitrogen to phosphorus ratio of 16:1. This suggests that algal growth in the Peace River downstream from the Beatton River may be phosphorus-limited. However, using mean values for ammonia, nitrite/nitrate and dissolved phosphorus gives an N:P ratio of 7:1, indicating co-limitation of algal growth by both phosphorus and nitrogen. This may indicate a trend of decreasing phosphorus limitation from sites upstream from the Beatton River (20:1) to those downstream from the Beatton River. The more nutrient-rich Beatton River (with an N:P ratio of 8:1) and Kiskatinaw River (N:P of 3:1) are likely important influences on the nutrient status of the lower Peace River.

Fecal coliform levels downstream from the Beatton River ranged from <2 to 240 MPN/100 mL and averaged 18.7 MPN/100 mL (geometric mean) for 16 samples (on 6 different occasions). This suggests that the lower Peace River would be safe for water-contact recreation (the working criteria are 200 MPN/100 mL geometric mean; 400 MPN/100 mL 90th percentile). These coliform levels would make filtration or equivalent treatment plus disinfection necessary prior to drinking use. Because these conclusions are based on a small sample size, more sampling is required to define the present situation.

Dissolved gases have been measured once at site 0400147 downstream from the Beatton River. Total dissolved gases measured 105.5 percent saturation (Table 49), which is considered within the safe limit for fish species.

5.5 PEACE RIVER AT DUNVEGAN, ALBERTA

Dunvegan, Alberta is located approximately 120 km downstream from the B.C.-Alberta border. The Dunvegan water quality site 07FD0002 has the largest data base over the longest period of record for the Peace River in the vicinity of the B.C.-Alberta border. Water quality data for this site over the period August, 1969 to December 1982 are summarized in Table 50.

The mean annual flow for the Peace River at Dunvegan (1 491 m^3/s) is three percent larger than the mean annual flow for the Peace River upstream from the Alces River (Figure 5). However, there is a 10 percent increase in drainage area between the border and Dunvegan, suggesting a small runoff from the additional 12 000 km^2 located on the Alberta Plateau Plains.

There are no municipal or industrial discharges in this reach of the Peace River, although there may be some diffuse loading from agricultural activities (suspended solids and nutrients). The Pouce Coupe River and the Clear River are the major tributaries to the Peace River between the border and Dunvegan.

General Characteristics

As for all upstream reaches, the Peace River at Dunvegan is alkaline (pH 7.6-8.4, total alkalinity 73-106 mg/L), well oxygenated (D.O. 8.7-15.1 mg/L), and moderately hard (94-123 mg/L). From a drinking water perspective, water of this hardness and alkalinity would be considered of good quality. The water color (<5-500 apparent color units), turbidity (1-800 JTU), and suspended solids (1-1605 mg/L) can reach extremely high seasonal levels. The high turbidity would necessitate filtration (or equivalent treatment) to eliminate turbidity prior to domestic use.

Metals

The following metal levels have been measured at site 07FD0002 in excess of working criteria:

		Maximum Level Recorded	No. of Values Exceeding/Equal to Criteria	Working Criteria
Aluminum	, Extractable	7.9 mg/L	11 of 17	Ir, L,5; A,R,In 0.1
Cadmium	, Extractable	10 µg/L	3 of 17	A 0.2-4
Cadmium	, Total Recoverable	<1 µg/L	2 of 11	A 0.2-4
Chromium	, Extractable	0.03 mg/L	1 of 19	A 0.02
Copper	, Extractable	25 µg/L	8 of 18	A 2
	, Total Recoverable	8 µg/L	4 of 11	A 2
Iron	, Extractable	27 mg/L	12 of 26	A,P 0.3; Ir 5
Lead	, Extractable	19 µg/L	4 of 17	A 5
	, Total Recoverable	14 µg/L	1 of 10	A 5
Manganese	, Extractable	0.97 mg/L	7 of 25	P 0.05;A 0.1;Ir 0.2
Mercury	, Total	0.15 µg/L	3 of 19	A 0.1
Nickel	, Extractable	60 µg/L	2 of 17	P 13; A 25
Silver	, Extractable	5 µg/L	1 of 27	A 0.1
Zinc	, Extractable	0.2 mg/L	1 of 18	A 0.05-0.3

A - working criteria for aquatic life.
P - working criteria for public water supplies.
R - working criteria for recreation.
Ir- working criteria for irrigation
In- working criteria for industrial purposes.

Metals which were most frequently and most severely in excess of the criteria include aluminum, copper, iron, and lead. The list of metals in excess of the aquatic life criteria at Dunvegan includes only one variable, silver, not found in excess at sites upstream in British Columbia (Figure 7). The list of metals in excess of the working criteria for public water supply at Dunvegan is similar to that for upstream reaches (Figure 8). Since all of the metals in excess of the working criteria for drinking water were in the total or extractable form, it is likely that the high levels are related to the high levels of suspended solids. Settling or filtration prior to domestic use could eliminate the problem. Further monitoring of the more important dissolved form of these metals is needed to determine whether high levels would remain after such treatment.

Nutrients. Total phosphorus levels at Dunvegan ranged from 0 to 2.1 mg/L. The maximum concentration occurred on May 5, 1981, the same day that a maximum suspended solids concentration was recorded (1 605 mg/L). This suggests that total phosphorus was in the particulate form. Dissolved phosphorus reached a maximum level of 0.06 mg/L. This is the highest value of dissolved phosphorus recorded in the upper Peace River mainstem. It is, however, lower than the maximum levels recorded in the Beatton River (0.08, the Kiskatinaw River (0.108 mg/L) or the Pouce Coupe River (0.09 mg/L). Dissolved phosphorus levels at Dunvegan reflect the high loadings from these upstream tributaries.

Nitrogen levels in the Peace River at Dunvegan have ranged as follows: dissolved nitrogen, 0.08-0.44 mg/L; nitrite/nitrate-N, <0.01-0.14 mg/L; and ammonia-N, <1 mg/L. To calculate an N:P ratio for this site, more measurements are needed of ammonia-N using lower detection limits.

Fecal Coliform bacteria levels in the Peace River at Dunvegan have been low in 56 samples with a range of 1 to 79 MPN/100 mL (geometric mean, 9 MPN/100 mL). Fecal streptococci are more resistant to natural purification processes and are taken to be a better indication of fecal pollution at points distant from the source. At Dunvegan, fecal streptococci levels have also been low, ranging from <2 to 144 MPN/100 mL and averaging 16 MPN/100 mL (geometric mean). These fecal bacteria levels would probably necessitate disinfection plus filtration or equivalent treatment of downstream raw water supplies prior to domestic use.

Pesticides. Thirty-seven separate pesticides, including both herbicides and insecticides, have been measured at the Dunvegan site (Table 50). Most of the pesticides were not detected, and those that were detected (2,4-D; 2,4,5-T; Ethion; a-BHC: b-BHC) did not exceed any published water quality criteria.

Polychlorinated Biphenyls. Total aroclors (chlorinated aromatic substances) and four aroclor formulations were measured at Dunvegan, but none were detected (Table 50).

5.6 SUMMARY OF WATER QUALITY AND DESIGNATED WATER USES

a) Peace River, W.A.C. Bennett Dam to Fort St. John

Upstream from Fort St. John, anthropogenic waste sources are small and available dilution is great. No effects on downstream water quality outside the dilution zones have been projected or observed from the available data. Elevated levels of fecal coliform bacteria have been measured upstream from Fort St. John. The source of the high levels is presently unknown, although diffuse non-point sources are implied. Dissolved metal levels have been in excess of working criteria for aquatic life, but reflect high background concentrations contributed from the Williston Reservoir and tributary streams. Dissolved gas supersaturation, usually a problem downstream from hydroelectric dams, has been measured at levels considered safe for fish or invertebrates.

The present uses of this upper reach of the Peace River are for drinking water (the Village of Hudson's Hope), for water-contact recreation during the open-water season (i.e. boating, wading, angling), industry, wildlife, livestock watering, and aquatic life. It is proposed that these designated water uses be protected by provisional water quality objectives. Protection of these uses would also provide coincident protection of potential irrigation use.

b) Peace River, Fort St. John to Taylor

The water quality of this reach is influenced by upstream diffuse loadings and the City of Fort St. John discharge (PE 389). Fertilizers and herbicides are likely the most significant source of non-point waste loads. Fecal coliform bacteria levels downstream from the Fort St. John discharge were observed in the past and predicted to exceed 200 MPN/100 mL (Section 5.2) i.e. levels unsafe for untreated drinking water use and water-contact recreation. Increases in nitrogen and phosphorus levels are not predicted to have any measurable effect on downstream water quality, although there are presently insufficient receiving water data to verify such predictions. It has been predicted that receiving water chlorine residual levels may at times exceed the level considered safe for salmonid fish species; however, actual measurements in the river have not been taken.

The present uses of this reach of the Peace River are public water supplies (the Village of Taylor and the Petro-Canada refinery), industry, wildlife, water-contact recreation, and aquatic life. It is proposed that these designated water uses be protected by the provisional objectives. Protection of these uses would also provide coincident protection of potential irrigation use.

c) Peace River, Taylor to the Beatton River

The water quality of this reach of the Peace River requires protection from the Petro-Canada refinery waste discharge as well as the upstream effluents noted in Sections 6.1 and 6.2.

The Petro-Canada refinery effluent receives high dilution in the Peace River. However, actual water quality data in concert with predicted concentrations have indicated downstream increases for temperature, surface oil films, phenol, some metals, and nutrients. The lack of paired upstream/downstream sites and the small sample size, create ambiguous interpretations of the available water quality data. Elevated levels of fecal coliform bacteria have been measured downstream from the refinery; however, this is not likely related to the discharge, but to high upstream levels (likely originating from the Fort St. John discharge). Fecals

The present uses of the Peace River between Taylor and the Beatton River include water-contact recreation (i.e. boating, wading, angling), aquatic life, wildlife, industry, and irrigation). There are no withdrawals for drinking water in this reach. It is proposed that these present uses and potential drinking water use (to protect possible future or downstream users) be the designated water uses, and be protected by provisional water quality objectives.

d) Beatton River, Downstream from Fort St. John

The water quality of the lower Beatton River is influenced by waste loading from the City of Fort St. John discharge (PE 388). Inadequate receiving water data have prevented an accurate assessment of actual present conditions. It is expected that immediately downstream from the initial dilution zone during the discharge period, there would be increased levels of nutrients and fecal coliforms.

The present uses of this reach of the Beatton River are water-contact recreation (boating, wading, angling), wildlife and aquatic life. There are no withdrawals for drinking water supplies, nor does it seem likely that it will be used for drinking water in the future given its naturally poor quality for drinking (i.e. high turbidity, colour, hardness, arsenic, iron, and manganese) that would necessitate extensive treatment prior to use. However, it is proposed that drinking water use after complete treatment be included as a designated water use to protect this possibility. Potential uses include irrigation, industry, and livestock watering. It is proposed that these present and potential water uses be protected by provisional objectives.

e) Peace River, Beatton River to the Alberta Border

The water quality of the lower Peace River upstream from the Alberta border is influenced by the sum of upstream diffuse and point-source waste discharges. There are no permitted waste discharges located within this reach. Input of Beatton River water appears to be responsible for elevations in the levels of turbidity, suspended solids, color, nutrients, and some metal concentrations. Fecal coliform levels have been high, necessitating filtration or equivalent treatment plus disinfection prior to domestic use.

The present uses of this reach of the Peace River are for water-contact recreation (boating, wading, angling), wildlife, industry, and aquatic life. Presently, there are no withdrawals for public water supplies within this reach (in British Columbia). Potential uses include irrigation, livestock watering, and drinking water. These present and potential uses can be protected by provisional water quality objectives as follows.

6. PROVISIONAL WATER QUALITY OBJECTIVES

Preceding sections of this report have shown the inadequacy of the available water quality information at certain locations in the Peace River mainstem sub-basin. Until future receiving water monitoring programs improve the data base, the following provisional and approved objectives are recommended for the protection of the Peace River aquatic life and other water uses.

The objectives apply to discrete samples from all parts of the water bodies, except from initial dilution zones of effluents. These excluded dilution zones are defined as extending 100 m downstream from the discharge point and no more than 25 percent across the width of the river, from the surface to the substratum. These objectives are recommended to protect water use within the British Columbia portion of the Peace River, and are without prejudice to any objectives that may be subsequently developed between the provinces of Alberta and British Columbia as a result of a future agreement on transboundary water quality objectives.

Water quality objectives have no legal standing and would not be directly enforced. The objectives can be considered as policy guidelines for resource managers to protect water uses in the specified water bodies. 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. 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.

For subsequent water quality objectives statements, 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.

6.1 PEACE RIVER , W.A.C. BENNETT DAM TO THE ALBERTA BORDER

The recommended provisional water quality objectives for the Peace River (Bennett Dam to the border) are as follows:

Fecal Coliforms

- the fecal coliform content should not exceed 100 MPN/100 mL in 90 percent of at least 5 weekly water samples taken in any consecutive 30-day period (B.C. Ministry of Health, 1982).

This objective is set on a year-round basis, to protect drinking water for use after filtration (or equivalent) and disinfection. This objective would also protect water-contact recreation in the Peace River.

Gas Supersaturation

- total dissolved gases in any sample should not exceed 110 percent saturation (U.S. EPA, 1977; Alderdice and Jensen, 1985).

This objective is set to protect aquatic life.

Total Chlorine Residual

- total chlorine residual shall not exceed 2 μg/L in any sample (E.P.A., 1976)

This objective is set to protect Peace River salmonid fish species. This objective is below the minimum detectable concentrations of routinely available methods, and thus it may not be possible to determine directly if the objective is being met in the receiving waters. It may be necessary to calculate receiving water concentrations from effluent loadings and stream dilution.

Periphyton Standing Crop

For the protection of recreation and aquatic life, a maximum standing crop biomass of 50 mg/m^2 chlorophyll a is recommended (Nordin, 1985). The average of at least ten samples collected at random from the streambed on one day should be below this maximum.

This objective applies outside the initial dilution zones and applies on a year-round basis to prevent aesthetic degradation. Since this objective is based upon the more stringent criterion to protect recreational use (Nordin, 1985), it would also act to prevent summer dissolved oxygen depletions and prevent the reduction of available fish habitat.

Nitrogen or phosphorus values above which nuisance algal growth would occur cannot be specified. A study of algal growth in Peace River and its multivariate correlation with temperature, light, flow, trace nutrients etc., would be necessary before absolute objectives could be set for nitrogen or phosphorus.

Total ammonia-N

- total ammonia-N not to exceed the 30-day average concentrations given in the following table (Nordin and Pommen, 1986).

AVERAGE 30-DAY CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF AQUATIC LIFE (mg/L-N)

pH	Temp. 0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.6	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.7	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.8	2.08	2.05	2.02	1.99	1.96	1.94	1.92	1.90	1.88	1.86	1.84
6.9	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.0	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.1	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.2	2.08	2.05	2.02	1.99	1.96	1.95	1.92	1.90	1.88	1.86	1.84
7.3	2.08	2.05	2.02	1.99	1.97	1.95	1.92	1.90	1.88	1.86	1.85
7.4	2.08	2.05	2.02	2.00	1.97	1.95	1.92	1.90	1.88	1.86	1.85
7.5	2.08	2.05	2.02	2.00	1.97	1.95	1.92	1.90	1.88	1.87	1.85
7.6	2.09	2.05	2.03	2.00	1.97	1.95	1.93	1.91	1.88	1.87	1.85
7.7	2.09	2.05	2.03	2.00	1.98	1.95	1.93	1.91	1.89	1.87	1.85
7.8	1.78	1.75	1.73	1.71	1.69	1.95	1.93	1.91	1.89	1.87	1.86
7.9	1.50	1.48	1.46	1.44	1.43	1.67	1.65	1.63	1.62	1.60	1.59
8.0	1.26	1.24	1.23	1.21	1.20	1.41	1.39	1.38	1.36	1.35	0.34
8.1	1.00	0.989	0.976	0.963	0.952	1.18	1.17	1.16	1.15	1.14	0.13
8.2	0.799	0.788	0.777	0.768	0.759	0.942	0.932	0.922	0.914	0.906	0.899
8.3	0.636	0.628	0.620	0.613	0.606	0.751	0.743	0.736	0.730	0.724	0.718
8.4	0.508	0.501	0.495	0.489	0.484	0.599	0.594	0.588	0.583	0.579	0.575
8.5	0.405	0.400	0.396	0.381	0.387	0.479	0.475	0.471	0.467	0.464	0.461
8.6	0.324	0.320	0.317	0.313	0.310	0.384	0.380	0.377	0.375	0.372	0.370
8.7	0.260	0.257	0.254	0.251	0.249	0.308	0.305	0.303	0.301	0.300	0.298
8.8	0.208	0.206	0.204	0.202	0.201	0.247	0.246	0.244	0.243	0.242	0.241
8.9	0.168	0.166	0.165	0.163	0.162	0.200	0.198	0.197	0.197	0.196	0.196
9.0	0.135	0.134	0.133	0.132	0.132	0.161	0.161	0.160	0.160	0.160	0.160

pH	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.6	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.7	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.8	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.42	1.32	1.22
6.9	1.82	1.81	1.80	1.78	1.77	1.64	1.53	1.42	1.32	1.22
7.0	1.83	1.81	1.80	1.79	1.77	1.64	1.53	1.42	1.32	1.22
7.1	1.83	1.81	1.80	1.79	1.77	1.65	1.53	1.42	1.32	1.23
7.2	1.83	1.81	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.3	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.4	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.5	1.83	1.82	1.81	1.80	1.78	1.66	1.54	1.43	1.33	1.23
7.6	1.84	1.82	1.81	1.80	1.79	1.66	1.54	1.43	1.33	1.23
7.7	1.84	1.83	1.81	1.80	1.79	1.66	1.54	1.44	1.34	1.24
7.8	1.57	1.56	1.55	1.54	1.53	1.42	1.32	1.23	1.14	1.24
7.9	1.33	1.32	1.31	1.31	1.30	1.21	1.12	1.04	0.970	1.07
8.0	1.12	1.11	1.10	1.10	1.09	1.02	0.944	0.878	0.818	0.904
8.1	0.893	0.887	0.882	0.878	0.874	0.812	0.756	0.704	0.655	0.762
8.2	0.714	0.709	0.706	0.703	0.700	0.651	0.606	0.565	0.527	0.611
8.3	0.571	0.568	0.566	0.564	0.562	0.523	0.487	0.455	0.424	0.491
8.4	0.458	0.456	0.455	0.453	0.452	0.421	0.393	0.367	0.343	0.396
8.5	0.369	0.367	0.366	0.366	0.365	0.341	0.318	0.298	0.278	0.321
8.6	0.297	0.297	0.296	0.296	0.296	0.277	0.259	0.242	0.227	0.261
8.7	0.241	0.240	0.240	0.241	0.241	0.226	0.212	0.198	0.186	0.213
8.8	0.196	0.196	0.196	0.197	0.198	0.185	0.174	0.164	0.154	0.175
8.9	0.160	0.161	0.161	0.162	0.163	0.153	0.144	0.136	0.128	0.145
9.0	0.132	0.132	0.133	0.134	0.135	0.128	0.121	0.114	0.108	0.121

- the average of the measured values must be less than the average of the corresponding individual values in this table.
- each measured value is compared to the corresponding individual values in this table. No more than one in five of the measured values can be greater than one-and-a-half times the corresponding criteria values in this table.

This objective applies everywhere except initial dilution zones, on a year round basis to protect aquatic life.

Dissolved Oxygen

- a minimum of 7.25 mg/L (Davis, 1975).

This objective corresponds to the Davis level A of protection for a freshwater mixed fish population with salmonids. It assures protection for all life-history stages of the fish (including the embryonic intergravel stages of mainstem spawners) and other aquatic life in the Peace River.

Suspended Solids and Turbidity

- induced suspended solids (nonfilterable residue) should not exceed 10 mg/L when background suspended solids is ≤100 mg/L and should not be more than 10 percent of background when background is greater than 100 mg/L (Singleton, 1985).

- induced turbidity should not exceed 5 NTU when background turbidity is less than 50 NTU and should not be more than 10 percent of background when background is greater than 50 NTU (Singleton, 1985).

These objectives are set to protect aquatic life, aquatic habitat, and aesthetic values.

Nitrite-N

- nitrite-N concentrations should not exceed the 30-day average concentrations (using a minimum of 5 weekly samples) and should not exceed the maximum concentrations (at any time) given in the following table (Nordin and Pommen, 1986).

Chloride Concentration (mg/L)	Maximum Nitrite Concentration (mg/L as N)	Average Nitrite Concentration* (mg/L as N)
less than 2	0.06	0.02
2-4	0.12	0.04
4-6	0.18	0.06
6-8	0.24	0.08
8-10	0.30	0.10
greater than 10	0.60	0.20

* the 30-d average chloride concentration should be used to determine the appropriate 30-d average nitrite criterion.

This objective is set to protect aquatic life.

pH

- pH range 6.5-9.0 with a maximum increase/decrease of 0.5 pH units over background levels when background levels are within this range or a maximum increase/decrease of 0.1 pH units over background levels when background levels are outside this range.

This objective is set to protect aquatic life and drinking water.

Temperature

- not more than a 1°C increase in temperature over background levels.

This objective applies on a year-round basis, outside the initial dilution zone (i.e. 100 m downstream from the refinery discharge) to protect aquatic life.

Cyanide

a) the 30-day average concentration of weak-acid dissociable cyanide (based on a minimum of 5 weekly samples; (expressed as CN) in unfiltered samples should be less than or equal to 5.0 µg/L. This recommended level is presently below the detection limit of the Provincial Environmental Laboratory. The minimum detectable concentration for weak-acid dissociable cyanide is 5 µg/L at this time, and until detection limits are improved, measurements of <5 µg/L (expressed as CN) will be considered acceptable.

b) the maximum concentration should not exceed 10 µg/L at any time. (Singleton, 1986).

Fluoride

- dissolved fluoride should not exceed 1.0 mg/L in any sample (Reeder, 1979).

This objective is set to protect aquatic life and drinking water use.

Total Copper

a) the 30-day average concentration of total copper (based on a minimum of 5 approximately weekly samples) should not exceed the numerical value (in µg/L) given by the relationship [0.04 (hardness)] when the average water hardness is reported as mg/L $CaCO_3$.

b) the maximum concentration of total copper should not exceed the numerical value (in µg/L) given by the relationship [0.094 (hardness) +2] at any time.

Examples based on these formulae for hardness found in the Peace River are as follows:

Water Hardness mg/L $CaCO_3$	30-day Average Copper Criteria µg/L	Maximum Copper Criteria µg/L
75	3	9
100	4	11.4
125	5	13.7
150	6	16.1
175	7	18.5
200	8	20.8

c) if natural background levels exceed (a) or (b) above, then the increase in total copper above background to be allowed, if any, should be based on site-specific conditions (Singleton, 1985).
This objective is set to protect aquatic life and drinking water use.

Total Lead

a) the 30-day average concentration of total lead (based on a minimum of 5 approximately weekly samples) should not exceed the numerical value (in µg/L) given by the relationship 3.31 + exp. [1.273 ln (average hardness) -4.705] when the average water hardness is reported as mg/L $CaCO_3$.

b) the maximum concentration of total lead should not exceed the numerical value (in µg/L) given by the relationship exp [1.273 ln (hardness)-1.46] at any time.

Examples based on these formulae for hardness found in the Peace River are as follows:

Water Hardness µg/L $CaCO_3$	30-day Average Lead Criteria µg/L	Maximum Lead Criteria µg/L
50	5	34
80	6	61
100	6	82
200	11	197

c) if natural background levels exceed (a) or (b) above, then the increase in total lead above background to be allowed, if any, should be based on site-specific conditions (Nagpal, 1987).

Zinc

- total zinc should not exceed 0.03 mg/L at any time (CCREM, 1987).

If background levels exceed the above objective, then total zinc levels should not be more than 20 percent greater than background levels.

This objective is set to protect aquatic life.

Chromium

- total chromium in any sample should not exceed 0.002 mg/L (CCREM, 1987).

This recommended level is presently below the detection limit of the Provincial Environmental Laboratory. The minimum detectable concentration for total chromium is 0.005 mg/L at this time, and until detection limits are improved, measurements of <0.005 mg/L will be considered acceptable.

If background levels exceed the above objective, then total chromium levels should not be more than 20 percent greater than background levels.

This objective is set to protect aquatic life.

Nickel

- total nickel should not exceed the following values:
  a) For hardness <60 mg/L: 0.025 mg/L maximum
  b) For hardness 60-120 mg/L: 0.065 mg/L maximum
  c) For hardness 120-180 mg/L: 0.11 mg/L maximum
  d) For hardness >180 mg/L: 0.15 mg/L maximum (CCREM, 1987)

If background levels exceed the above objectives, then total nickel levels should not be more than 20 percent greater than background levels.

This objective is set to protect aquatic life.

Sulphide

- un-ionized H_2S in any sample should not exceed 2 μg/L (E.P.A., 1976).

- if background levels exceed the above objective, then un-ionized H_2S levels should not be more than 20 percent greater than background levels.

This objective is set to protect aquatic life.

This objective is below the minimum detectable concentrations of routinely available methods, and thus it may not be possible to determine directly if the objective is being met in the receiving waters. It may be necessary to calculate receiving water concentrations from effluent loadings and stream dilution.

Phenol

- phenol should not exceed a 30-day average of 2 μg/L (E.P.A., 1976).

- if background levels exceed the above objective, then phenol levels should not be more than 20 percent greater than background levels.

This objective is set to protect against objectionable taste and odor in water and fish flesh.

It should be noted that 2 μg/L may be under- or over-restrictive, depending on the specific phenolic compounds that are present. Consequently, it should be considered as a guideline, and remedial action need not be taken unless objectionable taste and odor are observed in water or fish flesh.

Chlorinated Phenols

- the total concentration of all tri-, tetra-, and pentachlorophenols should not exceed a maximum of 0.2 μg/L (Swain and Holms, 1985).

These objectives are set to prevent aquatic life toxicity and objectionable tainting of fish flesh.

2,4-D

- ester formulations of 2,4-D should not exceed a maximum concentration of 4 μg/L (CCREM, 1987).

This objective is set to protect aquatic life.

6.2 BEATTON RIVER, DOWNSTREAM FROM FORT ST. JOHN

The recommended provisional water quality objectives for the Beatton River, downstream from the Fort St. John discharge are as follows:

Fecal Coliforms

- the fecal coliform content should not exceed a geometric mean of 200 MPN/100 mL for a minimum of five weekly samples. No more than 10 percent of total samples during any 30 day period should exceed 400 MPN/100 mL (Richards, 1983).

This objective is set to protect water-contact recreation and applies for a 6 month period covering the discharge period (April 1-June 30) and the open-water recreation season (June 1 to October 31).

pH

- pH range 6.5-9.0 with a maximum increase/decrease of 0.5 pH units over background levels when background levels are within this range or a maximum increase/decrease of 0.1 pH units over background levels when background levels are outside this range.

This objective is set to protect aquatic life and drinking water.

Dissolved Oxygen

- a minimum of 7.25 mg/L (Davis, 1975).

This objective corresponds to the Davis level A of protection for a freshwater mixed fish population with salmonids. It assures protection for all life-history stages of the fish and other aquatic life in the Peace River.

Nitrite-N

- nitrite-N concentrations should not exceed the 30-day average concentrations (using a maximum of 5 weekly samples) and should not exceed the maximum concentrations (at any time) given in the following table (Nordin and Pommen, 1986).

Chloride Concentration (mg/L)	Maximum Nitrite Concentration (mg/L as N)	Average Nitrite Concentration* (mg/L as N)
less than 2	0.06	0.02
2-4	0.12	0.04
4.6	0.18	0.06
6-8	0.24	0.08
8-10	0.30	0.10
greater than 10	0.60	0.20

* the 30-d average chloride concentration should be used to determine the appropriate 30-d average nitrite criterion.

Suspended Solids and Turbidity

- induced turbidity should not exceed 5 NTU when background turbidity is less than 50 NTU and should not be more than 10 percent of background when background isgreater than 50 NTU (Singleton, 1985).

- induced suspended solids (non-filterable residue) should not exceed 10 mg/L when background suspended solids is ≦100 mg/L and should not be more than 10 percent of background when background is greater than 100 mg/L (Singleton, 1985).

This objective is set to protect aquatic life, aquatic habitat, and aesthetic values.

Periphyton Standing Crop

For the protection of recreation and aquatic life, a maximum standing crop biomass of 50 mg/m^2 chlorophyll a is recommended (Nordin, 1985). The average of at least 10 samples collected at random from the streambed on one day should be below this maximum.

This objective applies outside the initial dilution zones and applies during the discharge period. Since this objective is based upon the more stringent criterion to protect recreational use (aesthetic degradation), it would also act to prevent summer dissolved oxygen depletions and the reduction of available fish habitat.

Nitrogen or phosphorus values above which nuisance algal growth would occur cannot be specified. A study of algal growth in the Beatton River and its multivariate correlation with temperature, light, flow, trace nutrients etc., would be necessary before absolute objectives could be set for nitrogen or phosphorus.

Total ammonia-N

- total ammonia-N should not exceed the 30-day average concentrations given in the table presented previously in this report (section 6.1).

This objective applies outside the initial dilution zone to protect aquatic life, especially the resident salmonid fish.

Metals

Although metals levels have been reported to be high in the Beatton River, metals objectives are not proposed because the metals levels are natural and there are no anthropogenic metal sources.

7. MONITORING RECOMMENDATIONS

The monitoring recommendations summarized in Table 51 and detailed in the following sections are made from a technical perspective. The extent to which the recommended monitoring is conducted in the Peace River Mainstem sub-basin will depend on the overall priorities and monitoring resources available for the Region and the Province. It is recommended that all monitoring data collected by the permittee and the Ministry of Environment and Parks meet Ministry data standards and be placed in the Ministry computer data bank.

A monitoring program for the discharge from the pulp mill now being built at Taylor has not been recommended in this report. A special monitoring program will be required to assess its possible impact.

7.1 G.M. SHRUM HYDROELECTRIC GENERATING STATION

Effluent monitoring by B. C. Hydro for BOD_5, suspended solids, and fecal coliform bacteria should continue on a quarterly basis. Chlorine residual should be added to this list of variables. Effluent flow should be recorded during the discharge period. Receiving water monitoring is at the discretion of the Regional Waste Management Branch, depending on effluent quality and quantity.

7.2 PEACE CANYON COAL PROJECT

Construction of the open-pit coal mine proposed by Cinnabar Peak Mines Ltd. for the Johnson Creek drainage has been delayed indefinitely. No permits for effluent discharge have been issued at this time. If mining proceeds in the future, there may be changes in the mine's water use and protection plan making it difficult to predict accurately the potential for water quality impact. From what is presently known about the water quality of Johnson Creek and the proposed mining plan, the following constituents may be of concern in the waste discharges:

pH	Sulphate
Alkalinity, Total	Oil and Grease
Turbidity	Copper, Total
	, Dissolved
Suspended Solids	Zinc , Total
Phosphorus, Total	, Dissolved
, Dissolved	Cadmium, Total
, (Ortho-P)	, Dissolved
Nitrogen, Nitrate-N	Mercury, Total
, Nitrite-N	
, Ammonia-N	

These constituents should be monitored at least monthly in the receiving waters if development plans proceed. Suspended solids, turbidity, and flow should be sampled more frequently than the other characteristics (e.g. weekly during spring freshet and rain events). Stage II environmental impact studies should include an evaluation of the potential for increases in these contaminants as well as a proposed monitoring program, so that water quality objectives can be prepared prior to project construction.

7.3 RECREATIONAL FISHERIES BRANCH HATCHERY

The trout hatchery at the Peace Canyon Dam has a negligible effect on Peace River water quality. The effluent characteristics and sampling frequencies given in the existing permit PE 6372 are appropriate and no modifications or additions are suggested. Receiving water monitoring for this discharge is not deemed necessary at this time.

7.4 PEACE CANYON HYDROELECTRIC GENERATING STATION

The discharge of treated domestic sewage from this facility has a negligible effect on receiving water quality as a result of the high dilution available in the Peace River. The permit (PE-5240) monitoring requirements are appropriate and require no modification. Receiving water monitoring for this discharge is not deemed necessary at this time.

7.5 THE CITY OF FORT ST. JOHN (PEACE RIVER DISCHARGE)

The quality of effluent from this discharge has improved since redesign of the treatment system (1983 permit). Present loadings of BOD_5, suspended solids, fecal coliforms, nitrogen, phosphorus, and metals appear to have a negligible effect on the Peace River water quality outside the initial dilution zone.

Table 52 summarizes the present effluent sampling program required of the permittee for discharge PE 389. Table 53 presents recommended revisions to the program, reflecting the findings of this study. The addition of several new effluent characteristics (total phosphorus, dissolved (ortho-) phosphorus, nitrite-N, nitrate-N, ammonia-N, pH, oil and grease, and chlorine residual) is suggested. It is important that effluent sampling coincide with effluent flow measurements so that accurate waste loadings can be calculated. Effluent sampling and receiving water monitoring should also coincide so that the effects of known waste loadings on the receiving environment can be observed directly.

7.6 THE CITY OF FORT ST. JOHN (BEATTON RIVER DISCHARGE)

This discharge has not received appropriate receiving water monitoring in the past. Analysis of the effects of present waste loading on the Beatton River has been hampered by the absence of data from a control site and from downstream sites proximate to the discharge. As a result, it has not been possible to determine accurately either the presence of water quality deterioration from upstream ambient conditions, or the extent of the zone of influence prior to complete dilution.

Table 54 presents a summary of the present effluent sampling program required of the permittee. Table 55 recommends revisions to this program, most notably the addition of more water quality variables.

7.7 PETRO-CANADA EXPLORATION INC. (TAYLOR REFINERY)

a) Effluent Sampling

Table 56 presents a summary of the present effluent sampling program required of the permittee. The findings of this study have suggested several changes for the improvement of effluent monitoring (Table 57).

Several characteristics of the cooling water effluent should be added to the monitoring program to determine if there is any waste load contribution from refinery processes. These include phenol, cyanide, fluoride, sulphide, total and ortho-phosphorus, ammonia-N, and hydrocarbons. Concurrent sampling of the cooling water both before it enters the refinery and after it leaves the refinery will be necessary. The present sampling of the process effluent is deemed adequate. The effluent characteristic, hydrocarbons, should be added to the sampling variables list.

Storm run-off effluent has not been monitored in the past as specified by the 1981 permit amendments. These data are necessary and this sampling should begin as soon as possible. Run-off sampling should occur during rain events at the point of flow-metering before combination with process effluent and cooling water.

All effluent sampling should coincide with effluent flow measurements.

b) Receiving Water Monitoring

A receiving water quality monitoring program is recommended in Table 57. This program entails monitoring at a minimum of 9-12 sites three times per year. One of the objectives of this program is the delineation of the full extent of the effluent mixing zone. Sites may be added or deleted at the discretion of the field sampling personnel in order to achieve this objective. Receiving water sampling should be conducted on the same day that the effluent is monitored. Sampling should be conducted at all stations on the same day. Visual observations of surface oil slicks, shoreline oil seeps and runoff, and attached algal growth should be recorded during the sampling periods.

7.8 DIFFUSE WASTE SOURCES

The extent of non-point source (diffuse) pollution loads from land-use practices in the Peace River system is unknown and the existing data on its effects are inadequate. Once the higher priority monitoring program recommended in this report is implemented, a special study of non-point source loading should be conducted. This study would add the pertinent water quality variables and monitoring sites which could evaluate diffuse loading from certain land use practices. These include the use of agricultural pesticides (mainly phenoxy herbicides) and fertilizers, runoff with high suspended solids from logged and cleared areas, municipal storm-sewers, the oiling of rural roads for the purpose of dust suppression, and the input of coliform bacteria from cattle watering sites and feedlots.

7.9 STUDY OF ORGANIC CONTAMINANTS FROM THE PETRO-CANADA REFINERY

An organic contaminant study, of the type conducted by Monenco Consultants Pacific Ltd. (1983) on one sample of the gas plant effluent, should be conducted on the combined refinery process effluent and gas plant effluent (i.e. after the API separators). Several samples should be taken at different times of the year. This study should emphasize the screening and identification of substances of known high toxicity such as the alkylbenzenes (e.g. toluene, ethylbenzene), the dialkylbenzenes (e.g. xylenes) aromatic hydrocarbons (e.g. benzene), polynuclear aromatic hydrocarbons (e.g. naphthalene, benzo(a)pyrene), and heterocyclic compounds (e.g. quinoline, pyridine) (modified from Cote, 1976).

7.10 REFINERY EFFLUENT EFFECTS ON FISH

Fish exposed to petroleum in water and sediments accumulate hydrocarbons in various tissues, such as the liver, brain, and muscle.

Countering this bioconcentration, there is some excretion of hydrocarbons as well as enzyme-mediated conversion to a variety of water-soluble metabolites. However, these processes offer only limited protection: a number of studies have shown that certain aromatic hydrocarbons such as benzo(a) pyrene are converted to carcinogenic/mutagenic compounds that react with DNA (Malins and Hodgins, 1981). The more visibly observed effects of this process are chemically induced tumors (neoplasia), including eye, mouth, and skin lesions and growths, and hepatic and gonadal cancers. At the physiological level, there are changes in the enzyme systems which mediate hydrocarbon conversion.

The present river monitoring program cannot provide an early or reliable warning of carcinogens in the environment downstream from the Petro-Canada refinery. In the specific analysis of hydrocarbons at the trace level, chemical analysis is both difficult and expensive. According to Malins and Hodgins, even the most advanced of generally applicable analytical techniques (i.e. gas chromatography/mass spectrometry) are largely restricted to the analysis of hydrocarbons with one to five benzenoid rings. Thus other components and the chemically and biologically altered hydrocarbons escape detection. Hence, the need to study the biological response to the total hydrocarbon input. The monthly bioassays presently conducted are not capable of filling this gap. They are of short duration and ignore the morbidity from longer exposures _in situ_, as well as changes in physiology and behavior.

The monitoring program should address the issue of finding better biological indicators of hydrocarbon contamination by planning and conducting the following types of monitoring.

a) Survey of Fish Neoplasia

An obvious first step would be to capture fishes that tend to be sedentary (e.g. the sculpins) in the vicinity of the refinery and determine the incidence of tumors and cancers, compared to other reaches of the Peace

River or other river systems. Observations should be made of both gross morphological abnormalities (e.g. epidermal papillomas, fin erosion, gonadal, and hepatic tumors) and histopathological effects. Since relatively low hydrocarbon concentrations can interfere with reproductive success, observations should also be made of malformed embryos and larvae, and decreased larval survival.

b) Monitoring of Aryl Hydrocarbon Hydroxylase Induction

The induction of the vertebrate liver enzyme aryl hydrocarbon hydroxylase (AHH) is a sensitive physiological response specific to hydrocarbon contamination. AHH is one of the mixed function oxidases which initiates the transformation of aromatic hydrocarbons to water-soluble compounds, thereby facilitating their removal from the body. The activity of this enzyme increases in relation to the severity of hydrocarbon exposure. Penrose (1978) reported a dramatic 40-fold induction of AHH in laboratory fish exposed to diluted oil refinery effluent. Field measurements supported these findings: AHH levels in brown trout livers from a lake known to be occasionally polluted with oil were 14 times higher than those from an upolluted lake. The virtue of this enzyme system as a monitoring tool is its specificity. There is no evidence linking AHH induction to any pollutant other than oil.

For monitoring purposes, a fish species that does not move extensively (e.g. the sculpins) would be the animal of choice. The objective of the monitoring would be to compare AHH levels in fishes in the vicinity of the Taylor refinery to those taken from different areas. AHH analysis is relatively cheap, easy, and reliable; however, this monitoring would require the aid of a laboratory (government, university, or private) experienced in this field.

c) Fish Tainting

Taste testing of sport fish from the Peace River in the vicinity of the refinery may provide some important qualitative information.

7.11 FISH TISSUE MERCURY SAMPLING

Health and Welfare Canada has identified high tissue mercury levels in some fish species taken from several locations in the Williston Reservoir. High mercury levels have also been recorded in water samples from some reaches of the Peace River and certain tributary rivers (Beatton River, Pine River, Moberly River). It is recommended that mercury levels in fish tissue be monitored in the vicinity of established water quality sites (if possible) on the Peace River, from the W.A.C. Bennett Dam to the Alberta border, and on all large tributary rivers. Sampling should be confined to food-fish species.

PERSONAL COMMUNICATION

Carmichael, B. Waste Management Branch, Prince George, December, 1985.

Clark, M. Waste Management Branch, Victoria, October, 1985.

Harcombe, R. Waste Management Branch, Fort St. John. April, 1984.

Keilo, B. Waste Management Branch, Fort St. John. April 3, 1984.

Pommen, L. Water Management Branch, Victoria. June 25, 1984.

Porter, R. Municipal Engineer, Hudson's Hope District Municipality. June 27, 1984.

Stone, M. Planning and Assessment Branch, Victoria, November, 1986.

Todd, N. Recreational Fisheries Branch, Victoria. May 29, 1984.

Weldon, W.H. Waste Management Branch, Victoria. April 18, 1984; October 23, 1985.

LITERATURE CITED

Abelson, D.H.G. 1974. Report on the results of a monitoring program for dissolved gases in the Fraser River and Peace River Systems, 1974. MS. Rep., Pollution Control Branch, British Columbia, Dept. of Lands, Forests and Water Resources. 40 p.

A.E.O.C. (Aquatic Ecosystem Objectives Committee). 1983. The 1983 annual report. Submitted to the Great Lakes Science Advisory Board, Report to the International Joint Commission.

Alderdice, D.F. and J.O.T. Jensen. 1985. Assessment of the influence of gas supersaturation on salmonids in the Nechako River in relation to Kemano Completion. Can. Tech. Rept. Fish. Aquat. Sci. No. 1386.

Barr, L. (Water Management Branch, Victoria). 1984. Peace River 10-year return period, 7-day low flows. Memorandum to G. Butcher, March 28, 1984.

B.C. Ministry of Health. 1982. British Columbia drinking water qualilty standards 1982. Victoria, B.C. 18 pp.

Bodaly, R.A. and R.E. Hecky. 1979. Post-impoundment increases in fish mercury levels in the Southern Indian Lake reservoir, Manitoba. Fisheries and Environment Canada, Fisheries and Marine Service Manuscript Report No. 1531. 15 p.

Bodaly, R.A. and R.E. Hecky. 1982. The potential for mercury accumulation in fish muscle as a result of the proposed Peace River site C reservoir. Department of Fisheries and Oceans, Freshwater Institute, Winnipeg, Manitoba. 12 p.

Bouck, G.R. 1980. Etiology of gas bubble disease. Trans. Am. Fish. Soc. 109:703-707.

Broderius, S.J. and L.L. Smith Jr. 1976. Effect of hydrogen sulphide on fish and invertebrates. Part II. Hydrogen sulphide determination and relationship between pH and sulphide toxicity. U.S. Environmental Protection Agency report 600/3-76-062b. Environmental Research Laboratory, Duluth, Minn. 102 p.

Butcher, G.A. 1985. Pine River Sub-basin: Water quality assessment and objectives. Technical Appendix. Resource Quality Section report. Water Management Branch, Ministry of Environment and Parks, Victoria, B.C. 53 p.

Canadian Bio Resources Consultants Ltd. 1979. Peace River site C hydro-electric development environmental and socio-economic assessment. Water qualilty and use. A report for British Columbia Hydro & Power Authority. 68 p.

Canadian Resourcecon Ltd. 1978. Peace River Site C hydroelectric project: resource evaluation. Prepared for B.C. Hydro and Power Authority by Canadian Resourcecon Ltd., Vancouver, B.C. 239 p.

CCREM (Canadian Council of Resource and Environment Ministers). 1987. Canadian water quality guidelines. March, 1987.

Cinnabar Peak Mines Ltd. 1981. The preliminary environmental assessment of the Peace River Canyon Coal Project. Submitted to the Government of British Columbia for Stage I approval. 135 p. + App.

Clark, M.J.R. 1977. Annotated extracts of some papers dealing with various aspects of dissolved atmospheric gases, with special emphasis regarding gas bubble disease in fish. Vol. 1, Report 77-8. Pollution Control Branch, B.C. Ministry of Environment.

Cote, R.P. 1976. The effects of petroleum refinery liquid wastes on aquatic life, with special emphasis on the Canadian environment. National Research Council of Canada, Associate Committee on Scientific Criteria for Environmental Quality report no. 15021. 77 p.

Cross, S.F. and P.G. Nix. 1986. Survey of benthos and water/sediment quality in the Peace River near Taylor, B.C. Prepared for Petro Canada Inc. by E.V.S. Consultants Ltd., Sidney, B.C. 57 p + App.

Davis, J.D. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: A review. J. Fish. Res. Board Can. 323:2295-2332.

Demayo, A. and M.C. Taylor. 1981. Copper. <u>In</u>: Guidelines for surface water quality. Vol. 1, Inorganic chemical substances. Inland Waters Directorate, Environment Canada, Ottawa. 36 p.

E.P.A. (Environmental Protection Agency). 1976. Quality criteria for water. Office of Water and Hazardous Materials, U.S. Environmental Protection Agency, Washington, D.C. 256 p.

E.P.A. (Environmental Protection Agency). 1980a. Ambient water quality criteria for polynuclear aromatic hydrocarbons. Criteria and Standards Division, Washington, D.C.

E.P.A. (Environmental Protection Agency). 1980b. Ambient water quality criteria for naphthalene. Criteria and Standards Division, Washington, D.C.

Esvelt, L.A., W.J. Kaufman, R.E. Selleck. 1973. Toxicity assessment of treated municipal wastewaters. J. Water. Pollut. Contr. Fed. 45(7):1558-1572.

Garrett, C.L., L.A. MacLeod and H.J. Sneddon. 1980. Mercury in the British Columbia and Yukon environments - summary of data to 1979. Environmental Protection Service, Pacific Region, Regional Program Report 80-4.

Geldreich, E.E. 1972. Buffalo Lake recreational water quality: A study in bacteriological data interpretation. Water Research 6 (8): 913-924.

Girard, R. 1982. Peace River Strategic Plan: Diffuse waste loadings. memorandum to G. Butcher, Water Management Branch, Victoria. September 15, 1982. File 61.2012. 4 p.

Malins, D.C. and H.O. Hodgins. 1981. Petroleum and marine fishes: a review of uptake, disposition, and effects. Environmental Science and Technology. Vol. 15, No. 11, p. 1272-1280.

McKee, P.M., R.P. Scroggins and D.M. Casson. 1984. Chlorinated phenols in the aquatic environment. Scientific Criteria document for standards development No. 2-84. Prepared for Water Resources Branch, Ontario Ministry of the Environment.

M.O.E. (Ministry of Environment and Parks) 1974. Pollution control objectives for the chemical and petroleum industries of British Columbia. Water Resources Service, Victoria, B.C. 36 p.

M.O.E. (Ministry of Environment and Parks) 1975. Pollution control objectives for municipal type waste discharges in British Columbia. Water Resources Service, Victoria, B.C. 35 p.

M.O.E. (Ministry of Environment and Parks) 1980. Guidelines for watershed management of crown lands used as community water supplies. Prepared by B.C. Government Inter-Ministry Task Force. Victoria, B.C. 43 p. + App.

M.O.E. (Ministry of Environment and Parks) 1982. Blue paper no. 2 Public safety, fisheries and wildlife considerations. A blue paper prepared by the Ministry of Environment for the British Columbia Utilities Commission public review of the British Columbia Hydro and Power Authority Site C generation/transmission project application. Victoria, 180 p.

Monenco Consultants Pacific Ltd. 1984. Identification of solid wastes and effluents and assessment of contaminant removal feasibility at natural gas plants. Draft report prepared for Supply and Services Canada, File No. 52SS. KE145-30358.

Nagpal, N. 1987. Water quality criteria for lead. Draft manuscript. B.C. Ministry of Environment and Parks, Water Management Branch, Victoria, B.C. 12 p.

Nordin, R. N. 1985. Water quality criteria for nutrients and algae. Technical Appendix. B.C. Ministry of Environment and Parks, Water Management Branch, Victoria, B.C. 104 p.

Nordin, R.N. and L.W. Pommen. 1986. Water quality criteria for nitrogen (nitrate, nitrite, and ammonia). Ministry of Environment and Parks, Water Management Branch, Victoria, B.C. 11p.

Noton, L. 1981. Survey of benthos and water quality in the Peace River near Taylor, B.C. Prepared for Petro-Canada Exploration Inc., by Chemical and Geological Laboratories Ltd., Edmonton, Alberta. 34 p. + App.

Noton, L. 1982. Water quality and benthic studies near the Petro-Canada and Westcoast Transmission Operations at Taylor, B.C. 83 p.

Obedkoff, W. 1982. Peace River Strategic Plan; Peak and low flow estimates. Memorandum to J. Bernard, Planning Branch, Victoria, October 15, 1982. File IE-4.1 Hy.

Penrose, W.R. 1978. Specific biological methods for petroleum baseline and pollution monitoring. Marine Pollution Bulletin 9:231-234.

Pommen, L.W. 1983. The effect on water quality of explosives use in surface mining. Volume 1: Nitrogen sources, water quality, and prediction and management of impacts. B.C. Ministry of Environment and Parks Technical Report 4, Victoria, B.C. 149 pp.

Pommen, L.W. 1986. Dilution calculations for water quality assessments and objectives reports. Memorandum to file WQU 64.15. B.C. Ministry of Environment and Parks, Water Management Branch, Resource Quality Section, Victoria, B.C. 3p.

Province of British Columbia. 1974. Pollution control objectives for the chemical and petroleum industries of British Columbia. Water Resources Service, Victoria, B.C. 36 p.

Province of British Columbia. 1975. Pollution control objectives for municipal type waste discharges in British Columbia. Water Resources Service, Victoria, B.C. 35 p.

Putsep, L. 1984. Memorandum from Manager/Civil and Environmental Engineering Dept., B.C. Hydro, Vancouver, to G. Butcher, Resource Quality Section, Water Management Branch, Ministry of Environment and Parks, Victoria. B.C. Hydro File No. 1006. 2 p.

Reeder, S.W. 1979. Preamble to: Guidelines for surface water quality. Vol. 1, Inorganic chemical substances. Inland Waters Directorate, Environment Canada, Ottawa. 21 p.

Renewable Resources Consulting Services Ltd. 1979. Peace River site C hydro-electric development. Fish and aquatic environment. Final report to Thurber Consultants Ltd., prepared by Renewable Resources Consulting Services Ltd., Edmonton, Alberta. 99 p + App.

Richards, H.M. 1983. Memorandum from Provincial Health Officer, Preventive Services Branch, Ministry of Health to R.J. Buchanan, Resource Quality Section, Water Management Branch, Ministry of Environment and Parks. May 20, 1983. Water Quality Unit File No. 64.15. 1 p.

Schaefer, D.G. 1976. Climatological impacts of Peace River regulation and a review of possible effects of climatic change on agriculture in the area. Report for B.C. Hydro and Power Authority by Atmospheric Environment Service, Environment Canada, Vancouver, B.C. 60 p.

Singleton, H.J. 1980. Fraser River estuary study: water quality. Acute toxicity of Effluents. Background report for the Fraser River Estuary Study Steering Committee. Co-published by the Government of Canada and the Province of British Columbia. 91 p.

Singleton, H.J. 1985. Water quality criteria for particulate matter. B.C. Ministry of Environment and Parks, Water Management Branch, Victoria, B.C. 76 pp.

Singleton, H.J. 1986. Water quality criteria for cyanide. B.C. Ministry of Environment and Parks, Water Management Branch, Victoria, B.C. 9 p.

Singleton, H.J. 1985. Water quality criteria for copper. Draft manuscript. B.C. Ministry of Environment and Parks, Water Management Branch, Victoria, B.C.

Stone, M. (Planning and Assessment Branch, Victoria) 1982. Peace River planning unit population projections, 1987 and 1992. Memorandum to L. Pommen, Aquatic Studies Branch (presently Water Management Branch), October 8, 1982. File no. 64.0307.

Swain, L.G. and G.B. Holms. 1985. Water quality assessment and objectives. Fraser-Delta area. Fraser River Sub-basin from Kanaka Creek to the mouth. Technical Appendix. B.C. Ministry of Environment, Water Management Branch, Victoria, B.C.

Taylor, M.C., S.W. Reeder and A. Demayo. 1979. Nickel. In: Guidelines for surface water quality. Vol. 1, Inorganic chemical substances. Inland Waters Directorate, Environment Canada, Ottawa. 12 p.

Taylor, M.C., S.W. Reeder and A. Demayo. 1979. Chromium. In: Guidelines for surface water quality. Vol. 1, Inorganic chemical substances. Inland Waters Directorate, Environment Canada, Ottawa. 9 p.

Thurber Consultants Ltd. 1976. Sites C & E Hydroelectric development proposals. Lower Peace River environmental study. Volume I. Development proposals and resource inventories. Part of a report to B.C. Hydro and Power Authority by Thurber Consultants Ltd. Victoria, B.C. 457 p.

Thurber Contultants Ltd. 1979. Peace River Site C hydroelectric development. Physical environment impact assessment. Report to B.C. Hydro and Power Authority, Generation Planning Department. Victoria, B.C. 123 p. + App.

Thurston, R.V., R.C. Russo, C.M. Fetterolf, Jr., T.A. Edsall, and Y.M. Barber, Jr. (ED.). 1979. A review of the EPA Red Book: Quality criteria for water. Water Quality Section, American Fisheries Society, Bethesda, Maryland, 313 p.

Truelson, R. 1984. Finlay-Omineca Planning Unit, Water quality assessment. Volume 2. Lower Finlay Sub-basin. Resource Quality Section, Water Management Branch, Ministry of Environment and Parks, Victoria. 42 p.

Trussell, R.P. 1972. The percent of un-ionized ammonia in aqueous ammonia solutions at different pH levels and temperatures. J. Fish. Res. Bd. Can. 19:1505-1507.

Water Survey of Canada. 1983. Historical streamflow summary. British Columbia to 1982. Ottawa 940 p.

Weitkamp, D.E. and M. Katz. 1980. A review of dissolved gas supersaturation literature. Trans. Am. Fish. Soc. 109:659-702.

W.I.B. (Water Investigations Branch). 1970. Kootenay air and water quality study. Phase II. Water quality in the Lower Columbia River Basin. Ministry of Environment and Parks, Victoria, B.C. 238 p.

Woodley, R.M. 1983. Memorandum from manager/Generation Planning Dept., B.C. Hydro, Vancouver to B. MacLock, Northern Region Planning Division, Alberta Environment, Edmonton, Alberta. November 18, 1983. B.C. Hydro File No. 1006. 3 p.

TABLE 1

MEAN PRE-REGULATION AND POST-REGULATION STREAMFLOWS*
FOR THE PEACE RIVER NEAR HUDSON'S HOPE AND TAYLOR

MONTH	NEAR HUDSON'S HOPE - STATION 07EF001			NEAR TAYLOR- STATION 07FD002		
	MEAN STREAMFLOWS m3/s		RATIO	MEAN STREAMFLOWS m3/s		RATIO
	PRE-REGULATION 1955-1967	POST-REGULATION 1970-1982	POST-REGULATION/ PRE REGULATION	PRE-REGULATION 1955-1967	POST-REGULATION 1970-1982	POST-REGULATION PRE-REGULATION
January	277	1240	4.5	330	1337	4.1
February	252	1224	4.8	300	1305	4.4
March	232	1121	4.8	282	1196	4.2
April	435	1051	2.4	579	1233	2.1
May	2278	837	0.4	3194	1639	0.5
June	4135	871	0.2	5358	1928	0.4
July	2299	906	0.4	3082	1522	0.5
August	1159	910	0.8	1625	1231	0.8
September	839	925	1.1	1069	1158	1.1
October	888	1115	1.3	1163	1349	1.2
November	602	1270	2.1	774	1398	1.8
December	326	1278	3.9	388	1387	3.6

* data from Water Survey of Canada (1983)

TABLE 2

REQUIRED MINIMUM FLOWS TO BE RELEASED FROM THE W.A.C. BENNETT DAM
PURSUANT TO CLAUSE Q OF WATER LICENCE NO. 27722
(DATED DEC. 21, 1962)
HELD BY B.C. HYDRO AND POWER AUTHORITY

PERIOD	MINIMUM FLOW
December 1 to March 31	Calculated natural inflows to the reservoir
April 1 to July 15	283.2 m^3/s (10 000 C.F.S.) or the natural flow whichever is the lesser, as measured...near Taylor
July 16 to September 15	283.2 m^3/s (10 000 C.F.S.), as measured...near Hudson Hope
September 16 to November 30	283.2 m^3/s (10 000 C.F.S.) or the natural flow whichever is the lesser, as measured near Taylor

TABLE 3

SUMMARY OF LICENSED CONSUMPTIVE WATER WITHDRAWALS FROM THE PEACE RIVER DOWNSTREAM FROM THE W.A.C. BENNETT DAM

NAME	QUANTITY (m^3/d)	PURPOSE
Imperial Oil Ltd. (near Clayhurst)	15 898.5	Industrial
Texaco Canada Ltd. (near Clayhurst)	4 769.6	Industrial
	2 445.9	Industrial
Petro Canada Inc. (Taylor)	21 034.9	Industrial
	156 538.9	Industrial-Cooling
	272.5	Water works
Village of Taylor	454.2	Water works
D. Peck Holdings Ltd. (16 km upstream from Fort St. John)	13.6	Domestic (livestock watering)
District of Hudson's Hope	908.5	Water works
Mr. W.S. Hammack (at Site One Dam)	16 353.0	Industrial (gravel washing)
	218 689.6 (2.53 m^3/s)	

TABLE 4

FISH SPECIES COLLECTED* IN THE PEACE RIVER
BY CONSULTANTS TO B.C. HYDRO

COMMON NAME	SCIENTIFIC NAME
Mountain Whitefish	*Prosopium williamsoni*
Arctic grayling	*Thymallus arcticus*
Rainbow trout	*Salmo gairdneri*
Dolly Varden char	*Salvelinus malma*
Yellow Walleye	*Stizostedion vitreum*
Northern Pike	*Esox lucius*
Burbot	*Lota lota*
Goldeye	*Hiodon alosoides*
Lake whitefish	*Coregonus clupeaformis*
Longnose sucker	*Catostomus catostomus*
Laregescale sucker	*Catostomus macrocheilus*
White sucker	*Catostomus commersoni*
Lake chub	*Couesius plumbeus*
Flathead chub	*Platygobio gracilis*
Redside shiner	*Richaradsonius balteatus*
Longnose dace	*Rhinichthys cataractae*
Trout-perch	*Percopsis omiscomaycus*
Prickly sculpin	*Cottus asper*
Spoonhead sculpin	*Cottus ricei*
Slimy sculpin	*Cottus cognatus*
Northern squawfish	*Ptychocheilus oregonensis*

*other species reported for the area include: Peamouth (*Mylocheilus caurinus*), Pygmy whitefish (*Prosopium coulteri*), Pearl dace (*Semotilus margarita*), Northern redbelly dace (*Chrosomus eos*), Brook stickleback (*Culaea inconstans*) and Lake Trout (*Salvelinus namaycus*).

TABLE 5

SUMMARY OF EFFLUENT DISCHARGE PERMITS FOR THE PEACE RIVER SUB-BASIN
(EXCLUDING REFUSE SITES AND AIR EMISSIONS)

PERMIT HOLDERS	PERMIT NUMBER	DISCHARGED TO	WASTE DISCHARGE FLOW	TYPE OF DISCHARGE AND TREATMENT
B.C. Hydro	PE 5240	Peace River	maximum - 13 m^3/d	- tourist and staff washroom facilities - extended aeration sewage treatment plant and chlorination
Recreational Fisheries Branch	PE 6372	Unnamed creek flowing into Peace River	1310 m^3/d	- fish hatchery effluent
District of Hudson's Hope	PE 411	ground	455 m^3/d	
City of Fort St. John	PE 389	Peace River	maximum - 5 180 m^3/d	- municipal sewage effluent - anaerobic and aerobic lagoon treatment
City of Fort St. John	PE 388	Beatton River (approx. 32 km upstream from Peace River)	maximum - 11 000 m^3/d (during April-June 30)	- municipal sewage effluent - anaerobic and aerobic lagoon treatment
Village of Taylor *	PE 1836	ground	4546 m^3/d	- municipal effluent
Petro-Canada	PE 1379	Peace River	cooling water-205 000 m^3/d process effluent-2050 m^3/d	- oil refinery, natural gas plant cooling water, storm runoff, and process effluent - treatment includes oil skimmers and separators, sour water stripper, aeration, settling ponds, and run-off retention ponds

TABLE 6

SUMMARY OF TREATED SEWAGE DISCHARGE (UNPERMITTED) FROM THE B.C. HYDRO G.M. SHRUM GENERATING STATION (OCTOBER, 1979 - OCTOBER, 1983)

CHARACTERISTICS		MONITORED LEVELS[1] NUMBER OF VALUES	RANGE OF VALUES	MEAN	PRESENT MAXIMUM THEORETICAL LOADING	PREDICTED INCREASE IN RECEIVING WATER CONCENTRATIONS
POWERHOUSE[2]						
BOD_5	mg/L	10	6-340	103	0.3 kg/d	1.2×10^{-5} mg/L
Coliforms, Fecal	MPN/100 mL	4	<10-5.4x 10^5	720[4]	4.9×10^9 MPN/d	0.02 MPN/100 mL
pH		4	5.0-6.5	5.7	-	-
Solids , Suspended	mg/L	10	92-860	248	0.8 kg/d	3.3×10^{-5} mg/L
Flow	m^3/d	-	-	0.91	-	-
CONTROL ROOM[3]						
BOD_5	mg/L	11	<5-183	40	1.0 kg/d	4.1×10^{-5} mg/L
Coliforms, Fecal	MPN/100 mL	6	<10-5.6 x 10^4	2092[4]	3.1×10^9 MPN/d	0.01 MPN/100 mL
pH		6	5.5-7.2	6.7	-	-
Solids , Suspended	mg/L	11	8-348	78	1.9 kg/d	7.8×10^{-5} mg/L
, Dissolved	mg/L	2	394-432	413	2.4 kg/d	9.8×10^{-5} mg/L
Flow	m^3/d	-	-	5.5	-	-

[1] provided by B.C. Hydro
[2] maintenance personnel washroom facilities
[3] tourist and staff washroom facilities
[4] geometric mean

TABLE 7

RECREATIONAL FISHERIES BRANCH FISH HATCHERY (PE 6372), SAMPLING OF EFFLUENT AND SUMMARY OF PERMITTED AND ACTUAL WASTE LOADS

CHARACTERISTICS			MONITORED LEVELS			PERMIT CONDITIONS		MAX. PRESENT LOADING[2] kg/d	MAXIMUM PREDICTED INCREASE IN RECEIVING WATER CONCENTRATIONS[3] mg/L
			No. of Values	Mean	Range of Values	Maximum Level or Concentrations	Loading kg/d		
BOD_5		mg/L	2	<10	<10	10	13	<13	0.0
Coliforms	, Fecal	MPN/100 mL	1	-	<200	-	-	-	-
	, Total	MPN/100 mL	1	-	<200	-	-	-	-
Conductivity,	Specific	uS/cm	2	217	215-219	-	-	85	-
Nitrogen	, Ammonia	mg/L	1	-	0.071	0.5	0.66	0.09	0.0
	, Nitrate	mg/L	1	-	0.07	1.2	1.6	0.06	0.0
	, Nitrite	mg/L	2	-	<0.005	-	-	<0.004	0.0
	, Nitrite/Nitrate	mg/L	1	-	0.07	-	-	0.06	0.0
pH			2	8.0	7.9-8.1	-	-	-	-
Phosphorus	, Total	mg/L	1	-	0.037	0.2	0.26	0.03	0.0
Solids,	, Dissolved	mg/L	2	130	128-132	-	-	112	0.004
	, Suspended	mg/L	2	4	2-6	5	6.6	5.1	0.0
Flow		m^3/d	1	-	846[1]	1310	-	-	-

[1]hatchery outflow value given by N. Todd, Supervisor of Hatcheries, (Feb. 8, 1984)
[2]not actual loads but theoretical loads calculated from the one effluent flow value.
[3]under conditions of present maximum loading and assuming the August 7-day 10-year low flow for the Peace River at Hudson's Hope (343 m^3/s).

TABLE 8

B.C. HYDRO PEACE CANYON GENERATING STATION (PE 5240), SAMPLING OF TREATED SEWAGE EFFLUENT AND SUMMARY OF PERMITTED AND ACTUAL WASTE LOADS

CHARACTERISTICS			MONITORED LEVELS			PERMIT CONDITIONS		MAX. PRESENT LOADING[1]	MAXIMUM PREDICTED INCREASE IN RECEIVING WATER CONCENTRATIONS[4]
			No. of Values	Mean	Range of Values	Level or Concentrations	Loading kg/d		
BOD_5		mg/L	10	51.7	<10-216	100	1.3	1.27 kg/d	0.0 mg/L
Chlorine	, Residual	mg/L	7	0.14	0-0.3	-	-	0.002 kg/d	0.0 mg/L
Coliforms	, Fecal	MPN/100 mL	9	1213[2]	$2-1.6x10^5$	-	-	$9.4x10^9$ MPN/d	0.003 MPN/100 mL
	, Total	MPN/100 mL	5	455[2]	<20-9200	-	-	$5.4x10^8$ MPN/d	0.002 MPN/100 mL
Conductivity,	Specific	mg/L	10	542	211-1740	-	-	-	-
Nitrogen	, Ammonia	mg/L	1	-	1.05	-	-	0.006 kg/d	0.0 mg/L
	, Nitrate	mg/L	1	-	1.18	-	-	0.007 kg/d	0.0 mg/L
	, Nitrite	mg/L	1	-	0.015	-	-	0.0 kg/d	0.0 mg/L
	, Nitrite/Nitrate	mg/L	1	-	1.2	-	-	0.007 kg/d	0.0 mg/L
pH			10	8.0	7.4-8.5	-	-	-	-
Phosphorus	, Total	mg/L	1	-	0.04	-	-	0.0 kg/d	0.0 mg/L
Solids,	, Dissolved	mg/L	4	147	134-170	-	-	1.0 kg/d	0.0 mg/L
	, Total	mg/L	1	-	802	-	-	4.7 kg/d	0.0 mg/L
	, Suspended	mg/L	10	65.5	9-180	100	1.3	1.1 kg/d	0.0 mg/L
	, Sus. Inorganic	mg/L	1	-	15	-	-	0.09 kg/d	0.0 mg/L
Flow		m^3/d	12	5.1	3.9-5.9[3]	13	-	-	-

[1]calculated by multiplying maximum effluent flow recorded by maximum concentration, thus providing a conservative estimate of actual loadings

[2]geometric mean

[3]data supplied by R. Hamilton, Waste Management Branch, Fort St. John

[4]under conditions of present maximum loading and assuming the August 7-day, 10-year low flow for the Peace River at Hudson Hope (343 m^3/d). Concentration is taken as 0.0 if not significant to the fourth decimal place

TABLE 9

POPULATION PROJECTIONS FOR URBAN AREAS IN THE PEACE RIVER MAINSTEM SUB-BASIN

	1981[1]	1982[2]	1985[3]	1990[4]
City of Fort St. John	13 624	14 184	13 493	14 897
Village of Taylor	959	998	858	947
District Municipality of Hudson's Hope	1 350	1 405	1 086	1 200

[1] 1981 census results
[2] based on a growth rate of 4.07 percent per annum (after Stone, 1982)
[3] B.C. Municipal Population Estimates. Central Statistics Bureau. Ministry of Industry and Small Business Development.
[4] based on a growth rate of 2 percent per annum over the 1985 estimate.

TABLE 10

CITY OF FORT ST. JOHN (PE 389) CHARACTERISTICS OF TREATED MUNICIPAL EFFLUENT
DISCHARGED TO THE PEACE RIVER BETWEEN APRIL, 1973, and OCTOBER, 1983

Characteristics		ALL RECORDED DATA APRIL, 1973 - OCTOBER, 1983			DISCHARGE TO UNNAMED STREAM APRIL, 1973 - OCTOBER, 1980			DISCHARGE TO PEACE R. VIA OUTFALL MARCH, 1980 - OCTOBER, 1983			FOLLOWING LAGOON RE-DESIGN JANUARY, 1984 - JUNE, 1985 (Data provided by Region)		
		Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values
BOD_5	mg/L	50	4-171	75	33	4-110	33	63	5-171	42	17	< 1-53	20
Chlorine, Residual	mg/L	2.0	<0.1-20	16	0.9	<0.1-1.8	7	7.8	<0.1-20	9	-	-	-
Chromium, Total	µg/L	5.5	<5-6	2	-	-	-	5.5	<5-6	2	-	-	-
COD	mg/L	162	53-365	19	-	-	-	162	53-365	19	-	-	-
Coliforms, Fecal MPN/100 mL		915*	$<2\text{-}920x10^3$	33	148*	$<2\text{-}24x10^3$	13	2982*	$<2\text{-}920x10^3$	20	Nil	-	17
, Total MPN/100 mL		2850*	$<2\text{-}2.4x10^6$	25	106*	<2-2400	7	10^4*	$<2\text{-}2.4x10^6$	18	-	-	-
Conductivity, Specific	µS/cm	739	468-1100	34	780	468-1020	15	787	540-1100	19	757	680-860	4
Copper, Total	mgL	0.045	0.04-0.05	2	-	-	-	0.045	0.04-0.05	2	-	-	-
Cyanide, Total	mgL	-	<0.01	1	-	-	-	-	<0.01	1	-	-	-
Flow	m^3/d	-	5500	1	-	5500	1	-	-	-	-	5500	-
Lead, Total	µg/L	9	8-10	2	-	-	-	9	8-10	2	-	-	-
Nickel, Total	mg/L	<0.001	<0.01	2	-	-	-	<0.01	<0.01	2	-	-	-
Nitrogen, Total	mg/L	21.4	7.2-30	8	15.1	7.2-17	4	28	25-30	4	-	-	-
, Kjeldahl	mg/L	21.4	7-30	8	15	7-21	4	28	25-30	4	-	-	-
, Nitrite/Nitrate	mg/L	0.07	0.02-0.21	6	0.15	0.08-0.21	2	0.025	0.02-0.03	4	-	-	-
, Total Nitrate	mg/L	<0.02	<0.02	3	-	-	-	<0.02	<0.02	3	-	-	-
, Diss. Nitrate	mg/L	0.025	<0.02-0.03	2	0.025	<0.02-0.03	2	-	-	-	-	-	-
, Diss. Nitrite	mg/L	0.008	<0.005-0.014	5	0.01	<0.005-0.014	2	0.007	0.005-0.009	3	-	-	-
, Total Organic	mg/L	3.7	2.3-4.4	7	3.7	2.3-4.4	4	3.7	3-4	3	-	-	-
, Ammonia	mg/L	16.1	4.7-26.4	8	11.7	4.7-16.6	5	23.5	22-26.4	3	15.6	10.6-21.9	4
Oil and Grease	mg/L	7.1	1.5-11.8	5	-	-	-	7.1	1.5-11.8	5	-	-	-
pH		7.7	6.9-10.8	33	7.9	7-10.8	14	7.6	6.9-8.6	19	7.3	6.9-7.6	4
Phenol	mg/L	-	0.029	1	-	-	-	-	0.029	1	-	-	-
Phosphorus, Total	mg/L	5.2	3-7	8	4.2	3.0-5.1	4	6.3	5.7-7.0	4	-	-	-
, Total Dissolved	mg/L	5.8	5.4-6.4	3	-	-	-	5.8	5.4-6.4	3	4.0	3.8-4.6	3
, Diss. (Ortho)	mg/L	5.1	3.8-6.4	7	4.8	3.8-6.4	4	5.6	5.1-6.1	3	-	-	-
Sodium, Dissolved	mg/L[1]	-	82	1	-	-	-	-	82	1	-	-	-
Solids, Total	mg/L	481	328-694	16	481	328-694	16	-	-	-	-	-	-
, Dissolved	mg/L	365	326-418	3	-	-	-	365	326-418	3	-	-	-
, Suspended	mg/L	28.3	<1-153	67	32	5-153	27	26	<1-68	40	19.3	4-59	20
, Total Inorganic	mg/L	346	228-470	5	346	228-470	5	-	-	-	-	-	-
, Susp. Inorganic	mg/L	-	3	1	-	3	1	-	-	-	-	-	-
Sulphide, Total	mg/L	3.3	<0.5-6.0	2	-	-	-	3.3	<0.5-6.0	2	-	-	-
Zinc, Total	mg/L	0.06	0.05-0.07	2	-	-	-	0.06	0.05-0.07	2	-	-	-

*geometric mean

TABLE 11

AVAILABLE EFFLUENT FLOW DATA FOR FORT ST. JOHN MUNICIPAL DISCHARGE (PE 389)

WASTE MANAGEMENT BRANCH DATA			
	July 11, 1973	-	5 500 m³/d
CITY OF FORT ST. JOHN DATA*			
1981	Total Lagoon outflow	-	1 731 980 m³
	Mean daily outflow*	-	4 745 m³/d
1982	Total Lagoon outflow	-	- 1 616 585 m³
	Mean daily outflow*	-	4 429 m³/d
	Maximum daily discharge	-	11 365 m³/d (Aug. 26/82)
1983	Total Lagoon outflow	-	902 372.4 m³ (279 days)
	Mean daily outflow*		3 234 m³/d
	Actual data (Jan. 4-Dec.31)		
	Maximum daily discharge	-	11 252 m³/d (Aug. 19/83)
	Mean daily discharge	-	3 466 m³/d (278 days)
1984	Actual data (Jan. 4-April 10)		
	Maximum daily discharge	-	6 365 m³/d (April 3/84)
	Mean daily discharge	-	4 773 m³/d

*calculated from total lagoon outflow

TABLE 12

CITY OF FORT ST. JOHN (PE 389) SUMMARY OF PROJECTED LOADS

CHARACTERISTICS	PERMIT LEVEL OR CONCENTRATION	PERMIT LOADING kg/d	MAX. LEVEL OR CONCENTRATION	EFFLUENT FLOW m^3/d	PRESENT LOADING	PROJECTED FUTURE LOADING[1] 1990[2]
Flow	5 180 m^3/d	-	11 365 m^3/d (Aug.26/82)	-		
BOD_5	45 mg/L	233	171 mg/L (Mar. 11/81)	8,300	1 419 kg/d	
			93 mg/L (Feb. 9/83)	3 978	370 kg/d	
			53 mg/L (1984,85 data)	5 500[3]	292 kg/d	321 kg/d
Suspended Solids	60 mg/L	310	68 mg/L (Mar. 3/82)	3 410	232 kg/d	
			59 mg/L (1984,85 data)	5 500[3]	324 kg/d	356 kg/d
Coliforms, Fecal	-	-	$9.2x10^5$ MPN/100 mL (Dec. 14/81)	3 410	$3.14x10^{13}$ MPN/d	3.45×10^{13} MPN/d
			$2.4x10^4$ MPN/100 mL (Feb. 9/83)	3 978	$9.5x10^{12}$ MPN/d	10^{13} MPN/d
Nitrogen, Ammonia	-	-	26 mg/L (Mar. 11/81)	8 300	220 kg/d	
			22 mg/L (1984,85 data)	5 500[3]	121 kg/d	133 kg/d
, Nitrite/ nitrate	-	-	0.03 mg/L (Mar. 11/81)	8 300	0.25 kg/d	0.28 kg/d
Phosphorus, Diss.(ortho)	-	-	6.1 mg/L (Mar. 11/81)	8 300	50 kg/d	55 kg/d
Diss.(total)	-	-	4.6 mg/L (1984,85 data)	5 500[3]	25 kg/d	28 kg/d
Metals						
Chromium, Total	-	-	0.006 mg/L (April 22/81)	6 820	0.04 kg/d	0.044 kg/d
Copper, Total	-	-	0.05 mg/L (April 22/81)	6 820	0.34 kg/d	0.37 kg/d
Lead, Total	-	-	0.01 mg/L (April 13/81)	4 546	0.05 kg/d	0.055 kg/d
Zinc, Total	-	-	0.07 mg/L (April 22/81)	6 820	0.5 kg/d	0.55 kg/d

[1]assuming that effluent loading increases relative to population increase.
[2]based on a projected 1990 population of 14 897, a 10% increase over the 1985 population estimate, and assuming a concomitant percentage increase in effluent discharge to the Peace River.
[3]flow for the period January, 1984 - June, 1985, provided by B. Carmichael, Waste Management Branch, Prince George.

TABLE 13

PREDICTED INCREASES IN PEACE RIVER RECEIVING WATER CONCENTRATIONS FOR PRESENT AND FUTURE PROJECTED WASTE LOADS DURING MINIMUM FLOWS, DOWNSTREAM FROM THE FORT ST. JOHN OUTFALL (PE 389)

CHARACTERISTICS	MAXIMUM PRESENT WASTE LOADS[2]	CONCENTRATION INCREASE AT MAXIMUM PRESENT LOADING[1]		CONCENTRATION INCREASE AT PROJECTED LOADING[2] FOR 1990 (Mean August low flow)	
		Oct.-Apr[3] Mean Low Flow	Aug[4] Mean Low Flow	Assuming Permit Compliance[5]	Assuming Continuation of Present Trend[6]
BOD_5	1419 kg/d(Mar.11/81)	20 µg/L	18 mg/L	3 µg/L	-
	292 kg/d (1984,85)	5 µg/L	4 µg/L	-	4 µg/L
Suspended Solids	232 kg/d (Mar.3/82)	3.6 µg/L	3 µg/L	4 µg/L	-
	324 kg/d(1984,85)	5 µg/L	4µg/L	-	4 µg/L
Chlorine Residual	34 kg/d (assumed)[7]	0.5 µg/L	0.4 µg/L	-	-
Fecal Coliforms	3.1×10^{13} MPN/d	49 MPN/100 mL	41 MPN/100 mL	-	45 MPN/100 mL
Ammonia-nitrogen	220 kg/d (Mar.11/81)	3.5 µg/L	3 µg/L	-	-
	121 kg/d (1984,85)	2 µg/L	1.5 µg/L	-	2 µg/L
Nitrite/nitrate	0.25 kg/d	0.004 µg/L	0.003 µg/L	-	0.004 µg/L
Phosphorus, Diss.(Ortho)	50 kg/d	0.8 µg/L	0.7 µg/L	-	0.7 µg/L
, Diss.(Total)	25 kg/d	0.4 µg/L	0.3 µg/L	-	0.36 µg/L
Metals:					
Chromium , Total	0.04 kg/d	<0.001 µg/L	<0.001 µg/L	-	<0.001 µg/L
Copper , Total	0.34 kg/d	0.005 µg/L	0.004 µg/L	-	0.005 µg/L
Lead , Total	0.05 kg/d	<0.001 µg/L	<0.001 µg/L	-	<0.001 µg/L
Zinc , Total	0.5 kg/d	0.008 µg/L	0.007 µg/L	-	0.007 µg/L

assuming complete mixing of effluent and river water
[1] from Table 12
[2] total low flow = October-April low flow estimate (734 m^3/s) + maximum effluent flow (11 365 m^3/d)
[3] total low flow = August low flow estimate (881 m^3/s) + maximum effluent flow (11 365 m^3/d)
[4] using permitted loading from Table 12
[5] using maximum projected waste loads from Table 12
[6] loading under conditions of a recommended permit maximum of 3 mg/L chlorine residual.
[7]

TABLE 14

WATER QUALITY OF THE PEACE RIVER DOWNSTREAM FROM DISCHARGE PE 389 (FORT ST. JOHN) AT SITES 0400491 and 0400492

Characteristics			0400491 200 m DOWNSTREAM FROM DISCHARGE PE 389			0400492 25 m DOWNSTREAM FROM DISCHARGE PE 389			CRITERIA EXCEEDED
			Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	
Alkalinity	Total	mg/L	-	100	1	106	101-110	2	
BOD_5		mg/L	<10	<10	2	-	<10	1	
Cadmium	Total	mg/L	-	0.5*	1	-	0.5*	1	A 0.2-4.0
Calcium	Total	mg/L	-	33.5	1	-	33.5	1	
	Dissolved	mg/L	-	32.1	1	35	33.1-37.2	2	
Chromium	Total	µg/L	-	7	1	-	<5	1	
Coliforms	Fecal	MPN/100 mL	100[1]*	50*-200*	2	-	<200	1	P 10-100
	Total	MPN/100 mL	-	<200	1	-	<200	1	
Color		T.A.C.	-	6	1	5.5	5-6	2	
Conductivity	Specific	µS/cm	217	211-225	3	260	223-305	3	
Copper	Total	mgL	-	2*	1	-	<1	1	A 2
Gases	Total Diss.	%	-	-	-	102.7	101.5-104.6	7	
	Diss. Nitrogen	%	-	-	-	105.2	101.3-107	7	
Hardness	Dissolved	mg/L	-	112	1	122	114-129	2	
Iron	Total	mg/L	-	1.4*	1	-	0.3	1	P 0.3, A 0.3-1.0
Lead	Total	µg/L	-	<1	1	-	<1	1	
Magnesium	Total	mg/L	-	7.8	1	-	7.7	1	
	Dissolved	mg/L	-	7.7	1	-	7.7-8.7	2	
Manganese	Total	mg/L	-	0.03	1	-	<0.02	1	
Molybdenum	Total	µg/L	-	1.1	1	-	1.1	1	
Nickel	Total	mg/L	-	<0.01	1	-	<0.01	1	
Nitrogen	Ammonia	µg/L	-	70	1	10	9-11	2	
	Kjeldahl	mg/L	-	0.33	1	0.19	0.17-0.21	2	
	Nitrate	mg/L	-	-	1	<0.02	<0.02	2	
	Nitrite/Nitrate	mg/L	-	-	-	<0.02	<0.02	2	
	Nitrite	µg/L	-	-	-	<5	<5	2	
	Organic	mg/L	-	0.26	1	0.18	0.16-0.2	2	
	Total	mg/L	-	-	-	0.19	0.17-0.21	2	
Oxygen	Dissolved	mg/L	-	-	-	10.1	9.4-11.3	8	
pH			8.2	8.1-8.3	3	8.2	8.1-8.2	3	
Phosphorus	Total	mg/L	-	0.13*	1	0.026	0.02-0.03	2	P, R 0.1
	Dissolved	mg/L	-	0.024	1	<0.003	<0.003	2	

TABLE 14 (Continued)

Characteristics			0400491 200 m DOWNSTREAM FROM DISCHARGE PE 389			0400492 25 m DOWNSTREAM FROM DISCHARGE PE 389			CRITERIA EXCEEDED
			Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	
Sodium	, Dissolved	mg/L	-	2.5	1	2.6	2.2-3	2	
Solids	, Total	mg/L	-	326	1	158	144-172	2	
	, Dissolved	mg/L	-	136	1	146	134-158	2	
	, Suspended	mg/L	35	22-48	2	-	30*	1	
Temperature		°C	-	-	-	12.1	5-18	8	
Turbidity		N.T.U.	-	21	1	7.2	5.1-9.2	2	

[1] geometric mean
A working water quality criteria for aquatic life
P working water quality criteria for public water supplies
R working water quality criteria for recreation and aesthetics
* exceed working criteria

TABLE 15

WATER QUALITY OF THE PEACE RIVER UPSTREAM FROM DISCHARGE PE 389 (FORT ST. JOHN) AT SITES 0400134-0400136 (NOVEMBER, 1971-OCTOBER, 1974)

TABLE 15 (Continued)

Characteristics			0400134 STN. #1 NORTH SHORE			0400135 STN. #2 MIDSTREAM			0400136 STN. #3 SOUTH SHORE			SUMMATION OF TRANSECT VALUES 0400134 - 0400136			CRITERIA EXCEEDED
			Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	
Alkalinity	, Total	mg/L	80	80-109	8	88.1	80-102	7	87	80-95	8	84.9	80-109	23	
	, Phenolphthalein	mg/L	0	0	7	0	0	8	0	0	7	0	0	22	
Calcium	, Total	mg/L	-	29.2	1	-	28.8	1	-	28.6	1	28.9	28.6-29.2	3	
	, Dissolved	mg/L	28.4	24.8-31.2	9	26.9	24.8-29.6	8	26.9	24.5-28.8	9	27.4	24.5-31.2	26	
Carbon	, Organic	mg/L	8.5	<1-15	8	5.8	<1-11	8	15.3	4-60	8	9.3	<1-60	24	
	, Inorganic	mg/L	23	22-24	2	20	20	2	20	19-21	2	21	19-24	6	
Chloride	, Total	mg/L	-	0.3	1	-	0	1	-	0	1	0.1	0-0.3	3	
	, Dissolved	mg/L	0.6	<0.3-1.1	7	0.5	<0.3-0.9	7	0.5	<0.3-0.7	7	0.53	<0.3-1.1	21	
Chromium	, Total	µg/L	-	<5	1	-	<5	1	-	<5	1	<5	<5	3	
	, Dissolved	µg/L	<5	<5	8	<5	<5	7	<5	<5	8	<5	<5	23	
COD		mg/L	-	5.8	1	24.7	7.4-42	2	-	7.7	1	15.7	5.3-42	4	
Coliforms	, Fecal	MPN/100 mL	8.3[1]	<2-130*	7	4.1[1]	<2-33*	7	13.1[1]*	<2*-130*	7	6.0[1]	<2*-130*	21	P 10-100, R 200-400
	, Total	MPN/100 mL	50.4[1]*	8-350*	9	14.2[1]*	2-540*	9	37.6[1]*	2-350*	9	21.5[1]	2-540*	27	P 100-1000-5000
Color		T.C.U.	12.3	<1-23*	4	6.7	<1-12	3	10.3	<1-23*	4	10.0	<1-23*	11	R 15-100; P 15-75 (true)
Conductivity,	Specific	µS/cm	204	170-220	6	189	155-210	6	185	155-200	6	193	155-220	18	
Copper	, Total	µg/L	-	<10	1	-	<10	1	-	<10	1	<10	<10	3	
	, Dissolved	µg/L	2.4*	<1-9*	8	1.7	<1-4*	7	1.9	<1-7*	8	2.0*	<1-9*	23	A2
Hardness	, Total	mg/L	-	92	1	-	95	1	-	96	1	94.3	92-96	3	
	, Dissolved	mg/L	97.1	81.3-108	9	91.5	82.5-104	8	91.4	83.4-99	9	93.4	81.3-108	26	
Iron	, Total	mg/L	-	<0.02	1	-	<0.02	1	-	<0.02	1	<0.02	<0.02	3	
	, Dissolved	mg/L	0.07	<0.02-0.14	7	0.05	<0.02-0.1	6	0.06	<0.02-0.11	7	0.06	<0.02-0.14	20	
Lead	, Total	µg/L	-	4	1	-	4	1	-	3	1	3.7	3-4	3	
	, Dissolved	µg/L	3.2	<1-15*	8	2.3	<1-6*	7	2	<1-4	8	2.5	<1-15*	23	A 5-10
Magnesium	, Dissolved	mg/L	6.2	4.7-7.2	9	5.7	5-6.6	8	5.7	5-6.3	9	5.9	4.7-7.2	26	
Manganese	, Total	mg/L	-	0.02	1	-	0.02	1	-	0.02	1	0.02	0.02	3	
	, Dissolved	mg/L	0.013	<0.01-0.02	7	0.012	<0.01-0.02	6	0.013	<0.01-0.02	7	0.013	<0.01-0.02	20	
Mercury	, Total	µg/L	-	-	-	-	<20	1	-	-	-	-	<20	1	
	, Dissolved	µg/L	-	-	-	0.06	0.05-0.14*	8	-	-	-	0.06	0.05-0.14*	8	A 0.1-0.2
Nickel	, Total	µg/L	-	<10	1	-	<10	1	-	<10	1	<10	<10	3	
Nitrogen	, Ammonia (Tot.)	µg/L	-	<10	1	-	-	-	-	-	-	-	<10	1	
	, Ammonia (Diss.)	µg/L	14	<5-23	2	8.5	<5-12	2	8.7	<5-15	3	10.2	<5-23	7	
	, Kjeldahl	mg/L	0.4	0.03-0.84	6	0.27	0.07-0.5	6	0.3	0.08-0.6	6	0.32	0.03-0.34	18	
	, Nitrate	mg/L	0.05	<0.02-0.12	9	0.05	<0.02-0.11	9	0.05	<0.02-0.08	9	0.05	<0.02-0.12	27	
	, Nitrite/Nitrate	µg/L	0.06	0.03-0.12	6	0.06	0.03-0.11	6	0.05	0.03-0.08	6	0.06	0.03-0.12	18	
	, Nitrite	µg/L	<5	<5	6	<5	<5	6	<5	<5	6	<5	<5	18	
	, Organic	mg/L	0.23	0.16-0.31	3	0.185	0.18-0.19	2	0.20	0.13-0.27	3	0.21	0.13-0.31	8	
	, Total	mg/L	0.3	0.2-0.38	4	0.28	0.22-0.37	3	0.27	0.28-0.33	4	0.28	0.18-0.38	11	

TABLE 15 (Continued)

Characteristics			0400134 STN. #1 NORTH SHORE			0400135 STN. #2 MIDSTREAM			0400136 STN. #3 SOUTH SHORE			SUMMATION OF TRANSECT VALUES 0400134 - 0400136			CRITERIA EXCEEDED
			Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	
Oxygen	, Dissolved	mg/L	11.3	9.6-13.4	6	10.9	9.4-13.2	6	10.9	9.6-13.2	6	11.0	9.4-13.4	18	
pH			8.0	7.9-8.2	7	8.0	7.9-8.3	6	8	7.9-8.1	6	8	7.9-8.3	19	
Phosphorus	, Total	mg/L	0.07	0.01-0.3*	10	0.04	<0.003-0.14*	10	0.06	0.09-0.24*	10	0.06	<0.003-0.3*	30	
Potassium	, Total	mg/L	-	0.7	1	-	-	-	-	-	-	-	0.7	1	
	, Dissolved	mg/L	0.6	0.3-0.9	7	0.6	0.4-0.7	7	0.6	0.4-0.9	7	0.6	0.3-0.9	21	
Silica	, Dissolved	mg/L	3.8	3.4-4.2	6	3.8	3.4-4.1	6	3.8	3.4-4.3	6	3.8	3.4-4.3	18	
Sodium	, Total	mg/L	-	1.1	1	-	1	1	-	-	1	1.0	1-1.1	1	
	, Dissolved	mg/L	1.4	1.1-2.3	7	1.3	1.1-1.8	7	1.3	1.2-1.6	7	1.3	1.1-2.3	21	
Solids	, Total	mg/L	-	136	1	-	138	1	-	134	1	136	134-138	3	
	, Dissolved	mg/L	123.3	114-134	3	109	106-112	2	107	100-118	3	114	100-134	8	
	, Suspended	mg/L	155.4	10-770	9	98	8.8-572	9	103	7.2-475	9	119	7.2-770	27	
	, Inorganic	mg/L	-	100	1	-	112	1	-	114	1	109	100-113	3	
Sulphate	, Total	mg/L	-	11	1	-	9.8	1	-	11	1	10.6	9.8-11	3	
	, Dissolved	mg/L	10.4	7.8-12	7	10.3	7.8-12	7	8.9	6.8-12	7	9.9	6.8-12	21	
Surfactants	, Total	mg/L	0.025	0-0.03	6	0.025	0-0.03	6	0.025	0-0.03	6	0.025	0-0.03	18	
	, Dissolved	mg/L	-	<0.03	1	-	<0.03	1	-	<0.03	1	<0.03	<0.03	3	
Tannin and Lignin, Total		mg/L	0.43*	<0.1-1*	6	0.26	<0.1-0.4*	5	0.6*	<0.1-2.2*	6	0.44*	<0.1-2.2*	17	P 0.4
	, Dissolved	mg/L	-	0.1	1	0.25	0.2-0.3	2	-	0.2	1	0.2	0.1-0.3	4	
Temperature		°C	7.3	3-11.2	8	7.3	3-10.8	7	7.1	3-10.5	8	7.2	3-11.2	23	
Turbidity		N.T.U.	48	1.3-160	10	28	1.9-110	9	34	2-120	10	37	1.3-160	29	
Zinc	, Total	µg/L	-	30	1	-	30	1	-	30	1	30	30	3	
	, Dissolved	µg/L	17.6	<5-100*	8	12.9	<5-60*	7	14.8	<5-70*	8	15.2	<5-100*	23	A 50

[1]geometric mean
A=working water quality criteria for aquatic life
P=working water quality criteria for public water supplies
R=working water quality criteria for recreation and aesthetics
*=in excess of working water quality criteria

TABLE 16

CITY OF FORT ST. JOHN (PE 388) CHARACTERISTICS OF TREATED MUNICIPAL EFFLUENT AND SUMMARY OF WASTE LOADS DISCHARGED TO THE BEATTON RIVER BETWEEN JUNE, 1974 AND MAY, 1983

Characteristics			MONITORED LEVELS			PERMIT CONDITIONS		MAX. PRESENT LOADING[1]	PREDICTED FUTURE LOADIN
			Mean	Range of Values	Number of Values	Maximum Level or Concentration	Loading kg/d		1990[2]
BOD_5		mg/L	23.6	<5-185	14	45 mg/L	495	2 035 kg/d	2239 kg/d
Coliforms	, Fecal	MPN/100 mL	92[3]	5-4000	7	-	-	4.4×10^{11} MPN/d	4.8×10^{11} MPN/d
	, Total	MPN/100 mL	140.5[3]	7-4000	8	-	-	4.4×10^{11} MPN/d	4.8×10^{11} MPN/d
Conductivity,	Specific	µS/cm	807	638-961	10	-	-	-	-
Flow			-	-	-	11 000 m^3/d	-	-	-
Nitrogen	, Ammonia	mg/L	1.7	0.9-3.0	3	-	-	33 kg/d	36 kg/d
	, Kjeldahl	mg/L	7.5	3-18.2	5	-	-	200 kg/d	220 kg/d
	, Organic	mg/L	2.3	1.7-3.1	3	-	-	34 kg/d	37 kg/d
	, Nitrite/Nitrate	mg/L	0.26	0.03-0.9	5	-	-	10 kg/d	11 kg/d
	, Total	mg/L	7.8	3.2-18.2	5	-	-	200 kg/d	220 kg/d
pH			8.0	7.3-8.6	11	-	-	-	-
Phosphorus	, Total	mg/L	2.3	0.5-5.7	5	-	-	63 kg/d	69 kg/d
Solids	, Dissolved	mg/L	480	392-568	2	-	-	6 250 kg/d	6875 kg/d
	, Inorganic	mg/L	526	498-570	3	-	-	6 270 kg/d	6897 kg/d
	, Suspended	mg/L	43.8	6-222	13	60 mg/L	660	2 442 kg/d	2686 kg/d
	, Total	mg/L	611	468-708	6	-	-	7 800 kg/d	8580 kg/d

[1]In the absence of daily flow data, these loads were calculated by multiplying the maximum permitted effluent flow by the maximum actual concentration, thus providing a conservative estimate of actual loadings.
[2]based on a projected 1990 population of 14 897, a 10% increase over the 1985 population estimate and assuming a concomitant percentage increase in effluent discharge.
[3]geometric mean

TABLE 17

PREDICTED INCREASES IN BEATTON RIVER RECEIVING WATER CONCENTRATIONS FOR FUTURE AND PROJECTED WASTE LOADS DURING MINIMUM FLOWS DOWNSTREAM FROM THE FORT ST. JOHN OUTFALL (PE 388)

CHARACTERISTICS	MAXIMUM PRESENT WASTE LOAD[1]	CONCENTRATION INCREASE AT MAXIMUM PRESENT LOADINGS[2]	CONCENTRATION INCREASE AT PROJECTED LOADINGS FOR 1990 (April 1-June 30 Discharge)	
			Assuming Permit Compliance[3]	Assuming Continuation of Present Trends[4]
BOD_5	2 035 kg/d	0.63 mg/L	0.15 mg/L	0.7 mg/L
Suspended Solids	2 442 kg/d	0.76 mg/L	0.2 mg/L	0.8 mg/L
Fecal Colforms	$4.4x10^{11}$ MPN/d	13.7 MPN/100 mL	-	14.8 MPN/100mL
Ammonia-nitrogen	150 kg/d	0.05 mg/L	-	0.05 mg/L
Nitrite/nitrate	10 kg/d	3 µg/L	-	3 µg/L
Phosphorus, Total	63 kg/d	20 µg/L	-	21 µg/L

[1]loading values (Table 16) assume complete mixing of effluent and river water.
[2]total low flow = "end-of-freshet" 7-day average, mean return low flow (37.2 m^3/s) + maximum permitted effluent flow (11 000 m^3/d).
[3]using permitted loading from Table 16.
[4]using maximum projected waste loads from Table 16 except for ammonia-N (165 kg/d) which was calculated from 150 kg/d plus the 2 percent annual increase .

TABLE 18

WATER QUALITY OF THE BEATTON RIVER AT SITE 0400145 AT THE MOUTH

CHARACTERISTICS			SITE 0400145 Nov. 1971 - Oct. 1984 Mean	Range of Values	No. of Values	CRITERIA EXCEEDED
Alkalinity	, Phenolphthalein	mg/L	0	0	7	
	, Total	mg/L	69	29.5-129	8	
Calcium	, Dissolved	mg/L	21	14-28	8	
	, Total	mg/L	-	41.6	1	
Carbon	, Inorganic	mg/L	8.7	6-12	3	
	, Organic	mg/L	36	25-51	8	
Chloride	, Dissolved	mg/L	1.8	1.4-2.2	6	
	, Total	mg/L	-	2.5	1	
Chromium	, Dissolved	µg/L	-	<5	7	
	, Total	µg/L	-	<5	2	
C.O.D.		mg/L	-	80	1	
Coliforms	, Fecal	MPN/100 mL	54.4[1]*	20*-170*	6	P-10-100
	, Total	MPN/100 mL	166[1]*	11-5400*	8	P-100-1000
Color		T.A.C.	177*	144*-205*	3	P 15-75 (true) R 15-100 (true)
Conductivity, Specific		µS/cm	209	112-385	5	
Copper	, Dissolved	µg/L	10*	2*-50*	7	A 2
	, Total	µg/L	25*	20*-30*	2	A 2
Hardness	, Dissolved	mg/L	73	50-102	7	
	, Total	mg/L	-	155	1	
Iron	, Dissolved	mg/L	1.2*	0.5*-2.6*	7	P 0.3;A 0.3-1.0
	, Total	mg/L	-	1.7*	1	P 0.3;A 0.3-1.0
Lead	, Dissolved	µg/L	2.7	<1-6*	7	A 5
	, Total	µg/L	13*	12*-14*	2	A 5
Magnesium	, Dissolved	mg/L	5.3	3.7-8	7	
	, Total	mg/L	-	7.6	1	
Manganese	, Dissolved	mg/L	0.03	0.01-0.08*	7	P 0.05
	, Total	mg/L	-	0.09*	1	P 0.05
Mercury	, Dissolved	µg/L	0.22*	0.05-0.83*	7	P 1.0;A 0.1
	, Total	µg/L	-	<20	1	
Nickel	, Total	mg/L	-	0.01	1	
Nitrogen	, Dissolved Ammonia	mg/L	0.04	0.03-0.05	3	
	, Kjeldahl	mg/L	1.2	0.5-3.5	7	
	, Organic	mg/L	0.9	0.6-1	3	
	, Nitrite/Nitrate	mg/L	0.024	<0.02-0.04	5	
	, Nitrite	µg/L	6.6	<5-13	8	
	, Nitrate	mg/L	0.05	<0.02-0.18	9	
	, Total	mg/L	0.9	0.7-1.0	4	
Oxygen	, Dissolved	mg/L	11	8.2-13.3	6	
pH			7.9	7.5-8.2	2	
Phosphorus	, Total	mg/L	0.34*	<0.003-1.6*	9	P, R 0.1
Potassium	, Dissolved	mg/L	2.0	0.9-5.5	6	

TABLE 18 (Continued)

Silica	, Dissolved	mg/L	5.5	4.1-7.2	5	
Sodium	, Dissolved	mg/L	10.6	4-16	6	
	, Total	mg/L	-	29.5	1	
Solids	, Dissolved	mg/L	163	138-178	3	
	, Total Inorganic	mg/L	-	1086	1	
	, Suspended	mg/L	491	6.4-2229	8	
	, Total	mg/L	-	1234	1	
Sulphate	, Dissolved	mg/L	39	27-57	6	
	, Total	mg/L	-	75.5	1	
Surfactants	, Dissolved	mg/L	<0.03	<0.03	2	
	, Total	mg/L	0.02	0-0.03	4	
Tannins and Lignins, Diss.		mg/L	1.6*	1*-2.1*	2	P 0.4
	, Total	mg/L	2.8*	2*-3.7*	4	P 0.4
Temperature (field)		°C	11	3-17	8	
Turbidity		N.T.U.	175	13-680	8	
Zinc	, Dissolved	µg/L	15.6	5-33	7	
	, Total	mg/L	0.08*	0.005-0.11*	2	A 0.05

[1]geometric mean
*in excess of working water quality criteria
A-working water quality criteria for aquatic life.
P-working water quality criteria for public wate supplies.
R-working water quality criteria for recreation and aesthetics.

TABLE 19

WATER QUALITY OF THE BEATTON RIVER AT THE MOUTH AS MEASURED BY ENVIRONMENT CANADA, INLAND WATERS DIRECTORATE (MARCH-SEPTEMBER, 1976)

CHARACTERISTICS			SITE 07FC0002 Mean ± Std. Deviation	Range of Values	No. of Values	CRITERIA EXCEEDED
Alkalinity	, Total	mg/L	79.5±87	28-276	9	
Arsenic	, Extractable	μg/L	10±17	1.6-440*	6	A, P, R 50
Barium	, Extractable	mg/L	0.3±0.1	0.16-0.38	6	
Cadmium	, Extractable	μg/L	0.4*±0.3	0.2*-1.1*	8	A 0.2-4.0
Calcium	, Dissolved	mg/L	30±20	15-76	8	
Carbon	, Particulate	mg/L	0.7±1.5	0.02-3.3	5	
	, Total Organic	mg/L	31±14	7-57	8	
	, Total Inorganic	mg/L	22±20	6-59	8	
Chloride	, Dissolved	mg/L	4.6±2.3	2.2-7.8	6	
Cobalt	, Extractable	μg/L	3±3	<1-8	8	
Color	, Apparent	A.C.U.	171*±126	50*-400*	8	P 15-75 (true) R 15-100 (true)
Conductance	, Specific (Lab.)	μS/cm	268±241	118-805	8	
Copper	, Extractable	μg/L	10*±8	3*-25*	8	A 2
	, Total	μg/L	25*	20*-30*	2	A 2
Fluoride	, Dissolved	mg/L	0.13±0.06	0.09-0.25	8	
Hardness	, Total ($CaCO_3$)	mg/L	99±71	48-257	8	
Iron	, Dissolved	mg/L	-	0.6*	1	A 0.3-1;P 0.3
	, Extractable	mg/L	2.9*±2.3	1.4*-8.4*	8	A 0.3-1; P 0.3
Lead	, Extractable	μg/L	2±1	<1-4	8	
Manganese	, Extractable	mg/L	0.2*±0.13	0.05*-0.33*	8	P 0.05;A 0.1-1
Mercury	, Extractable	μg/L	0.07±0.03	<0.05-0.13*	6	A 0.1-0.2; P 1.
Nickel	, Extractable	μg/L	9±9	4-30*	8	A 25
Nitrogen	, Nitrite/nitrate	mg/L	0.2±0.3	0.01-0.71	8	
	, Diss. Ammonia-N	mg/L	0.1±0.16	0.02-0.5	8	
	, Total Dissolved	mg/L	1.0±0.5	0.6-2.0	8	
pH			7.5±0.3	7.2-8.0	8	
Phosphorus	, Dissolved	μg/L	38	21-79	5	
	, Total	mg/L	0.7*±0.7	0.1*-1.9*	6	P, R 0.1
Selenium	, Extractable	μg/L	1.1*±1.1	0.3-3.4*	7	A 1
Silica	, Reactive	mg/L	6.2±0.7	5.4-7.2	6	
Solids	, Suspended	mg/L	294±260	52-802	8	
	, Dissolved	mg/L	230±136	148-548*	8	P 500
	, Diss. Inorganic	mg/L	160±131	58-466	8	
	, Susp. Inorganic	mg/L	273±242	46-736	8	
Sulphate	, Dissolved	mg/L	65±48	34-155*	6	P 5, R 25-50
Temperature		°C	10.3±6.6	0.5-17.0	8	
Turbidity		J.T.U.	186±164	39-550	8	
Zinc	, Extractable	μg/L	15±20	2-60*	8	A 50

*in excess of working water quality criteria
A-working water quality criteria for aquatic life
P-working water quality criteria for public water supplies
R-working water quality criteria for recreation and aesthetics

TABLE 20

PETRO-CANADA REFINERY, COMPARISON OF PERMITTED EFFLUENT CHARACTERISTICS BETWEEN THE ORIGINAL PERMIT (ISSUED IN 1973) AND THE AMENDED PERMIT (ISSUED IN 1981)

EFFLUENT TYPE	EFFLUENT CHARACTERISTIC		ORIGINAL PERMIT (ISSUED 1973)	AFTER AMENDMENT (1981)	AFTER AMENDMENT (1985)
COOLING WATER	Flow	m^3/d	144 000	205 000	205,000
	Suspended solids (above background)	mg/L	10	deleted	deleted
	Oil & grease (above background)	mg/L	1.0	2.0	2.0
	pH		6.5-8.5	6.5-8.5	6.5-8.5
	Temperature	°C	32°C max.	32°C max.	32°C max.
PROCESS EFFLUENT	Flow	m^3/d	2 050	2 050	2 060
	pH		6.5-9.0	6.5-8.5	6.5-8.5
	Suspended solids	mg/L	20	60	60
	Total solids	mg/L	2 000	1 500	1 500
	BOD_5	g/m^3*	22.8	22.8	-
		kd/g			80.6
	Phenol	g/m^3*	0.33	0.17	-
		kg/d			0.6
	Ammonia-N	g/m^3*	10.8	5.3	-
		kg/d			32.1
	Ortho-phosphorus (P)	mg/L	3.0	1.0	1.0
	Oil & grease	g/m^3*	10.8	8.0	-
		kg/d			28.4
	Cyanide	mg/L	0.2	0.1	0.1
	Fluoride	mg/L	15	10	10
	Sulphides & mercaptans	g/m^3*	0.3	-	-
	Sulphides & mercaptans	mg/L	-	1.0	1.0
	Chromium	mg/L	0.2	deleted	deleted
	Copper	mg/L	0.1	deleted	deleted
	Lead	mg/L	0.2	deleted	deleted
	Nickel	mg/L	0.1	deleted	deleted
	Zinc	mg/L	0.2	deleted	deleted
	Temperature	°C	32°C max.	32°C max.	deleted
STORM RUNOFF	Flow	m^3/d	not specified	Variable	variable
	Oil & grease	g/m^3*	not specified	2.9	-
		kg/d			10.2
	pH	kg/d	not specified	6.5-8.5	6.5-8.5
	Phenol	g/m^3*	not specified	0.17	-
		kg/d			0.6
	Suspended solids	mg/L	not specified	60	+10 mg/L if background ≤100 mg/L +10% if background > 100 mg/L.

*g/m^3 of refinery throughput

TABLE 21

PETRO-CANADA TAYLOR REFINERY (PE 1379) SAMPLING OF COOLING WATER/PROCESS EFFLUENT MIXTURE AND PROCESS EFFLUENTS BY THE PROVINCE AND PETRO CANADA (1972-1983)

CHARACTERISTICS			PROCESS EFFLUENT EQUIS 0410135			PROCESS EFFLUENT/ COOLING WATER MIXTURE EQUIS 0410136		
			Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values
Alkalinity	,	mg/L	159.4	98-221	2	-	99.3	1
Bioassay (96h LC_{50})		% effluent	72.2	3.8-100	22			
BOD_5		mg/L	135	<5-1091	294	81.2	<10-675	19
		g/m^3	32	1.4-244	96	-	-	-
Cadmium	, Total	mg/L	-	0.01	1	-	<0.5	1
Carbon	, Organic	µg/L	36.5	17-56	2	6	1-11	2
Chloride	, Dissolved	mg/L	-	173	1			
Chromium	, Total	µg/L	12.7	<5-50	25	9	<5-23	8
	, Dissolved	µg/L	19.7	<5-220	92	<5	<5	2
COD		µg/L	430	16-2000	426	427	<10-1958	33
Coliforms	, Total Fecal	MPN/100 mL	-	790	1	-	130	1
Conductance	, Specific	µS/cm	1192	447-3770	38	905	182-2730	26
Copper	, Total	µg/L	12.5	<1-40	25	9.8	<1-28	8
	, Dissolved	µg/L	81.2	<1-3200	104	5.5	<1-10	2
Cyanide	, Total	mg/L	0.21	0-3.5	450	0.07	<0.01-0.32	19
Flow		m^3/d	3697	0-4706	2072	$164x10^3$	$120x10^3$-$198x10^3$	2070
Fluoride	, Total	mg/L	10.4	0.4-113	389	-	-	-
	, Dissolved	mg/L	6.9	0.5-59	33	13.9	0.12-38.3	10
Iron	, Total	mg/L	-	3.6	1	-	3.6	1
Lead	, Total	µg/L	10.3	<1-100	25	4	<1-9	8
	, Dissolved	µg/L	67	0-560	92	<3	<3	2
Manganese	, Dissolved	mg/L	0.1	0.04-0.6	5	-	-	-
Mercury	, Total	µg/L	-	0.5	1	0.47	0.05-0.88	2
Nickel	, Total	µg/L	12	<10-30	25	15	<10-50	8
	, Dissolved	µg/L	36	<10-160	92	<10	<10	2
Nitrogen	, Ammonia, Dissolved	mg/L	28	1.2-108	25	30	10-66.5	8
	, Ammonia, Total	mg/L	41.4	0.05-249	517	8.7	*0.01-47	11
	, Ammonia, Total	g/m^3	19	0.6-92	96	-	-	-
	, Nitrite/Nitrate	mg/L	-	<0.02	1	-	-	-
	, Nitrate	mg/L	-	<0.02	1	-	-	-
	, Nitrite	mg/L	-	<0.005	1	-	-	-
	, Organic	mg/L	21.6	4.8-56	6	0.12	0.07-0.16	6
	, Kjeldahl	mg/L	63	28-94	6	-	-	-
Oil and Grease		mg/L	7.1	0-612	511	1.8	0-90	487
		g/m^3	2.0	0.2-10.5	94	-	-	-
Oxygen	, Dissolved	mg/L	1.4	1-1.7	2	-	-	-
pH (Lab.)			8.2	3.5-11.8	547	8.1	6.4-11	497

TABLE 21 (Continued)

CHARACTERISTICS			PROCESS EFFLUENT EQUIS 0410135			PROCESS EFFLUENT/ COOLING WATER MIXTURE EQUIS 0410136		
			Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values
Phenols	, Total	mg/L	1.3	0.002-17.6	235	2.2	<0.002-26.4	28
	, Total	g/m³	0.5	0.001-28.6	99	-	-	-
Phosphorus	, Total	mg/L	0.33	0.01-2.1	8	0.9	0.007-6	7
	, Diss. (Ortho-P)	mg/L	0.56	0-28.3	456	0.5	<0.003-1.6	10
Solids	, Total	mg/L	672	66-4920	426	583	118-3876	27
	, Total Inorganic	mg/L	477	246-814	4	122	116-128	2
	, Dissolved	mg/L	1215	796-1990	7	1086	796-1600	6
	, Suspended	mg/L	68.6	1.8-2240	512	88	0-3044	390
	, Suspended Inorganic	mg/L	-	30	2	13.7	2-22	3
Sulphide	, Total	mg/L	34.5	0-1326	548	1.9	<0.5-14.8	19
Temperature	(Field)	°C	16.3	0-45.6	1591	22.5	0-50	229
Turbidity		N.T.U.	-	23	1	-	7.3	1
Zinc	, Total	µg/L	39	6-170	25	20	5-40	8
	, Dissolved	µg/L	60	<5-470	87	20	20	2

TABLE 22

SUMMARY OF PERMITTED AND ACTUAL INFLOW WASTE LOADS FOR THE COOLING WATER FROM THE PETRO-CANADA REFINERY AT TAYLOR (PE 1379)

CHARACTERISTICS	PERMIT CONDITIONS		MAXIMUM INFLOW LOAD[1]	
	LEVEL OR CONCENTRATIONS	LOADING kg/d	MAXIMUM INFLOW LEVEL OR CONCENTRATION RECORDED	MAXIMUM INFLOW LOAD kg/d
Flow	205 000 m³/d	-	-	-
Oil and Grease	2.0 mg/L above bkgd	410	2.9 mg/L 2.9 -	- 504 -
pH	6.5-8.5	-	7.7-8.9	-
Temperature	32°C Max.	-	8°C	-
Solids, Suspended	-	-	no comparable data	-
BOD_5	-	-	10 mg/L	1 600
Phenols	-	-	- 0.008 mg/L	- 1.2
Sulphides	-	-	1.0 mg/L	174
Fluoride	-	-	- 0.13 mg/L (site 07FA003)	- 20
Cyanide, Total	-	-	0.01 mg/L	1.7
Ammonia-nitrogen	-	-	0.11 mg/L	20
Phosphorus, Diss.	-	-	0.11 mg/L	16

[1]inflow loads were calculated from maximum concentrations (site 0400157 or 07FA003)

TABLE 23

SUMMARY OF PERMITTED, ACTUAL AND PROJECTED FUTURE WASTE LOADS FOR THE PROCESS EFFLUENT FROM THE PETRO-CANADA REFINERY AT TAYLOR (PE 1378)

CHARACTERISTICS	PERMIT CONDITIONS		MAXIMUM ACTUAL LOADING			PROJECTED 1992 LOADINGS[3] kg/d	
				MAXIMUM DAILY LOADING			
	LEVEL OR CONCENTRATIONS	LOADING kg/d	MAXIMUM LEVEL OR CONCENTRATION RECORDED[2]	PRODUCTION OR ESTIMATED FLOW m^3/d	LOAD kg/d	ASSUMING PERMIT COMPLIANCE	ASSUMING CONTINUATION OF PRESENT TRENDS
Flow	2 050 m^3/d	-	4 706 m^3/d (Jan. 20/76)	-	-	3 075 m^3/d	-
BOD_5	22.8 g/m^3 [1]	46.7	1 091 mg/L (Jan. 6/75) 244 g/m^3 (Feb. 16/82)	no data 3 039	- 740	- 70	- 1 112
Cyanide, Total	0.1 mg/L	0.2	3.5 mg/L (Dec. 13/77) 1.6 mg/L (May 5/80)	1 668 991	5.8 1.6	0.3	8.7
Fluoride, Total	10 mg/L	20.5	113 mg/L (Mar. 30/82)	1 672	189	31	284
Nitrogen, Amm. Total	5.3 g/m^3 [1]	10.9	92 g/m^3 (Aug. 17/82)	933	85.8	16.3	129
Oil and Grease	8.0 g/m^3 [1]	16.4	10.5 g/m^3 (May 25/83)	1 302	14	25	20.5
pH	6.5-8.5	-	3.5-11.8	-	-	-	-
Phenols	0.17 g/m^3 [1]	0.3	28.6 g/m^3 (May 10/83) 3.8 g/m^3 (April 12/83)	no data 1 577	- 6	- 0.5	- 9
Phosphorus, Diss.(as P)	1.0 mg/L	2.1	28.3 mg/L (April 27/82)	1 319	37	3.1	56
Solids, Suspended	60 mg/L	123	2 240 mg/L (July 16/74) 155 mg/L (Dec. 21/82)	no data no data	- 172	- 185	- 258
, Total	1 500 mg/L	3 075	4 920 mg/L (Jan. 6/75)	no data	-	4 613	-
, Dissolved	-	-	1 704 mg/L (June 8/82) 1 530 mg/L (Jan. 25/83)	1 211 1 330	2 064 2 035	- -	3 096 3 053
Sulphides, Total	1.0 mg/L	2.1	1 326 mg/L (Jan. 6/75) 18.9 mg/L (Jan. 5/82)	no data 1 068	- 20	- 3	- 30
Chromium , Dissolved	-	-	0.22 mg/L (Dec. 3/80)	2 922	0.64	-	1.0
Copper , Dissolved	-	-	3.2 mg/L (Dec. 10/74) 0.4 mg/L (June 2/81)	no data 1 174	- 0.5	- -	- 0.75

TABLE 23 (Continued)

CHARACTERISTICS	PERMIT CONDITIONS		MAXIMUM ACTUAL LOADING			PROJECTED 1992 LOADINGS[3] kg/d	
	LEVEL OR CONCENTRATIONS	LOADING kg/d	MAXIMUM LEVEL OR CONCENTRATION RECORDED[2]	MAXIMUM DAILY LOADING: PRODUCTION OR ESTIMATED FLOW m^3/d	MAXIMUM DAILY LOADING: LOAD kg/d	ASSUMING PERMIT COMPLIANCE	ASSUMING CONTINUATION OF PRESENT TRENDS
Lead , Dissolved	-	-	0.6 mg/L (Dec. 22/74)	no data	-	-	-
			0.29 mg/L (Jan. 28/75)	930	0.3	-	0.45
			0.02 mg/L (May 5/81)	1 076	0.02	-	0.03
Nickel, Dissolved	-	-	0.16 mg/L (Jan. 1/74)	no data	-	-	-
			0.14 mg/L (Sept. 6/77)	1 930	0.27	-	0.4
Zinc , Dissolved	-	-	0.47 mg/L (Dec. 22/74)	no data	-	-	-
			0.24 mg/L (Sept. 5/78)	1 759	0.4	-	0.6

[1]grams per cubic metre of refinery throughput (production) including crude oil, LPG, and pipeline liquids
[2]if effluent flow data are not available for the day of maximum variable concentration, the next highest concentration, for which flow data exist, is given. More recent data (1980-1983) may also be given in addition to maximum levels recorded
[3]assuming 50 percent increase in process effluent discharge due to estimated increases in refinery production

TABLE 24

EFFLUENT DILUTION RATIOS FOR THE PETRO-CANADA REFINERY DISCHARGE UNDER POST-REGULATION LOW FLOW CONDITIONS

		October-April Mean Low Flow	August Mean Low Flow
Streamflow	m^3/s	832	1080
Process Effluent[1]			
i) at maximum discharge	(4 706 m^3/d)	15 300:1	20 000:1
ii) at permitted discharge	(2 050 m^3/d)	35 000:1	45 500:1
Cooling Water[2]			
i) at maximum discharge	(198 000 m^3/d	363:1	471:1
ii) at permitted discharge	(205 000 m^3/d)	350:1	455:1
Combined Discharge			
i) at maximum discharge	(202 706 m^3/d)	355:1	460:1
ii) at permitted discharge	(207 050 m^3/d)	347:1	450:1

[1]assumes no cooling water dilution and complete mixing of the effluent with the Peace River

[2]assumes no mixing with process effluent and complete mixing of the cooling water with the Peace River

TABLE 25

PREDICTED INCREASES IN PEACE RIVER RECEIVING WATER CONCENTRATIONS FOR PRESENT AND FUTURE PROJECTED WASTE LOADS (PROCESS EFFLUENT AND COOLING WATER) DURING MINIMUM FLOWS DOWNSTREAM FROM THE PETRO-CANADA REFINERY AT TAYLOR

Characteristics	PROCESS EFFLUENT				
	Maximum Present Waste Loads kg/d	CONCENTRATION INCREASE[1] AT MAXIMUM PRESENT LOADING µg/L		CONCENTRATION INCREASE AT FUTURE (1992) PROJECTED LOADING[4] µg/L	
		Oct.-April Low Flow[2] (Q_{10})	August Low Flow[3] (Q_{10})	Assuming Permit Compliance[5]	Assuming Continuation of Recent Trends[6]
BOD_5	740	10	8	1.0	15
Solids , Suspended	172	2	1.8	2.6	3.5
, Dissolved	2 035	28	22	-	42
Oil & Grease	14	0.2	0.15	0.31	0.3
Phenols	6	0.08	0.06	0.007	0.12
Sulphide, Total	20	0.3	0.2	0.04	0.41
, Un-ionized H_2S	-	0.06	0.04	0.008	0.08
Fluoride	190	2.6	2.0	0.43	3.9
Cyanide	6	0.08	0.06	0.004	0.12
Phosphorus (Ortho-)	37	0.5	0.4	0.04	0.8
Ammonia-Nitrogen	86	1.2	0.9	0.22	1.8
Chromium, Dissolved	0.64	0.008	0.007	-	0.01
Copper , Dissolved	0.5	0.007	0.005	-	0.01
Lead , Dissolved	0.3	0.004	0.003	-	0.006
Nickel , Dissolved	0.27	0.004	0.003	-	0.005
Zinc , Dissolved	0.4	0.006	0.004	-	0.008

Q^2 - 2-year return period, 7 day average low flow

[1] - assuming complete mixing of effluent and river water

- total October-April low flow = 2-year minimum flow (832 m³/2) + present permitted effluent flow (2 050 m³/d)

[3] - total August low flow = 2-year minimum flow (1 080 m³/s) + present permitted process effluent flow (2 050 m³/d)

- assuming a 50 percent increase in process effluent discharge over present rates (3 075 m³/d) and assuming an (Oct.-Apr.) low flow (832 m³/s)

[5] - permitted loading

- using maximum projected waste loads
- un-ionized H_2S is taken to be 20 percent of total sulphides, assuming pH = 7.8, temp. = 5° and no acid soluble metallic sulphides (Broderius and Smith, 1976)

TABLE 26

WATER QUALITY OF COOLING WATER INPUT (SITE 0400157) TO THE PETRO-CANADA REFINERY AT TAYLOR (MARCH, 1972-JUNE, 1976)

CHARACTERISTICS			PETRO CANADA REFINERY COOLING WATER Number of Values	Range of Values	Mean	CRITERIA EXCEEDED
BOD_5		mg/L	3	<10	<10	
Carbon	, Total	mg/L	2	<1-18	9.5	
Chromium	, Dissolved	µg/L	1	<5	-	
	, Total	µg/L	5	<5	-	
COD		mg/L	4	<10-17	12.5	
Conductivity		µS/cm	9	181-204	194	
Copper	, Dissolved	mg/L	1	0.010*	-	A 0.002
	, Total	mg/L	5	0.006-0.1*	0.050*	A 0.002
Cyanide	, Total	mg/L	5	<0.01	<0.01	
Iron	, Total	mg/L	1	3.5	-	
Lead	, Dissolved	µg/L	1	<3	-	
	, Total	µg/L	5	<1-35*	11	A 5
Mercury	, Total	µg/L	1	0.7*	-	A 0.1
Nickel	, Dissolved	mg/L	1	<0.01		
	, Total	mg/L	5	<0.01-0.02	0.014	
Nitrogen	, Ammonia	mg/L	6	<0.01-0.11	0.03	
	, Organic	mg/L	6	0.11-0.31	0.17	
Oil and Grease		mg/L	13	<0.1-2.9	1.3	
Oxygen	, Dissolved	mg/L	1	10	-	
pH			11	7.7-8.9	8.1	
Phenol	, Total	µg/L	3	<2-8*	4*	P 2, A 1
Phosphorus	, Total	mg/L	6	0.016-0.11*	0.05	P, R 0.1
Solids	, Total	mg/L	9	118-228	166	
	, Suspended	mg/L	14	1-102	36	
	, Total Inorganic	mg/L	2	148-202	175	
	, Susp. Inorganic	mg/L	1	19	-	
Sulphide	, Total	mg/L	5	<0.5-1*	0.6*	A0.002,P0.05
Temperature (field)		°C	2	2-8	5	
Zinc	, Dissolved	mg/L	1	0.02	-	
	, Total	mg/L	5	<0.005-0.04	0.02	

* in excess of working water quality criteria
A working water quality criteria for aquatic life
P working water quality criteria for public water supplies
R working water quality criteria for recreation and aesthetics

TABLE 27

WATER QUALITY OF THE PEACE RIVER DOWNSTREAM FROM FORT ST. JOHN
AT SITES 0400138-0400140 (NOVEMBER, 1971-OCTOBER, 1980)

Characteristics			0400138 STN. #1 NORTH SHORE			0400139 STN. #2 MIDSTREAM			0400140 STN. #3 SOUTH SHORE			SUMMATION OF TRANSECT VALUES 0400138 - 0400140			CRITERIA EXCEEDED
			Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	
Alkalinity	, Total	mg/L	92.4	80-109	8	91	80-108	7	88	80-102	8	90.4	80-109	23	
	, Phenolphthalein	mg/L	0.14	0-1	7	0	0	7	0	0	7	0.05	0-11	21	
BOD,		mg/L	<10	<10	2	-	-	-	-	-	-	<10	<10	2	
Calcium	, Total	mg/L	-	29.6	1	-	29.6	1	-	29.6	1	29.6	29.6	3	
	, Dissolved	mg/L	29	25-32	9	27.7	24.8-30.6	8	27	24.8-29.4	9	27.9	24.8-32	26	
Carbon	, Organic	mg/L	9.1	2-16	8	7.1	2-15	7	8.1	3-16	8	8.1	2-16	23	
	, Inorganic	mg/L	22	22	2	-	22	1	20	19-21	2	21.2	19-22	5	
Chloride	, Total	mg/L	-	0.3	1	-	-	-	-	0	1	0.15	0-0.3	2	
	, Dissolved	mg/L	0.6	<0.3-1.3	7	0.6	<0.3-1	7	0.6	<0.3-1.4	7	0.6	<0.3-1.4	21	
Chromium	, Total	µg/L	-	-	-	-	<5	1	-	-	-	-	<5	1	
	, Dissolved	µg/L	<5	<5	8	<5	<5	7	<5	<5	8	<5	<5	23	
COD		mg/L	-	12.5	1	-	8.3	1	-	9.3	1	10	8.3-12.5	3	
Coliforms	, Fecal	MPN/100 mL	17[1]*	<2-490*	9	13[1]*	<2-80*	8	7.7[1]	<2-22*	9	12[1]*	<2-490*	26	P 10-100, R 200-400
	, Total	MPN/100 mL	70[1]*	13*-3500*	10	42[1]*	8-1300*	9	35[1]*	5-490*	10	47[1]*	5-3500*	29	P 100-1000
Color		T.A.C.	12.5	<1-25*	4	7	<1-14	3	8.8	<1-13	4	9.7	<1-25*	11	P, R 15 (true)
Conductivity,	Specific	µS/cm	194	168-211	8	194	160-215	6	189	155-210	6	193	155-215	20	
Copper	, Total	µg/L	-	-	-	-	<10	1	-	-	-	-	<10	1	
	, Dissolved	µg/L	20*	<1-150*	8	2*	<1-7*	7	3.1*	<1-9*	8	8.6*	<1-150*	23	A 2.0
Hardness	, Total	mg/L	-	98	1	-	98	1	-	98	1	98	98	3	
	, Dissolved	mg/L	97	83-108	8	94	82-107	7	91	82-103	8	94	82-108	23	
Iron	, Total	mg/L	-	-	-	-	<0.02	1	-	-	-	-	<0.02	1	
	, Dissolved	mg/L	0.08	<0.04-0.18	7	0.06	<0.04-0.1	6	0.08	<0.04-0.14	7	0.074	<0.04-0.18	20	
Lead	, Total	µg/L	-	-	-	-	5	1	-	-	-	-	5	1	
	, Dissolved	µg/L	2	<1-5*	8	2.	<1-8*	7	5*	<1-29*	8	3.3	<1-29*	23	A 5.0
Magnesium	, Dissolved	mg/L	6.1	5-7	9	5.8	4.8-6.5	8	5.7	4.8-6.4	9	5.92	4.8-7	26	
Manganese	, Total	mg/L	-	-	-	-	0.02	1	-	-	-	-	0.02	1	
	, Dissolved	mg/L	0.012	<0.01-0.02	7	0.012	<0.01-0.02	6	0.012	<0.01-0.02	7	0.012	<0.01-0.02	20	
Mercury	, Total	µg/L	-	-	-	-	<20	1	-	-	-	-	<20	1	
	, Dissolved	µg/L	-	-	-	0.05	0.05-0.06	7	-	-	-	0.05	<0.05-0.06	7	
Nickel	, Total	µg/L	-	-	-	-	<10	1	-	-	-	-	<10	1	
Nitrogen	, Ammonia (Diss.)	µg/L	8.6	<5-13	3	10	<5-15	2	8.5	<5-12	2	9	<5-15	7	
	, Kjeldahl	mg/L	0.38	0.11-0.8	6	0.32	0.06-0.7	6	0.26	0.06-0.44	6	0.32	0.06-0.8	18	
	, Nitrate	mg/L	0.05	<0.02-0.08	9	0.05	<0.02-0.08	8	0.05	<0.02*-0.1	9	0.05	<0.02-0.1	26	
	, Nitrite/Nitrate	mg/L	0.05	0.03-0.08	6	0.05	0.03-0.08	5	0.05	0.03-0.1	6	0.05	0.03-0.1	17	
	, Nitrite	µg/L	<5	<5	6	<5	<5	5	<5	<5	6	<5	<5	17	
	, Organic	mg/L	0.22	0.2-0.3	3	0.17	0.13-0.21	2	0.22	0.11-0.3	3	0.21	0.11-0.3	8	
	, Total	mg/L	0.29	0.22-0.36	4	0.25	0.17-0.33	3	0.27	0.15-0.34	4	0.27	0.15-0.36	11	

TABLE 27 (Continued)

TABLE 27 (Continued)

Characteristics			0400138 STN. #1 NORTH SHORE			0400139 STN. #2 MIDSTREAM			0400140 STN. #3 SOUTH SHORE			SUMMATION OF TRANSECT VALUES 0400138 - 0400140			CRITERIA EXCEEDED
			Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	
Oxygen	, Dissolved	mg/L	11.2	9.8-13.2	6	11	9.5-13	6	11.2	9.8-13.5	6	11.1	9.5-13.5	18	
pH			8.1	7.8-8.5	9	8.0	7.9-8.1	5	8.0	8-8.2	6	8	7.3-8.5	20	
Phosphorus	, Total	mg/L	0.08	0.01-0.3*	10	0.05	<0.003-0.2*	9	0.05	0.005-0.2*	10	0.06	<0.003-0.3*	29	P, R 0.1
Potassium	, Dissolved	mg/L	0.66	0.5-0.7	7	0.6	0.4-0.8	7	0.6	0.4-0.7	7	0.5	0.4-0.8	21	
Silica	, Dissolved	mg/L	3.8	3.5-4.1	6	3.7	3.5-4.1	6	3.8	3.5-4.1	6	3.8	3.5-4.1	18	
Sodium	, Total	mg/L	-	1.1	1	-	1	1	-	1	1	1	1-1.1	3	
	, Dissolved	mg/L	1.6	1.1-2.6	7	1.4	1.1-2.1	7	1.4	1.1-2.3	7	1.5	1.1-2.6	21	
Solids	, Total	mg/L	-	162	1	-	148	1	-	160	1	157	148-162	3	
	, Dissolved	mg/L	116	104-124	3	114	108-120	2	107	100-114	3	112	100-124	8	
	, Suspended	mg/L	136	10.6-822	11	127	9.5-648	8	123	7.7-681	9	129	7.7-822	28	
	, Inorganic	mg/L	-	124	1	-	124	1	-	128	1	125	124-128	3	
Sulphate	, Total	mg/L	-	10	1	-	10	1	-	12.2	1	10.7	10-12.2	3	
	, Dissolved	mg/L	9.8	7.8-14	7	10.3	7.8-14.5	7	10.1	8.2-14.5	7	10.1	6.3-14.5	21	
Surfactants	, Total	mg/L	0.035	0-0.06	7	0.025	0-0.03	6	0.025	0-0.03	6		0-0.06	19	
	, Dissolved	mg/L	-	-	-	-	0.31*	1	-	0.03	1	0.17	0.03-0.31*	2	A 0.2
Tannin and Lignin	, Total	mg/L	0.8*	<0.1-3.5*	6	0.26	<0.1-0.4*	5	0.6*	<0.1-2.2*	6	0.57*	<0.1-3.5*	17	P 0.4
	, Dissolved	mg/L	-	0.2	1	0.3	0.2-0.4*	2	-	0.2	1	0.25	0.2-0.4*	4	P 0.4
Temperature		°C	8.1	4-13.2	8	8.1	4-11.5	7	7.3	3.5-11	8	7.8	3.5-13.2	23	
Turbidity		N.T.U.	49	1-170	10	40	2.3-170	9	34.7	1.8-130	10	41.3	1-170	29	
Zinc	, Total	µg/L	-	-	-	-	30	1	-	-	-	-	30	1	
	, Dissolved	µg/L	17	<5-60*	8	13.7	<5-60*	7	18.5	<5-90*	8	16.5	<5-90*	23	A 50

' geometric mean
* in excess of working water quality criteria
A working water quality criteria for aquatic life
P working water quality criteria for public water supplies
R working water quality criteria for recreation and aesthetics

TABLE 28

WATER QUALITY OF THE HALFWAY RIVER AT SITE 0400494 AND THE MOBERLY RIVER AT SITE 0400302

Characteristics			Halfway River at mouth (Site 0400494) July 30, 1975	Moberly River at Mouth (Site 0400302) April, 1973 - October, 1974			Criteria Exceeded
			Values	Mean	Range of Values	No. of Values	
Alkalinity	Total	mg/L	168	118	103-157	4	
Cadmium	Dissolved	µg/L	0.5*				A 0.2-4
Calcium	Total	mg/L	56.2	-	-	-	
	Dissolved	mg/L	53	33	27-46	6	
Carbon	Organic	mg/L	-	16	5-39	6	
	Inorganic	mg/L	-	25	24-27	3	
Chloride	Dissolved	mg/L	-	0.8	0.5-1.2	4	
Chromium	Total	µg/L	7	-	-	-	
	Dissolved	µg/L	-	<5	<5	6	
Coliforms	Total	MPN/100 mL	-	195[1]*	23*-920*	6	P 100-1000
	Fecal	MPN/100 mL	-	10.8[1]*	<2-23*	4	P 10-100
Color	Apparent	A.C.U.	5	48	10-160	6	
	True	T.C.U.	5	20*	3-34*	4	P,R 15; A, 2
Conductivity	Specific	uS/cm	354	237	213-280	3	
Copper	Total	µg/L	3*	-	-	-	A 2
	Dissolved	µg/L	-	2*	1-4*	6	A 2
Hardness	Dissolved	mg/L	188	121	99-165	6	
	Total	mg/L	1.5*	-	-	-	PO.3, AO.3-1.0
Iron	Dissolved	mg/L	-	0.12	0.04-0.3*	6	PO.3, AO.3-1.0
Lead	Total	µg/L	1	-	-	-	
	Dissolved	µg/L	-	<1	<1-1	6	
Magnesium	Total	mg/L	13.5	-	-	-	
	Dissolved	mg/L	13.5	9.4	7.6-12.6	6	
Manganese	Total	mg/L	0.02	-	-	-	
	Dissolved	mg/L	-	0.016	<0.01-0.02	6	
Mercury	Dissolved	µg/L	-	0.16*	0.05-0.6*	5	A 0.1
Molybdenum	Total	µg/L	2.1	-	-	-	
Nickel	Total	mg/L	<0.01	-	-	-	
Nitrogen	Ammonia	µg/L	7	9.5	9-10	2	
	Kjeldahl	mg/L	0.11	0.9	0.24-2.2	3	
	Nitrate	mg/L	<0.02	0.03	<0.02-0.08	5	
	Nitrite	µg/L	<5	<5	<5	4	
	Nitrite/Nitrate	mg/L	<0.02	0.04	<0.02-0.08	4	
	Organic	mg/L	0.1	0.5	0.23-1.0	3	
	Total	mg/L	0.11	0.5	0.24-1.0	3	
Oxygen	Dissolved	mg/L	-	10.3	8.8-12.3	3	
pH			8.3	-	7.2	1	
Phosphorus	Dissolved(ortho-)	µg/L	<3	-	-	-	
	Total	mg/L	0.06	0.33*	0.01-1.3*	6	P, R 0.1

TABLE 28 (Continued)

Potassium , Dissolved		-	1.3	0.7-2.7	4	
Silica , Dissolved	mg/L	-	4.4	3.6-5.6	3	
Sodium , Dissolved	mg/L	2.1	3.1	2.5-4.4	4	
Solids , Total	mg/L	256	-	-	-	
, Dissolved	mg/L	206	129	128-130	3	
, Suspended	mg/L	-	310	6.2-1249	6	
Sulphate , Dissolved	mg/L	-	13.1	8.7-16.9	4	
Surfactants, Dissolved	mg/L	-	<0.03	<0.03	3	
Tannin and Lignins	mg/L	-	0.6*	0.1-1.4*	3	P 0.4
Temperature (Field)		-	9.6	5-16.5*	5	P 15
Turbidity	NTU	27	140	8.2*-550	6	
Zinc , Dissolved	µg/L	-	14.5	<5-60*	6	A 50

* in excess of working water quality criteria
[1] geometric mean
A working water quality criteria for aquatic life
P working water quality criteria for public water supplies
R working water quality criteria for recreation and aesthetics

TABLE 29

DESCRIPTIONS OF WATER QUALITY SAMPLING SITES IN THE PEACE RIVER MAINSTEM SUB-BASIN

SITE NUMBER	SITE DESCRIPTION
UPSTREAM FROM FORT ST. JOHN	
0900191	W.A.C. Bennett Dam tailrace; 100 m downstream from convergence of the two channels
0900192	below W.A.C. Bennett Dam; from tailrace access road
0920074	150 m below W.A.C. Bennett Dam turbine outlet
0920075	directly downstream from Bennett Dam spillway outfall
0920076	0.4 km downstream from Bennett Dam spillway and turbine discharge
0900193	12 km downstream from W.A.C. Bennett Dam at end of King Guthing Coal Mine Road
0400496	Peace River at Alwin Holland Park (downstream from Peace Canyon Dam)
0920077	Peace River at Alwin Holland Park
0900194	Peace River at Alwin Holland Park approximately 23 km downstream from W.A.C. Bennett Dam
0400493	Peace River at the Rodeo grounds, approximately 23 km downstream from Hudson's Hope
0400495	Peace River immediately upstream from Halfway River confluence
0400134	Peace River 3.2 km upstream from the City of Fort St. John outfall; north bank station
0400135	Peace River 3.2 km upstream from the City of Fort St. John outfall, midstream station

TABLE 29 (Continued)

SITE NUMBER	SITE DESCRIPTION
0400136	Peace River 3.2 km upstream from the City of Fort St. John outfall, south bank station
0410016	Peace River at Old Fort, 0.5 km upstream from the City of Fort St. John outfall
0410017	Peace River at Old Fort, 200 m upstream from the City of Fort St. John outfall
FORT ST JOHN TO TAYLOR	
0400492	Peace River near Old Fort, 25 m downstream from the City of Fort St. John outfall
0400491	Peace River, approximately 200 m downstream from the City of Fort St. John outfall
0410018	Peace River, approximately 500 m downstream from the City of Fort St. John outfall
0400138	Peace River, 100 m upstream from the B.C. Railway Bridge, north bank station
0400139	Peace River, 100 m upstream from the B.C. Railway Bridge, mid-stream station
0400140	Peace River, 100 m upstream from the B.C. Railway Bridge, south bank station
0410053	Peace River, 100 m upstream from the Petro-Canada refinery outfall
0400157	Peace River, immediately upstream from the Petro-Canada refinery outfall, raw water input to the refinery cooling water supply line
0920080	Peace River at Taylor, upstream from highway bridge, downstream from Peace Island Provincial Park
07FA0003	Peace River upstream from Taylor at B.C. Railway Bridge

TABLE 29 (Continued)

SITE NUMBER	SITE DESCRIPTION
TAYLOR TO ALBERTA BORDER	
0410054	Peace River, 100 m downstream from Petro-Canada refinery outfall
0410055	Peace River, 400 m downstream from Petro-Canada refinery outfall
0400142	Peace River, 6.4 km downstream from Alaska Highway bridge, north bank station
0400143	Peace River, 6.4 km downstream from Alaska Highway bridge, mid-stream station
0400144	Peace River, 6.4 km downstream from Alaska Highway bridge, south bank station
0400146	Peace River, 10 km downstream from Alaska Highway bridge, north bank station
0400147	Peace River, 10 km downstream from Alaska Highway bridge, mid-stream station
0400148	Peace River, 10 km downstream from Alaska Highway bridge, south bank station
07FD0005	Peace River at Clayhurst ferry (above Alces River)
LOWER BEATTON RIVER	
0400145	Beatton River, above confluence with the Peace River
07FC0002	Beatton River, above confluence with the Peace River
PEACE RIVER IN ALBERTA	
07FD0002	Peace River at Highway 2, Dunvegan, Alberta

TABLE 30

WATER QUALITY OF THE PEACE RIVER BETWEEN THE W.A.C. BENNETT DAM AND HUDSON'S HOPE AT SITES 0900191-0900194 (July, 1972-August, 1974)

Characteristics	0800191 W.A.C Bennett Dam Tailrace			0900192 Below W.A.C. Bennett Dam			0900193 at King-Guthing Rd. (near Johnson Creek)			0900194 at Alwin Holland Park (near Hudson Hope)			Criteria Exceeded
	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Gases, Total Diss. %	101.2	100.7-101.6	2	110.4*	106.7-114.1*	2	-	108.1	1	104.3	102.2-109.3	8	A 110
, Dissolved N_2 %	101.6	101-102.1	2	-	109.5	1	-	109.4	1	105.3	99.9-109.9	8	
Oxygen, Dissolved mg/L	11.6	11.1-12	2	-	11.2	1	-	11.8	1	11.2	9.5-12.6	8	
Temperature °C	8.5	8-8.9	2	8	8	2	-	8.5	1	8.4	4-12	8	

* in excess of working water quality criteria
A working water quality criteria for aquatic life

TABLE 31

WATER QUALITY OF THE PEACE RIVER BETWEEN THE W.A.C. BENNETT DAM AND TAYLOR AT SITES 0920074-0920080 (May, 1974-July, 1978)

Characteristics	0920074 downstream from turbine			0920075 downstream from spillway			0920076 downstream from spillway			0920077 at Holland Park			0920080 at Taylor			Criteria Exceeded
	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Gases, Total Diss. %	102.9	101-106.9	4	101.9	101.2-102.6	2	101.3	99-102.5	6	103.6	102.8-105.9	7	101.6	100.7-102.6	3	
, Dissolved N_2 %	104.4	102.2-108.6	2	103.4	102.9-103.9	2	102.6	98.2-106	6	104.6	99.9-108.8	7	106.8	103.5-109	3	
Oxygen, Dissolved mg/L	10.1	10-10.2	2	10.5	10-11	2	10.9	10-12.4	6	11	9.5-12.5	7	9.2	8.3-10	3	
Temperature °C	9.5	7.2-11.2	4	9.6	7-12.2	2	7	3-11	6	8.4	4-12	7	8	5-11	3	

TABLE 32

WATER QUALITY OF THE PEACE RIVER BETWEEN THE PEACE CANYON DAM AND THE HALFWAY RIVER AT SITES 0400493, 0400495, 0400496 (MAY, 1974 - JULY, 1975)

Characteristics			0400496 at Alwin Holland Park Upstream from Hudson's Hope			0400493 at rodeo grounds downstream from Hudson's Hope			0400495 at Halfway River			Criteria Exceeded
			Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	Mean	Range of Values	Number of Values	
Alkalinity	, Total	mg/L	-	83.4	1	-	505	1	-	162	1	
Cadmium	, Total	mg/L	-	<0.5	1	-	-	-	-	<0.5	1	
Calcium	, Total	mg/L	-	26.5	1	-	-	-	-	55.7	1	
	, Dissolved	mg/L	-	26.5	1	-	-	-	-	51.5	1	
Chromium	, Total	µg/L	-	<5	1	-	-	-	-	7	1	
Color		T.A.C.	-	6	1	-	-	-	-	4	1	
Conductivity	, Specific	µS/cm	-	178	1	-	1360	1	-	347	1	
Copper	, Total	µg/L	-	<1	1	-	-	-	-	<1	1	
Gases	, Total Diss.	%	-	-	-	104.6	101.5-109	6	-	-	-	
	, Dissolved N_2	%	-	-	-	104.3	101.5-110.6	6	-	-	-	
Hardness	, Dissolved	mg/L		90.5	1	-	-	-	-	181	1	
Iron	, Total	mg/L		0.2	1	-	-	-	-	1.1*	1	P 0.3, A 0.3-1.0
Lead	, Total	µg/L	-	<1	1	-	-	-	-	<1	1	
Magnesium	, Total	mg/L	-	5.9	1	-	71	1	-	12.7	1	
	, Dissolved	mg/L	-	5.9	1	-	70.5	1	-	12.7	1	
Manganese	, Total	mg/L	-	<0.02	1	-	-	-	-	0.04	1	
Molybdenum	, Total	µg/L	-	0.8	1	-	-	-	-	2.1	1	
Nickel	, Total	mg/L	-	<0.01	1	-	-	-	-	<0.01	1	
Nitrogen	, Ammonia	µg/L		14	1	-	45	1	-	8	1	
	, Kjeldahl	mg/L	-	0.14	1	-	0.24	1	-	0.2	1	
	, Organic	mg/L	-	0.13	1	-	0.19	1	-	0.19	1	
	, Nitrate	mg/L	-	<0.02	1	-	<0.02	1	-	<0.02	1	
	, Nitrite	µg/L	-	<5	1	-	<5	1	-	<5	1	
	, Nitrite/Nitrate	µg/L	-	<0.02	1	-	<0.02	1	-	<0.02	1	
	, Total	mg/L	-	0.14	1	-	0.24	1	-	0.2	1	
Oxygen	, Dissolved	mg/L	-	-	-	11.0	10-12.4	6	-	-	-	
pH			-	8	1	-	7.8	1	-	8.1	1	
Phosphorus	, Total	mg/L	-	0.012	1	-	0.039	1	-	0.111*	1	P,R 0.1
	, Dissolved	µg/L	-	<3	1	-	<3	1	-	<3	1	
Sodium	, Dissolved	mg/L	-	1.4	1	-	70.8	1	-	3.3	1	
Solids	, Total	mg/L	-	104	1	-	954	1	-	252	1	
	, Dissolved	mg/L	-	98	1	-	910	1	-	206	1	
Temperature		°C	-	-	-	11.0	9-13.2	6	-	-	-	
Turbidity		NTU	-	2.6	1	-	7.3	1	-	22	1	

* in excess of working water quality criteria
A working water quality criteria for aquatic life
P working water quality criteria for public water supplies
R working water quality criteria for recreation and aesthetics
I working water quality criteria for irrigation

TABLE 33

WATER QUALITY OF THE PEACE RIVER NEAR DISCHARGE PE 389 (FORT ST. JOHN) AT SITES 0410016 - 0410018 (OCTOBER, 1980)

Characteristics	0410016 0.5 km upstream from discharge at Old Fort			0410017 200 m upstream from discharge			0410018 500 m downstream from discharge			Criteria Exceeded
	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Coliforms, Fecal MPN/100 mL	-	<20	1	-	200*	1	-	<200	1	P 10-100 R 200-400
, Total MPN/100 mL	-	<20	1	-	500*	1	-	<200	1	P 100-1000

* in excess of working water quality criteria
P working water quality criteria for public water supplies
R working water quality criteria for recreation and aesthetics

TABLE 34

WATER QUALITY OF THE PINE RIVER AT THE MOUTH

Characteristics		Site 0400141 Nov. 1971-Oct. 1974 Mean	Range of Values	No. of Values	Site 1177703 May, 1976-Sept. 1977 Mean	Range of Values	No. of Values	Site 07FB0001 Sept. 1975-Sept. 1976 Mean	Range of Values	No. of Values	Site 0410006	Criteria Exceeded
Acidity, Total	mg/L	-	-	-	0.8	<0.5-1.7	4	-	-	-	-	
Alkalinity, Total	mg/L	135	98.5-177	6	115	96.2-153	14	115	87-160	12	-	
, Phenolphthalein	mg/L	0.14	0-1	7	-	-	-	0	0	12	-	
Aluminum, Total	mg/L	-	-	-	0.21*	<0.01-1*	5	-	-	-	-	A 0.05-0.1
Arsenic, Total	µg/L	-	-	-	5.8	<5-10	6	-	-	-	-	
, Extractable	µg/L	-	-	-	-	-	-	2.6	0.2-9	7		
Barium, Extractable	mg/L	-	-	-	-	-	-	0.27	0.22-0.38	6	-	
Cadmium, Total	µg/L	-	-	-	<0.5	<0.5	7	-	-	-	-	
, Extractable	µg/L	-	-	-	-	-	-	0.3*	<0.2-0.7	8	-	A 0.2-4
Calcium, Total	mg/L	-	46	1	-	-	-	-	-	-	-	
, Dissolved	mg/L	37.5	27.4-53	9	32.5	27.2-44.8	17	38	22.5-57	12	-	
Carbon, Organic	mg/L	13.9	<1-48	9	4.7	1-10	9	6.9	<1-22	11	-	
, Inorganic	mg/L	24.3	23-25	3	-	-	-	29	20-40	11	-	
Chloride, Total	mg/L	-	0.8	1	-	-	-	-	-	-	-	
, Dissolved	mg/L	0.9	0.5-1.7	7	-	1	1	1.1	0.6-1.9	12	-	
Chromium, Total	µg/L	-	<5	1	8.4	<5-18	5	-	-	-	-	
, Dissolved	µg/L	<5	<5	9	-	-	-	-	-	-	-	
Cobalt, Extractable	µg/L	-	-	-	-	-	-	2	<1-6	8	-	
C.O.D.	mg/L	-	3.2	1								
Coliform, Fecal	MPN/100 mL	41[1]*	8-920*	10	<2[1]	<2-2	2	-	-	-	<200	P 10-100
, Total	MPN/100 mL	7.2[1]	<2-280*	9	8.4[1]	<2-14	2	-	-	-	<200	P 100-1000
Color, Apparent	A.C.U.	40	<5-225	10	20	5-40	16	25	5-80	12	-	
, True	T.C.U.	14.5	<1-39*	4	-	-	-	-	-	-	-	P,R 15
Conductivity, Specific	µS/cm	273	182-360	6	178	122-390	12	294	210-460	8	-	
Copper, Total	mg/L	-	0.01	1	0.009	<0.001-0.04	12	-	-	-	-	
, Dissolved	µg/L	1.8	<1-4*	9	1.7	<1-3*	6	-	-	-	-	A 2
, Extractable	µg/L	-	-	-	-	-	-	5*	1-13*	8	-	A 2
Fluoride, Dissolved	mg/L	-	-	-	<0.1	<0.1	5	0.09	0.06-0.16	12	-	
Hardness, Total	mg/L	-	164	1	-	-	-	126	98-180	12	-	
, Dissolved	mg/L	129	93-187	8	112.5	91-160	17	-	-	-	-	
Iron, Total	mg/L	-	<0.02	1	8.0	0.3-34*	12	-	-	-	-	P,A 0.3-1.0
, Dissolved	mg/L	0.08	<0.04-0.11	8	0.13	<0.1-0.3	6	-	-	-	-	
, Extractable	mg/L	-	-	-	-	-	-	0.8*	0.24-2.8*	12	-	P,A 0.3
Lead, Total	µg/L	-	4	1	4.2	1-12*	12	-	-	-	-	A 5-10-30
, Dissolved	µg/L	1.9	<1-5*	9	<1	<1	5	-	-	-	-	P 5-10-30
, Extractable	µg/L	-	-	-	-	-	-	2	<1-8*	8	-	P 5-10-30
Magnesium, Dissolved	mg/L	9.1	5.1-13.2	9	7.6	5.5-11.7	17	-	-	-	-	
Manganese, Total	mg/L	-	0.02	1	0.11*	<0.02-0.4*	11	-	-	-	-	P 0.05, A 0.1
, Dissolved	mg/L	0.015	<0.01-0.02	8	-	-	-	-	-	-	-	
, Extractable	mg/L	-	-	-	-	-	-	0.11*	<0.01-0.4*	8	-	P 0.05, A 0.1

TABLE 34 (Continued)

Mercury	, Dissolved	µg/L	0.07	0.05-0.17*	5	-	-	-	-	-	-	-	A 0.1
	, Extractable	µg/L	-	-	-	-	-	-	<0.05	<0.05	6	-	
Nickel	, Total		-	0.01	1	-	-	-	-	-	-	-	
	, Extractable		-	-	-	-	-	-	4	<1-10	8	-	
Nitrogen	, Ammonia	µg/L	8	6-12	3	16.2	5-30	10	19	8-34	12	-	
	, Kjeldahl	mg/L	0.6	0.02-1.8	6	0.4	0.1-2	14	-	-	-	-	
	, Nitrate	mg/L	0.006	<0.02-0.12	9	-	-	-	-	-	-	-	
	, Nitrite	µg/L	<5	<5	6	-	-	-	-	-	-	-	
	, Nitrite/nitrate	mg/L	0.06	<0.02-0.12	6	0.05	<0.02-0.16	14	0.05	0.006-0.1	12	-	
	, Organic	mg/L	0.32	0.01-0.68	3	0.21	0.08-0.5	9				-	
	, Total	mg/L	0.36	0.02-0.8	4	0.7	0.1-2.1	7	0.17	0.08-0.35	12	-	
Oxygen	, Dissolved	mg/L	10.4	8.7-12.4	6	10.8	7.9-12.8	10	-	-	-	-	
pH	, (Field)		8.1	7.8-8.4	2	8.2	8-8.3	15	7.9	7.5-8.3	11	-	
Phenol	, Total	µg/L	-	-	-	2.2*	<2-3*	5	<1	<1-1*	3	1	A 1; P 2
Phosphorus	, Diss. (ortho)	µg/L	-	-	-	3.9	<3-7	10	13	5-44	6	-	
	, Total	mg/L	0.18*	0.006-0.82*	10	0.19*	0.007-0.97*	16	0.3*	0.02-1.4*	12	-	P, R 0.1
Potassium	, Dissolved	mg/L	0.7	0.3-1	7	-	-	-	0.8	0.4-1.9	12	-	
Salinity	, Total	mg/L	-	-	-	16.7	0-100	6				-	
Silica	, Dissolved	mg/L	3.4	2.9-4.3	6	-	-	-	3.0	2.4-3.7	12		
Selenium	, Extractable		-	-	-	-	-	-	0.5	0.2-0.9	7	-	
Sodium	, Dissolved	mg/L	3.0	1.3-4.2	7	-	-	-	2.3	1.3-4.7	12	-	
	, Total	mg/L	-	3	1	-	-	-	-	-	-	-	
Solids	, Total	mg/L	-	280	1	357	148-1494	16	-	-	-	-	
	, Dissolved	mg/L	-	-	-	137	118-188	15	172	122-242	12	-	
	, Suspended	mg/L	613*	4.4-3721*	9	35.5	35-36	2	130	4.3-643	12	-	
	, Susp. Inorganic		-	-	-	-	-	-	121	3-613	12	-	
	, Diss. Inorganic		-	-	-	-	-	-	110	56-180	12	-	
	, Total Inorganic	mg/L	-	216	1	-	-	-	-	-	-	-	
Sulphate	, Total	mg/L	-	19.5	1	-	-	-	-	-	-	-	
	, Disolved	mg/L	16.1	8.5-21.2	7	12.5	6.4-21.5	6	15	8-27	12	-	
Surfactants	, Total	mg/L	0.03	<0.03-0.05	7	-	-	-	-	-	-	-	
Tannins and Lignins	, Total	mg/L	1.0*	<0.1-5*	6	0.6*	0.2-1.2*	7	0.18	0.14-0.24	4	-	P 0.4
	, Dissolved	mg/L	-	0.1	1	-	-	-	-	-	-	-	
Temperature		°C	9.0	4.5-16.5	8	10.6	5.6-18.2*	13	10	0.5-20*	11	-	P 15
Turbidity		N.T.U.	86.4	3.3-340	10	79.4	7-460	16	-	-	-	-	
		J.T.U.	-	-	-	-	-	-	54*	4.2-160*	12	-	R 25-50
Vanadium	, Total	µg/L	-	-	-	5	<1-14	4	-	-	-	-	
Zinc	, Dissolved	µg/L	11.4	<5-60*	9	-	-	-	-	-	-	-	A 50-300
	, Extractable	µg/L	-	-	-	-	-	-	6	<1-17	7	-	
	, Total	µg/L	-	40	1	20	<5-160*	12	-	-	-	-	A 50-300

* in excess of working water quality criteria
[1] geometric mean
A working water quality criteria for aquatic life
P working water quality criteria for public water supplies
R working water quality criteria for recreation and aesthetics

TABLE 35

WATER QUALITY OF THE PEACE RIVER MAINSTEM AS MEASURED BY ENVIRONMENT CANADA
INLAND WATERS DIRECTORATE (MAY 1975 - SEPTEMBER, 1976)

Characteristics			Site 07FA0003 Upstream from Taylor			Site 07FD0005 at Clayhurst Ferry (several points across river)			Criteria Exceeded
			Mean± Std. Deviation	Range of Values	Number of Values	Mean ± Std. Deviation	Range of Values	Number of Values	
Alkalinity	, Phenolphthalein	mg/L	0	0	12	-	-	-	
	, Total	mg/L	82±3.6	76-91.4	12	85±6.7	69.5-93.6	31	
Arsenic	, Extractable	µg/L	0.6±0.5	0.2-1.4	7	1.9±1.8	0.1-5.8	19	
Barium	, Extractable	mg/L	0.14±0.03	0.11-0.2	6	0.27±0.1	0.11-0.38	22	
Boron	, Dissolved	µg/L	-	-	-	4	4-5	9	
Cadmium	, Extractable	µg/L	<0.2	<0.2	7	0.2±0.1	<0.2-0.4*	25	A 0.2-4
Calcium	, Dissolved	mg/L	27±3.3	21-32	12	28±3.2	20-32	31	
Carbon	, Particulate	mg/L	0.38	0.21-0.55	2	-	-	-	
	, Total Organic	mg/L	4.5±1.6	2.7-8.1	12	5.9±5.9	2.1-19.5	13	
	, Total Inorganic	mg/L	20±1.3	17.5-21.8	11	20.4±1.3	18.9-23	13	
	, Diss. Organic	mg/L	-	4.6	1	21.2	20.5-21.8	2	
	, Diss. Inorganic	mg/L	-	24	1	8.0	8-8.1	2	
Cobalt	, Extractable	µg/L	<1	<1	3	1±1	<1-4	23	
Color	, Apparent		11±13	5-50*	11	31*±31	5-120*	31	A15-75; R15-100 (true color)
Conductance	, Specific	µs/cm	176±4	169-184	11	185±10	166-203	31	
Copper	, Extractable	µg/L	3*	3*	3	3*±2	<1-10*	25	A 2
Chloride	, Dissolved	mg/L	0.7±0.1	0.5-0.9	12	1.0±0.5	0.5-2.5	31	
Fluoride	, Dissolved	mg/L	0.08±0.03	0.04-0.13	12	0.07±0.03	0.05-0.18	31	
Hardness	, Total ($CaCO_3$)	mg/L	91±4.6	85-103	12	96±5.5	83-104	31	
Iron	, Dissolved	mg/L	-	0.015	1	-	0.009	1	
	, Extractable	mg/L	0.25±0.17	0.05-0.6*	12	1.1*±1.1	0.11-3.4*	31	A 0.3-1; P 0.3
Lead	, Extractable	µg/L	<1	<1	7	2±2	<1-7*	25	A 5-10
Manganese	, Extractable	mg/L	0.01±0.01	<0.01-0.04	8	0.1*±0.2	<0.01-1.2*	25	P0.05; A0.1-1
Mercury	, Extractable	µg/L	<0.05	<0.05	6	<0.05	<0.05	13	
Molybdenum	, Extractable	µg/L	-	-	-	0.5	<0.5-0.5	9	
Nickel	, Extractable	µg/L	2	1-3	3	3±2	<1-9	25	
Nitrogen	, Nitrate/nitrite	mg/L	0.038±0.01	0.015-0.54	12	0.06±0.4	0.008-0.24	30	
	, Diss. Ammonia-N	mg/L	-	-	-	0.02±0.01	0.001-0.04	15	
	, Total Diss.	mg/L	-	-	-	0.27±0.1	0.11-0.79	31	
pH			7.8±0.2	7.6-8.1	12	8.0±0.1	7.7-8.2	31	
Phenol		µg/L	<1	<1	3	0.6±0.3	0.4-<1.0	7	
Phosphorus	, Dissolved	µg/L	-	-	-	9±2	4-18	9	
	, Total	µg/L	7±2	4-10	6	146*±159	14-528*	30	P, R 100
Potassium	, Dissolved	mg/L	0.6±0.1	0.5-0.8	12	0.9±0.4	0.5-1.8	31	
Selenium	, Extractable	µg/L	0.8±1.7	0.1-4.7*	7	0.4±0.3	0.2-1.1*	15	A 1

TABLE 35 (Continued)

Characteristics			Site 07FA0003 Upstream from Taylor			Site 07FD0005 at Clayhurst Ferry (several point across river)			Criteria Exceeded
			Mean± Std. Deviation	Range of Values	Number of Values	Mean ± Std. Deviation	Range of Values	Number of Values	
Silica	, Reactive	mg/L	3.9±0.3	3.5-4.3	12	3.8±0.3	3.2-4.6	31	
Sodium	, Dissolved	mg/L	1.4±0.1	1.2-1.6	12	1.8±0.3	1.3-2.7	31	
Solids	, Suspended	mg/L	23.8±28	1.2-103	12	111±119	6-449	23	
	, Dissolved	mg/L	137±44	60-228	12	139±29	95-184	23	
	, Diss. Inorganic	mg/L	79±30	32-132	12	81±32	22-158	23	
	, Susp. Inorganic	mg/L	21.4±25	<1-94	12	102±111	4.3-418	23	
Strontium	, Extractable	mg/L	-	-	-	0.1±0.01	0.08-0.11	9	
Sulphate	, Dissolved	mg/L	11±1	9-13	12	12±2	9-17	31	
Tannin and Lignin		mg/L	0.25	0.23-0.26	4	0.2±0.02	0.19-0.24	10	
Temperature		°C	11.2±4.8	2.5-16.5	10	9.1±3.4	3-14.5	27	
Turbidity		J.T.U.	22.2±36	0.6-120	12	57±614	1.3-210	31	
Zinc	, Extractable	µg/L	2±2	1-5	7	8±6	<1-21	25	

* in excess of working water quality criteria
A working water quality criteria for aquatic life
P working water quality criteria for public water supplies
R working water quality criteria for recreation and aesthetics
I working water quality criteria for irrigation

TABLE 36

WATER QUALITY OF THE PEACE RIVER NEAR THE PETRO-CANADA REFINERY AT SITES 0410053-0410055 (APRIL, 1978)

Characteristics			0410053 100 m upstream from outfall		0410054 100 m downstream from outfall		0410055 400 m downstream from outfall	
			No. of Values	Range of Values	No. of Values	Range of Values	No. of Values	Range of Values
BOD_5		mg/L	1	<10	1	<10	1	<10
C.O.D.		mg/L	1	11.4	1	11.4	1	11.4
Conductivity		uS/cm	1	179	1	179	1	179
Copper	, Total	µg/L	1	5	1	4	1	7
Cyanide	, Total	mg/L	1	<0.01	1	<0.01	1	<0.01
Fluoride	, Total	mg/L	1	<0.1	1	<0.1	1	<0.1
Lead	, Total	µg/L	1	<1	2	2	1	2
Nickel	, Total	mg/L	1	<0.01	1	<0.01	1	0.03
Nitrogen	, Ammonia	µg/L	1	13	1	26	1	26
Oil and Grease		mg/L	-	-	1	24.4	1	1.0
pH			1	7.8	1	7.9	1	7.9
Phenol	, Total	µg/L	1	2	1	2	1	2
Phosphorus	, Dissolved	µg/L	1	9	1	4	1	4
Solids	, Total	mg/L	1	118	1	120	1	118
	, Suspended	mg/L	1	31	1	28	1	26
Sulphide	, Total	mg/L	1	<0.5	1	<0.5	1	<0.5
Zinc	, Total	µg/L	1	14	1	14	1	7

TABLE 37

COMPARISON OF GENERAL WATER QUALITY CHARACTERISTICS FOR PEACE RIVER FOR SITES UPSTREAM AND DOWNSTREAM FROM FORT ST. JOHN (PE 389)

Characteristics		Site 0400492 25 m downstream from PE 389	Site 0400491 200 m downstream from PE 389	Site 0410018 500 m downstream from PE 389	Sites 0400138-0400140 6 km downstream from PE 389	Site 07FA003 6 km downstream from PE 389
Alkalinity	mg/L	101-110 (2)*	100 (2)	-	80-109 (23)	76-91 (12)
pH		8.1-8.2 (3)	8.1-8.3 (3)	-	7.8-8.5 (20)	7.6-8.1 (12)
Dissolved Oxygen	mg/L	9.4-11.3 (8)	-	-	9.5-13.5 (18)	-
Hardness, Dissolved	mg/L	114-129 (2)	112 (1)	-	82-108 (23)	-
, Total		-	-	-	-	85-103 (12)
Color , True		5-6 (2)	6 (1)	-	<1-25 (11)	-
, Apparent		-	-	-	-	5-50 (11)
Turbidity	NTU	5.1-9.2 (2)	21 (1)	-	1-170 (29)	-
	JTU	-	-	-	-	0.6-120 (12)
Suspended Solids	mg/L	30 (1)	22-48 (2)	-	7.7-822 (28)	1.2-103 (12)
Tannin and Lignin, Total	mg/L	-	-	-	<0.1-3.5 (17)	0.23-0.26(4)
BOD_5	mg/L	<10 (1)	<10 (2)	-	<10 (2)	-

Characteristics		Site 0410053 11.5 km downstream from PE 389	Site 0400157 12 km downstream from PE 389	Summation of downstream values	Summation of values for upstream sites
Alkalinity	mg/L	-	-	76-110 (38)	80-505 (26)
pH		7.8 (1)	7.7-8.9 (11)	7.6-8.9 (50)	7.8-8.3 (22)
Dissolved Oxygen	mg/L	-	10 (1)	9.4-13.5 (27)	9.4-13.4 (24)
Hardness, Dissolved	mg/L	-	-	82-129 (26)	81-181 (28)
, Total		-	-	85-103 (12)	92-96 (3)
Color , True		-	-	<1-25 (14)	<1-23 (13)
, Apparent		-	-	5-50 (11)	-
Turbidity	NTU	-	-	1-170 (32)	1.3-160 (32)
	JTU	-	-	0.6-120 (12)	-
Suspended Solids	mg/L	31	1-102 (14)	1-822 (58)	7.2-770 (27)
Tannin and Lignin, Total	mg/L	-	-	<0.1-3.5 (21)	<0.1-2.2 (17)
BOD_5	mg/L	<10 (1)	<10 (3)	<10 (9)	-

*sample size given in brackets

TABLE 38

NUTRIENT AND METALS CONCENTRATIONS FOR PEACE RIVER SITES DOWNSTREAM FROM FORT ST. JOHN (PE 389)

Characteristics			Site 0400492 25 m downstream from PE 389	Site 0400491 200 m downstream from PE 389	Site 0410018 500 m downstream from PE 389	Sites 0400138-0400140 6 km downstream from PE 389	Site 07FA0003 6 km downstream from PE 389
METALS (µg/L)							
Cadmium	, Total		0.5* (1)	0.5* (1)	-	-	-
	, Dissolved		-	-	-	-	<0.2 (7)
Chromium	, Total		<5 (1)	7 (1)	-	<5 (1)	-
Copper	, Total		<1 (1)	2 (1)	-	<10 (1)	-
	, Dissolved		-	-	-	-	-
	, Extractable		-	-	-	-	3 (3)
Lead	, Total		<1 (1)	<1 (1)	-	5 (1)	-
	, Dissolved		-	-	-	<1-20* (23)	-
	, Extractable		-	-	-	-	<1 (7)
Mercury	, Total		-	-	-	<20 (1)	-
	, Dissolved		-	-	-	0.005-0.06 (2)	-
	, Extractable		-	-	-	-	<0.05 (6)
Nickel	, Total		<10 (1)	<10 (1)	-	<10 (1)	-
	, Dissolved		-	-	-	-	-
	, Extractable		-	-	-	-	1-3 (3)
Zinc	, Total		-	-	-	30 (1)	-
	, Dissolved		-	-	-	-	1-5 (7)
	, Extractable		-	-	-	<5-90* (23)	-
NUTRIENTS							
Phosphorus	, Total	mg/L	0.02-0.03 (2)	0.13* (1)	-	<0.003-0.3* (29)	0.004-0.01 (6)
	, Dissolved	mg/L	<0.003 (2)	0.024 (1)	-	-	-
Nitrogen	, Nitrate	mg/L	<0.02 (2)	-	-	<0.02-0.1 (26)	-
	, Nitrite/nitrate	mg/L	<0.02 (2)	-	-	0.03-0.1 (17)	0.015-0.54 (12)
	, Ammonia	mg/L	0.009-0.011 (2)	0.07 (1)	-	<0.005-0.015(7)	-

Sample size is given in brackets
* in excess of working water quality criteria
A working water quality criteria for aquatic life
P working water quality criteria for public water supplies

TABLE 38 (Continued)

Characteristics			Site 0410053 11.5 km downstream from PE 389		Site 0400157 12 km downstream from PE 389		Summation of Downstream Values		Summation of Values for Upstream Sites		Criteria Exceeded
METALS (µg/L)											
Cadmium	, Total		-		-		0.5*	(2)	<0.5	(2)	A 0.2 - 4
	, Dissolved		-		-		<0.2	(7)	-		
Chromium	, Total		-		<5	(5)	<5-7	(8)	<5-7	(5)	
Copper	, Total		5*	(1)	6*-100*	(5)	<1-100*	(9)	<10	(5)	A 2
	, Dissolved		-		10*	(1)	10*	(1)	<1-9*	(23)	A 2
	, Extractable		-		-		3*	(3)	-		A 2
Lead	, Total		<1	(1)	<1-35*	(5)	<1-35*	(9)	<1-4	(5)	A 5-10-30
	, Dissolved		-		<3	(1)	<1-29*	(24)	<1-15*	(23)	A 5-10-30
	, Extractable		-		-		<1	(7)	-		
Mercury	, Total		-		0.7*	(1)	<20	(2)	<20	(1)	A 0.1, P 1.0
	, Dissolved		-		-		0.05-0.06	(2)	0.14*		A 0.1, P. 1.0
	, Extractable		-		-		<0.05	(6)	-		
Nickel	, Total		<10	(1)	<10-20	(5)	<10-20	(9)	<10	(5)	A 25
	, Dissolved		-		<10	(1)	<10	(1)	-		
	, Extractable		-		-		1-3	(3)	-		
Zinc	, Total		14	(1)	<5-40	(5)	<5-40	(7)	30	(3)	
	, Dissolved		-		-		1-5	(7)	<5-100*	(23)	A 50
	, Extractable		-		20		<5-90*	(24)	-		A 50
NUTRIENTS											
Phosphorus	, Total	mg/L	-		0.016-0.11*	(6)	<0.003-0.3*	(44)	<0.003-0.3*	(30)	P, R 0.1
	, Dissolved	mg/L	0.009	(1)	-		<0.003-0.024	(4)	<0.003	(3)	
Nitrogen	, Nitrate	mg/L	-		-		<0.02-0.1	(28)	<0.02-0.12	(30)	
	, Nitrite/nitrate	mg/L	-		-		<0.02-0.54	(31)	<0.02-0.12	(21)	
	, Ammonia	mg/L	0.013	(1)	<0.01-0.11	(6)	<0.005-0.15	(11)	<0.005-0.045	(10)	

Sample size is given in brackets
* in excess of working water quality criteria
A working water quality criteria for aquatic life
P working water quality criteria for public water supplies

TABLE 39

WATER QUALITY OF THE PEACE RIVER NEAR THE PETRO-CANADA REFINERY OUTFALL, AS MEASURED BY CHEMICAL AND GEOLOGICAL LABORATORIES LTD., JUNE 11, 1980

Characteristics	SITES									
	W1			W2a	W2b	W3			W4	W5
	0m from shore	30m from shore	75 from shore			10m from shore	50m from shore	100 m from shore		
Field analysis										
pH	8.2	8.2	8.2	8.1	8.1	8.1	8.1	8.1	8.2	8.2
Oxygen, Dissolved	10.5	10.7	10.7	10.5	10.6	11.3	11.2	11.3	11.0	10.6
Laboratory analysis										
Suspended Solids	32	37	37	38	33	30	38	33	29	22
Nitrogen, Ammonia	0.15	0.15	0.10	0.10	0.20	0.25	0.10	0.10	0.10	0.25
Cyanide , Total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fluoride	0.13	0.12	0.10	0.13	-.14	0.10	0.11	0.11	0.12	<0.10
Sulphide	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Carbon , Total organic	18.2	6.2	5.1	13.3	6.8	9.5	4.6	27.2	5.2	16.8
Phenols	0.006	0.004	0.004	0.004	0.011	0.004	<0.002	<0.002	<0.002	<0.002
Oil and grease	<1	<1	<1	<1	<1	3	<1	<1	<1	<1

Results as mg/L, except pH.
W1 - control site, upstream from outfall (PE 1379).
W2a- 70m downstream from outfall.
W2b- 10m downstream from outfall (in line with discharge).
W3 - 400m downstream from outfall.
W4 - 1 km downstream from outfall.
W5 - 1.5 km downstream from outfall.
See Noton (1981) for site map.

TABLE 40

WATER QUALITY OF THE PEACE RIVER UPSTREAM FROM THE BEATTON RIVER ACROSS A TRANSECT AT SITES 0400142-0400144
(NOVEMBER, 1971-OCTOBER, 1974)

Characteristics			Site 0400142 (North Side)			Site 0400143 (Midstream)			Site 0400144 (South Side)			Summation of Transect Values			Criteria Exceeded
			Mean ± Std. Deviation	Range of Values	No. of Values	Mean ± Std. Deviation	Range of Values	No. of Values	Mean ± Std. Deviation	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Alkalinity	, Phenolphthalein	mg/L	-	-	-	-	-	-	0.14±0.4	0-1	7	0.14±0.4	0-1	7	
	, Total	mg/L	90±6	83-98	6	88.5±5	82.5±93	5	100±6.3	88-107	6	93.1	82.5-107	17	
Cadmium	, Dissolved	µg/L	-	<1*	1	-	-	-	-	<1*	1	-	<1	2	
Calcium	, Total	mg/L	28±1.4	26-30	7	28±1.6	25.5-29.6	6	31±3.2	28.1-37	7	29.1	25.5-37	20	A 0.2-4
	, Dissolved	mg/L	-	29.3	1	-	30.2	1	-	33.4	1	31.1	29.3-33.4	3	
Carbon	, Inorganic	mg/L	-	22	1	-	22	1	23.5±2.1	22-25	2	23	22-25	4	
	, Organic	mg/L	10.5±5	3-16	6	11.3±9	3-27	6	15.3±13	2-36	7	12.5	3-36	19	
Chloride	, Dissolved	mg/L	0.4+0.08	0.3-0.5	6	0.5±0.08	<0.3-0.5	6	0.6±0.2	0.3-0.9	6	0.5	<0.3-0.9	18	
	, Total	mg/L	-	-	-	-	-	-	-	0.5	1	-	0.5	1	
Chromium	, Dissolved	µg/L	<5	<5	5	<5	<5	5	<5	<5	5	<5	<5	15	
	, Total	µg/L	<5	<5	2	<5	<5	2	<5	<5	2	<5	<5	6	
C.O.D.		mg/L	-	7.4	1	-	9.3	1	-	9	1	8.6	7.4-9.3	3	
Coliforms	, Fecal	MPN/100 mL	48.2*¹	<2*-350*	5	18.1*¹	<2-220*	5	20.2*¹	<2-140*	5	26.0*¹	<2-350*	15	
	, Total	MPN/100 mL	107.3*¹	8-1400*	7	106*¹	22*-700*	7	109*¹	8-920*	7	107.5*¹	8-1400*	21	P 10-100, R 200-400
Color		T.A.C.	11.5±6	7-16*	2	-	8	1	10.5±3.5	8-13	2	10.4	7-16*	5	P 100-1000
Conductance	, Specific	µS/cm	202±20	170-225	5	199±22	165-225	5	224±28	195-270	5	208.3	165-270	15	P 15-75, R 15-100
Copper	, Dissolved	µg/L	1.4±5	<1-2*	5	1.4±0.5	<1-2*	5	1.6±0.5	<1-2*	5	1.5	*1-2*	15	
	, Total	µg/L	15*±7	10*-20*	2	7*±4	4*-10*	2	6.5*±5.0	3*-10*	2	9.5*	3*-20*	6	A 2.0
Hardness	, Dissolved	mg/L	96.3±6.7	87-104	6	95±6.5	86-103	5	105±14	93-130	6	98.9	86-130	17	A 2.0
	, Total	mg/L	-	99	1	-	100	1	-	113	1	104	99-113	3	
Iron	, Dissolved	mg/L	0.05±0.05	0.04-0.17	5	0.09±0.04	0.04-0.14	5	0.1±0.07	0.04-0.20	5	0.09	0.04-0.20	15	
	, Total	mg/L	-	<0.02	1	-	<0.02	1	-	<0.02	1	<0.02	<0.02	3	
Lead	, Dissolved	µg/L	1.8±1	<1-3	5	1.8±1	<1-3	5	-	-	-	1.3	<1-3	10	
	, Total	µg/L	8*±2.3	6*-10*	2	6*±1.4	5*-7*	5	-	-	-	6.6*	5*-10*	7	
Magnesium	, Dissolved	mg/L	6.0±0.5	5.4-6.7	6	5.3±0.5	5.4-6.5	5	6.8±1.4	5-9.2	6	6.2	5-9.2	17	A 5-10
	, Total	mg/L	-	7.9	1	-	6.2	1	-	6.9	1	7.0	6.2-7.9	3	
Manganese	, Dissolved	mg/L	0.01±0.004	<0.01-0.02	5	0.01±0.004	<0.01-0.02	5	0.01±0.005	<0.01-0.02	5	0.01	<0.01-0.02	15	
	, Total	mg/L	-	0.03	1	-	0.01	1	-	0.01	1	0.016	0.01-0.03	3	
Mercury	, Dissolved	µg/L	-	-	-	0.1*±0.1	0.05-0.4*	6	-	-	-	0.1	0.05-0.4*	6	
	, Total	µg/L	-	-	-	-	<20.0	1	-	-	-	-	<20.0	1	A 0.1-0.2
Nickel	, Total	mg/L	-	<0.01	1	-	<0.01	1	-	<0.01	1	<0.01	<0.01	3	
Nitrogen	, Ammonia Diss.	mg/L		<0.005	1	-	<0.005	1	0.009±0.003	0.006-0.011	2	0.02	0.005-0.011	4	
	, Ammonia Total	mg/L	-	0.01	1	-	-	-	-	-	-	-	0.01	1	
	, Kjeldahl	mg/L	0.3±0.2	0.09-0.65	6	0.5±0.5	0.07-1.6	6	0.9±1	0.07-2.8	6	0.56	0.07-2.8	18	
	, Organic	mg/L	0.3±0.7	0.23-0.34	2	-	0.26	1	0.4±0.13	0.3-0.5	2	0.33	0.26-0.5	5	
	, Nitrite/Nitrate	mg/L	0.06±0.03	0.03-0.11	5	0.06±0.02	0.03-0.09	5	0.06±0.04	0.03-0.11	5	0.06	0.03-0.11	15	
	, Nitrite	mg/L	<0.005	<0.005	6	<0.005	<0.005	4	<0.005	<0.005	6	<0.005	<0.005	16	

TABLE 40 (Continued)

WATER QUALITY OF THE PEACE RIVER UPSTREAM FROM THE BEATTON RIVER ACROSS A TRANSECT AT SITES 0400142-0400144 (NOVEMBER, 1971-OCTOBER, 1974) Continued

Characteristics		Site 0400142 (North Side)			Site 0400143 (Midstream)			Site 0400144 (South Side)			Summation of Transect Values			Criteria Exceeded
		Mean ± Std. Deviation	Range of Values	No. of Values	Mean ± Std. Deviation	Range of Values	No. of Values	Mean ± Std. Deviation	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
, Nitrate	mg/L	0.05±0.03	<0.02-0.11	8	0.005±0.02	<0.03-0.09	7	0.06±0.04	<0.02-0.13	8	0.053	<0.02-0.13	23	
Oxygen , Dissolved	mg/L	11.4	8.9-12.8	5	11.5±1.5	9.1-12.8	5	11.3±1.6	9.2-13	5	11.4	8.9-13	15	
pH		7.9±0.04	7.9-8	5	7.9±0.05	7.9-8.0	4	8±0.1	7.9-8.2	5	7.9	7.9-8.2	14	
Phosphorus , Total	mg/L	0.1*±0.1	0.005-0.32*	3	0.06±0.1*	0.004-0.35*	7	0.2*±0.3	<0.003-0.9*	8	0.12*	<0.003-0.9*	23	P, R 0.1
Potassium , Dissolved	mg/L	0.75±0.3	0.5-1.1	5	0.65±0.2	0.5-0.9	6	0.7±0.3	0.5-1.2	6	0.70	0.5-1.2	18	
Silica , Dissolved	mg/L	3.8±0.4	3.2-4.2	5	3.7±0.4	3.2-4.1	5	3.5±0.5	2.9-4.1	5	2.7	2.9-4.2	15	
Sodium , Dissolved	mg/L	1.4±0.2	1.2-1.7	6	1.3±0.2	1.1-1.6	6	1.8±0.7	1.1-3	6	1.5	1.1-3	18	
, Total	mg/L	-	1.1	1	-	1.4	1	-	1.5	1	1.33	1.1-1.5	3	
Solids , Dissolved	mg/L	114±2.8	112-116	2	-	110	1	118±2.8	116-120	2	115	110-120	5	
, Inorganic, Total	mg/L	-	666	1	-	244	1	-	246	1	385	244-666	3	
, Suspended	mg/L	174.5*±265	8.3-713*	7	457*±927	9.2-2329*	6	555*±814	8.7-2159*	7	415.6	8.7-2329	20	
, Total	mg/L	-	744	1	-	296	1	-	266	1	435.3	266-744	3	
Sulphate , Dissolved	mg/L	11±1.7	9.2-13	6	10.3±1.8	8.7-13	6	12.4±4.2	8.2-19	6	11.2	8.2-19	18	
, Total	mg/L	-	12	1	-	11.5	1	-	13	1	12.1	11.5-13	3	
Surfactants, Dissolved	mg/L	-	<0.03	1	-	<0.03	1	-	0.13	1	0.06	<0.03-0.13	3	
, Total	mg/L	0.02±0.01	0-0.03	5	0.02±0.01	0-0.03	5	0.02±0.01	0-0.03	5	0.02	0-0.03	15	
Tannins and Lignins, Diss.	mg/L	0.23±0.006	0.2-0.3	3	-	0.2	1	-	0.2	1	0.22	0.2-0.3	5	
, Total	mg/L	0.33±0.15	0.1-0.3	3	0.9±0.8	0.2-2.0*	5	2.5*±4.2	0.2-10*	5	1.4*	0.2-10*	13	P 0.4
Temperature	°C	7.1±3.7	3-12	7	7.2±3.5	3-11.2	6	7.4±3.6	4-12.5	7	7.2	3-12.5	20	
Turbidity	N.T.U.	71.3*±72	2.5-160*	8	159*±309	1.9-850*	7	205*±307	1.9-850*	3	144.5	1.9-650	23	
Zinc , Dissolved	µg/L	<5	<5	5	<5	<5	5	14±20	<5-50	5	8	<5-50*	15	A 50
, Total	µg/L	50*±28	30-70*	2	17.5±17	<5-30	2	12.5±10	<5-20	2	26.7	<5-70*	6	A 50

** geometric mean
* in excess of water quality criteria
A working water quality criteria for aquatic life
P working water quality criteria for public water supplies
R working water quality criteria for recreation and aesthetics

TABLE 41

WATER QUALITY OF THE PEACE RIVER NEAR THE PETRO-CANADA REFINERY OUTFALL, AS MEASURED BY CHEMICAL AND GEOLOGICAL LABORATORIES LTD., SEPTEMBER 11, 1980

Characteristics	SITES W1	W2a	W2b	W2c	W3	W4	W5
Field analysis							
pH	8.2	8.2	8.1	8.3	8.4	8.2	8.2
Oxygen, Dissolved	10.3	10.9	9.4	10.3	10.1	10.3	10.6
Laboratory analysis							
Suspended solids	10	10	6	6	6	8	8
Nitrogen, Ammonia	0.05	<0.05	0.12	<0.05	<0.05	<0.05	<0.05
,Total Kjeldahl	<0.1	<0.10	0.13	<0.1	<0.1	<0.1	<0.1
, NO_2+NO_3	0.02	0.02	0.03	0.02	0.02	0.02	0.02
Phosphorus, Total	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016
, Dissolved	<0.016	<0.016	<0.016	<0.016	<0.016	<0.01	<0.016
Cyanide, Total	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulphide	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Carbon, Total organic	9.3	5.4	7.8	2.0	9.1	5.6	5.0
Phenols	<0.002	<0.003	0.027	<0.002	<0.002	<0.002	<0.002
Oil and grease	3	4	9	2	6	3	3

Results as mg/L, except pH
W1 - control site, upstream from outfall (PE 1379)
W2a - 70 m downstream from outfall
W2b - 10 m downstream from outfall in end-of-pipe turbulence
W2c - 10 m downstream from outfall (inshore)
W3 - 400 m downstream from outfall
W4 - 1 km downstream from outfall
W5 - 1.5 km downstream from outfall
see Noton (1981) for site map

TABLE 42

COMPARISON OF EFFLUENT LOADING AND DILUTION FOR THE PETRO-CANADA REFINERY DICHARGE ON THREE DAYS OF RECEIVING WATER MONITORING

Water Quality Monitor	Date of Monitoring	Peace River Flow m^3/s	Process Effluent Flow m^3/d	Cooling Water Flow m^3/d	Dilution Ratio	Size of Overall Effluent Loading
Ministry of Environment (0410053 - 0410055)	April 12/78	1 266	1 787	178 570	606:1	lower than average
Chemical & Geological Laboratories Ltd.	June 11/80	946	1 534	197 950	410:1	low to average
	Sept. 11/80	1 310	1 243	141 740	792:1	average
Worst-Case Values		832 (Oct.-Apr. low flow)	4 706 (maximum recorded)	205 000 (maximum permitted)	343:1 (Oct-Apr)	

TABLE 43

WATER TEMPERATURES OF THE PEACE RIVER NEAR THE PETRO-CANADA REFINERY RECORDED BY CHEMICAL & GEOLOGICAL LABORATORIES LTD., 1980

	Temperature °C						
Distance from N. shore	At Shore	15 m	30 m	50 m	75 m	100 m	Channel centre
May 8							
W1							
W2a							
W3			8				
W4	7.5						
W5	7						
June 11							
W1	9			9	9		
W2a			10				
W2b*	14						
W3	10			9.5	9		
W4	10		9.5	9		8.5	8
W5		10					
August 8							
W1	14	14		14			
W2a	15		15				
W2b*	19						
W3				15			14
September 11							
W1	12						
W2a			13.5	12.5			
W2b*	18.5						
W2c	14						
W3				13		13	
W4		13.5	13.5	13			
W5	13.5		13.5	13	12.5		12.5

* Located in discharge turbulence
W1 - control site, upstream from outfall (PE 1379)
W2a - 70 m downstream from outfall
W2b - 10 m downstream from outfall in end-of-pipe turbulence
W2c - 10 m downstream from outfall (inshore)
W3 - 400 m downstream from outfall
W4 - 1 km downstream from outfall
W5 - 1.5 km downstream from outfall
see Noton (1981) for site map

TABLE 44

MEAN NUMBERS AND % COMPOSITION OF BENTHIC ORGANISMS IN HESS SAMPLES FROM THE PEACE RIVER, B.C., JUNE 11 - 12, 1980

Taxon	Station H1 Mean	H1 % of Total	H2 Mean	H2 % of Total	H3 Mean	H3 % of Total	H4 Mean	H4 % of Total
Nemata	37.7	7.1	66.7	3.6	148.7	22.9	386.7	55.1
Hydrozoa	13.3	2.5	5.3	0.3	17.3	2.7	3.3	0.5
Oligochaeta	171.0	32.0	1606.7	85.9	370.7	57.1	176.0	25.1
Hydracarina	11.0	2.1	6.0	0.3			4.7	
Insecta								
Ephemeroptera								
Baetis	0.7	0.1						
Rhithrogena			0.7	0.04				
Ephemerella			1.3	0.1				
E. (Ephemerella) inermis	24.0	4.5	14.7	0.8	2.0	0.3	0.7	0.1
Plecoptera	2.0	0.4						
Chloroperlinae	3.3	0.6					1.3	0.2
Perlodidae	6.0	1.1						
Isoperla ebria	0.7	0.1						
I. fulva	0.3	0.1					1.3	0.2
Cultis	0.3	0.1						
Trichoptera	0.3	0.1						
Diptera								
Chironomidae (unident.)	28.0	5.2	22.7	1.2	6.0	0.9	5.3	0.8
Chironomini	47.3	8.9	15.3	0.8	18.7	2.9	46.7	6.7
Orthocladiinae	171.0	32.1	123.3	6.6	69.3	10.7	70.0	10.0
Tanypodinae	7.7	1.4	8.0	0.4	4.7	0.7	0.7	0.1
Empididae	5.0	0.9					2.7	0.4
Tipulidae	0.3	0.1	0.7	0.04				
Rhabdomastix sp.					8.0	1.2	2.0	0.3
Ceratopogonidae					4.0	0.6		
Total	532.6		1871.4		649.4		701.4	
Mean/m²	5326		18714		6494		7014	
Total taxa	22		12		10		13	
Mean diversity	2.59		0.97		1.82		1.76	

Three samples collected per site. Area of 1 sample = 0.1 m^2
H1 - control site, 1.25 km upstream from outfall
H2 - 0.4 km downstream from outfall
H3 - 0.9 km downstream from outfall
H4 - 1.4 km downstream from outfall
see Noton (1981) for site map

TABLE 45

MEAN NUMBERS AND % COMPOSITION OF BENTHIC ORGANISMS ON ARTIFICIAL SUBSTRATES FROM THE PEACE RIVER, B.C. JUNE 11, 1980

Taxon	Station A1 Mean	A1 % of Total	A2 Mean	A2 % of Total	A3 Mean	A3 % of Total	A4 Mean	A4 % of Total
Oligochaeta	4.5	1.1	10.7	5.1	29.3	12.3	50.0	22.8
Insecta								
Ephemeroptera	5.0	1.2						
Baetis			0.3	0.1	0.3	0.1		
Rhithrogena	11.0	2.7	2.0	1.0	7.0	2.9	10.0	4.6
Ephemerella	6.0	1.5			0.3	0.1		
E. (*Ephemerella*) *inermis*	89.5	22.1	166.7	79.0	153.7	64.3	115.3	52.6
E. (*Ephemerella*) *infrequens*	0.5	0.1			1.3	0.5	0.3	0.1
E. (*Drunella*) *flavilinea*	9.5	2.4	9.0	4.3	15.3	6.4	7.7	3.5
E. (*Drunella*) *spinifera*	4.5	1.1	0.7	0.3	1.0	0.4	2.7	1.2
E. (*Claudatella*) *edmundsi*	4.0	1.0	3.0	1.4	4.3	1.8	6.7	3.1
Plecoptera	2.0	0.5						
Chloroperlinae			0.3	0.1				
Pteronarcella badia	23.5	5.8	2.3	1.1	1.7	0.7		
Cultia	0.5	0.1						
Isoperla	1.0	0.3						
I. fulva	1.5	0.4					0.3	0.1
Trichoptera								
Brachycentris	0.5	0.1						
Arctopsyche	2.5	0.6			0.3	0.1	0.3	0.1
Hydropsyche	27.5	6.8	0.7	0.3	0.3	0.1	2.0	0.9
Diptera								
Chironomidae (unident.)	2.5	0.6	0.7	0.3	0.3	0.1		
Chironomini	2.0	0.5					1.0	0.5
Orthocladiinae	61.0	15.1	11.0	5.2	21.0	8.8	13.3	6.1
Diamesinae					0.3	0.1	0.7	0.3
Tanypodinae	2.0	0.5	0.3	0.1	0.3	0.1		
Simulidae	139.0	34.3	3.3	1.6	2.0	0.8	1.0	0.5
Empididae	0.5	0.1					7.7	3.5
Dolichopodidae	0.5	0.1						
Athericidae - *Atherix*	3.0				0.3	0.1	0.3	0.1
Total	404.0		211.0		239.0		219.3	
Mean/m²	20.5		10.3		11.3		11.5	
Total Taxa	25		14		18		16	
Mean diversity	2.86		1.41		1.86		2.13	
Number of baskets	2		3		3		3	

A1 - control site, 100 m upstream from outfall
A2 - 70 m downstream from outfall
A3 - 400 m downstream from outfall
A4 - 1 km downstream from outfall
see Noton (1981) for site map

TABLE 46

MEAN NUMBERS AND % COMPOSITION OF BENTHIC ORGANISMS IN HESS SAMPLES FROM THE PEACE RIVER, SEPTEMBER 11- 12, 1980

Taxon	H1 Mean	H1 % of Total	H2 Mean	H2 % of Total	H3 Mean	H3 % of Total	H4 Mean	H4 % of Total
Nemata			0.7	1.6	1.7	3.1	2.0	4.6
Hydrozoa	9.3	11.3	3.3	7.8				
Oligochaeta	39.3	47.6	36.0	84.4	48.7	89.2	37.3	86.2
Hydracarina					0.3	0.6		
Insecta								
Ephemeroptera								
Heptageniidae	0.7	0.9						
Heptagenia			0.3	0.8				
Rhithrogena	0.3	0.4						
Trichoptera								
Arctopsyche	0.3	0.4						
Diptera								
Chironomidae (unident.)	7.3	8.9	0.7	1.6			1.7	3.8
Orthocladiinae	24.3	29.5	0.7	1.6	1.3	2.4		
Tanypodinae	0.7	0.9			0.3	0.6		
Dolichopodidae			0.7	1.6	1.3	2.4	2.0	4.6
Empididae							0.3	0.8
Gastropoda								
Lymnaea	0.3	0.4	0.3	0.8	1.0	1.8		
Total	82.5		42.7		54.7		43.3	
Mean/m²	825		427		547		433	
Total taxa	9		8		7		5	
Diversity (pooled)	1.90		0.98		0.77		0.83	

Three samples collected per site. Area of 1 sample = 0.1 m^2
H1 - control site, 1.25 km upstream from outfall
H2 - 0.4 km downstream from outfall
H3 - 0.9 km downstream from outfall
H4 - 1.4 km downstream from outfall
see Noton (1981) for site map

TABLE 47

MEAN NUMBERS AND % COMPOSITION OF BENTHIC ORGANISMS COLLECTED FROM ARTIFICIAL SUBSTRATES FROM THE PEACE RIVER, SEPTEMBER 11 - 12, 1980

Taxon	Station A1 Mean	A1 % of Total	A2 Mean	A2 % of Total	A3 Mean	A3 % of Total
Oligochaeta			18.3	53.4	22.3	63.2
Insecta						
Epemeroptera						
Rhithrogena	2.3	0.8				
Heptagenia	0.7	0.3				
Ephemerella	20.0	7.1			0.7	2.0
E. (Ephemerella) inermis	54.3	19.3			0.3	0.9
E. (Drunella) spinifera	1.7	0.6				
E. (Claudatella) edmundsi	0.3	0.1				
Plecoptera						
Pteronarcella badia	1.0	0.4				
Pteronarcys californica	0.7	0.3				
Perlodidae	47.7	16.9			0.3	0.9
Isoperla	4.7	1.7				
Isogenoides	3.0	1.1				
Taeniopteryx	0.3	0.1				
Trichoptera						
Brachycentris	3.7	1.3				
Hydropsychidae	30.0	10.6				
Arctopsyche	22.3	7.9			0.3	0.9
Hydropsyche	50.0	17.7				
Diptera						
Chironomidae						
Tanytarsini	1.3	0.5				
Orthocladiinae	31.0	11.0	7.0	20.4	8.7	24.7
Tanypodinae	5.7	2.0	9.0	26.2	2.7	7.7
Dixidae	1.3	0.5				
Total	282.0		34.3		35.3	
Total Taxa	20		3		7	
Diversity (pooled)	3.22		1.46		1.50	
Number of baskets	3		3		3	

A1 - control site, 100 m upstream from outfall
A2 - 70 m downstream from outfall
A3 - 400 m downstream from outfall
see Noton (1981) for site map

TABLE 48
WATER QUALITY OF THE KISKATINAW RIVER AT SITES 0400149, 0400544, and 07FD0007 (1972-1976)

Characteristics		Site 0400149 above confluence with Peace R. April, 1972-October, 1974			Site 0400544 at Alaska Hwy. Bridge March-November, 1976			Site 07FD0007 at Alaska Hwy. Bridge March-September, 1976			Criteria Exceeded
		Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Alkalinity, Total	mg/L	218	183-236	4	234	207-249	3	171	103-223	7	
, Phenolphthalein	mg/L	3.9	0-13.5	7	4.9	2.7-7	2	0.7	0-5	7	
Aluminum , Total	µg/L	-	-	-	2.5*	<0.01-8.7*	5	-	-	-	A 0.05-0.1
Arsenic , Total	µg/L	-	-	-	6.2	5-11	6	-	-	-	
, Extractable	µg/L	-	-	-	-	-	-	2.6	0.3-10	6	
Barium , Extractable	mg/L	-	-	-	-	-	-	0.36	0.3-0.4	5	
Cadmium , Total	µg/L	-	-	-	0.7*	0.5*-1.1*	5	-	-	-	A 0.2-4
, Extractable	µg/L	-	-	-	-	-	-	0.5	0.2-1.0	7	
Calcium , Dissolved	mg/L	45	28-66	8	51.2	34.6-73.2	7	55	33.5-70.3	7	
Carbon , Organic	mg/L	37	9-84	8	16.3	<1-41	6	17.7	8.2-29.4	7	
, Inorganic	mg/L	44	33-58	3	54	40-69	4	40.6	25-52	7	
, Particulate	mg/L	-	-	-	-	-	-	0.03	0.005-0.11	5	
Chloride , Dissolved		0.9	0.8-1.1	6	-	1.7	1	1.5	0.8-2.2	7	
Chromium , Total	µg/L	-	<5	1	17	<5-50*	6	-	-	-	A 20
, Dissolved	µg/L	5.7	<5-10	7	-	-	-	-	-	-	
Cobalt , Extractable	µg/L	-	-	-	-	-	-	2	<1-6	7	
Coliforms , Fecal	MPN/100 mL	29[1]*	6-220*	6	-	-	-	-	-	-	P 10-100
, Total	MPN/100 mL	240[1]*	7-5400*	7	-	-	-	-	-	-	P 100-1000
Color , Apparent	(Rel.)	85	10-300	7	45	40-50	2	74	35-160	7	
, True	T.A.C.	40*	18*-57*	3	35*	11-78*	6	-	-	-	P,R 15
Conductance, Total	µS/cm	333	220-480	6	351	244-510	7	335	204-456	7	
Copper , Total	mg/L	-	0.1	1	0.02	0.002-0.07	6	-	-	-	
, Dissolved	µg/L	5*	1-10*	7	-	-	-	-	-	-	A 2
, Extractable	µg/L	-	-	-	-	-	-	7*	2*-20*	7	A 2
Fluoride , Total		-	-	-	-	-	-	-	-	-	
, Dissolved	mg/L	-	-	-	0.1	<0.1-0.11	5	0.12	0.008-0.17	7	
Hardness , Total		-	-	-	-	-	-	179	108-233	7	
, Dissolved	mg/L	172	102-235*	7	80	122-260*	7	-	-	-	P 200 (poor)
Iron , Total	mg/L	-	-	-	10.2*	1.4*-40.3*	6	-	-	-	PO.3;AO.3-1.0
, Dissolved	mg/L	0.16	0.04-0.35*	7	-	-	-	-	0.033	1	PO.3;AO.3-1.0
, Extractable	mg/L	-	-	-	-	-	-	1.5*	0.36*-4.5*	7	PO.3-AO.3-1.0
Lead , Total	µg/L	-	100*	1	5	1-17*	6	-	-	-	A 5-10
, Dissolved	µg/L	1.6	<1-3	7	-	-	-	-	-	-	
, Extractable	µg/L	-	-	-	-	-	-	3	<1-10*	7	A 5-10
Magnesium , Total	mg/L	-	19.6	1	15.7	13.2-18.1	2	-	-	-	
, Dissolved	mg/L	13	6-22	7	12.6	8.6-18.8	7	-	-	-	
Manganese , Total	mg/L	-	-	-	0.15*	0.04-0.56*	6	-	-	-	P 0.05
, Dissolved	mg/L	0.014	<0.01-0.02	7	-	-	-	-	-	-	
, Extractable	mg/L	-	-	-	-	-	-	0.12*	0.03-0.45*	7	P 0.05

TABLE 48 (Continued)

Mercury , Total	µg/L	-	-	-	0.06	0.05-0.1	5	-	-	-	A 0.1
, Dissolved	µg/L	0.05	0.05-0.06	6	-	-	-	-	-	-	
, Extractable	µg/L	-	-	-	-	-	-	<0.05	<0.05	5	
Molybdenum, Total	µg/L	-	-	-	1.1	0.5-2.9	6	-	-	-	
Nickel , Total	µg/L	-	-	-	20	10-60*	6	-	-	-	A 25
, Extractable	µg/L	-	-	-	-	-	-	5	1-14	7	
Nitrogen , Ammonia	µg/L	26	15-33	3	27	15-39	6	58	13-132	7	
, Kjeldahl	mg/L	1.8	0.4-4.9	6	0.97	0.3-3	6	-	-	-	
, Nitrate	mg/L	0.05	<0.02-0.1	8	<0.02	<0.02	2	-	-	-	
, Nitrite	µg/L	5	<5-6	6	5.3	<5-6	3	-	-	-	
, Nitrite/nitrate	mg/L	0.04	<0.02-0.11	6	0.05	<0.02-0.17	6	0.05	0.01-0.13	7	
, Organic	mg/L	0.7	0.4-1	3	0.9	0.3-2.9	6	-	-	-	
, Total	mg/L	0.7	0.4-1.0	3	1.1	0.3-3.0	4	0.51	0.29-0.68	7	
Oxygen , Diss. (Field)	mg/L	11.0	8.6-13.2	6	10	8.7-11.2	2	-	-	-	
pH , (Field)		8.3	7.9-8.6	7	8.2	7.9-8.6	6	7.9	7.5-8.5	7	
Phenol	µg/L	-	-	-	-	-	-	<1	<1	2	
Phosphorus, Dissolved	µg/L	-	-	-	8	5-11	2	34	5-108*	5	P, R 100
, Ortho	µg/L	-	-	-	6.6	3-16	5	-	-	-	
, Total	mg/L	0.4*	0.02-2.4*	8	0.3*	0.04-1.2*	7	0.3*	0.05-1.1*	7	P, R 0.1
Potassium , Dissolved	mg/L	2.2	1-5.5	6	-	3.1	1	2.2	1.1-4.3	7	
Selenium , Extractable	µg/L	-	-	-	-	-	-	0.5	0.2-1.4*	6	A 1
Silica , Dissolved	mg/L	4.7	3.7-5.9	5	-	-	-	5.5	4.7-6.3	7	
Sodium , Dissolved	mg/L	8.3	4-13.7	6	-	13.4	1	5.9	2.6-10	7	
Solids , Total	mg/L	-	2800	1	613	264-1638	7	-	-	-	
, Dissolved	mg./L	233	188-278	3	225	158-324	5	-	-	-	
, Diss. Inorganic	mg/L	-	-	-	-	-	-	186	120-236	6	
, Suspended	mg/L	1402	40-5726	7	388	29-1463	7	146	29-517	6	
, Susp. Inorganic	mg/L	-	-	-	-	-	-	136	25-487	6	
, Total Inorganic	mg/L	-	2542	1	-	-	-	-	-	-	
Sulphate , Dissolved	mg/L	25	6.8-44	6	16.6	6.3-35.2	6	15	6-31	7	
Surfactants, Total	mg/L	0.035	<0.03-0.05	4	-	-	-	-	-	-	
, Dissolved	mg/L	-	<0.03	1	-	-	-	-	-	-	
Tannin & Lignin, Total	mg/L	1.7*	0.2-5*	4	1.1*	0.5*-1.8*	6	-	-	-	P 0.4
, Dissolved	mg/L	-	0.9*	1	-	-	-	-	-	-	P 0.4
Temperature (Field)	°C	9.8	0-17*	8	10.5	4-17*	2	9.1	0.5-18*	7	P 15
Turbidity	N.T.U.	807	44-3400	8	229	26-750	7	-	-	-	
	J.T.U.	-	-	-	-	-	-	103	31-225	7	
Vanadium , Total	µg/L	-	-	-	9.3	0.3-18	4	-	-	-	
Zinc , Total	mg/L	-	0.34*	1	0.07*	0.007-0.26*	6	-	-	-	A 0.05-0.3
, Dissolved	mg/L	0.02	<0.005-0.09*	7	-	-	-	-	-	-	A 0.05-0.3
, Extractable	mg/L	-	-	-	-	-	-	0.02	0.001-0.04	2	

* in excess of preliminary water quality criteria
[1] geometric mean
A working water quality criteria for aquatic life
P working water quality criteria for public water supplies
R working water quality criteria for recreation and aesthetics

TABLE 49 WATER QUALITY OF THE PEACE RIVER DOWNSTREAM FROM THE BEATTON RIVER AT SITES 04000146-04000148
(November, 1971 - October, 1974)

Characteristics		Site 0400146			Site 0400147			Site 0400148			Summation of Transect Values			Criteria Exceeded
		Mean ± Std. Deviation	Range of Values	No. of Values	Mean ± Std. Deviation	Range of Values	No. of Values	Mean ± Std. Deviation	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Alkalinity, Phenolphthalein	mg/L	0	0	7	0	0	7	0	0	7	0	0	21	
, Total	mg/L	84 ±8	71-94.5	7	90 ±3.5	86-95	6	95 ±5.6	88.2 ±104	7	89.7	71-104	20	
Cadmium , Dissolved	µg/L	-	<1	1	-	-	-	-	-	-	-	<1	1	A 0.2-4
Calcium , Dissolved	mg/L	26 ±3.4	20.5-30.2	8	28.8 ±1.3	26.5-30	7	29.1 ±1.6	27.5-31.4	8	27.9	20.5-31.4	23	
, Total	mg/L	-	30.4	1	-	30.4	1	-	31.2	1	30.6	30.4-31.2	3	
Carbon , Inorganic	mg/L	18.3 ±3.5	15-22	3	22	22	2	22.3 ±2.1	20-24	3	20.7	15-24	8	
, Organic	mg/L	17 ±12	3-42	8	9.4 ±9.0	<1-25	7	11.3 ±9	2-24	8	12.7	<1-42	23	
Chloride , Dissolved	mg/L	0.7 ±0.3	0.3-1.1	6	0.5 ±0.13	0.3-0.7	6	0.8 ±0.8	0.3-2.5	6	0.7	0.3-2.5	18	
, Total	mg/L	-	0.3	1	-	0.3	1	0	0	1	0.2	0-0.3	3	
Chromium , Dissolved	µg/L	<5	<5	6	<5	<5	5	<5	<5	6	<5	<5	17	
, Total	µg/L	<5	<5	2	<5	<5	2	-	<5	1	<5	<5	5	
C.O.D.	mg/L	-	11.6	1	-	7.1	1	-	7.4	1	8.7	7.1-11.6	3	
Coliforms , Fecal	MPN/100 mL	36**	5-130*	5	12.5**	2-79*	5	15.3**	<2-240*	6	18.7**	<2-240*	16	P 10-100, R 200-400
, Total	MPN/100 mL	330**	17-2400*	9	103**	8-920*	7	99**	33-350*	8	157.1**	8-2400*	24	P 100-1000
Color	T.A.C.	50* ±32.5	14-77*	3	11.5 ±3.5	9-14	2	18.3* ±13.6	9-34*	3	28.5*	9-77*	8	P 15-75; R15-100
Conductance, Specific	uS/cm	185 ±14	164-198	5	190 ±5	187-198	4	192 ±9.9	184-209	5	189	164-209	14	
Copper , Dissolved	µg/L	2* ±0.8	<1-3*	6	1.6 ±0.9	<1-3*	5	3.2* ±3.3	<1-10*	6	2.3*	<1-10*	17	A 2.0
, Total	µg/L	9.5* ±0.7	9*-10*	2	5.5* ±6	1-10*	2	9.2* ±9.2	7*-20*	2	8.1*	1-20*	6	A 2.0
Gases , Dissolved	%	-	-	-	-	105.5	1	-	-	-	-	105.5	1	(A 110-115)
Hardness , Dissolved	mg/L	88 ±11	71-101	7	98 ±6	89 ±105	6	98 ±6.7	92.5 ±108	7	94.5	71-108	20	
, Total	mg/L	-	99	1	-	99	1	-	106	1	101.3	99-106	3	
Iron , Dissolved	mg/L	0.4* ±0.3	0.1-1.0*	6	0.08 ±0.04	<0.04-0.14	5	0.10 ±0.06	<0.04-0.2	6	0.2	<0.04-1.0*	17	P 0.3; A 0.3-1.0
, Total	mg/L	-	0.02	1	-	0.02	1	-	-	-	0.02	0.02	2	
Lead , Dissolved	µg/L	1.7 ±1	<1-3	6	1.8 ±1	<1-3	5	1.6 ±1	<1-3	6	1.7	<1-3	17	
, Total	µg/L	18.5* ±19	5*-32*	2	12* ±11	4-20*	2	-	0.08	1	6.9*	0.08-32*	5	A 5-10
Magnesium , Dissolved	mg/L	5.6 ±0.5	4.7-6.5	7	6.0 ±0.5	5.3-6.7	6	6.2 ±0.7	5-7.2	7	5.9	4.7-7.2	20	
, Total	mg/L	-	6.4	1	-	6.2	1	-	6.4	1	6.3	6.2-6.4	3	

TABLE 49 WATER QUALITY OF THE PEACE RIVER DOWNSTREAM FROM THE BEATTON RIVER AT SITES 0400146-0400148
(November, 1971 - October, 1974) (Continued)

Characteristics			Site 0400146			Site 0400147			Site 0400148			Summation of Transect Values			Criteria Exceeded
			Mean ± Std. Deviation	Range of Values	No. of Values	Mean ± Std. Deviation	Range of Values	No. of Values	Mean ± Std. Deviation	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Manganese	, Dissolved	mg/L	0.02 ±0.008	<0.01-0.03	6	0.01 ±0.004	<0.01-0.02	5	0.013 ±0.005	<0.01-0.02	6	0.015	<0.01-0.03	17	
	, Total	mg/L	-	0.02	1	-	0.01	1	-	0.03	1	0.02	0.1-0.03	3	
Mercury	, Dissolved	µg/L	-	-	-	0.2* ±0.36	0.05-0.95*	6	-	-	-	0.2*	0.05-0.95*	6	
	, Total	µg/L	-	-	-	-	<0.02	1	-	-	-	-	<0.02	1	P I; A 0.1-02
Nickel	, Total	mg/L	-	<0.01	1	-	<0.01	1	-	-	-	<0.01	<0.01	2	
Nitrogen	, Ammonia Diss.	mg/L	0.016 ±0.007	0.008-0.022	3	0.01 ±0.006	0.005-0.014	2	0.011 ±0.003	0.008-0.014	3	0.012	0.005-0.022	8	
	, Kjeldahl	mg/L	0.6 ±0.8	0.13-2.5	7	0.3 ±0.2	0.1-0.8	7	0.3 ±0.3	0.1-0.8	7	0.6	0.1-2.5	14	
	, Organic	mg/L	0.44 ±0.2	0.21-0.63	3	0.21 ±0.02	0.2-0.23	2	0.4 ±0.5	0.11-1.0	3	0.37	0.11-1.0	8	
	, Nitrite/Nitrate	mg/L	0.04 ±0.007	0.03-0.05	6	0.05 ±0.02	0.03-0.09	5	0.06 ±0.03	0.03-0.1	6	0.05	0.03-0.1	17	
	, Nitrite	mg/L	<0.005	<0.005	7	<0.005	<0.005	6	<0.005	<0.005	7	<0.005	<0.005	20	
	, Nitrate	mg/L	0.04 ±0.03	<0.02-0.11	9	0.05 ±0.03	<0.02-0.09	8	0.05 ±0.03	<0.02-0.1	9	0.05	<0.02-0.11	26	
	, Total	mg/L	0.43 ±0.21	0.25-0.69	4	0.3 ±0.07	0.24-0.37	3	0.5 ±0.4	0.15-1.1	4	0.42	0.15-1.1	11	
Oxygen	, Dissolved	mg/L	11.5 ±1.5	8.9-12.8	6	11 ±1.5	9.1-12.9	7	11.3 ±1.7	9.1-13.2	6	11.3	8.9-13.2	19	
pH			7.9 ±0.1	7.8-8.1	6	8.0 ±0.04	8-8.1	5	8.1 ±0.08	8-8.2	6	8	7.8-8.2	17	
Phosphorus	, Total	mg/L	0.2* ±0.35	0.01*-1.1*	9	0.1** ±0.16	0.01*-0.5*	8	0.15* ±0.2	0.01*-0.57*	9	0.15*	0.01*-1.1*	26	P, R 0.1
Potassium	, Dissolved	mg/L	1.1 ±0.6	0.5-1.9	6	0.7 ±0.2	0.4-1.0	6	0.8 ±0.3	0.5-1.3	6	0.9	0.4-1.9	18	
Silica	, Dissolved	mg/L	4.0 ±0.16	3.8-4.2	5	3.6 ±0.4	3.1-4.1	5	3.6 ±0.4	3-4.1	5	3.7	3.0-4.2	15	
Sodium	, Dissolved	mg/L	2.7 ±0.5	1.8-3.1	6	1.6 ±0.3	1.3-2	6	1.8 ±0.45	1.3-2.5	6	2.0	1.3-3.2	18	
	, Total	mg/L	-	1.8	1	-	1.3	1	-	1.4	1	1.5	1.3-1.8	3	
Solids	, Dissolved	mg/L	125 ±10	114-132	3	115 ±1.4	114-116	2	119 ±6	116-126	3	120.3	114-132	8	
	, Inorganic, Total	mg/L	-	656	1	-	212	1	-	150	1	339.3	150-656	3	
	, Suspended	mg/L	45[illegible] ±644	13-1560	8	322 ±584	11.4-1582	7	478 ±752	10.8-2098	7	423.5	10.8-2098	22	
	, Total	mg/L	-	748	1	-	238	1	-	190	1	392	190-748	3	
Sulphate	, Dissolved	mg/L	15 ±4.5	10.2-23.4	6	11.6 ±2.1	8.2-14.5	6	11.1 ±2.2	8.7-14.5	6	12.6	8.2-23.4	18	
	, Total	mg/L	-	12	1	-	11	1	-	11.0	1	11.3	11-12	3	
Surfactants	, Dissolved	mg/L	-	0.15	1	-	<0.03	1	-	<0.03	1	0.07	<0.03-0.15	3	
	, Total	mg/L	0.02 ±0.01	0-0.03	5	<0.03	<0.03	5	<0.03	<0.03	5	0.03	0-0.03	15	

TABLE 49 WATER QUALITY OF THE PEACE RIVER DOWNSTREAM FROM THE BEATTON RIVER AT SITES 0400146-0400148
(November, 1971 - October, 1974) Continued

Characteristics		Site 0400146			Site 0400147			Site 0400148			Summation of Transect Values			Criteria Exceeded
		Mean ± Std. Deviation	Range of Values	No. of Values	Mean ± Std. Deviation	Range of Values	No. of Values	Mean ± Std. Deviation	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Tannin and Lignins, Diss.	mg/L	0.25±0.07	0.2-0.33	2	-	<0.2	1	-	0.2	1	0.23	0.2-0.3	4	
, Total	mg/L	1.4*±0.9	0.6*-2.5*	4	1.4*±2.6	0.1-6.0*	5	1.8*±3.5	0.2-8*	5	1.5*	0.1-8*	14	P 0.4
Temperature	°C	7.7±4	0-13.5	8	7.4±4.2	0-13	8	7.6±4.0	1-13	8	7.6	0-13.5	24	
Turbidity	N.T.U.	136 ±147	3.3-410	9	70 ±88	2.4-240*	8	78 ±95.2	3.4-220	9	95.6	2.4-410	26	
Zinc , Dissolved	µg/L	7.6±3.8	<4-13	6	15±19	<5-50*	5	11.5±10	<5-29	6	11.2	<5-50*	17	A 50
, Total	µg/L	30	30	2	18±18	<5-30	2	-	13.0	1	21.6	<5-30	5	

* in excess of working water quality criteria
A working water quality criteria for aquatic life
P working water quality criteria for public water supplies
R working water quality criteria for recreation and aesthetics
** geometric mean

TABLE 50

WATER QUALITY OF THE PEACE RIVER AT SITE 07FD0002, DUNVEGAN ALBERTA
(AUGUST, 1969 - DECEMBER, 1982)

Characteristics			Site 07FD0002 Mean ± Std. Deviation	Range of Values	No. of Values	Criteria Exceeded
Alkalinity,	Total	mg/L	92.5±7.3	73-106	44	
	, Phenolphthalein	mg/L	0±1	0-4	59	
Aluminum	, Extractable	µg/L	1.1*±2	0.02-7.9*	17	Ir,L5;A,R.In 0.1
Arsenic	, Dissolved	µg/L	1.3±2.8	<0.5-15	48	
Barium	, Extractable	mg/L	0.1±0.1	0-0.5	16	
	, Tot. recoverable	mg/L	0.08-0.04	<0.05-0.16	11	
Bicarbonate	(Calculated)	mg/L	108±11	87-129	59	
Boron	, Dissolved	mg/L	0.04±0.03	<0.02-0.21	48	
Cadmium	, Extractable	µg/L	2*±3	<1-10*	17	P5, A 0.2-4
	, Tot. recoverable	µg/L	<1	<1	11	
Calcium	, Dissolved	mg/L	31.2±3	27.5-44	66	
Carbon	, Organic Part.	mg/L	2.8±6.9	0.09-43	55	
	, Diss. inorganic	mg/L	19.5±2.1	14-22	11	
	, Diss. organic	mg/L	3.7±2.5	1-13	60	
	, Tot. inorganic	mg/L	18.5±4.3	10-23	11	
Chloride	, Dissolved	mg/L	0.8±0.2	0.5-1.8	66	
Chlorophyll	a	µg/L	43±45	16-95	3	
Chromium	, Extractable	mg/L	0.013±0.005	<0.01-0.03*	19	A 0.02
Cobalt	, Extractable	µg/L	5±5	<1-17	19	
	, Tot. recoverable	µg/L	3±2	<2-7	11	
Coliforms	, Fecal	MPN/100 mL	9±16	1-79*	56	P 10-100
	, Total	MPN/100 mL	85±226	<2-1600*	56	P 100-1000
Color	, Apparent	A.C.U.	51±81	<5-500	44	
Conductance,	Specific	µS/cm	206±51	100-414	62	
Copper	, Extractable	µg/L	6*±7	<1-25*	18	A 2
	, Tot. recoverable	µg/L	3*±2	<1-8*	11	A 2
Fluoride	, Dissolved	mg/L	0.06±0.02	<0.05-0.13	60	
Hardness	, Total	mg/L	105±7.3	94-123	61	
Iron	, Extractable	mg/L	2.7±5.9	0.06-27*	26	A,P 0.3; Ir 5
	, Dissolved	mg/L	0.05±0.01	<0.04-0.06	2	
Lead	, Total	µg/L	8*±12	<1-19*	17	A 5
	, Tot. recoverable	µg/L	5*±3	<4-14*	10	A 5
Magnesium	, Dissolved	mg/L	7±7	5.9-8.9	61	
Manganese	, Extractable	mg/L	0.1*±0.2	<0.01-0.97*	25	P0.05;A0.1;Ir0.2
	, Dissolved	mg/L	<0.01	<0.01	2	
Mercury	, Extractable	µg/L	0.03±0.01	<0.02-0.05	14	
	, Total	µg/L	0.06±0.04	<0.02-0.15*	19	A 0.1
Molybdenum,	Extractable	mg/L	<0.05	<0.05	17	

TABLE 50 (Continued)

Characteristics			Site 07FD0002 Mean ± Std. Deviation	Range of Values	No. of Values	Criteria Exceeded
Nickel	, Extractable	µg/L	10±16	<1-60*	17	A 25
	, Tot. recoverable	µg/L	4±4	<2-14	10	
Nitrogen	, Dissolved	mg/L	0.16±0.08	0.08-0.44	56	
	, Particulate	mg/L	0.25±0.64	<0.01-3.9	55	
	, Ammonia, Total	mg/L	<1	<1	45	
	, Kjeldahl	mg/L	0.7±0.6	<1-2.1	10	
	, Nitrite/nitrate	mg/L	0.05±0.03	<0.01-0.14	61	
Oxygen	, Dissolved	mg/L	11.8±1.7	8.7-15.1	48	
pH			8.1±0.2	7.6-8.4	66	
Phenol		µg/L	1*±1	<1-5*	59	P 2, A1
Phosphorus,	Total	mg/L	0.14*±0.3	0-2.1*	61	P, R 0.1
	, Dissolved	µg/L	10±13	<3-62	54	
	, Ortho	µg/L	4±3	<2-13	18	
Potassium	, Dissolved	mg/L	0.6±0.5	<1-3.5	66	
Selenium,	Dissolved	µg/L	0.5±0	<0.5-0.6	42	
Silica,	Reactive	mg/L	4±0.7	2.8-8.6	62	
Silver,	Extractable	µg/L	6±3	<4-10	27	A.0.1
Sodium,	Dissolved	mg/L	2.2±1.1	1-8.3	66	
Solids,	Suspended	mg/L	154±358	<1-1605*	61	A 25-80-400
,	Susp. Inorganic	mg/L	535±762	19-1410	3	
Streptococci, Fecal		MPN/100 mL	16±33	<2-144	51	
Sulphate, Dissolved		mg/L	15±14	9-116	66	
Temperature		°C	8.1±7.2	0-22.8*	71	P 15
Turbidity		J.T.U.	56±*-111	1-800*	66	P 25-50, P5
Vanadium,	Extractable	µg/L	22±25	<1-50	14	
	Total Recoverable	µg/L	3±4	<1-11	11	
Zinc, Extractable		mg/L	0.02±0.05	0.001-0.2*	18	A 0.05-0.3
	Total Recoverable	µg/L	11±11	3-31	10	

*in excess of working water quality criteria
A working water quality criteria for aquatic life
P working water quality criteria for public water supplies
R working water quality criteria for irrigation water
Ir working water quality criteria for irrigation water
In working water quality criteria for industrial water
L working water quality criteria for livestock water

TABLE 50 (Continued)

Characteristics		Site 07FD0002 Mean ± Std. Deviation	Range of Values	No. of Values	Criteria Exceeded
PESTICIDES					
Silvex	µg/L	-	<0.004	17	
Carbo-phenothion	µg/L	-	<0.02	19	
Ethion	µg/L	-	<0.02-0.01	19	
Phorate	µg/L	-	<0.02	14	
Diazinon	µg/L	-	<0.02	18	
Fenchlorphos (Ronnel)	µg/L	-	<0.02	14	
Malathion	µg/L	-	<0.01-<0.05	19	
Parathion methyl	µg/L	-	<0.02	14	
Parthion	µg/L	-	<0.2	19	
Crufomate	µg/L	-	<0.2	14	
Disulfoton	µg/L	-	<0.02	8	
Imidan	µg/L	-	<0.2	14	
Azin-phosethyl	µg/L	-	<0.2	14	
Guthion	µg/L	-	<0.1-<0.5	19	
Picloram (Tordon)	µg/L	-	<0.2	11	
Mirex, Total	µg/L	-	<0.001	18	
2,4 DB	µg/L	-	<0.006-<0.009	21	
2,4,5-T	µg/L	-	<0.001-0.009	22	
2,4-D	µg/L	-	<0.004-0.05	22	
2,4 DP	µg/L	-	<0.002-<0.004	21	
MCPA	µg/L	-	<0.2	19	
p,p Methoxychlor	µg/L	-	<0.01-<0.012	24	
Gamma BHC (Lindane)	µg/L	-	<0.001-0.001	24	
Heptachlor epoxide	µg/L	-	<0.002	24	
Heptachlor	µg/L	-	<0.001	24	
Endrin	µg/L	-	<0.002	20	
b-Endosulfhan	µg/L	-	<0.003	24	
a-Endosulfhan	µg/L	-	<0.001	24	
Dieldrin	µg/L	-	<0.002	24	
p,p DDT	µg/L	-	<0.004	24	
p,p DDE	µg/L	-	<0.001	24	
p,p DDD	µg/L	-	<0.001-<0.002	24	
o,p DDT	µg/L	-	<0.001	18	
gamma Chlordane	µg/L	-	<0.002	20	
alpha Chlordane	µg/L	-	<0.003	20	
alpha BHC	µg/L	-	0.001-0.006	20	
Aldrin	µg/L	-	<0.001	19	
POLYCHLORINATED BIPHENYLS					
Aroclors, Total	µg/L	-	<0.02-<0.002	11	
Aroclor, 1248	µg/L	-	<0.002-<0.02	15	
Aroclor, 1254	µg/L	-	<0.002-<0.032	22	
Aroclor, 1260	µg/L	-	<0.005-<0.06	20	
Aroclor, 1242	µg/L	-	<0.002	7	

TABLE 51

SUMMARY OF THE RECOMMENDED EFFLUENT AND RECEIVING WATER MONITORING PROGRAMS FOR THE PEACE RIVER MAINSTEM SUB-BASIN

Sites	Frequency and Times	Characteristics to be Measured
G.M. Shrum Hydroelectric Generating Station. Effluent	Quarterly (record daily flow once per week)	Flow, BOD_5, Suspended Solids, Fecal Coliforms, Chlorine Residual
Peace Canyon Coal Project Receiving Waters (if project is reactivated)	Quarterly; more frequently for suspended solids and turbidity during freshet and rains	pH, Alkalinity, Turbidity, Suspended Solids, Total Phosphorus, Diss. Orthophosphorus Sulphate, Oil and Grease, Nitrate-N, Ammonia-N, Nitrite-N, Total Copper, Diss. Copper, Total Zinc, Diss. Zinc, Total Cadmium, Diss. Cadmium, Total Mercury,
Recreational Fisheries Branch Hatchery (PE 6372) Effluent	2 times per year	Flow, BOD_5, Suspended Solids, Total Phosphorus, Ammonia-N, Nitrite-Nitrate-N
Peace Canyon Hydroelectric Generating Station (PE 5240) Effluent	Quarterly	Flow, BOD_5, Suspended Solids, Chlorine Residual
Fort St. John; Peace River discharge (PE 389) Effluent	Monthly; record effluent flow daily	Flow, BOD_5, Suspended Solids, Fecal Coliforms, Total Phosphorus, Diss. Orthophosphorus Ammonia-N, pH, Nitrate-N, Nitrite-N, Oil and Grease, Chlorine Residual
Peace River upstream and downstream from Fort St. John discharge. Receiving Water Sites 0400134, 0400135, 0400136, 0400491, 0400138, 0400139, 0400140	To begin: 3 times per year during spring to late fall low flows (to coincide with effluent monitoring)	Flow (Water Survey of Canada data), Fecal Coliforms, Total Copper, Diss. Copper, Total Lead, Diss. Lead, pH, Total Mercury, Ammonia-N, Nitrite-N, Nitrate-N, D.O., Temp., Oil and Grease, Total Phosphorus, Diss. Orthophosphorus, Turbidity, Suspended Solids, Total Zinc, Diss. Zinc

TABLE 51 (Continued)

Sites	Frequency and Timing	Characteristics to be Measured
Fort St. John Beatton River discharge (PE 388) Effluent	Monthly (May 1-June 30); record daily flow once per week	Flow, BOD_5, Total Phosphorus, Diss. Orthophosphorus, Fecal Coliforms, Suspended Solids, Ammonia-N, Nitrite-N, Nitrate-N, pH, Oil and Grease, Chlorine Residual
Beatton River upstream and downstream from Fort St. John discharge. Receiving water site 0400145 plus upstream control site, and 3 new downstream sites	To begin: 2 times during discharge period (May 1 to June 30)	Flow (Water Survey of Canada data), Fecal Coliforms, Total Copper, Diss. Copper, Total Lead, Diss. Lead, Temp., pH, Total Mercury, Ammonia-N, Nitrite-N, Nitrate-N, Turbidity, D.O., Oil and Grease, Total Phosphorus, Diss. Orthophosphorus Suspended Solids, Total Zinc, Diss. Zinc
Petro-Canada Refinery PE 1379 i) Process Effluent	Weekly for all, except monthly for bioassays and dissolved phosphorus (Record daily discharge volumes)	Flow, BOD_5, Bioassay, pH, Fluoride, Suspended Solids, Phenol, Total Sulphide, Cyanide, Oil and Grease, Total Phosphorus, Diss. Orthophosphorus, Ammonia-N, Hydrocarbons, Temp.
ii) Cooling Water (inflow and outflow)	Weekly (flow, pH, temp.) (Record daily discharge volumes) Monthly (to begin) for others	Flow, pH, Fluoride, Phenol, Total Sulphide Cyanide, Total Phosphorus, Diss. Orthophosphorus Ammonia-N, Hydrocarbons, Temp.
iii) Storm Runoff	Monthly; during periods of storm runoff (Record daily discharge volumes)	Flow, pH, Suspended Solids, Oil and Grease, Phenols, Hydrocarbons Diss. Orthophosphorus, Total Phosphorus, Sulphide, Ammonia-N, Nitrite-N, Nitrate-N
iv) Combined Effluents	Annually (to begin)	Organic contaminants (e.g. Alkybenzenes, dialkybenzene aromatic hydrocarbons, polycyclic aromatic hydrocarbons, and hetero-cyclic compounds

TABLE 51 (Continued)

Sites	Frequency and Timing	Characteristics to be Measured
Peace River upstream and downstream from Petro-Canada discharge i) Receiving water sites 0400138, 0400139, 0400140, 0400157, 0410054, 0410055, 0400142, 0400143, 0400144 and 3 new sites	To begin: 3 times per year; spring to late fall low flows (to coincide with effluent monitoring)	Fecal Coliforms, Turbidity, Suspended Solids, Fluoride, Cyanide, Ammonia-N, Nitrate-N, Nitrite-N, D.O., pH, Temp., Total Cadmium, Diss. Cadmium, Total Chromium, Diss. Chromium, Total Copper, Diss. Copper, Total Iron, Diss. Iron, Total Lead, Diss. Lead, Total Mecury, Total Nickel, Diss. Nickel, Total Zinc, Diss. Zinc, Hydrocarbons, Color, Conductance, Total Hardness, Diss. Hardness, Flow (Water Survey of Canada data), Oil and Grease, Total Phosphorus, Diss. Orthophosphorus Total Sulphide, Surface Film Hydrocarbons (if observed)
ii) Upstream/downstream sites at discretion of sampler	Annually (to begin)	Benthic fauna (identification to lowest possible taxa). Sediments and surface film (analysis for hydrocarbons including polycyclic aromatic hydrocarbons and benzo(a)pyrene Fish Neoplasia (incidence of epidermal papillomas, fin erosion, gonadal and hepatic tumors and histopathological effects Fish Hydrocarbon Contamination (induction of liver enzyme aryl hydrocarbon hydroxylase)
Peace River; W.A.C. Bennett Dam to the Alberta border	Once	Fish Tainting (taste testing of captured sportfish) Fish Tissue Mercury Levels (confined to food fish species)
(Sites at discretion of sampler)	Once (after summer rain events)	Extent of non-point source (diffuse) pollution loads from land-use practices (agricultural pesticides, fertilizers, logging runoff, municipal storm sewers, coliform bacteria from cattle watering and feedlots, and fugitive hydrocarbons from road oiling)

TABLE 52

SUMMARY OF THE EXISTING EFFLUENT SAMPLING PROGRAM FOR PE-389
(THE CITY OF FORT ST. JOHN DISCHARGE TO THE PEACE RIVER)

The permittee is responsible for undertaking the following discharge monitoring program:

1. Sampling
   - obtain monthly grab samples throughout the year.
   - the need for increased or decreased monitoring will be based on the results submitted as well as any other data obtained by the Waste Management Branch.

2. Analysis
   - obtain analyses for:

BOD_5	(mg/L)
Suspended Solids	(mg/L)
Fecal coliform density	(MPN/100 mL)

3. Chlorination
   - maintain a chlorine residual in the effluent between 0.5 mg/L and 1.0 mg/L at all times (and not less than 1 hour contact time at average flow rates).

4. Effluent Flow Measurement
   - maintain continuous flow recording equipment and record daily discharge.

5. Reporting
   - maintain data of analyses and flow measurements for inspection and annually submit the data, suitably tabulated, for the previous year's monitoring.

TABLE 53

RECOMMENDED EFFLUENT SAMPLING AND RECEIVING WATER MONITORING PROGRAM FOR DISCHARGE PE-389 (CITY OF FORT ST. JOHN)

A. Revisions to the Existing (Effluent) Sampling Program.

1. Sampling - no change (once per month).
2. Analysis - add these characteristics: total phosphorus (mg/L), dissolved (Ortho-) phosphorus (mg/L), ammonia-N (mg/L), nitrite-N (mg/L), nitrate-N (mg/L), pH, Oil and Grease (mg/L), Chlorine Residual (mg/L).
3. Chlorination - no change.
4. Effluent Flow Measurement - add "effluent sampling to coincide with effluent flow measurements".
5. Reporting - emphasize the importance of submitting all daily effluent discharge data in a tabulated form. Submission of flow recorder strip charts is not sufficient.

B. Recommended Receiving Water Monitoring Program.

- note that a river water quality monitoring program has not been specified in the existing permit.

1. Sites - 0400134, 0400135, 0400136, 0400491, 0400138, 0400139, 0400140.
   - delete site 0400492 (25 m downstream from discharge). This site is within the initial dilution zone. A replacement site should be established at a point 100 m downstream from discharge PE-389.
   - consider adding a site to be located immediately upstream from the water intake for the Village of Taylor. This would ensure appropriate monitoring for the protection of this water use.

- an attempt to define the zone of influence for this discharge should be made. Downstream sites 0400491 and 0410018 would fit into this program. The need for adding monitoring sites to locate the zone of influence will be based on the analytic results and should be at the discretion of the Regional Waste Management Branch.

2. Frequency - three times per year (to begin with) as follows:

   - spring to late fall during low flow conditions
   - the receiving water monitoring should be conducted on the same day as the effluent monitoring, as noted above.

3. Analysis - obtain analysis of the samples as follows:

Coliforms, Fecal (MPN/100 mL)
Copper, Total (µg/L)
, Dissolved (µg/L)
Flow (m^3/s)
Lead, Total (µg/L)
, Dissolved
Mercury, Total (µg/L)
Nitrogen, Ammonia-N (mg/L
, Nitrite-N (mg/L)
, Nitrate-N (mg/L)
Oxygen, Dissolved (mg/L)
Oil and Grease (mg/L)
pH
Phosphorus, Total (mg/L)
, Dissolved (Ortho-) (mg/L)
Solids, Suspended (mg/L)
Temperature (°C)
Turbidity (NTU)
Zinc, Total (µg/L)
, Dissolved (µg/L)

TABLE 54

SUMMARY OF THE EXISTING EFFLUENT SAMPLING PROGRAM FOR PE-388
(THE CITY OF FORT ST. JOHN DISCHARGE TO THE BEATTON RIVER)

The permittee is responsible for undertaking the following discharge monitoring program:

1. Sampling

- obtain a composite of the effluent monthly during the discharge period. The sample is to consist of four grab samples taken over a 2-hour period during the maximum flow and mixed to form a single sample for subsequent analysis.

2. Analysis

- obtain analyses for:

BOD_5	(mg/L)
Suspended Solids	(mg/L)
Fecal Coliform density	(MPN/100 mL)

3. Effluent Flow Measuement

- record weekly the effluent volume discharged over a 24-hour period during the discharge period.

4. Reporting

- maintain data of analyses and flow measuements for inspection and annually submit the data, suitably tabulated, to the Regional Manager for the previous year's monitoring.

TABLE 55

RECOMMENDED EFFLUENT SAMPLING AND RECEIVING WATER MONITORING PROGRAM FOR DISCHARGE PE-388 (CITY OF FORT ST. JOHN DISCHARGE TO THE BEATTON RIVER)

A. Revisions to the Existing (Effluent) Sampling Program

1. Sampling - no change (once per month).

2. Analysis - add these characteristics: pH, total phosphorus (mg/L), dissolved orthophosphorus (mg/L), dissolved ammonia-N (mg/L), nitrite-N (mg/L), and nitrate-N mg/L, Oil and Grease (mg/L), Chlorine residual (mg/L),
   - add the condition that effluent sampling coincide with the timing of the Ministry of Environment and Parks monitoring of the receiving environment.

3. Effluent Flow Measurement
   - add "effluent sampling to coincide with effluent flow measurements".

4. Reporting - emphasize the importance of submitting all daily effluent discharge data in a tabulated form. Efforts to foil the vandalism of flow metering equipment must be taken. Discharge data calculated from lagoon volume estimates are not sufficient for the calculation of actual waste load effects.

B. Recommended Receiving Water Monitoring Program

- a river water quality monitoring program has not been specified in the existing permit. This recommended program is designed to fill this gap.

1. Sites - only one Ministry of Environment and Parks site exists on the lower Beatton River (0400145)
   - add an upstream control site
   - add three downstream sites to determine the extent of the plume (i.e., the zone of influence). The recommended distances downstream from the discharge are 100 m, 500 m and 1 km. To determine accurately the mixing zone, it may be necessary to alter these sites or add others. This would be at the discretion of the samplers from the Regional Waste Management Branch.

2. Frequency - to begin 2 times during the discharge period: once at startup (early April) and once before the termination of the discharge period (late June)
   - the receiving water monitoring should be conducted on the same day as the effluent monitoring, as noted above.

3. Analysis - obtain analysis of the samples as follows:

Coliforms, Fecal (MPN/100 mL)
Copper, Total (µg/L)
, Dissolved (µg/L)
Flow (m^3/s)
Lead, Total (µg/L)
, Dissolved (µg/L)
Mercury, Total (µg/L)
Nitrogen, Ammonia-N (mg/L)
, Nitrite-N (mg/L)
, Nitrate-N (mg/L)
Oxygen, Dissolved (mg/L)
Oil and Grease (mg/L)
pH
Phosphorus, Total (mg/L)
, Dissolved (Ortho-) (µg/L)
Solids, Suspended (mg/L)
Temperature (°C)
Turbidity (NTU)
Zinc, Total (µg/L)
, Dissolved (µg/L)

TABLE 56

SUMMARY OF THE EXISTING EFFLUENT SAMPLING PROGRAM FOR PE-1379
(PETRO-CANADA REFINERY)

1. Biological Studies of the Receiving Environment

The Permittee shall monitor the receiving water quality and carry out biological studies on the receiving environment as required by the Regional Manager. This program may be drawn up in such a manner as to include other similar major discharges in the area and with the participation of other dischargers.

A summary of the results of the program, including an interpretation of the effect on the receiving waters and environment, is to be submitted annually in a form which is suitable for release to the public. The data from the program will be reviewed periodically by the Director to determine cause and effect relationships and to facilitate modifications to the program as indicated by the data collected.

2. Sampling and Analysis

Sample the cooling water, process effluent, and surface water discharge prior to combining, and analyze in accordance with the following schedule:

Characteristic	Frequency Weekly Grab	Monthly Grab
pH	C, P	S
COD	P	
BOD_5	P	
Phenols	P	S
Suspended Solids	P	S
Total Solids		P
Oil and Grease	C, P	S
Total Sulphides	P	
Nitrogen-ammonia	P	
Cyanide	P	
Orthophosphorus (as P)		P
Fluoride	P	
Temperature	C	
Bioassay (96 hr TLm)		P

P = process effluent - Site No. 0410135
C = cooling water - Site No. 0410136
S - storm runoff discharge - Site No. 0410043

3. Flow Measurement

Install suitable flow measuring devices or employ other approved measuring systems to record the daily discharge volumes of cooling water, process effluent and storm runoff discharge.

4. Miscellaneous Measurements

Record the daily plant throughput of:

- Crude
- Pipeline Liquids
- LPG and;
- Raw Natural Gas

5. Reporting

Submit tabulated data of analyses, flow measurements, and production data monthly to the Director in duplicate. These reports should explain any deviation from Permit requirements and measues taken to prevent recurrence.

TABLE 57

RECOMMENDED EFFLUENT SAMPLING AND RECEIVING WATER MONITORING PROGRAM FOR DISCHARGE PE-1379 (PETRO-CANADA REFINERY)

A. Revisions to the Existing (Effluent) Sampling Program

1. Analysis

a) Cooling Water - add these characteristics: phenols (mg/L), total sulphides (mg/L), fluoride (mg/L), cyanide (mg/L), ammonia-N (mg/L), total and dissolved orthophosphorus (mg/L), and hydrocarbons (mg/L).

- add the requirement for paired inflow/outflow data. This is necessary to separate the incoming ambient load from the refinery input load.

b) Process Effluent -
delete the characteristic total solids.
- add the characteristics: hydrocarbons (mg/L), total phosphorus (mg/L), temp. (°C).

- define what is meant by the phrase normal dry weather flow, i.e., that it does not include storm runoff and that if the effluent volume discharged is greater than this level, then concentrations must be reduced proportionately.

c) Storm Runoff - add the characteristics: hydrocarbons (mg/L), total and dissolved orthophosphorus (mg/L), ammonia-N (mg/L), nitrite-N (mg/L), nitrate-N (mg/L), and total sulphide (mg/L).

2. Sampling

- specify a minimum of monthly sampling for all runoff characteristics (including the new additions) and specify that sampling coincide with peak rain events.
- specify weekly sampling for all process effluent characteristics except monthly for bioassays and diss. phosphorus.
- specify weekly sampling for cooling water monitoring of temp., pH, and flow. All other characteristics should be sampled monthly (to begin).
- add the condition that effluent sampling coincide with the timing of the Ministry of Environment and Parks monitoring of the receiving environment.

3. Effluent Flow Measurement

- add "effluent sampling to coincide with effluent flow measurements".

4. Miscellaneous Measurements - no changes.

5. Reporting - no changes.

6. Biological Studies of the Receiving Environment

- specify the requirement that the studies undertake to determine the full downstream extent of benthic faunal changes and the zone of influence.

- specify that the river bottom sediments downstream from the refinery be analyzed annually (to begin with) for hydrocarbons, (the polycyclic aromatic hydrocarbons (PAH) and including benzo(a)pyrene, BAP).

- specify the analysis of hydrocarbons from surface films if noted during sampling.

- specify that the sources of suspected hydrocarbon contaminated groundwater (Noton, 1981) be located and sampled.

- specify that observations of periphyton growth should be recorded.

B. Recommended Receiving Water Monitoring

1. Sites

- 0400138, 0400139, 0400140, 0400157, 0410054, 0410055, 0400142, 0400143, 0400144.

- delete site 0410053. This site is redundant and there are few data recorded for it.

- an attempt to define the zone of influence for this discharge should be made. The need for additional monitoring sites to achieve this objective will depend on the analytical results and should be at the discretion of the Regional Waste Management Branch. At the minimum, this would involve two or three more sites.

2. Frequency - three times per year (to begin) as follows:
   spring to late fall low flows.

   - the receiving water monitoring should be conducted on the same day as the effluent monitoring, as described above.

3. Analysis - obtain analysis of the samples as follows:

Cadmium, Total	(µg/L)	Mercury, Total	(µg/L)
, Dissolved	(µg/L)	Nickel, Total	(µg/L)
Chromium, Total	(µg/L)	, Dissolved	(µg/L)
, Dissolved	(µg/L)	Nitrogen, Ammonia-N	(mg/L)
Coliforms, Fecal	(MPN/100 mL)	, Nitrate-N	(mg/L)
Color	T.A.C.	, Nitrite-N	(mg/L)
Conductance, Specific	(µS/cm)	Oxygen, Dissolved	(mg/L)
Copper, Total	(µg/L)	Oil and Grease	(mg/L)
, Dissolved	(µg/L)	pH	
Cyanide (as CN)	(mg/L)	Phosphorus, Total	(mg/L)
Fluoride	(mg/L)	, Diss. (Ortho-)	(mg/L)
Flow	(m^3/s)	Solids, Suspended	(mg/L)
Hardness, Total	(mg/L)	Sulphide, Total	(mg/L)
, Dissolved	(mg/L)	Temperature	(°C)
Hydrocarbons*	(mg/L)	Turbidity	(N.T.U.)
Iron, Total	(mg/L)	Zinc, Total	(µg/L)
, Dissolved	(mg/L)	, Dissolved	(µg/L)
Lead, Total	(µg/L)		
, Dissolved	(µg/L)		

*analyze the hydrocarbon content of observed oily surface films (including PAH's).

FIGURE 1

Location of the Peace River Planning Unit.

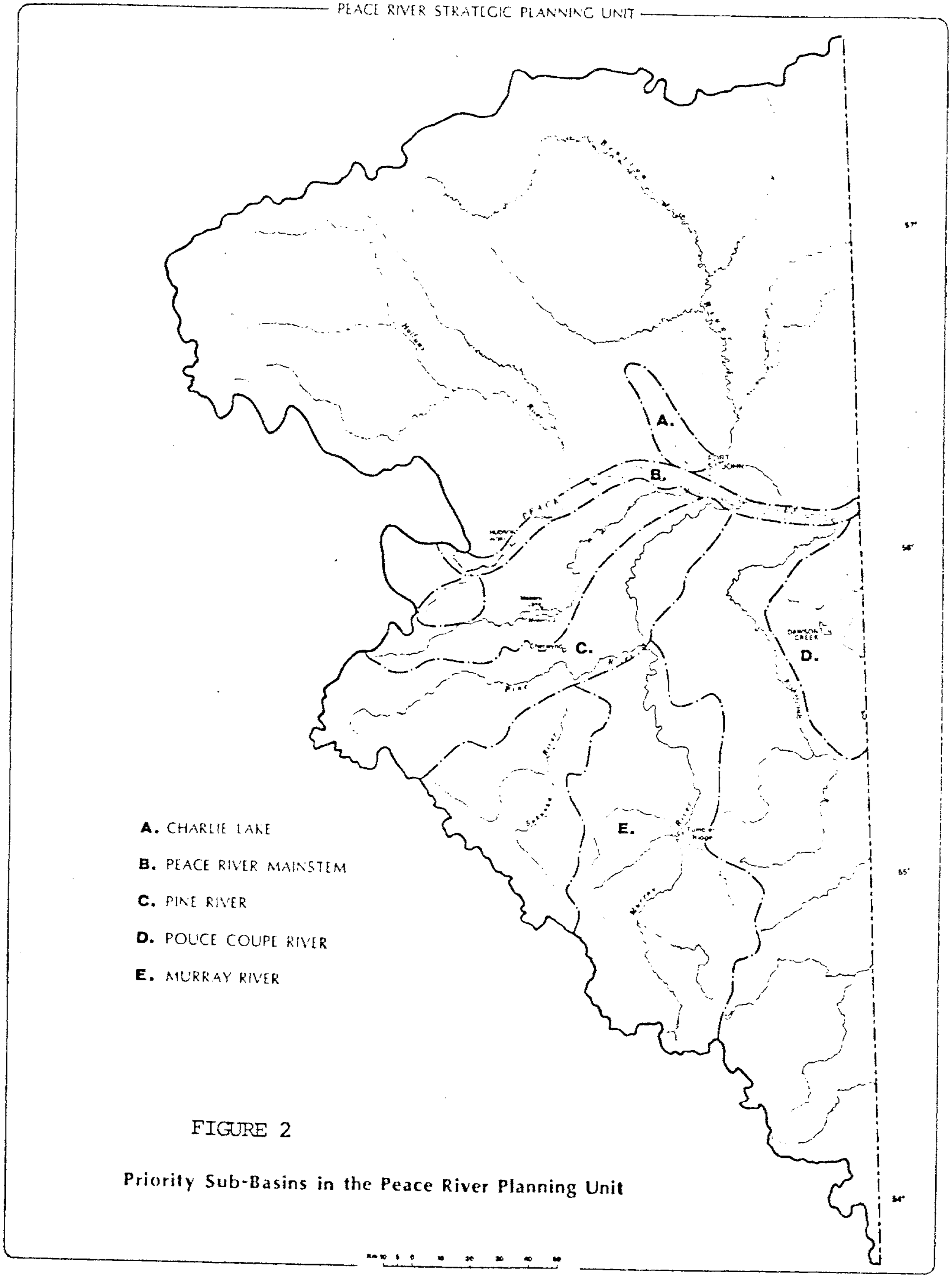

FIGURE 2

Priority Sub-Basins in the Peace River Planning Unit

WASTE DISCH. LIC. 9 NAMES ON WSB.

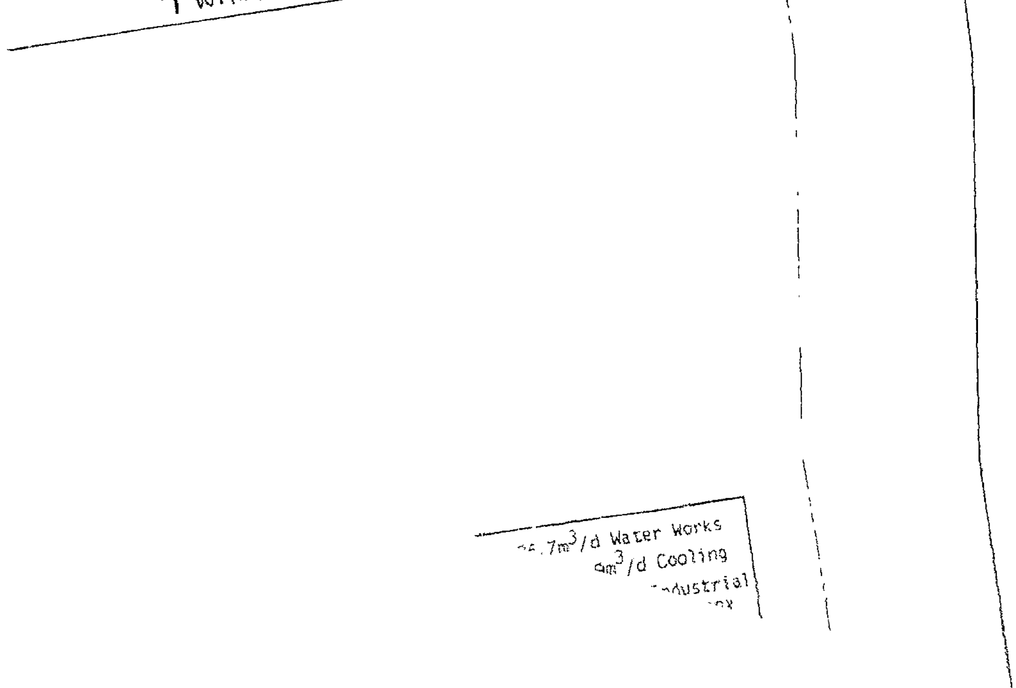

FIGURE 3

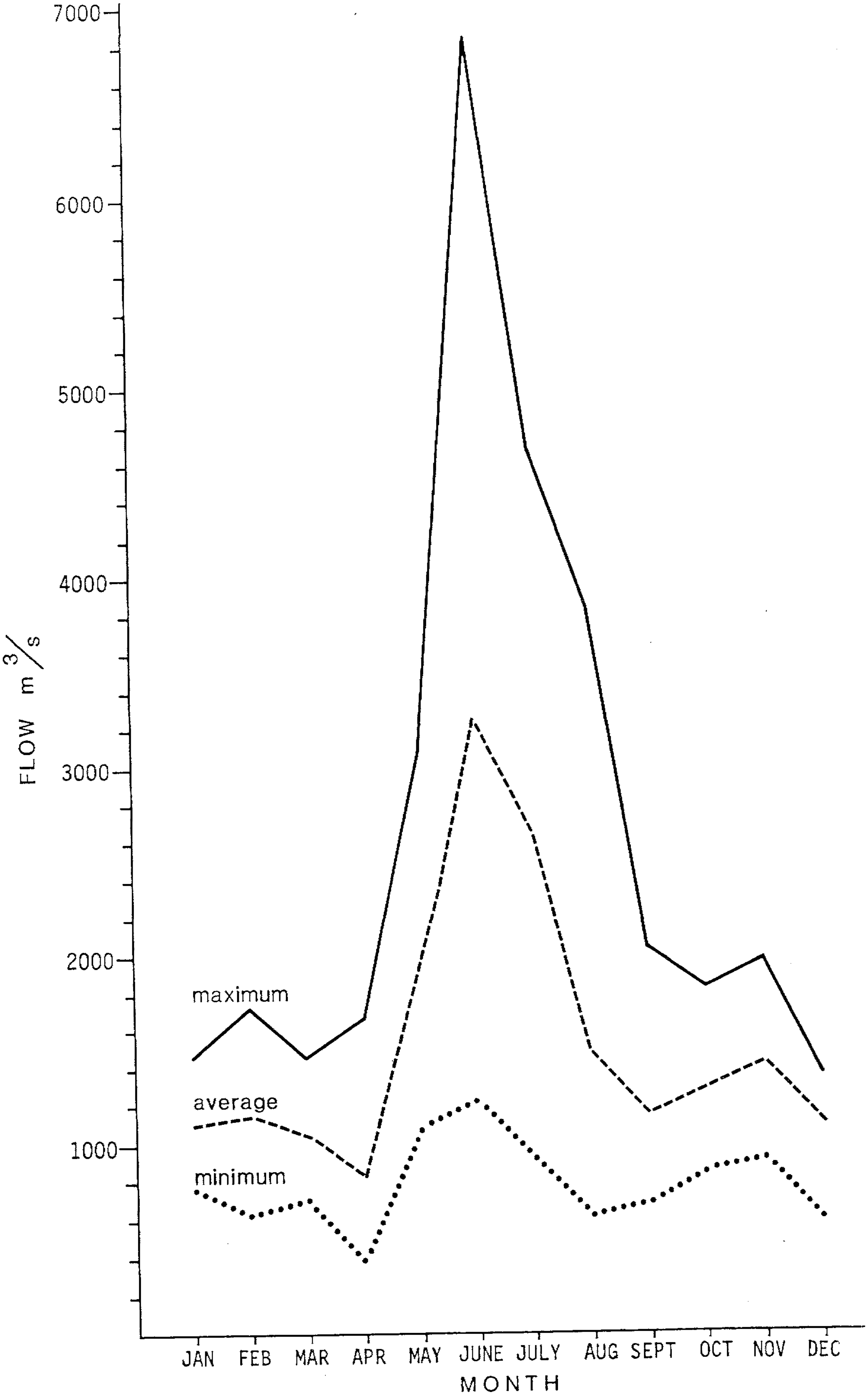

Figure 4 Hydrograph for the Peace River at Site E showing maximum, average, and minimum flows projected for the period 1985-1986 using probable load data for the W.A.C. Bennett Dam.

PEACE RIVER : W.A.C. BENNETT DAM TO DUNVEGAN

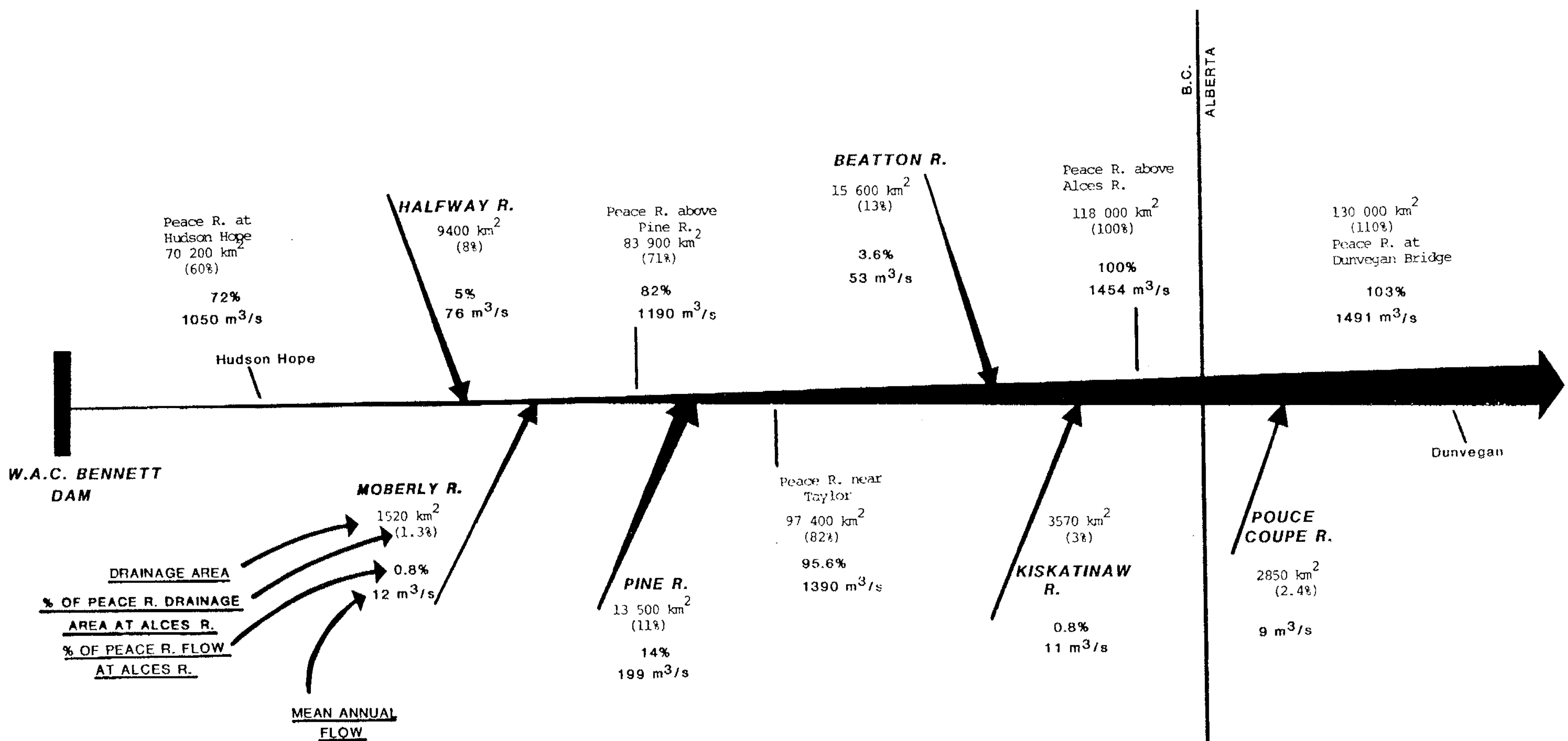

FIGURE 5 Annual Streamflow Balance for the Peace River

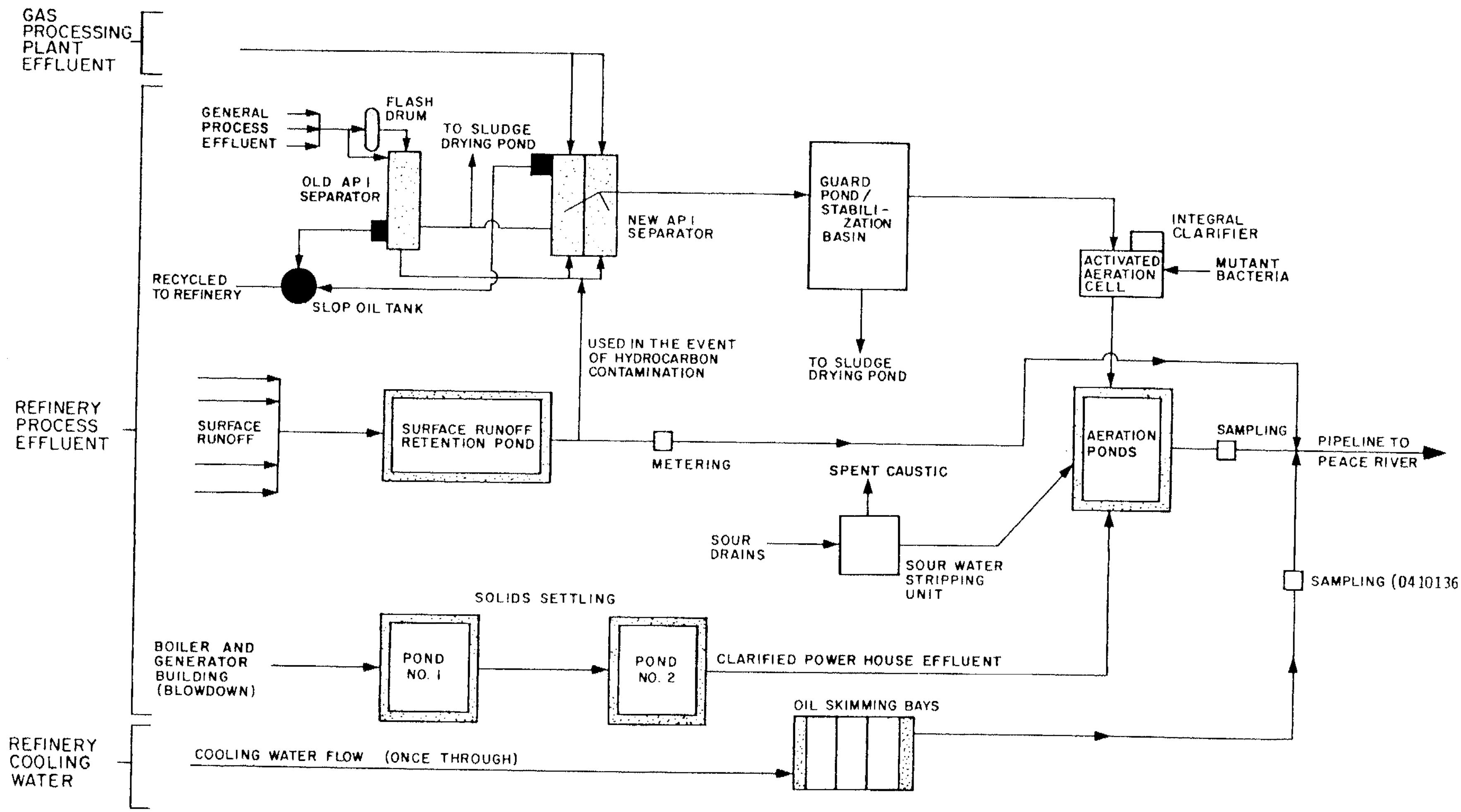

FIGURE 6 Simplified Flow Diagram of the Petro-Canada Refinery Effluent Treatment System

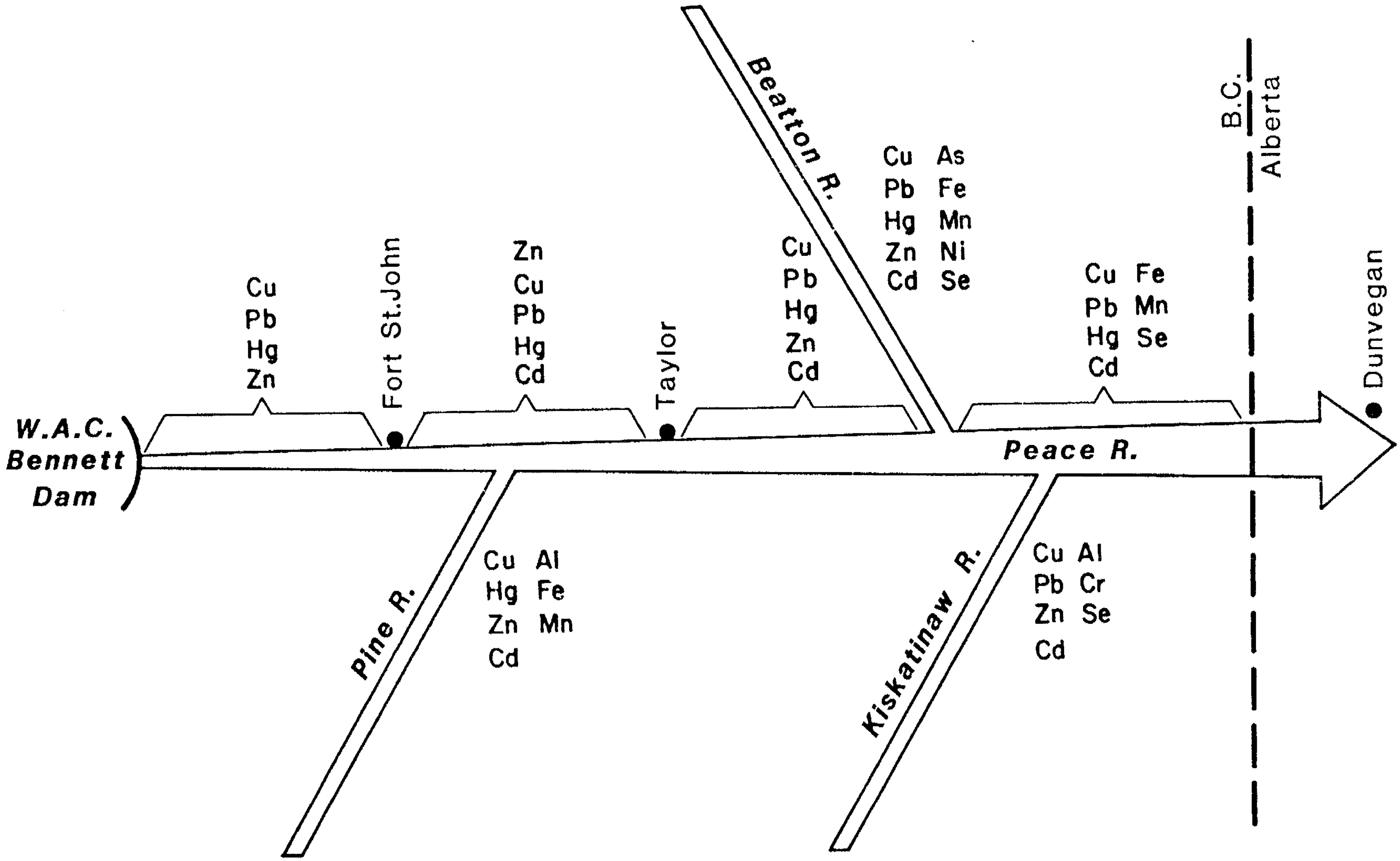

Figure 7: Metals for the Peace River and major tributaries which were in excess of working criteria for aquatic life.

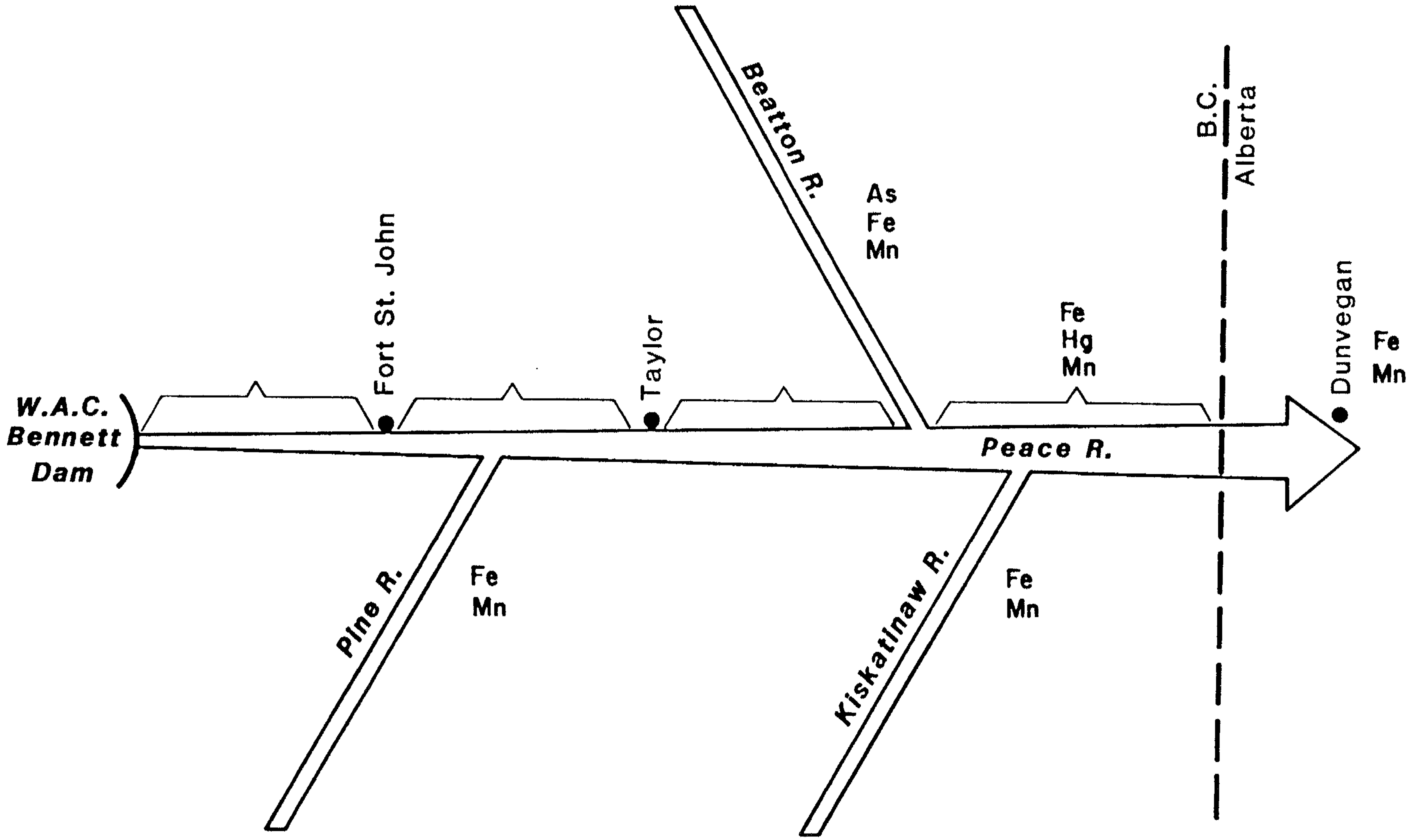

Figure 8: Metals for the Peace River and major tributaries which were in excess of working criteria for public water supplies.