DEPARTMENT OF ENVIRONMENT
WATER RESOURCES SERVICE

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KOOTENAY
AIR AND WATER QUALITY STUDY
PHASE I

ASSESSMENT OF INFORMATION AVAILABLE TO THE END OF 1974

WATER QUALITY IN REGION 4,
THE LOWER KOOTENAY RIVER BASIN

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SUMMARY

This report is an evaluation of the information available to the end of 1974 on the water quality of the Lower Kootenay River basin. It is one of a series of 12 similar reports which assess air and water quality in the Kootenay region. These reports constitute Phase I of the Kootenay air and water quality study.

The major influences on water quality in the region are the discharges from the Cominco Ltd. mine and fertilizer operation at Kimberley, the discharge from the Crestbrook Forest Industry Ltd. pulp mill at Skookumchuck, and the Libby Dam in Montana.

The effluents from Cominco's operations at Kimberley contain nutrients and toxic materials which have severely damaged aquatic life in the St. Mary River. The discharges of Cominco Ltd. have had a lesser effect in the Kootenay River. The Company plans to remove over 90 percent of the contaminants from the effluents by the end of 1977. This action should restore aquatic life in the St. Mary River and virtually eliminate the impact of the discharge on the Kootenay River.

The effluent from Crestbrook Forest Industries' pulp mill has caused colour, toxicity and fish tainting problems in the Kootenay River, up to the confluence with the St. Mary River. The Company is planning an effluent abatement program which will reduce these problems.

The water quality of the Libby Reservoir, which extends 40 miles into Canada, has remained fairly good since the reservoir was created. This result was probably due to rapid flushing action and fluctuating water levels which tended to counteract large nutrient loads. Stabilization of the reservoir could cause eutrophication problems, although the planned reduction in nutrient load from Cominco's operations at Kimberley will reduce the potential for algal blooms.

These general conclusions were made from an analysis of data collected over a number of years. Past data collection was not always coordinated with effluent analysis, river flow regime and biological sampling. We have therefore recommended a short, one year monitoring program to fill some of the gaps in our knowledge and to help predict water quality trends. The additional data will also be used to specify the best sites for future routine monitoring, and the type of measurements to be made at these sites. The results of our program will be presented in a Phase II report for the region. A chapter on water availability problems in the region will be included in the Phase II report.

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1. DESCRIPTION OF THE REGION

1.1 Introduction

The Lower Kootenay River Basin, Region 4, Figure 4-1, has an area of 4,280 sq. miles. The region straddles the Rocky Mountain Trench which divides the region into two halves. The Purcell Mountains occupy the western half and the Rocky Mountains occupy the eastern half. The Trench has a northwest-southeast orientation and lies at an elevation of 2,500 to 3,000 feet.

1.2 Climate

The climate of the region is largely determined by its topography. The warmest and driest portion of the region lies in a narrow, north-south band along the floor of the Rocky Mountain Trench. To the east and to the west of the Trench, the climate becomes progressively cooler and wetter as the slopes of the Purcells and Rockies are ascended.

The Rocky Mountain Trench is semi-arid, receiving an average of only 400 mm of precipitation per year(1). There is a marked increase in precipitation east and west of the Trench, reaching 1000 mm per year in the Rockies and 1000 to 1500 mm per year in the Purcells. Snowfall ranges from about 115 cm per year in the Trench to over 500 cm per year in the uplands of the Purcells. Mean temperatures follow a similar pattern. Temperatures are 18°C in July and -9 to -7°C in January along the Trench, 15.5°C in July and -12°C in January in the Purcells and along the western front of the Rockies and 13°C in July and -15°C in January in the eastern part of the Rockies. The frost-free period averages about 60 to 80 days in the Purcells and Rockies, and from 80 to 100 days along the Trench(2,3).

1.3 Geology

The western half of the region is occupied by the Purcell Mountains which are a north-westerly trending chain of peaks composed of thick quartzite, argillaceous quartzite, argillite and limestone beds with large granitic intrusions. In the Northern part of the region, the Purcells are extremely rugged with heights to 11,000 feet. The range gradually diminishes in height to about 7,000 feet with comparatively subdued topography at the international boundary[4].

The eastern half of the region is occupied by portions of four major Rocky Mountain Ranges. The Galton Range (Border Ranges) occupies the southeast corner of the region between the Elk River and the international boundary. This range is north-westerly trending, with elevations to 7,500 feet, and is composed of argillaceous sedimentary rocks. The Front Ranges, which are composed mostly of thick limestones, occupy the area between the Elk and Bull Rivers. The Kootenay Ranges parallel the Rocky Mountain Trench between the Bull River and Canal Flats, and the Park Ranges occupy the northeast corner of the region between the Bull River and the Kootenay Ranges. Many of the mountains of the Park Ranges are composed of thick limestone and quartzite formations[4].

The Rocky Mountain Trench, lying between the Purcells and the Rockies, extends from Canal Flats to the international boundary (83 miles), and varies in width from 3 to 17 miles. On the east, the Rockies rise abruptly from the valley floor, while on the west the Purcells begin as rounded and wooded foothills which give way to rugged mountains. The trench is basically a longitudinal depression filled with very thick sedimentary and glacial deposits[1]. These deposits vary in depth from 1500 ft. near the St. Mary River to 4500 ft. at the Elk River. The Kootenay River has entrenched itself some 200 to 300 feet into these deposits in a channel which is ½ to 2 miles wide[1][5].

1.4 Soils and Vegetation

The soils and vegetation of the Lower Kootenay Region are typical of the patterns and relationships found throughout the East Kootenays. The nature of the regional landscape has been largely determined by the combined influences of glaciation, topography, and climate. At all but the very highest elevations, glaciation resulted in the deposition of glacial till, an unsorted, compact surficial deposit derived from the erosion of local bedrock. Tills of the Purcells are generally noncalcareous. On slopes greater than 60 percent, the till has generally been removed by erosion; these are now mantled by colluvium or remain as exposed bedrock[6][7]. On slopes of 30 to 60 percent, the till has been modified by downslope movements and additions. Brunisolic and podzolic soils have developed on these materials, and support stands of Engelmann spruce mixed with alpine fir along with bunchberry-moss and huckleberry ground covers.

At lower elevations and in the valley bottoms, the surficial materials include glaciofluvial outwash, kame, and lacustrine materials and alluvial fan and floodplain deposits. A variety of soils have developed on these materials. White spruce stands are common on the floodplains and on the fans along the Kootenay River. Grassland and ponderosa pine predominate on the coarse-textured, well-drained soils of the lower valleys where rainfall is limited and summer temperatures are high. In regions of higher rainfall, imperfect soil drainage, and northern aspect, stands of cedar, hemlock, and white pine are common. Because of widespread wildfires in recent years, about 50 to 65 percent of the lands in this region support immature stands of lodgepole pine.

1.5 Hydrology

1.5.1 Stream flow.

The Kootenay River enters the region at Canal Flats and follows a slightly meandering course along the Rocky Mountain Trench for about 50 miles to the mouth of the Bull River. Downstream from the Bull River, the Kootenay enters the northern end of the Libby reservoir (Lake Koocanusa) which occupies the remaining 42 miles of river channel between the Bull River and the international boundary[8]. The Kootenay River upstream of the international boundary was unregulated prior to the first pool raise behind the Libby Dam in 1972.

The major west bank tributaries of the Kootenay are Findlay Creek, Skookumchuck Creek, and the St. Mary River. The Lussier, Bull and Elk Rivers are the major east bank tributaries. Roughly 50% of the total flow leaving the region via the Kootenay River originates within the region, while Region 2 (Elk R.) and Region 3 (Upper Kootenay R.) each contribute about 25% of the total flow.

The seasonal flow patterns of the Kootenay and its tributaries are characterized by snowmelt flood peaks during May and June, followed by a steady decline in discharge during the summer and fall. The minimum flows occur during the period from December through March. About 65 to 75% of the mean annual flow of these streams occurs during May, June and July.

The Kootenay drains an area of 7,660 sq. miles[15] by the time it reaches the international boundary. The mean annual flow in the Kootenay at this point was 10,500 CFS prior to the formation of Lake Koocanusa[9]. The flows of the Kootenay and its major tributaries are summarized in Table 4-1.

1.5.2 Lakes

The lake of major importance within the region is Lake Koocanusa which was created during 1972 and 1973 by the Libby Dam in Montana. When the reservoir is full, it occupies 27.6 square miles[10] of the Kootenay River valley in British Columbia, extending 42 miles from the international boundary to the mouth of the Bull River[8]. At the average drawdown elevation, the reservoir shrinks considerably, occupying the Kootenay valley only to the mouth of the Elk River. When the reservoir is drawn down to its minimum elevation, it retreats below the international boundary and Lake Koocanusa disappears entirely in British Columbia[8]. Other lakes of local importance are Wasa, Tie and Rosen Lakes where settlements may affect water quality.

1.5.3 Groundwater

Information regarding groundwater in the region is limited to data from individual wells[13]. No attempt has been made to date to produce a comprehensive assessment of this resource in the region. Speculation based on the general physiographic nature of the area, precipitation data and some borehole analysis indicates that the Rocky Mountain Trench portion of the region should be capable of producing up to 500 GPM per borehole[11].

A report was prepared on a preliminary assessment of the groundwater resources in the Tobacco Plains area of the Rocky Mountain Trench (i.e., the area south of the Elk River and east of the Kootenay River)[5]. The report concluded that the shallow glacial outwash deposits of the area were the most promising source of groundwater. The report recommended a program of monitoring wells to evaluate the groundwater potential and the effects of the Libby Reservoir on these shallow deposits. The report also noted that groundwater may be available in the deeper sediments of the Trench, but that deep and costly wells would be required to reach it.

In the Cranbrook area, the quantity of water obtained from groundwater sources has been extremely variable, ranging from wells that were dry to others producing up to 1,500 GPM. The groundwater of the Cranbrook area is generally very hard, which is in contrast to the general rule that surface waters from the Purcell Range are very soft[11].

Data on individual wells in the region show that 50% of the wells in the region are located around Cranbrook while 10% are located around Kimberley. The remainder of the wells are located around the smaller settlements of the region as shown in Table 4-2.

1.5.4 Dams

The Aberfeldie Dam on the Bull River is the only major dam in the region. The Libby Dam, while not located in Canada, does have a significant effect on the water resources of the region as discussed in sections 1.5.1 and 1.5.2.

The Aberfeldie Dam is located on the Bull River 6 miles upstream from the mouth and its sole purpose is power production. It is a small installation, with a capacity of only 5 megawatts (MW). The Dam has only a small storage reservoir and thus may be classed as a run-of-the-river plant[34].

The Libby Dam is located about 50 miles below the international boundary in Montana, but its reservoir extends 42 miles into British Columbia[8]. The primary purposes of the dam are flood control, hydro-electric power production, and recreation. The powerhouse is scheduled to have a capacity of 420 MW by 1976, with an ultimate capacity of 840 MW[10].

1.6 Water Uses

An analysis of the water licences issued in the region by the Water Rights Branch of the British Columbia Water Resources Service [69] shows that water usage is allocated as follows:

Domestic	-	23.6	CFS
Industrial	-	135.3	CFS
Irrigation	-	42.8	CFS
Power generation	-	408	CFS
Fish culture	-	20	CFS
Land improvement	-	30	CFS

The cities of Cranbrook and Kimberley account for 94% of the licenced domestic water usage. The Crestbrook Forest Industries Limited pulp mill at Skookumchuck and the Cominco mining operations at Kimberley account for over 99% of the licenced industrial water usage. Irrigation water usage is licenced to numerous small users scattered throughout the arable lands of the region. The Aberfeldie Dam accounts for 86% of the water used for power generation. The Bull River Fish Hatchery uses the entire 20 CFS allocated to fish culture.

Streams for which no more licences can be issued, or on which there is a possible shortage of water include: Maguire Creek, Flag Creek, Bowman Creek, Mause Creek, Norbury Creek, Ta Ta Creek, Jim Smith Creek, Joseph Creek, Gold Creek, Booth Creek, Lockspring Creek, Ha Ha Creek, Chipka Creek, Radar Lake, and Ballard Swamp.

A detailed summary of the water licences issued within the region is contained in Table 4-3.

1.7 Settlements and Industrial Centres

The major settlements within the region are the cities of Cranbrook and Kimberley. The 1971 census showed that Cranbrook had a population of 12,000 and Kimberley a population of 7,643[12]. The 1971 populations of the settlements in the region are listed in Table 4.4. The total population of the region in 1971 was estimated to be about 25,000.

The industrial centres in the region are Skookumchuck with the Crestbrook Forest Industries Limited bleached Kraft pulp mill, and Kimberley with Cominco's Sullivan mine, concentrator, and fertilizer plant.

1.8 Land Use

1.8.1 Agriculture

The major agricultural activity in the Lower Kootenay River Basin is restricted to the areas around the Bull River, St. Mary River, Fort Steele, the Grasmere Valley and Sand Creek. Possible nutrient contributions were estimated only for fertilized, irrigated cropland and cow-calf operations. The data are given in Section 3.5. Other agricultural sources were considered to be relatively insignificant. The area is the second most intensively farmed area in the entire Kootenay Region. The farms are moderately sized (250 acres) with hay and cattle production being the main source of income. The majority of the farms are situated in close proximity to the receiving waters since the land suited for crop production is located in the flat valley bottoms leading to and including the Kootenay River Valley.

1.8.2 Forestry

There are three main centres of timber harvesting activity in Region 4[16]. One area occurs east of the Kootenay River and represents a southern extension of the major logging activities in Region 3. Recent logging operations in this area have centred around the Coyote, Lussier, Wildhorse, and Quinn Creek drainages. It is anticipated that within the next few years, there will also be cutting operations on the Bull River and Galbraith, Tanglefoot, and Van creeks. A second large concentration of timber harvesting operations is found in the Purcells to the west and south of Kimberley. Major watersheds likely to be influenced by these operations include the St. Mary River and Dewar, Reading, Meachen, Angus, Pitt, and Perry creeks. A third and somewhat smaller area influenced significantly by logging is found in the southern part of Region 4 in the vicinity of

Yahk River, Teepee Creek, Gold Creek, and Bloom Creek.

Logging activity in Region 4 is largely restricted to harvesting mature and overmature Engelmann spruce-alpine fir stands. Such stands cover only 10 to 20 percent of the area, however, and are found mostly at higher elevations. Christmas tree plantations represent an industry of moderate but declining importance in the Rocky Mountain Trench. Plantations occupy sites with coarse-textured, droughty soils between Canal Flats and Cranbrook.

1.8.3 Mining

The major mining development in Region 4 is Cominco Limited's Sullivan Mine near the City of Kimberley. This underground mine is one of the two largest lead-zinc mines in the world. Total production mined to December, 1971 was 104,750,000 tons.

All other mining operations in this region are closed with the possible exception of smaller gold placer operations. Mines which were in production included the Estella and Kootenay King mines east of Wasa and the Placid Oil pit mine at the southern end of the Bull River. The Placid Oil mine closed in 1972, the Estella mine closed in the mid fifties and the Kootenay King closed in 1953[17].

Region 4 is primarily classified by the B.C. Department of Mines and Petroleum Resources as having no known significant ore deposits. Map notes claim, however, that there does appear to be a favourable geological environment for exploration. Exploration is at an advanced stage in the area around the Sullivan mine, an area south of Kimberley and an area east of the Kootenay River from the St. Mary River north to about Skookumchuk[17].

1.8.4 Recreation

Some of the most significant recreational opportunities within Region 4, are centred about the Rocky Mountain Trench. The Canada Land Inventory (C.L.I.)[18] classifies over 850 square miles in an 8-12 mile broad strip along the Kootenay River below Canal Flats as Class 4 (moderate recreational capability) or better. The Bull, Lussier, lower Findlay and St. Mary River valleys, as well as scattered pockets of upland, also have recreational importance. Intensive water-oriented recreation is limited in general however, because of water level fluctuations, small size of lakes and lack of developed shoreline.

Areas selected by the 1965 ARDA B.C. recreation pilot project[19] as having particularly high capability include (see Figures 4-2 and 4-3) the Price Lakes group, Premier Ridge and vicinity, St. Mary Prairie and vicinity, and the complex of small lakes within the Trench south of Fort Steele. An additional group of miscellaneous sites includes lakes at higher elevations and sub-alpine areas such as Top of the World Park.

a) Price Lakes Group

Over 20 small lakes and tarns comprise the Price Lakes Group, situated within a 50 square mile sub-alpine forest to alpine meadow plateau between White and Dewar Creeks, which are tributaries of the St. Mary River. Access to the area is difficult.

This scenic alpine area is rated as Class 2 and 3 recreational land by C.L.I.[18], with emphasis on wilderness hiking, camping and viewing opportunities. The lakes have little importance for sport fishing.

35 square miles of this territory has recently been incorporated into St. Mary Alpine Park.

b) Premier Ridge and Vicinity

The area immediately east of Skookumchuk is a focal point for recreation in Region 4. About 25 square miles around Premier Lake is designated Class 2 and 3 capability[18].

Premier Ridge supports one of the largest winter big game populations in Canada[19], and has wildlife viewing and hunting potential. Shoreline access to lakes is considerably limited by private ownership on these lakes. However, Wasa (or Hanson) Lake and Provincial Park, 15 miles south of Premier Lake, though limited by small size, is intensively used for all forms of water-oriented recreation.

c) St. Mary Prairie and Vicinity

St. Mary Prairie consists of about ten small lakes in a unique setting near Cranbrook of natural grassland and open yellow pine. The area supports a variety of waterfowl and small game. Attractions include sport fishing, viewing of wetlands wildlife and waterfowl hunting. Fort Steele National Historic Park at the confluence of St. Mary and Kootenay Rivers has national historic interest and has been given a Class 1 rating by C.L.I.[18].

Nearby areas with recreational importance include North Star Hill, west of Kimberley, which is a popular ski site, and the St. Mary River which has good fishing, canoeing and streamside camping potential between Mark and Dewar Creeks. This potential is lost below Mark Creek (see section 4.2.2).

d) Southern Trench Lakes Complex

Numerous small, easily accessible fishing lakes provide the chief recreational attraction between Ft. Steele and the international boundary. These lakes vary in recreational potential. Most of them are too small for intensive use. Rosen Lake is highly popular, since it is the only one with shoreland capable of supporting family beach activities. However, public access is restricted due to private development.

The Bull River valley, like the Lussier River further north, has good camping, hiking and fishing potential. Rapids below the Aberfeldie Dam provide a scenic attraction.

e) Additional Sites

Several small fishing lakes are situated west of Kootenay River between Skookumchuk and the St. Mary River. Jim Smith Lake and Provincial Park, 4 miles southwest of Cranbrook, offers organized camping and a sandy beach.

The largest (2 square miles) and most accessible high elevation lake is St. Mary Lake. It also has most potential for intensive use, including fishing, boating, camping and cottaging.

Most upland territory in the region presents topographical and climatic restrictions to intensive recreation, although it is generally capable of sustaining dispersed activities such as hiking, hunting and viewing of scenery. The two notable exceptions are the Price Lakes group (discussed earlier) and Top of the World Park, established in 1974 above the Lussier River head waters. Situated on a 6000-7000 ft. plateau, this 31 square mile wilderness park offers outstanding opportunities for nature study and wilderness experience.

1.8.5 Wildlife

a) Fish

Most streams and lakes within the region support viable sport fisheries. Dolly Varden char, and Yellowstone cutthroat trout make up the majority of summer river catches in the Kootenay and its tributaries. There is an important recreational winter whitefish and ling fishery in the Kootenay River.

Many of the lakes are stocked from the Fish and Wildlife Branch hatchery near Wardner. Species locations[20] are given in Table 4-5.

b) Waterfowl

Wetlands with capability for waterfowl production occur intermittently along the Kootenay River terraces and floodplain. Lake and river marshes are limited in extent and usefulness by topography and associated factors such as flooding, excessive water depth, inadequate marsh edge and dense forest cover. However, a short season and restricted public access due to agricultural development on most of the prime bottom land combine to reduce hunting pressure on the few productive areas.

The most productive wetlands are located on St. Mary Prairie (60% Class 2 and 4)[21] and south of Wardner (pockets of Class 3 and 4, mostly adjacent to the small lakes in the southern Trench complex). Other areas with some productive capability are scattered south and west of Cranbrook and immediately north of St. Mary Lake.

Common migrants include Mallard, Baldpate, teal, pintail and goldeneye, and small numbers of Canada geese.

c) Big Game

The Rocky Mountain Trench in Region 4 provides prime ungulate winter range, particularly along the east side of the Kootenay River. Within this portion of the Trench, the highest ungulate population concentrations are in the vicinity of Premier Ridge and the lower Bull River valley.

2. INDUSTRIAL EFFLUENTS AND SOLID WASTES

The major industrial effluent discharges in Region 4 are from the Crestbrook Forest Industry Ltd. bleached kraft pulp mill at Skookumchuk and the Cominco Ltd. complex near Kimberley. Both of these operations are described in the following sections. Other industrial effluents on record with the Pollution Control Branch include gravel washing, concrete wash-up, a trout hatchery and a sawmill. Data from the pollution control permits or applications for permit are summarized in Table 4-6.

2.1 Crestbrook Forest Industries Ltd.

2.1.1 Description of the Process

Crestbrook Forest Industries Ltd. built a kraft pulp mill in 1967-1968 at the junction of Skookumchuk Creek and the Kootenay River (Figure 4-2). The mill produces 400 tons per day of bleached kraft pulp, but the possibility of expansion is presently being investigated. The total volume of effluent discharged to the Kootenay River is approximately 11 million gallons per day. The following sections describe the process used at the mill and explain the sources of effluent.

a) Pulping and Washing of Unbleached Pulp

Chips for the pulping process are purchased from sawmills in the area. These chips are a mixture of about 55% spruce, 30% pine and 15% other woods. Simplified process diagrams are presented in Figures 4-4, 4-5 and 4-6. These diagrams outline the main component processes in the pulping and bleaching operations and also indicate the main sources of effluent, air emissions and solid wastes.

The chip mixture from the stockpile is screened to eliminate fines. The screened chips are fed to the presteamer then to a continuous Kamyr digester. The fine material is trucked to a refuse dump. The chips are cooked at high pressure and temperature with kraft liquor and then washed for about four hours at high temperature and pressure in the lower section of the digester. Extracted cooking liquor (black liquor) which contains the majority of the extracted lignin and other organic residue is discharged to a flash tank.

When the cooking liquor is discharged to atmospheric pressure in the flash tanks it produces steam which is highly contaminated with organics and other gases. These gases and relief gases from the digester are partly used for chip pre-steaming. The remaining gases are condensed in the flash steam condenser. The non-condensable fraction is a source of air emissions. The condensate is partially sewered, but the bulk of the condensate is returned to the digester for washing.

The pulp is discharged from the digester via a blow-tank. The pulp still contains a large amount of black liquor which is largely removed in a diffusion washer. Liquor removed in this washing operation is not sewered, but is partly reused, in countercurrent fashion, in the Kamyr digester washing operation. The washed pulp is diluted with recycled white water from the bleachery and machine room for further screening and washing. The pulp is screened to remove knots and shives which are returned to the digester. Three primary and one secondary brown stock screens,in combination with primary and secondary centricleaners,remove smaller shives, sand and other foreign material from the pulp prior to bleaching. Rejects from the secondary centricleaners are sewered. The volume sewered here is low, but this stream is highly contaminated with suspended solids. A brown stock decker removes much of the wash water from the pulp. The wash water overflows to the general sewer. This sewer accounts for approximately 40% of the total mill effluent. The wash water, discharged from the unbleached white water tank, forms the major flow in the general sewer.

b) Recovery

The liquor washed from the cooked pulp and flashed from the digester, is called weak black liquor. The liquor is oxidised in a tower by a countercurrent stream of air. The oxidised weak black liquor is stored, and at this point tall oil soap, which rises to the surface of the liquor, is skimmed off. The recovered soap is shipped out for processing.

Separation of tall oil soap, which contains the salts of fatty and resin acids, is through gravity and complete separation is not achieved.

The oxidised weak black liquor is evaporated in a Swenson five effect evaporator to remove much of the water. The condensate from the evaporators is contaminated by entrainment and distillation of volatile components. The condensate can be used to wash the pulp in the diffusion washer or as make-up in the recausticising plant, but may be sewered. The concentrated or strong black liquor is further evaporated in twin cascade direct contact evaporators to a concentration of 55 to 65% solids. The concentrated liquor is burned in a Mitsubishi C-E recovery boiler which has a capacity to recover 1,760,000 lb. of dry solids per day. Combustion gases from the recovery boiler are used as the source of heat in the direct contact evaporators. Much of the particulate matter in the exhaust gases from the direct contact evaporators is removed by a Cottrell Electrostatic Precipitator with a wet bottom stage. The solid material is dissolved in black liquor and reinjected into the recovery boiler. The gases are emitted via the main mill stack.

The molten ash or smelt from the recovery boiler consists mainly of sodium carbonate and sodium sulfide. The smelt is dissolved in make-up water, recycled from the lime mud washer, to form green liquor. Insoluble dregs are trucked to a refuse site. The green liquor is reacted with lime in a causticzer to form white liquor, which is separated from the calcium carbonate also formed in the reaction, and recycled to the digester as fresh kraft pulping liquor. The calcium carbonate, or lime mud, is washed and returned to a Dorr Oliver calciner with make-up limestone to produce calcium oxide. The calcium oxide is slaked and reused in the causticizer in making white liquor.

c) Bleaching and Sheet Formation

The pulp is bleached in Kamyr upflow high density towers. The bleaching sequence in use is CEDED (Chlorine, Extraction, chlorine Dioxide, Extraction, chlorine Dioxide). Crestbrook uses Kamyr continuous diffusion washers on the top of the bleaching towers rather than the displacement type washers used by other B.C. mills. Effluent from the first caustic extraction stage contains approximately 80% of the total colour in the mill effluent. Wash water from the two caustic extraction stages is discharged to the alkali sewer. Wash water from the initial chlorine stage and the chlorine dioxide stages is sewered via the acid sewer. The alkali sewer is approximately 25% of the total mill effluent and the acid sewer approximately 30%. The acid sewer is partially neutralised before mixing with the alkali sewer and with the general sewer. The combined sewers, now called the process sewer, are discharged to either of two parallel settling basins and thence to an aeration basin. The external treatment system is described in the following section. The bleached pulp is blended with white water and broke in a blending chest, and screened by three parallel primary Centriscreens followed by one secondary Impco screen. Rejects from the Impco screen are sewered. The bleached pulp is cleaned via four primary Radiclones followed by one secondary and one tertiary Radiclone. Rejects from the tertiary Radiclone cleaner are sewered. White water from the cleaning operations is recycled to the bleached white water tank. This white water is reused in cleaning the bleached pulp, diluting the pulp from the Kamyr brown stock washer, and for diluting the bleached pulp to the required consistency in the machine chest for use on the pulp machine.

Crestbrook Forest Industries has a Mitsubishi-Beloit fourdrinier pulp machine equipped with a suction press and a Ventra-nip press. White water from the pulp machine is largely recycled to the machine chest, but some excess is sewered via the general sewer. The pulp sheet is dried via a Flakt drier. About 136,000 tons of pulp are produced each year.

d) Effluent Treatment Facilities

The three main sewers from the mill, the alkali sewer, the acid sewer and the general sewer are combined into one flow called the process sewer. In addition, some miscellaneous discharges and effluent from the emergency spill basin are added to the process sewer. This process sewer discharges to one of two parallel settling basins, each 150' X 1400' with a maximum depth of 10'. The settling basins are used alternately, one basin is cleaned out while the other is being used. Solids removed from the settling basins are trucked to a refuse site.

Overflow from the settling basin is discharged over a riffle structure to a 33 acre aeration basin which has a retention time of approximately seven days with a flow of 11,000,000 Gallons per day and an average depth of nine feet. Nutrients in the form of fertilizer are added to the aeration pond to assist in the biological oxidation of the organic wastes.

The aeration pond was originally equipped with nine 25 HP surface aerators, but an additional seven aerators have been installed. Effluent from the aeration basin is discharged to the Kootenay River via a submerged diffuser. The outfall extends over 200 feet into the river and is equipped with 20 nozzles.

e) Pollution Control Permit PE-240

The B.C. Pollution Control Branch issued Permit PE-240 to Crestbrook Forest Industries on August 12, 1968. The permit allowed an average discharge of 15,000,000 GPD with a quality equivalent or better than the values listed in Table 4-7. These values were based on an average water usage of 37,500 gallons per ton of pulp produced and an average pulp production of 400 tons per day.

Additional conditions of the permit included:

(i) The effluent is to be regularly analyzed.

(ii) The receiving water is to be regularly analyzed both above and below the discharge.

(iii) Nutrient addition to the aeration pond is to be controlled so that excess nutrients are not discharged to the Kootenay River.

(iv) If foam, colour, taste or odour resulting from effluent discharged becomes a problem, additional treatment would be required to correct the situation.

On October 8, 1971 the Director of the Pollution Control Branch informed Crestbrook Forest Industries that the quality of the receiving waters below the mill was objectionable for extensive periods of time each year. The Director ordered Crestbrook Forest Industries to increase their degree of treatment to comply with limits set out as Level A in the Forestry Objectives(22) and to provide treatment to reduce the colour in the effluent by August 12, 1975.

f) Some general Methods for Reducing Effluent Colour and Toxic Components

The mill has been investigating various methods to reduce the colour of their effluent. Removal of colour from the total mill effluent is relatively expensive because of the large effluent volume involved. The first extraction stage from the bleachery contains up to 85% of the total effluent colour. It is therefore much easier to remove the colour from this smaller stream, since much smaller process equipment is required. Various publications outline the colour removal techniques in use by the industry [23,24]. Present methods involve some additional cost to the mills, ranging from \$1 to \$10 per ton of pulp produced. It is up to each individual mill to determine which method can be best used in their particular situation.

Crestbrook have outlined to the Pollution Control Branch plans to remove much of the contamination which is contained in the condensate from the black liquor evaporator. Various studies at similar mills[25] have shown that this condensate is extremely toxic and contains very high concentrations of sulfur-containing compounds which contribute to the hydrogen sulfide smell of the receiving water. These compounds are also thought to be the main cause of the tainting of fish in the receiving water[26] downstream of pulp mills. Digester flash steam condensate also contains similar contaminant material as those in black liquor evaporator condensate, but at lower concentrations. Crestbrook have plans to recycle all of this condensate. Condensates from the five-effect evaporator contain mainly water and methanol so that these condensates can be used in pulp washing, liquor preparation, etc.

Black liquor oxidation can be applied to the weak black liquor (as at Crestbrook Forest Industries) or to concentrated black liquor. The choice is often dependent on the foaming characteristics of the liquor. The efficiency of weak black liquor oxidation appears to be poor in most cases. Reversion often produces sulfides, even though initial oxidation may be more than 99% effective. The overall efficiency in sulfide reduction has been found to be better in mills which have installed concentrated black liquor oxidation. Current new-mill technology also includes designs which eliminate the direct contact between the black liquor and the flue gases from the recovery furnace.

Various mills have installed systems using air or steam to strip the malodorous constituents from the condensate. These stripped gases are burned in the lime kiln.

2.1.2 Presentation of Effluent Sampling Data

Since 1973, Crestbrook Forest Industries has been reporting to the Pollution Control Branch the daily results from their sampling program. A summary of these results for 1973 and 1974 are presented in Table 4-8. The results from the Biological Oxygen Demand (BOD_5) test as performed by Crestbrook can probably be compared directly with the results of the test performed by the B.C. Environmental Laboratory. The Suspended Solids test, however, is not the same one as performed by the Environmental Laboratory and results should not be compared. Crestbrook's results should only be used to detect relative changes in the mill's operating procedures which change the amount of suspended solids. The bio-assay test was conducted on Crestbrook's effluent by B.C. Research until November, 1974, using the same standard procedure as used by the Pollution Control Branch. Hence, results should be directly comparable. Since and including November, 1974, the bio-assays have been conducted by Beak Consultants using a similar method.

The Pollution Control Branch, starting in late 1972, regularly sampled and analyzed the effluent from Crestbrook Forest Industries on a monthly basis. A summary of these data is presented in Table 4-9. The location of the effluent sampling point is immediately after the biotreatment basin as it overflows to the discharge pipe. All analyses were performed by the B.C. Water Resources Environmental Laboratory. We have also presented, in Table 4-9, some of the permit limits as set out in Pollution Control Permit PE-240,issued to Crestbrook Forest Industries.

2.1.3 Discussion of Effluent Sampling Data and Recommendations

The Pollution Control Branch, in Permit PE-240, has set maximum limits for concentrations of many parameters in the effluent from Crestbrook

Forest Industries Ltd. (Table 4-7). These limits apply to daily composite samples of effluent from the mill.

The average of the year's sampling data obtained by the Pollution Control Branch, is compared with the permit limits in Table 4-9 for 1972 to 1974.

a) Suspended Solids

The suspended solids level in the effluent has usually been much higher than the limit set out in Pollution Control Permit PE-240 and has increased by more than 50% since 1972 (74.8 mg/l in 1972 compared to 121.8 mg/l in 1974). The increase may be caused by loss of capacity in the settling basin as the result of solids deposited over a length of time. The increase may also be due to more efficient biological oxidation resulting in an increased discharge of insoluble biomass.

The suspended solids in a pulp mill discharge can have a detrimental effect on the receiving water. Organic material on settling to the bottom can decompose and thus lower the dissolved oxygen content of the water. Both organic and inorganic material can blanket the bottom of a river and either smother organisms which normally inhabit these areas, or change the substrate. Biological data gathered so far do not indicate that suspended solids have had a direct influence on benthic invertebrates or periphyton (Chapter 5).

b) Dissolved Solids and BOD_5

The amount of total solids in the discharge from 1972 to 1974 was also well above the limits set out by the Pollution Control Permit PE-240. The values, however, have not increased over the last three years as the suspended solids have. The total solids includes the suspended solids, but the largest fraction is dissolved solids. The dissolved solids level in the effluent reflect, to a large extent, mill operation and housekeeping. The results indicate that there have been no major changes since 1972. The adverse effects caused by dissolved solids in pulp mill effluent are much more difficult to evaluate than the effect of suspended solids. Pulp mill effluent can cause foaming, fish tainting, and algae growth in the receiving water. However, it is thought that these problems are associated with constituents present in pulp mill effluent in very small amounts. These constituents form a negligible fraction of the dissolved solids. A large proportion of the dissolved solids in pulp mill effluent is made up of inorganic salts which are used or formed in the pulping and bleaching processes. The materials are mainly sodium and calcium sulphates, carbonates and chlorides. These compounds usually have very little detrimental effect on the receiving water. There may be some problems associated with salts such as nitrates and phosphates because of their nutrient value, but the amount normally present in pulp mill effluent is small.

The other major fraction of the dissolved solids is organic compounds which are extracted from the wood during pulping, washing and bleaching processes. The organic materials can be considered in two fractions. One fraction is made up of short chain carbohydrates and other simple organic compounds which are easily oxidised. This type of material constitutes the major Biological Oxygen Demand (BOD_5) load discharged from a pulp mill. The components are usually removed from the effluent in biological treatment systems. The other fraction of the organics comprises larger, more complex molecules, arising mainly through reaction and dissolution of the lignin in the wood. This fraction is not readily decomposable, so is not removed to any extent by biological treatment facilities. This fraction is also highly coloured and is the major cause of colour in the discharge from a pulp mill.

The BOD_5 results for the effluent during 1972 and 1973 were higher than allowed by the Pollution Control Branch Permit. Values have been decreasing and during 1974 the average was lower than the permit limit of 60 mg/l. This result is probably due to improved operation of the biological treatment facilities.

c) pH, Temperature, Colour and Other Contaminants

The pH, temperature, and sulphide concentration have been within limits set out in Permit PE-240 since 1972. The resin acid values have also been within acceptable limits, except for some high values during

1973, probably due to upsets in the mill process. The higher values of resin acid concentrations during 1973 were also probably related to the poor bio-assay results during this period (Table 4-8).

The major problems associated with the effluent are the discolouring of the river which is objectionable from an aesthetic point of view, and the changes in the biota of the Kootenay River (Chapter 5). The dark brown colour of the discharge causes the water to be discoloured for a long distance downstream of the outfall (Chapter 4). Fish caught downstream of the pulp mill were tainted and had a bad odour (Chapter 5). The tainting of fish and the effects of effluent on invertebrates and periphyton, documented in Chapter 5, are thought to be due to certain constituents of the effluent. These include methyl mercaptan, sulphides, chlorinated organics, resin and fatty acid soaps. The contaminants are present in low concentrations in the effluent and are difficult to measure accurately. After dilution with receiving water their presence cannot usually be detected by present analytical techniques, although biological effects were apparent.

d) Recommendations

The Company and the Pollution Control Branch are preparing a program to reduce colour in the mill effluent. Techniques involving both process changes and additional effluent treatment will be reviewed before methods are selected for mill trials. Systems which may be considered include lime precipitation, ion exchange, activated carbon, alum treatment, oxygen bleaching, solvent extraction, foam separation and bleaching of the first caustic extract. We recommend that special consideration be given to oxygen bleaching with recovery of the oxygen effluent via the weak black liquor circuit. This process change could combine high colour removal with some economic benefit. We do not recommend methods that cannot reduce chlorinated organics, such as chlorine bleaching of the effluent.

If the process chosen for colour removal treats the total mill effluent, the other contaminants present in low concentration may be removed with the colour. However, it is more likely that selected effluents from the bleach plant will be treated for colour removal. Such a scheme could also remove chlorinated organics. In this case we recommend that measures be taken to eliminate the other contaminants from the effluent. The measures may include the containment of spills with provision to return spilled liquor to the process, the stripping of volatile contaminants from condensates which are sewered, more effective black liquor oxidation and tall oil recovery.

We recommend that the routine monitoring carried out by the Company and the Pollution Control Branch be continued.

2.1.4 Solid Waste Disposal

a) Description of the Disposal Sites

There are two solid waste disposal sites at the pulp mill. Site A occupies an area of about 1/3 acre and receives an average of five cubic yards/day of office garbage, contaminated waste pulp and shop wastes. Site B occupies an area of about 15-20 acres and receives an average of 240 cubic yards/day (30 tons/day) of wood chip fines plus 1700 cubic yards/day (for 21 days per year) of solids (wood fibre and lime mud) dredged from the effluent settling ponds. Crestbrook applied for a pollution control permit (Application number AR-1756) for these two sites in August, 1972. On April 23, 1975, the Pollution Control Branch issued Permit PR-1756 for site A, but refused to issue a permit for site B. Site B was to be closed and the site rehabilitated as ordered by the Regional Manager.

Site B is located on the floodplain of the Kootenay River about 1000 feet west of the river channel. The groundwater table is at or near the ground surface, and during a year of high runoff, such as occurred in 1974, flood waters enter the landfill site. Site B has been in use for about five years (1970-1974 inclusive) and thus, theoretically 600,000 cubic yards (260,000 tons) of chip fines and dredged solids may have been deposited. A summary of pertinent information regarding sites A and B is contained in Table 4-10

b) Monitoring Data

One grab sample of the water standing around the waste chip fines deposited in site B was analysed. The results are given in Table 4-11.

c) Evaluation and Recommendations

The potential at site A for adverse effects on groundwater or surface water is considered to be nil because of the great depth to the water table, the considerable distance to surface water or water wells, and the excess of evapotranspiration over precipitation (see Table 4-10).

At site B, there is a large, leachate-contaminated pool between the landfill and the aeration basin, and several small pools around the perimeter of the landfill. These pools are stagnant and located more than 800 feet from the Kootenay River channel. The analysis, shown in Table 4-11, of a grab sample from the large pool indicates that the water is heavily contaminated with leachate-type substances. These leachates could enter the Kootenay River during a year of high runoff if flood waters extended across the floodplain and intercepted the leachate pools. The volume of leachate in the pools is very small in comparison to the flow in the Kootenay River necessary to flood the landfill site (more than 20,000 CFS). Therefore, the potential for adverse effects on the Kootenay River due to flooding is judged to be negligible. The possibility of leachates reaching the Kootenay River via groundwater flow is judged to be remote since leachates would have to travel for at least 800 feet through fairly impermeable river silts. Any seepage that might occur would be insignificant compared to the discharge of 20 CFS of kraft mill effluent from the aeration basin adjacent to the landfill.

No further monitoring is recommended at these landfills during Phase II.

2.2 Cominco Ltd.

Cominco Ltd. owns and operates the Sullivan Mine, a concentrator, and a phosphate fertilizer plant at Kimberley. They also own a plant for production of iron from concentrate, but this operation has been shut down since 1972. High grade ore, consisting of approximately 45% sulphides of lead, zinc and minor amounts of other metals are now obtained from deep within the Sullivan Mine. The ore is crushed underground and is shipped to a concentrator which removes the majority of the waste rock. Waste rock is used for fill in the mined out areas. The concentrated ore is processed and separated in flotation cells into lead, zinc, tin and iron concentrates and waste. The high grade lead and zinc concentrates are shipped to the Company's smelter in Trail. A portion of the iron concentrate is used in the fertilizer plant in Kimberley and the remainder is stockpiled in a tailing pond. The tin concentrate is marketed.

A schematic diagram showing the approximate locations of these operations is shown in Figure 4-7. Also shown on this diagram are surface streams and effluents which originate from these operations. These streams will be discussed in detail in the following sections.

2.2.1 Description of the Processes

a) The Sullivan Mine and Proposed Effluent Treatment

The Sullivan Mine is located near Kimberley. Ore was discovered in 1892 and the mine was initially worked as a surface mine. The mine is now completely underground with two main adits, one at the 3900 foot level and the other at the 3700 foot level. The former is primarily for miner access and the latter for ore removal.

The ore is composed mainly of siliceous rock and sulphides of lead, zinc and iron. From 1900 to 1973, total production was 7.18×10^6 tons of lead, 6.25×10^6 tons of zinc, 4,965 tons of copper and molybdenum and 24.2×10^6 ounces of silver. Total reserves are estimated at 1.09×10^6 tons of lead and 0.89×10^6 tons of zinc, and 38.0×10^6 ounces of silver.

Mining is presently by the pillar technique with backfilling to allow pillar removal. Ore is crushed underground and shipped four miles to the Cominco concentrator. Waste rock from the mining operation has been dumped in four disposal sites covering 96 acres. Due to its acidic nature the rock does not support plant growth.

Water enters the mine by groundwater seepage and by surface water infiltration. Water collected below the 3,500 foot level is used as service water in the mine. Above this level, the water is acidic because of the interaction of water, sulphide ores and air. The acidic water is pumped to the surface and discharged to Mark Creek mostly from the 3900 foot portal (Figure 4-7). Some mine drainage is discharged to Kimberley Creek from the 3700 foot portal. Crusher plant cooling water and sanitary wastes from the underground toilets are mixed with acid drainage and pumped to the surface and are included in the 3900 foot discharge.

Above ground, waste water originates mainly from surface drainage, domestic sewage, mine car shop wash water, compressor cooling water, and change room showers. Surface streams 1, 2 and 3 (Figure 4-7) discharge to Mark Creek and are the result of runoff from waste rock piles. Mine car shop wash water, compressor cooling water, and change room effluents are discharged without treatment to Mark Creek as separate effluents (Figure 4-7). Domestic sewage is treated by septic tanks and tile fields.

The amendment to Pollution Control Permit PE-189, issued October 9, 1975, covers all underground and surface discharges from the mine. The permit authorises an annual average discharge of 1,500,000 GPD to Mark Creek and a daily maximum of 300,000 GPD to Kimberley Creek. The effluent characteristics are to be upgraded by the end of 1977 to meet at least level B of the Mining Objectives[27]. Permit details are summarized in Table 4-12. In order to meet the permit conditions the Company plans to combine the mine drainage from the 3900 foot portal, the surface streams, the mine domestic wastes and shower water, and to treat the total effluent before discharge to Mark Creek.

The proposed effluent treatment process is shown, in simplified form, in Figure 4-15. Heavy metals will be precipitated by raising the pH of the effluent with limestone and lime in two separate reactors. Air and chlorine will also be used to oxidise iron and manganese to form insoluble compounds. The sludge is to be separated from the treated effluent in a thickener and partially recycled to the reactors. Excess sludge will be disposed of in the siliceous tailing pond.

The mine drainage from the 3700 foot portal is expected to meet level B objectives without treatment. The improvement in effluent quality will be due to diversion of mine crusher water from the 3700 foot portal discharge, to the 3900 foot portal discharge. The diversion was made in April 1975.

b) The Sullivan Concentrator

Crushed ore from Cominco's Sullivan Mine is shipped by rail to the concentrator plant about four miles from the mine (Figure 4-7). The original concentrator was started in 1923 to treat 2500 tons of ore per day, but modifications and enlargements have resulted in a plant capacity of 10,000 tons of ore per day.

The crushed ore first enters the sink and float plant (flow diagram Figure 4-8). Waste rock is separated from the ore by floating the rock in a heavy medium. A slurry of galena is used as the heavy medium. The ore sinks, is crushed and ground, and sent to the lead circuit for further separation. Waste rock floats and is used as mine backfill. The heavy medium is recovered for re-use and a portion of the water is recycled. Overflow from a fines thickener is pumped to the 165 acre siliceous tailing pond.

The ore from the sink and float circuit is ground to a flour fine size, suspended in water and subjected to flotation to give lead, zinc, iron and tin concentrates. In the flotation process, a froth is formed and sulphide mineral particles attach themselves to the air bubbles. The froth is separated to recover the mineral concentrate. Chemicals, called conditioners, are used at low concentrations to allow selective attachment of minerals to the air bubbles. Lime and sodium cyanide are used to depress zinc and iron sulphide and to float lead sulphide. Copper sulphate is used to increase the floatability of zinc sulphide over iron sulphide. Frothers, such as pine oil, are used in small amounts to stabilize the formation of air bubbles. Collectors, such as xanthate, are used to increase the adhesion of sulphide mineral particles to the air bubbles.

Simplified flow diagrams, showing the separation of lead and zinc sulphides, are given in Figures 4-9 and 4-10. The concentrates are dewatered in thickeners, and the zinc concentrate is passed through a drier. Both concentrates are shipped to the Company's Trail smelter. Water is recovered for recycle. A flow diagram for the iron and tin circuits is presented in Figure 4-11. The iron concentrate is separated by flotation and is partly used in the fertilizer operation to generate sulphuric acid. Unused iron concentrate is stored as a slurry in the 580 acre iron sulphide pond which overflows to James Creek. Tin concentrate is separated by a gravity process and marketed. Fines from the iron and tin circuits are pumped to the siliceous tailing pond which also overflows to James Creek.

The discharges from the siliceous and iron ponds are covered by the recently issued amended Permit PE-189. The permit authorizes annual average discharges of 1,200,000 GPD from the siliceous pond, and 600,000 GPD from the iron pond to James Creek. Effluent characteristics are to meet at least level B of the Mining Objectives[27] by the end of 1977. Permit details are summarized in Table 4-12.

Since 1973 iron sulphide has been sent to the siliceous pond due to weaknesses in the iron pond dykes. The dykes are being rebuilt and by the end of 1975 the iron sulphide will be discharged to the iron pond.

Surface runoff from an area north of the siliceous and iron ponds enters the ponds and increases the effluent overflow rate. The Company plans to build diversion ditches to channel runoff water to a small pond, known as the fire pond, which is adjacent to the iron pond. Water from the fire pond will be recycled to the concentrator. Completion date for the improvement is the end of 1975. Further reductions in the rate of effluent decant from the ponds is planned for the end of 1977 by dewatering siliceous and possibly iron tailings prior to disposal in the ponds. Water will be re-used in the concentrator. Modifications will also be carried out to recycle concentrator spills to the process.

To meet the effluent characteristics specified in the Permit, the overflow from the iron and siliceous ponds may require treatment before discharge to James Creek. The limestone-lime treatment, described in section 2.2.1.a, would be used, if necessary, and would be operational by the end of 1977.

The Company is experimenting with revegetation of portions of the filled ponds. Vegetation would improve the aesthetics of the area, increase water losses from the ponds to the air and stabilize the waste material.

c) Fertilizer Production

In 1953, Cominco Ltd. started up a fertilizer plant which was subsequently expanded in 1963 and 1965. The current yearly production is 166,000 tons of fertilizer. This production requires daily processing of 800 tons of iron sulphide and 1170 tons of phosphate rock. Iron sulphide is obtained from the Sullivan mine and concentrator as described in sections a and b above. Phosphate rock is obtained from Cominco owned mines in Montana, U.S.A., and ammonia from the Cominco Calgary plant. Simplified process flow diagrams of the plants are given in Figures 4-12 for the sulphuric acid plant, 4-13 for the phosphoric acid plant and 4-14 for the fertilizer plant.

The process consists of roasting iron sulphide to produce sulphur dioxide gas, conversion of sulphur dioxide gas to sulphuric acid, reaction of sulphuric acid with phosphate rock to produce phosphoric acid, and reaction of phosphoric acid with ammonia to produce the fertilizer, ammonium phosphate.

To produce sulphuric acid, the iron sulphide slurry from the concentrator is dewatered (Figure 4-12) and the excess sluicing water goes to Mark Creek via sewer 32. The iron sulphides are roasted with air to produce sulphur dioxide gas and iron oxide, called calcine. The iron oxide is stored in the calcine pond (Figure 4-7). The sulphur dioxide gas passes through a waste heat boiler, scrubbers and electrostatic precipitators. The gas is dried with concentrated sulphuric acid and oxidized with air to form sulphur trioxide in special converters containing a vanadium catalyst. The sulphur trioxide is absorbed in water plus acid to produce sulphuric acid. The acid is used in the phosphoric acid plant. Effluents which originate from scrubbers, demisters, acid spills and floor washings generally flow to Mark Creek via sewer 32. Sluice water carrying calcine to the calcine pond formerly overflowed to the gypsum pond.

The amended Pollution Control Permit PE-189 requires elimination of overflow from the calcine pond, effective August 31, 1976. This will be achieved by installing calcine dewatering facilities and recycling the water to the plant. Other acidic effluents, including scrubber waters, plant spills, floor washings, etc., will be taken out of sewer 32 and sent to the calcine pond. In cases of emergency these effluents will be discharged to the north pond (Figure 4-7). There will be no overflow from either the calcine pond or the north pond. The quality of iron sulphide sluicing water will be improved by the installation of an iron sulphide sluicing pond to settle contained solids. Pond overflow will be discharged to sewer 32. The project is due for completion by August 31, 1976.

In the phosphoric acid plant (Figure 4-13) phosphate rock from the mine is crushed and dried. Exhaust from the drier is scrubbed with water and the effluent is discharged via sewer 32. The phosphate rock is reacted with sulphuric acid (generated from the iron sulphide) to produce phosphoric acid and gypsum. The reaction liberates silicon tetrafluoride from a fluoride salt present in the phosphate rock. The silicon tetrafluoride and entrained acids are scrubbed from the exhaust gas with water and the effluent is discharged to sewer 32. The gypsum is separated from the phosphoric acid with filters and the acid is washed from the gypsum crystals. The wash is returned to the process and the gypsum is discharged, in slurry form, to the gypsum pond. Phosphoric acid is concentrated by evaporation then used in the fertilizer plant. Evaporator condensates, which can be contaminated with acid, are discharged through sewer 32.

Liquid ammonia is vapourised to gaseous ammonia in the fertilizer plant (Figure 4-14). Gaseous ammonia is reacted with concentrated phosphoric acid to form a slurry of ammonium phosphate. Fertilizer granules are formed by contacting recycled granules with the slurry in a blunger. The granules are enlarged by a coating of slurry, dried, screened and sent to bulk storage. Vapors from the phosphate reactor, blunger and drier are scrubbed with water and the effluent is discharged to sewer 32.

All discharges from the phosphoric acid plant and fertilizer plant are now covered by the amended Pollution Control Permit PE-189. Until 1975 the gypsum pond overflowed to James Creek. The permit stipulates no overflow by September 30, 1975, and this overflow has now ceased. This was achieved by recycling pond supernatant to the plant for re-use. A cooling pond was installed in the recycle line to precipitate excess fluoride and prevent fluoride build-up in the circuit. Facilities for collection and return of pond seepage are also being installed.

The amended Permit PE-189 authorizes a daily maximum discharge of 6,000,000 GPD in sewer 32 to Mark Creek. The effluent characteristics are to meet level A of the Mining Objectives[27] for all contaminants, by the end of 1977, (Table 4-12). This will be achieved by a series of in-plant changes which will consist mainly of recycling scrubber and impinger effluents, collection of spills and recycling of condensates. Effluent from the phosphate rock plant will be improved by settling in two phosphate rock ponds before discharge to the sewer. As mentioned previously, the iron sulphide sluice water will be clarified before discharge, and all other effluents from the roasting and sulphuric acid plants will be removed from sewer 32. Additional unspecified treatment of the effluent may be required by the end of 1977 if the measures described above do not bring the effluent within permit limits. Sanitary wastes from the phosphoric acid plant, which now flow to sewer 32, will be treated.

d) Iron and Steel Plant

Cominco Ltd. started production of pig iron in 1961 and steel in 1966. Production capacities in 1966 were 110,000 tons of pig iron per year and 80,000 tons of steel per year. A portion of the pig iron plant and the steel plant closed in January 1971, and the rest of the iron plant closed in August 1972. There are currently no plans to reactivate either plant.

e) Historical Summary of Pollution Control at the Cominco Operations

In 1953, Cominco began discharging gypsum waste to an impoundment pond adjacent to the St. Mary River. With the agreement of the Provincial Department of Recreation and Conservation the Company undertook to store waste for 10 months of the year, and to discharge the impounded material to the St. Mary River during freshet. In following years the load to the gypsum pond increased, from 375 tons dry weight daily in 1960 to 1800 tons dry weight daily in 1966. The pond was unable to store the increased load and the discharge of gypsum to the river became continuous.

Cominco applied for a permit from the Pollution Control Branch, in May 1967, to discharge 2500 GPM of phosphate contaminated water from the gypsum pond to the St. Mary River. Permit PE-189 was issued July 1967 for the discharge. The permit was amended in February 1968 to allow an increase in volume discharged to 2900 GPM. At this time the overflow from the gypsum pond joined the overflows from the siliceous pond and the iron pond, and the total effluent was discharged to James Creek and hence into the St. Mary River.

In 1970 Cominco registered additional discharges associated with the mine, concentrator and fertilizer plant. In January 1972, the Pollution Control Branch ordered the Company to prepare a schedule of works to upgrade the effluent quality. A program was submitted in June 1972 to achieve limits of effluent quality set by the Branch. Cominco then applied for an amendment to Permit PE-189, in July 1973, which covered discharges from all operations. The amended Permit PE-189 was issued October 9, 1975 , and covers all discharges. Permit conditions are discussed with the plant descriptions, and are summarized in Table 4-12. A comprehensive monitoring program is to be carried out by the Company as a condition of the permit. The program includes sampling of all major effluents and receiving water on either a weekly or monthly basis depending upon the parameter. Biological monitoring of the St. Mary River is also required and will include bioassays, benthic sampling and periphyton sampling.

2.2.2 Effluent Sampling Data: Discussion and Recommendations

a) The Sullivan Mine

The information on the quality and flow rate of effluents from the mine is limited. The data are summarized in Table 4-13 and were obtained mainly from Cominco's application for amendment to Pollution Control Permit PE-189. Using the concentration and flow rate data from the application we have calculated the loadings of certain contaminants to Mark Creek. The loadings, listed in Table 4-13, are expressed in lb/day and are derived by the addition of the major mine discharges as they now exist without treatment.

The data in Table 4-13 show that the largest single discharge is from the 3900 foot portal and that this flow generally contains the highest concentration of contaminants. After treatment by the lime rock-lime process the effluent characteristics must meet level B of the Mining Objectives(27), as discussed in section 2.2.1.a. The limited data available suggest that arsenic, copper and fluoride already meet level B. However, other contaminants exceed level B by a large factor. For example, iron at 275 mg/l compared to 1.0 mg/l, manganese at 25 mg/l compared to 0.5 mg/l, lead at 2.3 mg/l compared to 0.1 mg/l and zinc at 115 mg/l compared to 2.0 mg/l. The pH of 2.5-3.5 shows that the effluent is very acidic. The high concentrations of contaminants listed above make this effluent extremely toxic. The proposed treatment process is expected to produce an effluent which meets level B, with the possible exceptions of sulphate, magnesium and lead(28). Since only laboratory data are available on the process we must await operation of the full scale plant to judge treatment efficiency. We expect that 75 percent to 99 percent of the contaminants will be removed from the effluent by the process.

The values set in the Mining Objectives were generally based on a dilution ratio of 20:1 being available in the immediate receiving water. At an effluent flow of 1,500,000 GPD, Mark Creek will usually provide a 20:1 dilution for only two months of the year. For at least one month of the year the mine effluent will represent the majority of the flow in Mark Creek just downstream of the discharge. Thus, although treatment will remove a very high proportion of contaminants, Mark Creek is likely to remain toxic to aquatic life for a large part of the year. The effluent treatment will however, greatly improve water quality in the St. Mary River.

Due to the scarcity of information on present effluent quality we recommend that further samples of all mine discharges be collected. Analysis of initial samples should include arsenic, boron, organic carbon, chromium, cyanide, fluoride, iron, lead, manganese, mercury, molybdenum, nickel, phosphorus, suspended solids and zinc. Fewer parameters may be required on subsequent samples, depending upon results from initial samples.

b) Sewers 31 and 32

Before 1973 some of the major effluents from the fertilizer operations were discharged to Mark Creek through two separate outfalls named sewer 31 and sewer 32. Sewer 31 received effluent from the sulphuric acid plant, the fertilizer plant and also from the steel plant, which is now shut down. Sewer 32 received effluent from the phosphoric acid plant. Since 1973 the sewers have been combined into sewer 32, discharging to Mark Creek. Data on the separate and combined sewers were collected by the Pollution Control Branch in 1973 and are presented in Table 4-15. The results are given as concentrations and loadings calculated from the concentration and flow data.

The results show that large amounts of toxic materials were discharged into Mark Creek from these sources. The combined flow of sewers 31 and 32 exceeded nine million GPD, one quarter coming from sewer 31 and three quarters from sewer 32. The flow can apparently be much higher during the spring due to infiltration of runoff.

By the end of 1977, the discharge characteristics must meet level A of the Mining Objectives[27], and the flow must not exceed six million GPD. According to the data in Table 4-15, the major contaminants are presently dissolved fluoride, up to 240 mg/l (level A: 2.5 mg/l), dissolved iron, up to 3.5 mg/l (level A: 0.3 mg/l), dissolved lead, up to 0.7 mg/l (level A: 0.05 mg/l), total phosphorus up to 17.4 mg/l (level A: 2.0 mg/l) and pH of 2.9 to 3.8 (level A: 6.5-8.5). Other contaminants such as arsenic, cadmium and chromium have also at times significantly exceeded level A objectives. As presently constituted, this effluent is extremely toxic.

As discussed in section 2.2.2.a)for the Sullivan mine effluent, the available dilution in Mark Creek is much less than 20:1 for most of the year. During the low flow period, after freshet, the mine effluent and sewer 32 account for up to 90 percent of the total flow in Mark Creek. Thus, even when the effluents meet the new amended permit conditions, Mark Creek is unlikely to be suitable for aquatic life. Since the minimum flow in the St. Mary River is approximately 300 cubic feet/second, and the total effluent discharged to Mark Creek is of the order of 15 cubic feet/second, a 20:1 dilution will be available in the St. Mary River. At the present time, contaminants from sewer 32, as well as the mine effluent, are having a considerable effect on the St. Mary River, as discussed in Chapters 4 and 5. As the effluent quality is improved to meet permit limits, we expect conditions in the St. Mary River downstream from the discharges to improve considerably. In-plant and out-plant treatment should remove up to 94 percent of the fluoride, 91 percent of the iron, 92 percent of the lead and 88 percent of the phosphate from sewer 32.

Since only a limited number of effluent samples have been obtained to-date, and fluctuations in contaminant concentrations are expected, we recommend that further samples from sewer 32 be obtained at regular intervals. Parameters listed in Table 4-15 can serve as a guideline for the tests to be performed. We recommend that analysis for total as well as dissolved metals and ions be carried out. Contaminants discharged in an insoluble form may be converted to a soluble form by changing conditions in the receiving water. We also recommend that analysis of total phosphorus be used rather than total phosphate, since phosphorus in the organic form may contribute significantly to nutrient loading.

c) James Creek Discharge

Effluents from the concentrator are discharged to the siliceous tailing pond and the iron tailing pond (Figures 4-8, 4-9, 4-10 and 4-11). Overflows from the two ponds were combined with the overflow from the gypsum pond before discharge to James Creek (Figure 4-7). The flow in James Creek has been monitored regularly by Cominco. Their results are summarized in Table 4-14 in the form of yearly averages for the period 1970 to 1974. Average concentrations and loadings were calculated for each year from weekly analyses of the discharge. The results represent the quality of the combined effluents from the concentrator, the decant from the gypsum pond and surface runoff which enters the ponds. The gypsum pond receives effluent from the fertilizer plant and, up to 1973, it also received some effluent from the pig iron plant, which is now shut down. There are no analyses of individual effluents discharged from the concentrator.

The data in Table 4-14 show that the flow has varied from three to seven million GPD and the effluent has contained large amounts of fluoride (up to 237 mg/l), iron (up to 221 mg/l), phosphorus (up to 116 mg/l) and dissolved solids (over 4000 mg/l). Effluent of this composition is extremely toxic. James Creek discharges to the St. Mary River approximately one half mile downstream from the point of entry of Mark Creek. The effect of contaminants from both creeks on the St. Mary River and the Kootenay River is discussed in Chapter 4, for water quality and Chapter 5 for aquatic biology.

The discharge from the gypsum pond has now ceased, and by the end of 1977 the annual average flow from the siliceous and iron ponds is to be less than two million GPD. The effluent characteristics are to meet level B of the Mining Objectives[27]. There will therefore be reductions in loadings of up to 98 percent for fluoride, 99 percent for iron, 98 percent for phosphorus and 83 percent for zinc. It is difficult to judge whether these reductions can be achieved entirely by in-plant measures discussed in the sections on process descriptions (2.2.1 b) c)). The lime rock-lime treatment process, to be used on the mine effluent, will also be used on the iron pond effluent and may be needed for the siliceous pond effluent. When the James Creek and Mark Creek effluents are within the new amended permit limits, the quality of the St. Mary River should be improved to make it suitable for most aquatic life.

We recommend that a sampling program of tailing pond effluents be started since we have no information so far on the separate pond discharges. The same range of parameters as proposed for the mine discharge and sewer 32 should be examined.

2.2.3 Solid Waste Disposal

a) Description

Cominco has only one refuse disposal site at its Kimberley operations, which is authorized by Pollution Control Permit PR-1733. The refuse disposal site, which opened in September, 1973, is located one-quarter mile southeast of the fertilizer plant and has an area of 32 acres. The permit authorizes the disposal of 59 cubic yards/day of industrial refuse consisting of fertilizer, scale, paper, wood, metal and glass from Cominco's operations, plus 50 cubic yards/day of municipal refuse from the City of Kimberley. A summary of pertinent information regarding both operations is contained in Table 4-16. The location of the site is denoted in Figure 4-7 by its Pollution Control Permit number, 1733.

b) Evaluation and Recommendation

It is unlikely that either the industrial or municipal portions of the refuse site will adversely affect groundwater or surface water since:

(i) the groundwater table is more than 50 feet below the site and the nearest well is 4000 feet away,

(ii) evapotranspiration (22 inches/year) exceeds precipitation (15 inches/year) at Kimberley,

(iii) the nearest watercourse (Calf Creek) is 50 feet from the site, but is located at a higher elevation than the site, and the next watercourse (Mark Creek) is 1700 feet away.

No further monitoring of this site is recommended.

c) Miscellaneous

Another source of solid waste at Kimberley, which is not covered by pollution control permit or application, is the waste rock from the concentrator. Any runoff from the waste rock pile flows into the iron tailing pond south of the concentrator, and thus the waste rock pile is not considered to be a problem.

2.3 Miscellaneous Sources of Industrial Solid Waste

In addition to the major sources of industrial solid waste, discussed in sections 2.1.4 and 2.2.3, there are three minor sources of such waste in Region 4. These are from Crestbrook Forest Industries Ltd. at Cranbrook, Silver Ridge Sawmills (1968) Ltd. and Galloway Lumber. All operations are covered by pollution control permits, and details are presented in Table 4-17. Site locations are designated in Figures 4-2 and 4-3 by the permit number.

The potential for adverse effects on groundwater or surface water at these sites is considered to be negligible. Accordingly, no special monitoring at these sites is recommended.

3. MUNICIPAL AND NON POINT SOURCES OF EFFLUENT AND SOLID WASTE

The largest municipal centres in the region are Cranbrook (population 12,000 in 1971) and Kimberley (population 7641 in 1971)[12]. Other population centres are substantially smaller with 1971 populations ranging up to 355. The total 1971 population in the region was approximately 25,000. About 4,500 use septic tanks and tile fields to dispose of sewage. The remaining 19,500 use sewage collection and common treatment systems.

3.1 The City of Cranbrook

3.1.1 Description of Municipal Treatment Works

The City of Cranbrook is the largest community in the region with an estimated population in 1975 of approximately 15,500[29]. The city is predominantly residential with some light industrial development.

Sewage from the city has been treated in lagoons and discharged to Joseph Creek since the 1950's. Initially there were three lagoons in parallel operated under Pollution Control Permit PE-55. In 1970, operation of the lagoons was improved by the installation of five surface aerators and by operation of the lagoons in series. A new Pollution Control Permit, PE-346, was issued in 1970. Since Joseph Creek is used as a source of water supply the permit required that the effluent be piped to the St. Mary River by the end of 1976. The City then looked into the alternative of spray irrigation of the effluent on land. Following investigation by the Pollution Control Branch and the City of Cranbrook, the feasibility of spray irrigation was established.

Pollution Control Permit PE-4148 was issued in August 1975 to allow spray irrigation of treated effluent on to land. The effluent will be treated in the existing aerated lagoons and pumped approximately six miles to a storage lagoon located on land northeast of Cranbrook. The storage lagoon will occupy 150 to 180 acres. It will have a storage capacity of eight months. The minimum residence time of effluent in the lagoon will be one month. An area of 1600 acres will be required for irrigation, which will take place between May and September at an application rate of 0.2 inches/day. Treed buffer zones, 150 feet wide,will surround the area. The irrigated soil will be used to cultivate forage crops. The scheme will be carefully monitored and records of effluent quality, soil quality, crop production, nutrient balance, etc. will be kept.

Details of permit conditions are given in Table 4-18.

3.1.2 Effluent Sampling Results

In the period 1966 to 1968 sampling was carried out mainly by the Health Branch and the lagoons were operated in parallel without aeration. Results of analysis of the effluent from each cell are given in Table 4-19. Pollution Control Branch sampling of the effluent was carried out when the lagoons were operated in series with aeration. Results are presented in Table 4-20.

When the lagoons operated in parallel without aeration the BOD_5 averaged approximately 35 mg/l and the suspended solids 60 mg/l. Later, with aeration and operation of lagoons in series, the BOD_5 averaged approximately 20 mg/l and the suspended solids 40 mg/l. These results show a significant improvement in effluent quality from the 1960's to the 1970's in spite of a large increase in population in that time. The BOD_5 and suspended solids are presently within limits of Permit PE-346. Since there is no chlorination of the effluent, coliform levels have been quite high resulting in contamination of Joseph Creek and the St. Mary River. The installation of spray irrigation by the end of 1976 will remove the effluent from the receiving water. Such a scheme is a good solution to the problem of effluent disposal in this case, provided that spray irrigation is carried out under controlled conditions as specified in Permit PE-4148.

3.2 City of Kimberley

3.2.1 Description of Municipal Treatment Works

In 1965 Kimberley received Pollution Control Permit PE-148 to treat sewage from the City of Kimberley and the Village of Chapman Camp. (See Table 4-18 for permit details).

The treatment facilities comprise a barminutor and screen to comminute the sewage, followed by treatment of the entire effluent in two Spiragesters. This equipment consists of two circular tanks into which effluent enters tangentially. Suspended solids are settled by gravity and reside in the tanks for several months. Periodically the solids are pumped out to drying beds. The effluent retention time is about one hour. Clarified effluent is chlorinated and discharged to the St. Mary River. If properly maintained, the system can provide the equivalent of primary treatment.

The plant began operation in 1967 and experienced problems in the initial stages. By 1971 the plant was operating according to design and in November 1971 it was connected to the Marysville sewer. The permit was amended in 1972 in order to extend its validity for one more year. Upon expiry in 1973 the City applied for a renewal of the permit. After connection of the Marysville sewer the plant became hydraulically overloaded due to infiltration of groundwater into the Marysville collection system. Tracer tests in 1974 showed that much of the groundwater infiltrating the sewer lines originated as seepage from Cominco's tailing ponds. The infiltration was such that the discharge from the Marysville section (population 1200) was at least equal to the discharge from the remainder of Kimberley (population 6500). As an interim measure the Pollution Control Branch authorised the discharge of a portion of the sewage to the river. An unknown amount of raw sewage was discharged to the St. Mary River during the winter of 1974-75.

In November, 1975, the City agreed to upgrade the collection system so that groundwater infiltration will be eliminated[70]. The City also agreed to construct a sewage treatment plant by December 31, 1978, that will meet Pollution Control Board policy for a level AA discharge to the St. Mary River[71].

3.2.2 Effluent Sampling Results and Recommendations

Pollution Control Branch monitoring results, from 1972 to 1974, are presented in Table 4-21. The City of Kimberley also monitored the discharge during this time but their analyses are considered unreliable. For example, BOD_5 tests were carried out without temperature control. During 1974-75 excessive dilution of effluent due to infiltration from Marysville gave results which are not typical of municipal effluent.

The results in Table 4-21 show that effluent characteristics were within the limits set by Permit PE-148 (130 mg/l for BOD_5 and suspended solids). The results are not representative of the total pollution load since, during the winter of 1974/75, an appreciable fraction of sewage was discharged without treatment. Also, the degree of treatment is probably not as high as indicated since treated effluent was diluted by the infiltration of water.

Cominco plans to reduce the discharge of contaminants to the St. Mary River from its operations by approximately 90 percent or more, by the end of 1977 (section 2.2). The City of Cranbrook will remove municipal effluent from the St. Mary River by the end of 1976 (section 3.1). The upgrading of the City of Kimberley's collection and treatment system by 1978 will deal effectively with the last significant source of pollution to the St. Mary River .

3.3 Subsurface Disposal of Wastes From Single Family Dwellings

Domestic wastes in many areas of the Kootenays are commonly discharged to ground through privies or septic tank tile fields. These systems have little effect on water quality if they are of low density and separated from groundwater supplies and surface water-bodies. Where any of these conditions are not met, however, problems of water contamination with nutrients or pathogenic microorganisms may develop. Data gathered by the East Kootenay Health Unit[33] indicate that the degree of contamination has fluctuated widely over the years. In 1967, 4 percent of the samples taken from Wasa Lake showed total coliform counts greater than 240/100 ml. In 1968 and 1970 no samples exceeded 240/100 ml. In 1969, however, 24 percent of samples taken had coliform levels greater than 240/100 ml. Only 6 percent of the samples taken in 1971 had greater than 240 total coliforms/100 ml. Each year a majority of samples taken showed coliform levels of less than 50/100 ml. Coliform levels in Tie and Rosen lakes were similar to those in Wasa Lake. Fecal coliform counts were only available for 1970 and 1972, but in both years were less than 10/100 ml.

Household sewage systems do not appear to be the major contributor of coliform organisms to lakes. High counts were normally observed in public beach areas, campsite areas (especially overloaded campsites and ones where owners of campers and trailers emptied their holding tanks near the lake waters), and areas where cattle had easy access to the water bodies.

Soils around Tie and Rosen lakes consist of two to three feet of well-drained loamy materials over compact, impervious glacial till. The sub-surface discharge of effluents from houses in close proximity to these lakes is therefore likely to result in contamination of the lakes with sewage nutrients. There seems to be little data available concerning the nutrient status or trophic state of Wasa and Rosen lakes. A recent report on Tie lake showed that nutrient levels were fairly high and the lake was considered mesotrophic[68].

We recommend preliminary sampling of the lakes to determine the influence of septic tank discharges and of public beach areas. Samples should be taken near the shoreline and in the middle of the lake in mid-summer and early fall. Samples should be analysed for nitrates, phosphates, dissolved oxygen, temperature, conductivity, chlorophyll, total phytoplankton, total coliform and fecal coliform.

3.4 Municipal Solid Waste Sites

The cities of Cranbrook and Kimberley are the two major sources of municipal solid waste in the region. Minor quantities of municipal solid waste come from the areas around the communities of Wasa, Fort Steele, Jaffray, Baynes Lake and Grasmere. The solid wastes from all the above sources are disposed of in landfills. Details of each municipal landfill in the region are summarized in Table 4-22. The location of each landfill site is shown in Figures 4-2 and 4-3 by the Pollution Control application or permit number as given in Table 4-22.

An evaluation of the information available for each landfill site indicates that it is unlikely that any of the municipal landfills are adversely affecting groundwater or surface water. One landfill site at

Cranbrook (Pollution Control Permit PR-1673), has been assigned a moderate potential for adversely affecting groundwater, but the site has never been used, and the permit states that it cannot be used until all domestic well water users within 1000 feet of the site are provided with a piped water supply.

No special monitoring is recommended for the municipal refuse sites of Region 4.

3.5 Effects of Agriculture

Agricultural activity in Region 4 is fairly intensive compared to the rest of the Kootenays. Farms are located along watercourses with the highest densities occurring along the Bull and St. Mary rivers, at Fort Steele, in the Grasmere Valley and along Sand Creek[30].

Most farms are less than 300 acres and are situated on Class 2 and 3 soils[31]. The land usually requires irrigation and is used for growing hay crops. Sources which were considered to contribute nutrients to the receiving waters were fertilized, irrigated cropland and livestock.

3.5.1 Nutrients From Irrigated Cropland

The acreage and location of irrigated lands were obtained from issued water licences[69]. We assumed that all irrigated land was fertilized, although this is probably an overestimate according to the 1971 Agricultural Census[30]. Fertilizer applied to non-irrigated land was believed to contribute a negligible amount of nutrients to creeks and rivers.

To calculate potential source loadings of nutrients we assumed a fertilizer application rate of 50 lb. nitrogen per acre and 10 lb. phosphorus per acre. The method used to estimate the fraction of applied nutrient ultimately reaching the receiving water was based on results derived in the Okanagan Basin Study[32]. In this study lysimeter tests were used to obtain the fraction of nutrients reaching the groundwater. These fractions were 0.168 of the nitrogen applied as fertilizer and 0.021 of the phosphorus applied as fertilizer.

We then assumed that 80% of the nitrogen and phosphorus reaching the groundwater would enter the receiving water. Therefore each irrigated acre was assumed to contribute the following amount of nutrient per year to the receiving water:

Nitrogen: 50 X 0.168 X 0.8 = 6.7 lb/year/acre

Phosphorus: 10 X 0.021 X 0.8 = 0.17 lb/year/acre

Table 4-23 gives nutrient loadings to the receiving water from irrigated crop lands, based on the above assumptions and calculations. All calculated values in Table 4-23 were rounded off. The results show that irrigated crop land could contribute in the order of 92,000 lb/year of nitrogen and 2400 lb/year of phosphorus to the Kootenay River.

3.5.2 Nutrients From Livestock

The major contribution from livestock is considered to occur during winter. During the summer cattle graze over wide areas away from watercourses. The nutrient contribution from this activity was considered to be negligible. However, beef cattle are often wintered near streams because of the natural shelter and water supply provided. A significant amount of animal waste can thus accumulate near the streams. When the spring thaw occurs the runoff can flush this waste into the streams.

The method used to derive nutrient loadings to the river from livestock operations was also based on results from the Okanagan Basin Study[32]. The total potential loading from each animal per year was assumed to be 137 lb/year of nitrogen and 9.1 lb/year of phosphorus. The fraction of the total potential loading which reached the river was assumed to be 0.07 for nitrogen and 0.022 for phosphorus. An estimate of the number of farms and livestock was obtained from the 1971 agricultural census[30]. Results are presented in Table 4-23 and show a total yearly contribution from livestock of 112,000 lb. of nitrogen and 2300 lb. of phosphorus.

3.5.3 Evaluation of Results

To evaluate the effect of agricultural operations on the Kootenay

River we calculated some theoretical nutrient concentrations which could occur. We assumed that the total contributions calculated in Table 4-23 reached the river during a five month period, from April to August. The daily load was therefore calculated by dividing the annual load by 150. The loads from the various tributaries were added and the resulting concentrations of phosphorus and nitrogen were calculated at four different locations on the Kootenay River, during high and low flow. Results are presented in Table 4-24. Concentrations of nitrogen do not exceed 0.06 mg/l and all phosphorus concentrations are below 0.002 mg/l.

Due to the large number of simplifying assumptions made in this analysis we can only derive order of magnitude values for nutrient loading and concentration. On an annual basis the loadings are considered to be small. The concentrations which could result in the river over a five month period are also considered small. Higher loadings and concentrations could occur if a quick spring thaw produced very heavy runoff. In this situation much of the runoff would be intercepted by land depressions before reaching a watercourse so only localized problems would be expected. We conclude that in most circumstances the nutrients from agricultural operations in Region 4 will not cause a measurable deterioration of water quality.

3.6 Effects of Forestry

Logging operations can be expected to contribute to soil erosion and stream sedimentation. Increased stream temperatures and nutrients may also result. Skidding is the most common technique used for log hauling. Soil erosion, especially on steep slopes, could be significantly reduced by use of more suitable techniques such as high lead, skyline cable, or balloons.

Erosion of surface materials has been observed in the northeastern part of Region 4, particularly along access roads in the Wild Horse, Galbraith, and Lussier valleys.

The impact of logging activities on water quality is understood in only a general and qualitative way. This applies not only to the Lower Kootenay River Basin, or indeed not only to the Kootenay region but also to the

Province as a whole. Several long-term inter-agency studies are presently being conducted by the Provincial Government to analyse logging impact processes (e.g., the Slim-Tumuch Watershed Study, near Prince George, and the Carnation Creek Watershed Study, near Port Alberni). These studies will eventually aid in our understanding of logging impacts in the Kootenays. However, the differences in biology, climate and geology between the Kootenays and these study areas are very great.

The influence of logging practices on the aquatic environment in the Kootenays should therefore be assessed as information becomes available. The nature and scope of the project will be limited by the time and monitoring resources available.

For this reason, it will be necessary to rely heavily on existing information. Potential watershed study areas should therefore be ones for which much is already known of landforms, climate, aquatic and terrestrial biota, and land use history.

The Environment and Land Use Committee Secretariat is coordinating a pilot study in the Kootenays, called the Springbrook Biophysical Project. A number of agencies are compiling biophysical information for purposes of resource management. Through its Hydrology Division, the Water Investigations Branch is providing information on flow regimes, and assessing the impact of various land use practices on water quantity. The boundaries of the Springbrook Project fall primarily within Region 4. Because of the similarity of landform and vegetation patterns and harvesting methods throughout the East Kootenays, the results of a detailed examination of the impacts of timber harvesting activities in the Springbrook Project area can be extrapolated to the entire East Kootenay region. Furthermore, the Springbrook Project study area is close to the Skookumchuck mill and in the very centre of the area most intensively committed to forestry in the entire Kootenay region.

A study of the effects of forestry on water quality and quantity should include:

a) changes in water quantity (in streams) associated with the nature and timing of various harvesting operations, and the relationship between these changes and the biology, geology and climate of the area.

b) changes in the nutrient status, temperature, dissolved oxygen levels, and sediment loads of streams (and other parameters as necessary), associated with the timing and nature of various harvesting operations, and the relationship between these changes and the biology, geology and climate of the area.

c) an assessment of various models for predicting the effects of logging practices on water quality and quantity.

3.7 Effects of Mining

The largest mine in the region is the Sullivan Mine, which is owned and operated by Cominco Ltd. The operation is described in section 2.2.1 a)

Other mines in the region are of relatively little importance. The Estella mine, east of Wasa, was operated in the 1950's as a gold mine. It was reopened in the 1960's to process lead and zinc from the tailings and is now closed. The tailing pond overflowed to Wasa Lake via Lewis Creek. The Kootenay Base Metals Mine extracted lead-zinc ore at Wild Horse Creek south of Wasa. It is also now closed. There is no information on the effects of these operations on water quality. We recommend that the sites be inspected to check if runoff from the area is affecting water quality.

The Placid Oil Company Ltd. opened a copper strip mine in 1969 near the mouth of the Bull River. The mine was shutdown in 1972. The Company strip mined two areas. The overburden from the first mine was piled, sloped and seeded. The overburden from the second mine was backfilled into the first mine and then seeded. The walls of the second mine were sloped and the pit was turned into a lake. The site is recognised as one of the best reclamation projects in the Province. The Fish and Wildlife Branch are presently conducting a study which will assess the use of reclaimed areas by wild ungulates.

Another mining operation which may affect water quality is gold placer mining. Current placer mines are usually one or two man hydraulic operations. If adequate precautions are not taken the operation can impede fish movement, destroy spawning areas and affect water quality by adding silt and contaminants through soil erosion. Gold has been found in the Wild Horse River, the Bull River, Perry Creek, Findlay Creek and Boulder Creek. It is not known whether any placer mines are now in operation in the area.

3.8 Effects of Dams and Diversions

3.8.1 Aberfeldie

The Aberfeldie Dam is located on the Bull River, six miles upstream from the mouth, and is used solely for power generation. It is a small installation, having a capacity of only five megawatts (MW). The development of the Aberfeldie site was undertaken by the East Kootenay Power Co. Ltd., with initial construction completed in 1922. A new dam, completed in 1953, brought the site to its present state of development. The Aberfeldie dam and powerhouse are now owned by B.C. Hydro[34].

The reservoir behind the dam is relatively small with a fetch of only ½ mile and is confined mainly to the natural river channel. The usable storage capacity of the reservoir is 503 acre-feet in summer and 700 acre-feet in winter. Reservoir water levels normally fluctuate over a range of 15 feet[34]. Since the storage reservoir is relatively small, Aberfeldie can be classed as a run-of-the-river plant.

No studies have been reported in the literature regarding the impact of Aberfeldie Dam on the Bull River. Whately[8] reported that the Bull River has excellent sport fish habitat from the mouth to the Aberfeldie Dam. A partly destroyed dam exists on the river about 3/4 of a mile upstream of the Kootenay River. Between the two dams, there is a resident cutthroat trout population of limited size. Below the partly destroyed dam, Dolly Varden and mountain whitefish are often observed and angled. The partly destroyed dam apparently prevents fish in the Kootenay River from reaching the foot of the Aberfeldie Dam[8].

The above information suggests that the impact of Aberfeldie Dam on the natural regime of the Bull River is probably small. The reservoir is too small to affect significantly the natural flow pattern in the river downstream from the dam. Upstream, the reservoir extends for only ½ mile and lies mostly within the natural river channel, thus minimizing the ill-effects associated with large storage reservoirs.

3.8.2 Libby

The Libby Dam is located on the Kootenay River, 50 miles south of the international boundary in Montana. The purposes of the dam are flood water storage for local flood control protection in Montana and Idaho, mainstem flood control for the lower Columbia River, hydro-electric power generation at the site and at downstream plants[8], and recreation[10]. The dam was authorized by the United States Congress in the Flood Control Act of May 17, 1950[10] and by the joint Canadian-United States Columbia River Treaty of September 16, 1964. Construction of the dam began in the spring of 1966 and the first pool raise behind the dam was started on March 21, 1972. Full operation of water storage started on April 17, 1973.

The dam is a concrete gravity structure with a spillway section, and reaches a maximum height of 370 feet above the streambed. The reservoir behind the dam (Lake Koocanusa) is 92 miles long at a full pool elevation and extends 42 miles into British Columbia to the mouth of the Bull River. Pertinent information regarding the dam and reservoir are contained in Table 4-25.

a) Reservoir Operation

The operation of the Libby Reservoir reflects its use for both power generation and flood control. In a year of average runoff, the reservoir will be full during August, September and October, with drawdown for power generation and flood control commencing in November and reaching a maximum in April. The reservoir level will then begin to rise again during May, June and July as a result of the storage of spring runoff. The minimum annual drawdown will be 60 feet for the first 15 years of the project, and 40 feet thereafter. The average annual drawdown will be about 100 feet while the maximum drawdown will be 172 feet[36]. Projected drawdown statistics for the Libby Reservoir during wet, median and dry years are shown in Table 4-26.

b) Predicted Effects of the Libby Project

In a report prepared prior to the completion of the Libby project, Whatley[8] predicted the physical, chemical and biological effects that the Libby project would have upstream from the dam in the reservoir, and downstream from the dam in the Kootenay River and Kootenay Lake. The following is a brief summary of the upstream effects predicted by Whatley. The downstream effects will be discussed in the water quality report on Region 5.

c) Upstream Effects - Libby Reservoir

(i) Deposition of sediment over much of the upstream portion of the reservoir due to the settling of suspended sediment transported by the glacial silt-laden Kootenay River.

(ii) Erosion and sloughing of reservoir banks in the vicinity of Gold Creek, adding to the problem of sedimentation.

(iii) Changes in the temperature characteristics caused by the change from a river to a lake regime. It is predicted that the surface waters of the reservoir will be warmer in summer than those in the Kootenay River, and that temperatures throughout the deeper portions of the reservoir will be warmer in winter than those in the Kootenay River.

(iv) Formation of density currents or layers in the reservoir because of differences in temperature and solids concentration between the reservoir water and the inflowing Kootenay River water.

(v) Initially high concentrations of total dissolved solids in the reservoir due to a heavy influx of nutrients leached from newly flooded land. This high level of dissolved solids should decrease rapidly through assimilation by aquatic organisms and reservoir flushing, and eventually should approximate pre-impoundment, Kootenay River levels.

(vi) Reduction in the dissolved oxygen concentration of the reservoir as a result of the decomposition of recently flooded organic material. (There is no evidence that this has occurred in the Canadian portion of the reservoir). In addition, water level fluctuations will inhibit the development of the littoral zone in which aquatic plants normally thrive and contribute oxygen to the surrounding water. The reservoir may act as a settling basin for wood fibre waste from the Skookumchuck pulp mill which would add to the loss of oxygen.

(vii) Initially high productivity in the reservoir during the first three to five years of its existence. The high initial nutrient concentration leached from the newly flooded land will cause an increase in the primary productivity of the reservoir, followed by increases in the zooplankton and fish populations. (The present productivity of the reservoir appears to be low, further discussion is given in Chapter 5). Following this period of high productivity, productivity should decline with the possibility that the populations of desirable fish species will decrease and that of coarse fish species will increase.

(viii) Reduction in the diversity and populations of bottom fauna, due to water level fluctuations in the littoral zone and deposition of silt over much of the reservoir bottom.

(ix) Loss of about 15 percent of the spawning area in the streams tributary to the reservoir due to flooding.

In a preliminary assessment of the groundwater resources east of the Libby Reservoir and south of the Elk River, Foweraker[5] indicated that 80 to 120 foot fluctuations in the reservoir level may produce associated groundwater level fluctuations of less than 20 to 50 feet within two miles of the reservoir, and less than ten feet at a distance of more than two miles from the reservoir. A monitoring program was recommended to assess the effect of the Libby Reservoir on the groundwater resources[5].

3.8.3 Proposed Kootenay Diversion (Canal Flats)

The Columbia River Treaty permits the diversion of up to 1,500,000 acre-feet of water per year after September 1984 from the Kootenay River near Canal Flats to the headwaters of the Columbia River (Columbia Lake). The maximum diversion flow would be 5,000 CFS and the diversion would not be allowed to reduce the flow of the Kootenay below the lesser of 200 CFS or the natural flow. The average diversion flow would be 1,937 CFS. The proposed diversion would be accomplished by a low dam across the Kootenay River, a gated concrete intake structure on the right bank, and a 7,000 foot canal to Columbia Lake[35].

The proposed diversion would divert up to 2/3 of the average annual flow of the Kootenay River at Canal Flats into Columbia Lake, leaving only 1/3 of the flow for downstream uses. This would reduce the average flow in the Kootenay River by 47% at Skookumchuck, by 43% upstream from the St. Mary River and by 30% downstream from the St. Mary River. The diversion could substantially reduce the low flows in the Kootenay River since the minimum allowable flow of 200 CFS in the Kootenay River at Canal Flats is considerably smaller than the recorded natural low flows. (Minimum daily discharge: 310 CFS; minimum mean monthly discharge: 519 CFS; 1939-1970[9]). Figure 4-16 illustrates the effect on the flow in the Kootenay River below Canal Flats of diverting 1,500,000 acre-feet of water during a year of average flow.

The construction of such a diversion would probably require an improvement in the quality of the discharges to the Kootenay River and its tributaries to prevent a deterioration in water quality downstream from Canal Flats. Of particular concern is the discharge from the pulp mill at Skookumchuck. B.C. Hydro has retained consultants to carry out an environmental impact study of the proposed diversion.

A provision of the Columbia River Treaty allows for diversion, in 2024, of the total flow of the Kootenay River at the Bull River confluence into the Columbia River system. No reserves have been registered on lands affected by this potential development[11].

4. WATER SAMPLING AND SEDIMENT DATA

To analyse the water quality data, the region was divided into three subregions, which we have named Upper Kootenay River, St. Mary River and Lower Kootenay River. The Upper Kootenay River contains the Kootenay River drainage basin between Canal Flats and the confluence with the St. Mary River. The Lower Kootenay River is between the confluence with the St. Mary River and the international border.

Over 350 river samples were collected in the three subregions between 1969 and 1974, and each sample was analysed for approximately 30 parameters. The resulting 10,000 analyses are summarized and discussed in this chapter.

Twenty sediment samples were collected in the St. Mary River and Lower Kootenay River subregions. These results are also presented and discussed in this chapter.

4.1 Upper Kootenay River Water Sampling Data

4.1.1 Presentation of Data

There are three Pollution Control Branch sampling sites on this section of the river. Their locations are shown on Figure 4-17 and are described below:

Site 20: 20 miles upstream from the Skookumchuck pulp mill.
Site 48: 2 miles downstream from the mill.
Site 19: 10 miles downstream from the mill and approximately 15 miles upstream from the St. Mary River confluence.

A summary of the water quality data from the 80 samples collected at these stations, between 1969 and 1974, is presented in Table 4-27. The values presented are those which were judged to be most representative. Concentrations appeared to depend on flow for many parameters, and thus concentrations were considered for both the high and low flow period. The high flow period was considered to occur between May and August, and the low flow period during the remaining months. The parameters presented in

Table 4-27 were selected either on the basis of relationship to the discharge from the Skookumchuck pulp mill, the major discharge in the area, or as indicators of change in the natural water quality of the river. The maximum permissible limits for drinking water[37] are also shown in Table 4-27 for comparative purposes. A summary of sublethal and lethal toxicity values for freshwater aquatic organisms is given in Table 4-28. The summary is primarily from Clarke[38] who noted that the values were not intended as effluent or receiving water standards. In this report they are used as guidelines in assessing harmful effects on aquatic life.

Certain parameters were below or near the concentrations recommended for drinking water and did not appear to change significantly within the region. Typical values for these parameters are presented in Table 4-29 but are not discussed further.

In addition to the discharge from the Crestbrook Forest Industries kraft pulp mill at Skookumchuck, there are some minor sources of contamination to the river. These include septic tank discharges from the towns of Skookumchuck and Wasa, agricultural runoff and discharges from small resort areas.

To assess the influence of the Skookumchuck pulp mill effluent on the water quality of the Kootenay River, we calculated the total weight, or loadings, of certain contaminants discharged using effluent sampling data and flow estimates. We also calculated loadings in the river at site 20, twenty miles upstream from the mill using water quality data for this location. The addition of background loadings and pulp mill loadings gave an estimate of total loadings immediately below the pulp mill discharge. The pulp mill loadings were then expressed as a percentage of the total calculated loading at this location. We also calculated loadings at site 48, two miles downstream from the pulp mill, based on water quality data and flow estimates obtained at this location. The difference in loadings between site 48 and a point immediately downstream from the discharge were then expressed as a percentage of the loadings at site 48. Results are given in Table 4-30, which also incorporates an explanatory diagram.

4.1.2 Discussion and Recommendations

a) Water Quality Changes

At sites 20, 48 and 19 on the Upper Kootenay River the water quality showed typical seasonal variations (Table 4-27). Lower concentrations occurred during high flow, with the exception of turbidity.

The water quality parameters that changed significantly from upstream to downstream were: colour, turbidity, phenols, total phosphorus, tannin and lignin like compounds and fecal coliforms. No significant changes were found in other parameters measured at sites 20, 48 and 19.

At site 48, two miles downstream from the pulp mill, the increase in tannin and lignin, compared to background site 20, was greatest during the low flow period (from 0.1 mg/l to 1.0 mg/l). Phenols increased from 0.002 to 0.004 mg/l. There were large increases in total phosphorus (from 0.006 mg/l to 0.05 mg/l) and fecal coliforms (from 2 to 2500 MPN/100 ml). The turbidity decreased from 40 J.T.U. to 10 J.T.U., due possibly to a decrease in river bed slope.

At site 19, located 10 miles downstream from the pulp mill, the total phosphorus concentration decreased to below background values and there was a significant decrease in fecal coliform counts. However, during low flow, the colour (25 colour units), tannin and lignin (1.0 mg/l), and phenols (0.004 mg/l) remained approximately the same at site 19 as at site 48.

b) Pulp Mill Loadings

The data presented in Table 4-30 show that the pulp mill contributes approximately 70 percent of the total loading to the river of tannin and lignin, colour, phenols, total phosphorus and fecal coliforms.

A comparison of total pulp mill loadings with total loadings calculated at the downstream site 48, based on water quality measured at that site, shows little difference in totals except for phosphorus (Table 4-30).

The percentage difference between the totals for phosphorus was large, and indicates that the pulp mill may not be the major source of the phosphorus measured at site 48. On occasion concentrations as high as 0.67 mg/l of total phosphorus have been recorded at background site 20 although the concentration is usually about 0.006 mg/l as reported in Table 4-27. If we assume that concentrations measured at site 48 are representative, then the pulp mill would contribute only 20 percent of the total phosphorus in the river at this point.

c) Comparison With Drinking Water Standards and Toxicity Values for Freshwater Organisms

Only colour at 35 colour units, turbidity at 10 J.T.U., phenols at 0.004 mg/l and fecal coliform exceeded drinking water standards. None of the values exceeded the lethal and sublethal levels for fish and invertebrates. However tannin and lignin type compounds, which are indicative of pulp mill contaminants, increased ten-fold below Skookumchuck.

These results indicate that, except for colour, phenol, coliforms and possibly tannin and lignin, the pulp mill does not have a major effect on water quality, at least on the basis of the usual parameters measured in receiving waters. However, biological data presented in Chapter 5 show that changes have occurred. There was a pronounced difference in the aquatic fauna and flora above and below the pulp mill and a deterioration in the taste and odour of fish downstream from the mill. These changes are thought to be due to the salts of resin and fatty acids, or to mercaptans, chlorinated organics and other toxic constituents discharged by the pulp mill. These components cannot be measured in the receiving water due to their low concentrations. In the effluent, the concentration of resin and fatty acid salts is usually high enough for measurement. The presence of these constituents in the river has been deduced by analysis of the mill effluent, evaluation of the mill operation and, indirectly, by measurement of downstream biological effects. Recommendations for improving the effluent discharged, especially with respect to colour and toxic constituents, are presented in Chapter 2.

d) Recommendations

In addition to improvements in the pulp mill operation suggested in Chapter 2, we recommend that an additional sampling site be established on the Kootenay River just upstream from the St. Mary River confluence. This site will show the extent to which pulp mill wastes are degraded and assimilated by the Kootenay River before dilution by the St. Mary River. We also recommend that site 175 just upstream from the pulp mill be sampled regularly. This site will give better control data than site 20 which is 20 miles upstream from the mill.

4.2 St. Mary River, Mark Creek, Joseph Creek and James Creek Water Sampling Data

4.2.1 Presentation of Data

There are 11 Pollution Control Branch sampling sites on the St. Mary River and its tributaries, Mark and Joseph Creeks (Figure 4-17). Four sites are on the St. Mary River, two on Mark Creek and five on Joseph Creek. As James Creek is considered to be mainly effluent, its sampling data are discussed in Chapter 2.

The sampling sites are described in more detail below:

a) St. Mary River

Site 29: a control site located at Cominco's water pump station, 100 feet upstream from the Kimberley sewage treatment plant discharge.

Site 132: 100 feet downstream from the Kimberley sewage treatment plant diffuser, and 300 feet upstream from the Mark Creek confluence.

Site 135: at Wycliffe, midway between Mark Creek and Joseph Creek confluences.

Site 18: 0.5 mile downstream from the Joesph Creek confluence.

b) Mark Creek

Site 37: a control site, downstream of the Kimberley water reservoir and 100 yards upstream from Cominco's mine discharge.

Site 36: west of Marysville and 0.4 mile above the confluence with the St. Mary River.

c) Joseph Creek

Sites 96 and 95 are no longer used.

Site 151: 0.5 mile upstream from the discharge from Cranbrook's sewage lagoons.

Site 152: 0.5 mile downstream from sewage lagoon discharge.

Site 153: 1 mile downstream from sewage lagoon discharge.

d) James Creek

Has one site, considered as an effluent sampling site and discussed in Chapter 2.

Between 1969 and 1974 the Pollution Control Branch collected over 175 samples at these sites. The data are summarized in Table 4-31 for St. Mary River and Mark Creek, Table 4-32 for Joseph Creek and Table 4-33 for James Creek. Concentrations are presented generally as ranges for the high and low flow periods. The ranges do not indicate the maximum and minimum levels which were recorded but show the most representative high and low values for each period. Drinking water standards are also listed for comparative purposes. The increases in concentration of certain parameters between background site 29 and site 135 on the St. Mary River are listed in Table 4-34.

Site 132 on the St. Mary River was sampled infrequently. The discharge from the Kimberley sewage treatment plant is approximately 100 feet upstream from the site and we believe that there is incomplete mixing of effluent and receiving water in this distance. Results from this sampling site are therefore not presented since the samples were not considered to be representative of the river water quality at this location. The site cannot be moved further downstream without coming under the influence of

Mark Creek.

In order to evaluate the effect of the various discharges to the St. Mary River we calculated total quantities discharged per day, or loadings, of the most important contaminants. In Table 4-35, the concentration and loading data for Mark Creek and all known discharges to Mark Creek are presented. Loadings of various contaminants are expressed in lb/day. For each contaminant, the sum of the loadings from all discharges is compared to the loading in the creek at site 36. In Table 4-36 we present similar data for the St. Mary River, adding loadings from the Kimberley sewage treatment plant, Mark Creek, James Creek and Joseph Creek, and comparing these sums to the loadings measured to be present in the river at site 18.

4.2.2 Discussion and Recommendations

In this subregion the major discharges of effluent are from the mining and fertilizer operation of Cominco Ltd. at Kimberley. Other significant sources of effluent are the smaller discharges from the sewage treatment plants of Kimberley and Cranbrook. The discussion of water quality data for the subregion begins with the upper St. Mary River and deals with sites in downstream order.

a) Upstream Site on the St. Mary River

Site 29 on the St. Mary River is near the Kimberley golf course and is located upstream from all major sources of industrial and municipal discharges. The water at this location is typical of natural runoff streams: low in metals, nutrients, alkalinity and hardness, with pH approximately 7 (Table 4-31). The water,when disinfected, would be within acceptable limits for drinking water for all parameters measured.

b) Site Downstream From Kimberley Sewage Treatment Plant

It is not possible to determine from the data the effect of the sewage treatment plant discharge on the St. Mary River, because the effluent discharges within a short distance of Mark Creek. Incomplete mixing of effluent and receiving water occurs close to the discharge, hence samples taken at this point are not representative of receiving water quality and analyses show large variations.

c) Mark Creek

The major effluents discharged to Mark Creek are from the mining and fertilizer operations of Cominco Ltd. In addition to the direct discharges,the creek receives surface runoff from the Cominco operations.

Mark Creek has been sampled regularly at two locations (Figure 4-17). At site 37, upstream from all industrial discharges, the water quality met drinking water standards for all parameters measured except for dissolved iron (0.5 mg/1), manganese (0.2 mg/1) and turbidity (70 J.T.U.). These high values occurred mainly during low flow and may be due to high metal levels in the soil.

Analysis of the water sampled at site 36, downstream from the Cominco discharges, showed a definite deterioration in water quality (Table 4-31). At site 36 the creek was polluted with acidic material. There were large increases in concentration of certain contaminants, especially during the low flow period. Values for arsenic, chloride, fluoride, dissolved iron, dissolved lead, phosphorus, dissolved solids, and zinc increased by factors of 10 to 1000 above background levels (Table 4-31). Several values for pH were below 3.0 during the winter, and the alkalinity was less than 10 mg/1.

The data in Tables 4-31 and 4-28 show that during most of the year the concentrations of fluoride, iron, lead, manganese and phosphorus exceeded the recommended drinking water standards, and exceeded values known to be toxic or inhibitory to fish and invertebrates. During the low flow period, arsenic, pH, zinc, dissolved solids and turbidity did not meet the recommended drinking water standards. Arsenic, pH and zinc in this period also exceeded levels that are toxic to aquatic organisms. These data indicate that the effluents discharged to Mark Creek have seriously affected the water quality and limited the use of water in Mark Creek.

For certain parameters there was a large discrepancy between the amount of material present in Mark Creek according to analysis of the water at site 36, and the amount calculated to be added by the various known discharges. The fluoride, iron, lead, phosphorus and dissolved solids content of the water in Mark Creek at site 36 were much higher than could be accounted for by the known discharges and inputs. For example, the creek carried more than 1000 lb/day of fluoride compared to an input from discharges of 190 lb/day. For dissolved iron the values were 4000 lb/day compared to 400 lb/day, for dissolved lead, 25 lb/day compared to 8 lb/day, for total phosphorus, 6000 lb/day compared to 350 lb/day and for dissolved solids, 100,000 lb/day compared to 4600 lb/day (Table 4-35).

To assess the future improvements in water quality of Mark Creek we must learn more about the source of contaminants and resolve the discrepancies mentioned above. We recommend that all discharges to Mark Creek be sampled at the same time as the receiving water sites are sampled. Suggested parameters and monitoring frequency are summarized in Table 4-37. The area should also be observed during high runoff periods since runoff during rainstorms may contribute to stream loading. Other sources such as groundwater, pond leachate and dissolution of stream sediments may also contribute to stream loading, and should be estimated whenever possible by field observation and sampling. To isolate the effect of the mine drainage we recommend that an additional sampling site be established on Mark Creek. The site should be located immediately upstream from the discharge of sewer 32 from the fertilizer plant, but downstream from the mine drainage discharge. The additional site will help determine the source of major contaminants.

d) James Creek

James Creek enters the St. Mary River immediately downstream of the confluence with Mark Creek. James Creek contains a large proportion of the effluent discharged from the Cominco fertilizer operations, and is currently considered as an industrial discharge. Data available on the flow and quality of the creek were discussed in detail in Chapter 2. Parameters such as arsenic, fluoride, iron, lead, pH, phosphorus and zinc greatly exceed both drinking water standards and levels known to be toxic to aquatic organisms. The concentration ranges shown in Table 4-33 indicate that the creek is essentially an industrial discharge.

The calculation of loadings based on measured concentrations indicates that James Creek is the main contributor of contaminants to the St. Mary River from the Cominco operations. Data in Table 4-36 suggest that James Creek discharges more than 70% of the lead and phosphorus, more than 80% of the fluoride and iron and more than 99% of the arsenic. To confirm this information we recommend that a new sampling site be located on James Creek, immediately before the confluence with the St. Mary River. Parameters to be measured and the preferred sampling frequency are summarized in Table 4-37. A site should also be located on the St. Mary River between the confluences with Mark and James Creeks, if access permits. Such a site will allow us to distinguish between the influences of the two creeks discharging into the St. Mary River.

e) The St. Mary River at Wycliffe (site 135)

The influence of the combined discharges from the Kimberley sewage treatment plant, Mark Creek and James Creek caused a marked deterioration in the St. Mary River at Wycliffe (site 135). The effect was most pronounced during the low flow period. The percent increase in concentration of various parameters at site 135 over control site 29 is presented in Table 4-34 for this period. The data show concentration increases of from 300% to 100,000%.

During a large part of the year the concentrations of fluoride, dissolved iron and dissolved phosphorus at site 135 were more than 10 times higher than drinking water standards (Table 4-31), and exceeded levels toxic, or inhibitory, to aquatic organisms (Table 4-28). The manganese levels were up to four times higher than drinking water standards (Table 4-32), and lead, arsenic, ammonia and pH generally exceeded the standards. The lead may cause reproductive impairment of some invertebrates. For short periods at high flow the freshet dilutes the water so that parameters other than fluoride, iron and phosphorus are within drinking water standards. The detrimental effect of the water on aquatic life is documented in more detail in Chapter 5, which deals with aquatic biology.

f) Joseph Creek

The major discharge affecting water quality in the creek is from the Cranbrook sewage treatment plant. Data in Table 4-32 show that levels of fecal coliform, organic nitrogen, total and dissolved phosphorus and solids were significantly higher at sites 152 and 153 below the sewage plant discharge, than at site 151 upstream from the discharge. The fecal coliform count in the creek was higher than the Canadian standard for raw water supplies (up to 2400 MPN/100 ml compared to the standard of 1000 MPN/100 ml). By the end of 1976 the sewage plant discharge will be completely removed from Joseph Creek and will be disposed of by spray irrigation (see Chapter 3).

g) The St. Mary River Downstream From all Major Discharges (site 18)

In Table 4-36 we have presented the total loadings of certain contaminants discharged to the St. Mary River, calculated by adding the loadings from known discharges. Although the data show large variations, due in part to the lack of accuracy in sampling and flow measurement, the values indicate the order of magnitude of amounts being discharged to the river. The amount of arsenic varied from 20 to 550 lb/day, fluoride from 5000 to 100,000 lb/day, lead 50 to 250 lb/day, phosphorus 2000 to 20,000 lb/day and zinc up to 800 lb/day.

We also compared, in Table 4-36, these calculated loading values to the loading measured to be present from analysis of water at site 18. For phosphorus we obtained a similar value of 25,000 lb/day at site 18. For arsenic and fluoride we found that 80% or more of the material discharged in the effluents had disappeared from the water column at site 18. For lead and zinc we found that approximately 50% more of the contaminant than discharged in effluents was present in the water at site 18. These results may be due to inaccurate data for the effluents. It is also possible that arsenic and fluoride may be accumulating in the sediments at this location. (These two parameters were not measured in the 1971 sediment samples). In the case of lead and zinc, some unknown source may be adding to the river load or leaching may be taking place from sediments in the river. The concentration of lead and zinc increased by a factor of approximately 10 or more from site 29 to site 18 (Table 4-31). These elements may therefore be available for leaching from the sediments. A more detailed program of sediment analysis will be required to determine if pollutants are being deposited, or possibly leached. Initially we recommend that sediment samples be obtained at sites 29 and 135 and fractionated according to size. Each major size fraction can be analysed for parameters listed in Table 4-37. The results will indicate which sediment fraction is most important for further study. These fractions can then be measured at each site on the St. Mary River, Mark Creek, James Creek and the Lower Kootenay River.

At site 18 the concentrations of fluoride (up to 15 mg/l), iron (up to 5 mg/l), manganese (up to 0.4 mg/l) and phosphorus (up to 8.0 mg/l) were at least five times higher than drinking water standards (Table 4-31). Fluoride and phosphorus exceeded levels known to be toxic or inhibitory to aquatic life (Table 4-28). The effect was particularly severe during the low flow period, when the water became very acidic, with pH values as low as 3.5. Lead and arsenic values were also above desirable levels during most of the year. The effects on aquatic biology are detailed in Chapter 5.

The data indicate that a general decrease in the concentration of contaminants took place in the St. Mary River in 1974. The concentration of mercury at site 135 reached 0.4 µg/l in 1973 but was less than 0.005 µg/l in 1974. Samples from site 36 on Mark Creek and sites 135 and 18 on the St. Mary River contained less fluoride, phosphorus, silica and arsenic after May 1974. The decreases were most probably due to the halt in operations from the strike at Cominco in the summer of 1974.

h) Summary of Recommendations

We need to trace the sources of the contaminants in the St. Mary River with greater accuracy and to establish the fate of contaminants present in the river. The following recommendations were therefore made:

-Sample all discharges at approximately the same time as the receiving water.

-Establish an extra sampling site on Mark Creek between the Mine discharge and sewer 32.

-Establish a sampling site on James Creek immediately before its entry into the St. Mary River.

-Establish, if possible, a new sampling site on the St. Mary River between Mark and James Creeks.

-Carry out sediment analyses on the creeks and the river.

Many of these recommendations were incorporated in the monitoring program which is part of amended Permit PE-189, issued to Cominco October 9, 1975. Cominco will be upgrading its discharges in the next two years, as discussed in Chapter 2. As a result we expect a substantial improvement in the water quality of the St. Mary River.

4.3 Lower Kootenay River Water Sampling Data

4.3.1 Presentation of Data

On this section of the river, between Fort Steele and the international border, there are four Pollution Control Branch sampling stations. Three of these stations are on the impounded section of the river (Libby reservoir also known as Lake Koocanusa), downstream from Wardner. The two major tributaries of the Kootenay River, the Bull and Elk Rivers, were also monitored. The site locations are shown in Figure 4-18 and are described in more detail below:

Site 38: on the Kootenay River, 7 miles downstream from the St. Mary River confluence.

Site 169: on Lake Koocanusa, 35 miles downstream from the St. Mary River confluence and 22 miles from the international border.

Site 101: on Lake Koocanusa, 1 mile north of the Elk River confluence, and 16 miles upstream from the international border.

Site 100: on Lake Koocanusa at the international border.

Site 30: on the Bull River, near its confluence with the Kootenay River.

Site 16: on the Elk River, near its confluence with the Kootenay River.

Before formation of Lake Koocanusa only site 38 was used to monitor the water quality of the lower Kootenay River.

Between 1969 and 1974, 80 samples were collected at the stations. A summary of the data, showing concentrations of pertinent parameters during high and low flow periods, is given in Table 4-27. Some concentrations changed only slightly relative to upstream stations and were not found to affect the water quality adversely. They are tabulated for station 38 in Table 4-29.

Effluents discharged in the lower Kootenay River are believed to have a minor influence on water quality. The major discharge is from the B.C. Fish and Wildlife hatchery on the Bull River. Non point discharges may occur from agricultural activity or by infiltration from septic tanks. Most contaminants occurring in the lower Kootenay River originate either from the St. Mary River or the upper Kootenay River. We have therefore calculated the contribution of contaminants from these sources and expressed the results as a percent loading in Table 4-38. The differences between the calculated loadings and those derived from measurements in the river are also presented in the Table.

The dissolved gas content of the Kootenay River was measured at the Wardner Bridge, which is four miles south of the Bull River confluence. The results are given in Table 4-39 as percent saturation, together with approximate standards used to evaluate the data.

4.3.2 Discussion and Recommendations

a) The Effect of the St. Mary River on the Kootenay River Near its Confluence

In Table 4-27 we can compare water quality values for site 19, 15 miles upstream from the St. Mary River confluence, with site 38, seven miles downstream from the confluence. The concentrations of dissolved fluoride, iron, phosphorus and zinc increased by a factor of 10 or more from site 19 to 38. At site 38 the concentrations during low flow when values were highest were 3.0 mg/l for fluoride, 0.8 mg/l for iron, 0.5 mg/l for phosphorus and 0.08 mg/l for zinc. Except for zinc, these values exceeded permissible limits for drinking water (Table 4-27) and levels known to be toxic or inhibitory to aquatic organisms (Table 4-28).

Loading values, expressed as percentages in Table 4-38, indicate that the St. Mary River contributed 80 percent or more of fluoride, phosphorus and heavy metals to the Kootenay River. The loading values, which are calculated from sampling and flow rate data, are probably subject to some uncertainty. In Table 4-38 the percent difference in loadings between site 38 and sites 18 and 19 varies from 25 percent to 50 percent for most parameters, indicating loss of material from the water column. In a few cases, such as fluoride, the percent difference is negative, indicating a possible gain of material. These discrepancies may be due partly to errors in measurement and partly to precipitation of materials from the water column or leaching of materials from the sediments. (Some results of sediment analyses are discussed in section 4.4). Allowing for possible errors, the results in Tables 4-27 and 4-38, together with those discussed in Section 4.2, suggest that effluents from the Cominco operations in Kimberley have a significant effect on water quality in the Kootenay River, close to the St. Mary River confluence.

b) The Assimilation of Contaminants From Site 38 to Site 100 at the International Border

At site 169, approximately 35 miles downstream from the St. Mary River confluence, the concentration values for all parameters except coliforms were less than maximum permissible drinking water values (Table 4-27). Typical concentrations were: fluoride 0.3 mg/l, iron 0.15 mg/l, lead 0.001 mg/l, phosphorus 0.01 mg/l and zinc 0.006 mg/l. These values indicate that contaminants were lost from the water column and may be accumulating in the sediments. The sediments will eventually be washed into the Libby reservoir during spring freshet and contaminants would tend to accumulate in the sediments at this point. Whether most contaminants would be stabilized by the sediments or whether they would be leached back into the water column is not yet known. The results suggest that, in the short term, the Cominco operations in Kimberley do not have a significant effect on water quality at site 169, well downstream from the St. Mary

River confluence. However, a program of sediment sampling, together with water sampling, will be required to determine possible long term effects. The effects on aquatic biology are discussed in Chapter 5.

Colour in the river dropped from a high value of 25 at site 19 to 12 at site 38, and then to 5 at site 169 and all other downstream sites. These results suggest that the influence of the Skookumchuck pulp mill on the colour of the Kootenay River is negligible some 30 miles below the St. Mary River confluence.

To measure the assimilation of contaminants by lake Koocanusa we calculated material balances and expressed the results as a percent difference between loadings entering and leaving the lake (Table 4-38). For most contaminants,there was a further loss from the water column of 50 percent to 90 percent between site 169 and the international border. For total phosphorus, the load at the international border was of the order of 6000 lb/day during high flow and 1500 lb/day during low flow, compared to 20,000 to 25,000 lb/day being discharged by the St. Mary River. We assume that most of the phosphorus was lost to the sediments, and further sampling will be required to confirm this mechanism. The Bull and Elk Rivers appeared to have a minimal effect on the Kootenay River according to results in Tables 4-27 and 4-38. The dissolved gas values measured at the Wardner Bridge (Table 4-39) were satisfactory. This result was expected since there are no upstream dams. The measurements were intended to serve as a control for measurements made at the Libby Dam in Montana.

c) Recommendations

Sediment sampling should be carried out between site 38 and Lake Koocanusa. For comparative purposes some sediment samples should also be taken in the Kootenay River above the St. Mary River confluence. Since the water level of the reservoir fluctuates during the year, sediments from the Kootenay River are deposited in different areas of Lake Koocanusa. Initial sediment samples should therefore be taken at the upstream high water and the upstream low water marks of Lake Koocanusa. The monitoring frequency and stations to be measured are summarised in Table 4-37. The Table also outlines the water quality sampling program required. Not all parameters listed in the Table, for either water or sediments, will necessarily be measured each time the sites are sampled. Also certain sites may be dropped or added as results of the field study are evaluated.

4.4 Sediment Data

4.4.1 Data Presentation

Sediment samples were collected from the St. Mary River, Kootenay River, Lake Koocanusa, and Goat River in November, 1973. The results of analyses performed on the dried sediment are summarized in Table 4-40. Each value is the mean of duplicate samples. In cases where a discrepancy was apparent, the two values are given.

Some variation was observed among the values at the three stations in the St. Mary River above the discharges from Cominco-Kimberley. Downstream from the discharges, substantial changes were found. At Wycliffe, there was an increase in the concentrations of copper, lead, zinc, cadmium, iron, and phosphorus; approximately 9 miles further downstream these parameters showed a further increase. This was followed by a decrease at the mouth of the St. Mary River.

In the Kootenay River samples, the values of all parameters increased between Fort Steele and Wardner and decreased (except cadmium) between Wardner and Lake Koocanusa.

The Goat River values were, in general, higher than the control sample values from the St. Mary River.

4.4.2 Discussion

The sediment was only sampled once and simultaneous water quality samples were not taken. The particle size distributions of the sediment were not measured. Increasing amounts of heavy metals and phosphorus appeared to occur in the sediment of the St. Mary River up to at least 15 miles downstream from the Cominco discharges. These trends suggest that over this distance there was an accumulation of certain contaminants in the sediments.

Little work has been done in assessing the effects of metals in the substrate on aquatic life, possibly because high sediment levels are often associated with high concentrations in the water column. Also, the values are variable over time and over relatively short distances.

There are several possible explanations for these variations. The water flow influences the extent of sedimentation and the amount of substrate washed downstream. The water flow also affects the particle-size distribution which may influence the concentrations because some metals (or other parameters) may be more closely associated with particular sizes or types of substrate. For example, Collinson and Shimp[43] found that most trace metals concentrated in the organically rich, fine-grained surficial sediments. In the St. Mary River, the cobbles and boulders appear to be coated with iron complexes.

The water chemistry will have an influence on any equilibria established between the water and the sediment. Factors such as pH, solubility, anionic content of the water, ionic activity and redox potential will influence the amount of precipitation and exchange between the water column and the sediment. Both micro and macro chemistry are important. For instance, at a macro level carbonates are quite insoluble but at a micro level they are sufficiently soluble to have an important effect.

The biological activity is also important. Bacteria are constantly acting to release nutrients (particularly nitrogen and phosphorus) from organic debris which enters the water. The net flow of these released nutrients is from the water to the sediment. The iron bacterium, *Thiobacillus ferrooxidans* will accelerate hydrolysis of ferric salts[44].

5. AQUATIC BIOLOGY

The data from several biological studies are presented and discussed in three subsections:

5.1 St. Mary River

5.2 Kootenay River

5.3 Libby Reservoir

The biological data include information on invertebrates, periphyton, and fisheries. Benthic invertebrates and, to a lesser extent, periphyton, can be used as indicator organisms. They are relatively sessile and different members vary in their sensitivity to changes in water and substrate quality. Invertebrates and periphyton constitute a major part of fish diet, different orders and genera being consumed during different life stages.

There is interaction between invertebrates and periphyton. Some invertebrates depend on certain genera of periphyton for shelter or for food. Others compete with periphyton for space on rock surfaces. A fine balance exists among the individuals inhabiting given areas. Changes in the water and substrate quality can disrupt the more sessile populations and, ultimately, the migratory fish populations.

A change which results in the predominance of one or two species to the exclusion of others formerly present is an unstable situation. The number of prey and predators could be limited to such an extent that all of the individuals may die.

A knowledge of indicator organisms and of the variations among them enables detection of subtle changes in water quality and allows us to predict future changes in the aquatic community.

5.1 St. Mary River

5.1.1 Data Presentation

Benthic invertebrate surveys were conducted by Sinclair[45], Bull et.al.[46], and as part of the Libby Dam pre- and post-impoundment studies[47,48]. Chris Bull basket samplers or Surber samplers were used to collect the 70 samples from the nine sample stations included in the surveys. The sampling stations shown in Figure 4-17 are the same as certain water quality stations described in Chapter 4. The precise location of the other stations is not known but a general description is given in the data presentation. The samples were preserved, sorted, taxonomically identified, and counted. The number of individuals in each representative invertebrate order (or family) at each sampling site, and for each sampling period is summarized in Table 4-41 and Figures 4-19 and 4-20.

Periphyton samples were collected from 1972 to 1974[47,48] from Pollution Control Branch water quality stations 29, 135 and 18 (Figure 4-17). Nineteen samples were obtained by submerging artificial substrates (2.5 cm X 7.5 cm glass microscope slides) attached to Chris Bull samplers. After submergence from four to eight weeks, the periphyton growth attached to the substrate was preserved, identified and counted. The total number of cells per square millimeter and the percent composition of the representative species are given in Figure 4-21.

In situ fish-caging experiments in the St. Mary River have been carried out by Sinclair[45], Whately[49] and the Pollution Control Branch[50]. The results are summarized in Table 4-42.

5.1.2 Discussion

The major influence on the aquatic flora and fauna of the St. Mary River is the effluent from the Cominco operations. A strike from July to November, 1974, halted work at the plant and significantly reduced the amount of effluent discharged. We will discuss the data obtained during normal operations and during the strike separately.

a) During Normal Operations

There was a pronounced difference in the invertebrate and periphyton populations between the sites upstream and downstream from the Cominco discharges. In the St. Mary River upstream from the confluence with Mark Creek the four representative groups of invertebrates were relatively abundant (Table 4-41, Figures 4-19, and 4-20). Downstream from Mark and James Creeks the number of individuals was reduced by up to 95%. At the downstream sites the pollution sensitive orders of Ephemeroptera (mayflies), Plecoptera (stonefiles) and Trichoptera (caddisflies) were rare or absent; where invertebrates were present, the pollution-tolerant chironomids predominated.

There is generally a variation in tolerance among the genera of the so-called "sensitive" and "tolerant" orders, or families, particularly among chironomids. Most of the data were from one or two samples which are insufficient to give truly quantitative results. However, the abrupt change in representative groups combined with little change in the natural habitat (flow, substrate type), make it safe to assume that the chironomids present in the downstream samples were pollution-tolerant.

The periphyton populations upstream from the discharges at station 29 were diverse but dominated by the relatively clean-water genera Achnanthes, Synedra and Gomphonema. Downstream from the discharges, at sites 135 and 18, the diversity decreased. The pollution-tolerant genera of filamentous algae Stigeoclonium, Ulothrix and Oscillatoria dominated and often accounted for more than 95 percent of the total number of cells (Figure 4-21). At stations 135 and 18 there was a decrease in the biomass and the total number of cells compared to station 29. The decrease may be due to the higher level of contaminants in the water since the samples were taken mainly during low flow periods. During high flow periods more filamentous algae were observed at the downstream sites.

The invertebrate and periphyton data indicate that the Cominco discharges were having a detrimental effect on the sensitive invertebrate and periphyton populations of the St. Mary River. Similar conclusions were arrived at by Bull et al.[52] concerning the periphyton communities.

The results of in situ fish-caging experiments demonstrated the presence of toxicants in the water. In 1973, 47.5 percent of rainbow trout survived after 96 hours in cages at Wycliffe (site 135) compared to 100 percent survival upstream from Kimberley. Water quality data also show the presence of contaminants at toxic levels. Certain parameters such as iron, fluoride, phosphorus, zinc and pH, listed in Table 4-31, are in a range of possible lethal or sublethal toxicity as shown by data in Table 4-28.

b) During the Strike

While the strike lasted, from July 1 to November 6, 1974, mine drainage continued to flow into Mark Creek but the discharges from sewer 32 and the tailing ponds were greatly reduced. Although no water samples were taken during the strike, James Creek was sampled as operations resumed. Results in Table 4-43 show that fluoride, phosphate and zinc were lower than during normal operations but gradually increased as the plant achieved full production.

The improved water quality was reflected by the invertebrate and fisheries data obtained during the strike. There was an increase in numbers and diversity of invertebrates at stations 135 and 18 (Figure 4-20); there was 100 percent survival of rainbow trout after 76 hours in cages at site 135. However, caged rainbow trout all died within 50 hours in Mark Creek. The results indicate that the heavy metals from mine drainage water were toxic in Mark Creek and that dilution by the St. Mary River neutralized toxicity by site 135, seven miles downstream from the confluence.

These results demonstrate that when contaminants are removed from the river the aquatic fauna tends to recover in a relatively short period of time. The effluents discharged by Cominco will be considerably upgraded in the next two years, as discussed in Chapter 2. We expect a marked improvement in the aquatic flora and fauna of the St. Mary River as a result of the Company's abatement program.

c) Effect of Cranbrook's Municipal Effluent

Fish-caging experiments were carried out downstream of site 135, near the mouth of Joseph Creek, during the strike at Cominco. Results gave

55 percent survival after 96 hours. Since treated municipal effluent from Cranbrook is discharged into Joseph Creek, the trout mortality may have been due to the municipal effluent. The effluent will be completely removed from the creek after 1976 as described in Chapter 3.

5.1.3 Recommendations

Biological monitoring of the St. Mary River is required as a condition of the amended Pollution Control Permit PE-189 issued to Cominco. The program should be similar to the one followed by the Pollution Control Branch, with the following modifications:

a) Station 18 should be moved closer to the confluence of the St. Mary River with the Kootenay River. The new station will give better information on the condition of the river water entering the Kootenay River.

b) At least three invertebrate and periphyton samples should be collected at each station during each sampling period.

c) The biological samples should be collected at the same time as water and sediment samples. However, biological samples need to be collected only two or three times a year.

d) The possibility of carrying out long and short term fish-caging experiments should be considered.

e) A fish survey of the St. Mary River should be carried out. It should include information on the location of spawning areas, the direction of fish movement near Kimberley, and the numbers of fish entering the St. Mary River from the Kootenay River.

5.2 Kootenay River

5.2.1 Data presentation

The major influences on the Kootenay River are the effluent from the Crestbrook pulp mill at Skookumchuck and the St. Mary River which meets the Kootenay River at Fort Steele. Biological studies designed to assess these influences date back to 1965. The studies, carried out primarily by government groups, include data on invertebrates, periphyton and fisheries at sites extending from Canal Flats to Wardner (Figures 4-17 and 4-18).

Langford[53] summarized the biological data from the vicinity of the pulp mill, up to 1974. Other data cover the influence of the St. Mary River[49] or were obtained as part of a post-impoundment study of the Libby Reservoir[48].

Benthic invertebrates were collected before[45,46] and after[46,47,48,54,55] the pulp mill started to discharge effluent in late 1968. Chris Bull samplers were used in all the studies with the exception of Sinclair[45] and Reid[54], who used Surber samplers. Bull et.al.[46] also used Surber samplers to obtain additional information. Data from Reid[54] obtained with a sampler containing a screen of 1½ mm are not used in our assessment, since the screen would have permitted most of the invertebrates to pass through. A total of 159 invertebrate samples were collected in the studies, each of which was preserved, sorted, identified and counted. The numbers of individuals in each order (or family) at each site and sample period are summarized in Tables 4-44 and 4-45 and Figures 4-19, 4-22 and 4-23. To determine the type of invertebrates most commonly eaten by fish, Bull et. al.[46] examined the stomach contents of 97 whitefish caught in the Kootenay and Bull Rivers in 1967 and 1968. The results are summarized in Table 4-46.

Periphyton samples were collected[48] from 1972 to 1974 at stations 20, 175, 48, 19 and 38 on the Kootenay River and station 30 on the Bull River (Figures 4-17 and 4-18 show station location). The samples, collected after the Libby reservoir had started to fill, were obtained using the same procedure described for the St. Mary River samples. The percent composition of the species from 24 samples is given in Figure 4-21. A summary of biomass and total number of cells per square millimeter is presented in Table 4-47.

Creel censuses between Fort Steele and the international border were carried out in the winters of 1962, 1963 and 1966[56]. Mountain whitefish was the major winter fish caught. The angler catch effort, expressed as fish/angler/hour, was 6.4 in 1962, 4.0 in 1963 and 4.2 in 1966. In situ fish experiments have been carried out upstream and downstream from the St. Mary River confluence, both before[45] and after[49,50] the pulp mill started operations. The results are summarized in Table 4-48.

There have been numerous complaints concerning flavour and odour of fish caught near the pulp mill[53]. Three studies were carried out to establish the difference in flavour and odour between fish caught below the pulp mill outfall and fish from other areas (White River, Bulkley River and Kootenay River above the mill). In each case the flavour and odour of whitefish and cutthroat trout caught near the mill scored significantly lower than fish from other areas[53].

5.2.2 Discussion

a) The Influence of the Pulp Mill Effluent

Invertebrate data collected before the pulp mill start-up in 1968 showed diverse populations dominated by pollution-sensitive, clean-water ephemeropterans and plecopterans (Table 4-44). Data from the upstream site obtained after mill start-up gave similar results with some generic variations[53].

Data collected from 1969 to 1974 downstream from the pulp mill showed up to 100 percent decrease in the numbers of pollution-sensitive ephemeropterans (and to a lesser extent plecopterans). Pollution-tolerant chironomids increased and became dominant (Figure 4-23). The invertebrate biomass was ten times greater upstream from the discharge compared to downstream (Figure 4-22). This result was due to the decrease in total number of individuals and to the dominance of the lighter chironomids at the downstream site.

Changes also occurred in the periphyton populations. At station 20, near Canal Flats, the genera Achnanthes and Gomphonema dominated and the cell numbers and biomass were low (Figure 4-21 and Table 4-47). Downstream from the mill, at stations 48 and 19, there was a progressive increase in biomass, one or two species generally accounting for more than 90percent of the total number of cells. Similar changes in periphyton population were cited by Langford[53]. Bull et.al.[52] also noted a reduction in generic diversity downstream from the mill.

The changes in invertebrate population may be due partly to changes in substrate type[47]. The substrate was rocky and silt-free at Canal Flats and became progressively more silty downstream[48]. The reduction of biomass and diversity, however, was too abrupt to be accounted for by this gradual change in substrate.

According to stomach analyses, whitefish caught away from the mill ate the same orders of invertebrates as found in samples upstream from the mill (Table 4-46). The fish ate mainly plecopterons, the numbers of which were reduced near the mill. According to odour and taste tests, few of the fish caught near the mill appeared desirable or palatable.

The data we have presented indicate that the pulp mill effluent has a pronounced effect on invertebrate and periphyton populations and on the flavour and odour of fish. The contaminants in the effluent which cause these effects are believed to be present in low concentrations. They include mercaptans, sulphides, resin and fatty acid soaps and chlorinated organics (Section 4.1.2 c), and Drew[57]).

b) The Influence of the St. Mary River

Sinclair[45] and Bull et.al.[46] sampled the Kootenay River before the pulp mill started discharging but while Cominco was in operation. They found that the sensitive invertebrates Ephemeroptera, Plecoptera and Trichoptera decreased in numbers from Canal Flats upstream from the confluence to Fort Steele at the confluence (Table 4-44, Figure 4-19). In 1969, following start-up of the pulp mill, Bull et.al.[46] observed little difference between samples at Wasa (upstream from the confluence) and at Fort Steele (Table 4-45). Data collected by the Pollution Control Branch from 1971 to 1974 showed an increase in the number of sensitive, clean-water invertebrates at Wardner (downstream from the confluence), compared to Wasa, (between the mill and the confluence) and Wycliffe (on the St. Mary River). However, the samples at Wardner still showed a decrease in invertebrates compared to the control stations 20 on the Kootenay River and 29 on the

St. Mary River, located upstream from the discharges. These data indicate that the St. Mary River is having some detrimental effect on invertebrate populations in the Kootenay River at Wardner.

No periphyton data are available from the Kootenay River before the pulp mill start-up in 1968. Data from 1972-1973 show an increase in biomass at stations downstream from the confluence (Table 4-47). Pollution tolerant genera Stigeoclonium and Ulothrix, as well as more sensitive species, were present at the downstream sites (Figure 4-21).

Fish-caging experiments showed 100% survival of rainbow trout after 48 hours and 96 hours at Fort Steele on the east and west sides of the Kootenay River, and at Wardner (Table 4-48). Data from Fort Steele are perhaps inconclusive as the water level rose three feet during the test, diluting any potential contaminants.

c) The Influence of The Bull River

The data from the mouth of the Bull River at station 30 indicate relatively undisturbed periphyton and invertebrate populations (Figures 4-21 and 4-23). These results confirm the water quality data (Chapter 4) which showed that the Bull River was not being contaminated.

5.2.3 Recommendations

No detailed biological studies need be carried out in the vicinity of the pulp mill until the effluent from the mill is upgraded. Monitoring of the Kootenay River should be continued to assess the effect of the improvements to be carried out at the Cominco operations. Further monitoring should include the following points:

a) Station 175, just upstream from the pulp mill should be sampled regularly, as well as station 20 located several miles further upstream.

b) A new station should be established just upstream from the confluence with the St. Mary River.

c) At least three invertebrate and periphyton samples should be collected at each station during each sampling period.

d) Biological samples should be collected at the same time as water and sediment samples. However, biological samples need to be collected only two or three times a year.

e) The possibility of carrying out long and short term fish-caging experiments should be considered.

f) A fish survey of the Kootenay River should be carried out, in conjunction with the fish survey suggested for the St. Mary River.

5.3 Libby Reservoir (Lake Koocanusa)

The Libby Dam was built to provide flood control and hydro electric power generation on the Kootenay River. Construction was initiated in 1971 and full reservoir capacity was reached in June, 1974. At full pool the reservoir inundates an area from the dam site, near Libby, Montana, to Wardner, B.C. At full pool the water is at an elevation of 2549 feet (above sea level). Normal drawdown is 100 feet, and maximum vertical drop is 172 feet. The fluctuation in water level, as well as the relatively short residence time of water behind the dam, have a significant effect on both the physical structure and biota of the water body.

5.3.1 Presentation and Interpretation of the Data

The effects of the reservoir on water quality and aquatic biology have been studied. The U.S. Corps of Engineers has studied the American portion and the Pollution Control Branch, the Canadian portion. The studies were divided into a pre-impoundment phase[47], covering the period 1966-1971, and a post-impoundment phase[48]. The biological data presented in this section were obtained during the post-impoundment phase.

Data were collected to measure the productivity of the reservoir and to estimate whether excessive productivity was likely to occur. Excessive productivity is manifested by algae blooms and a deterioration in water quality.

Measurements of phytoplankton and zooplankton species and numbers, chlorophyll a concentrations and carbon 14 productivity were made from 1971 to 1974 at four sampling stations (sites 187, 169, 101, 100, Figure 4-18). Approximately 200 measurements were carried out. The collection of samples, the analytical methods and the interpretation of data are described in detail in two technical reports[58,59]. A summary of the information is presented in Table 4-49 together with data from other lakes for comparative purposes.

Phytoplankton were obtained with a three litre Van Dorn bottle from depths of 1, 5, 10, 15 and 20 m. The samples from the five depths were composited into a single sample. The biomass productivity data, which we have calculated according to Vollenweider[60], were based on this method.

There was a large variation, both qualitative and quantitative, in the composition of the phytoplankton species. A marked change in dominant species occurred between 1973 and 1974. The 1973 photoplankton were generally dominated by diatoms (e.g., Asterionella, Fragilaria, Synedra). The 1974 phytoplankton were dominated by greens and blue-greens in the summer (e.g., Aphanathece, Chroococcus, Pandorina, Anabaena). Diatoms regained dominance in the autumn.

Algal growth increased in June or July, peaked in September or October, and then decreased. The increase in early summer was due to lower turbidity after freshet which allowed more active photosynthesis to occur. The algal growth in 1973 and 1974, given in Table 4-49, was much lower than expected from the high loading of phosphorus. The loading of phosphorus to the Libby reservoir is shown graphically in Figure 4-24. One indication of excess algal growth occurred in October, 1974, when there was a bloom of Aphanizomenon flos-aquae[61]. This species had not been reported in any previous sampling. The samples taken before and after the bloom showed no presence of the organism, indicating a rapid reproduction and decline of the population.

Zooplankton samples were collected with a No. 20 mesh Wisconsin net until June 1973 and with a No. 10 mesh Wisconsin net after this date. Duplicate vertical hauls were taken from near the bottom to the surface.

Zooplankton numbers were lower than results from other lakes at the same latitude (Table 4-49). There was generally a peak of the population in July, a minimum in August and another peak in October. The dominant zooplankton genus was a species of Daphnia. In the autumn with colder water, Cyclops and Diaptomus became dominant. The spatial distribution of the zooplankton was very heterogeneous. Stations sampled on the same day showed large variations in numbers.

Chlorophyll a was sampled in conjunction with phytoplankton and analyzed by the method of Strickland and Parsons[62]. The chlorophyll a concentrations indicated low productivity levels (Table 4-49).

Productivity by the carbon 14 method was measured using standard procedures[59]. The carbon 14 uptake rates also indicated low productivity (Table 4-49).

5.3.2 Discussion of Results

The high phosphorus loadings to the Libby reservoir, documented in Chapter 4, were expected to produce high productivity, as indicated in Figure 4-24. However, the productivity of the reservoir has been low so far. This result can be explained in a number of ways:

a) Thermal Stability

The reservoir has not achieved thermal stability in part due to the irregular drawdown and filling regime used during construction of the dam. This operation, together with wind action, resulted in a weak or absent thermocline and allowed deep mixing of the water in the reservoir. The phytoplankton were removed from the photic zone and productivity was inhibited. Once the reservoir is operated regularly these effects may be negated and large algal blooms may result. Retention of water in the reservoir is approximately 230 days, which is considered low. The short retention time contributes to the instability of the reservoir.

b) Light Penetration

Light penetration into the water may have been limited by the turbidity carried from the Kootenay River. This phenomenon would keep phytoplankton production at a low level for a large portion of the growing period.

c) Phosphate

There was evidence of a significant loss of phosphate from the water column (Chapter 4) which may have reduced productivity.

d) Water Flow

The flow of the Kootenay River during the summer was along the bottom of the reservoir. Some of the incoming nutrients were thus carried below the photic zone and away from possible uptake.

5.3.3 Recommendations

a) The reservoir is now in a dynamic state and will probably remain this way for a number of years. Sufficient data will have been collected by the end of 1975 to document the early stages of the reservoir. A review of the program should be made, after the 1975 data have been analyzed, to determine whether additional data collection is justified. Resumption of sampling will depend on the stability of the reservoir and the degree to which nutrients have been eliminated from the discharges of Cominco's operation.

b) The location, accumulation and chemistry of allochthonous sediments (sediments which have been transported) should be studied.

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69. Water Register, Fernie Water District, Tobacco Plains, Rock Creek, Wasa, Fort Steele, Sheep Creek and Bull River Precints, and Cranbrook Water District, Cherry Creek, Cranbrook, Gold Creek, Skookumchuck, St. Mary and Wardner Precints, Administrative Division, Water Rights Branch, Victoria, B.C.

70. Poll. Contr. Br. File PE-148, Minutes of Meeting of Nov. 4, 1975.

71. Pollution Control Objectives for Municipal Type Waste Discharges in B.C., Water Resources Service, Victoria, B.C., Sept., 1975.

FIGURE 4-1
REGION 4

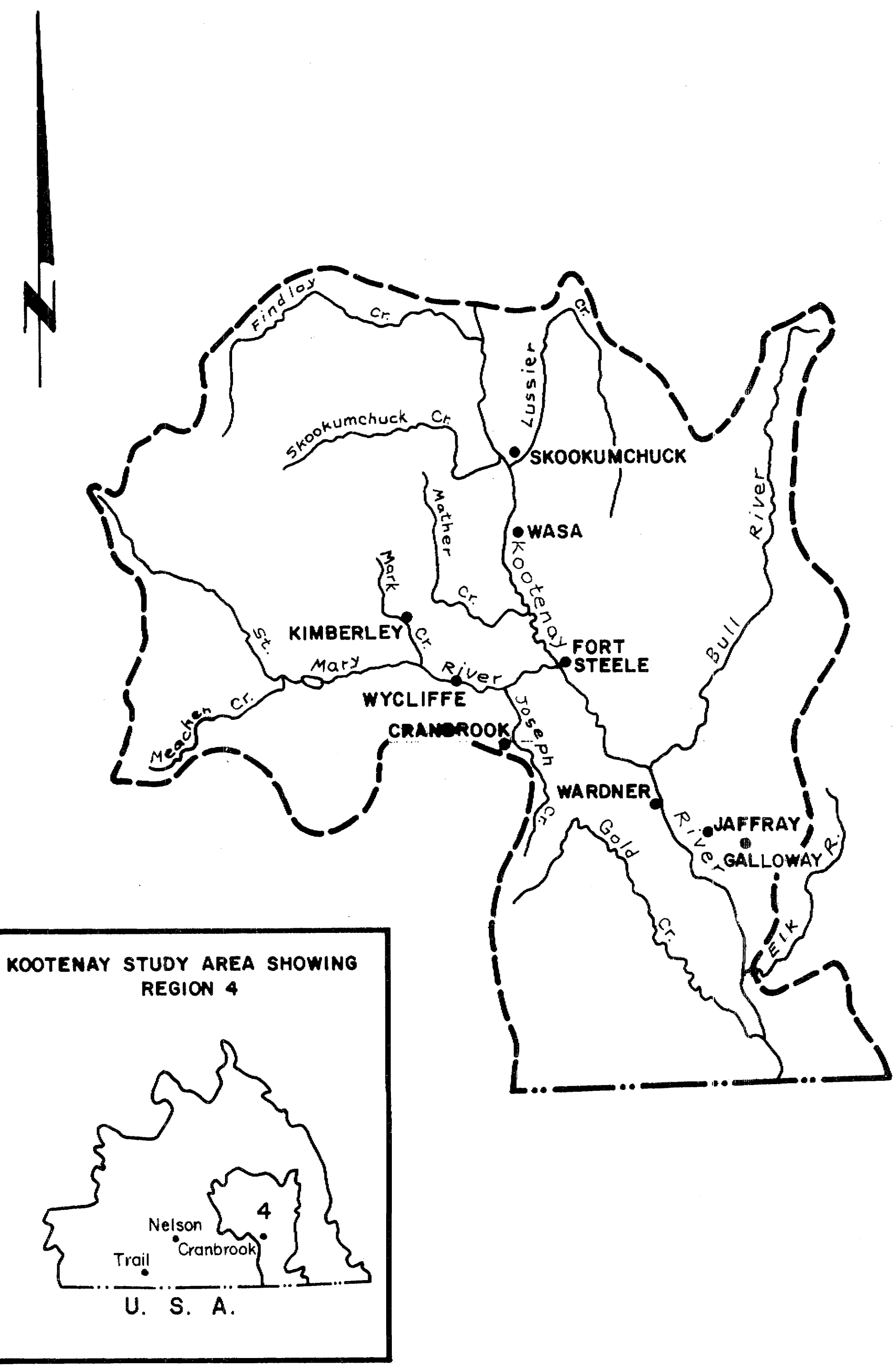


FIGURE 4-2
REGION 4, NORTH SECTION

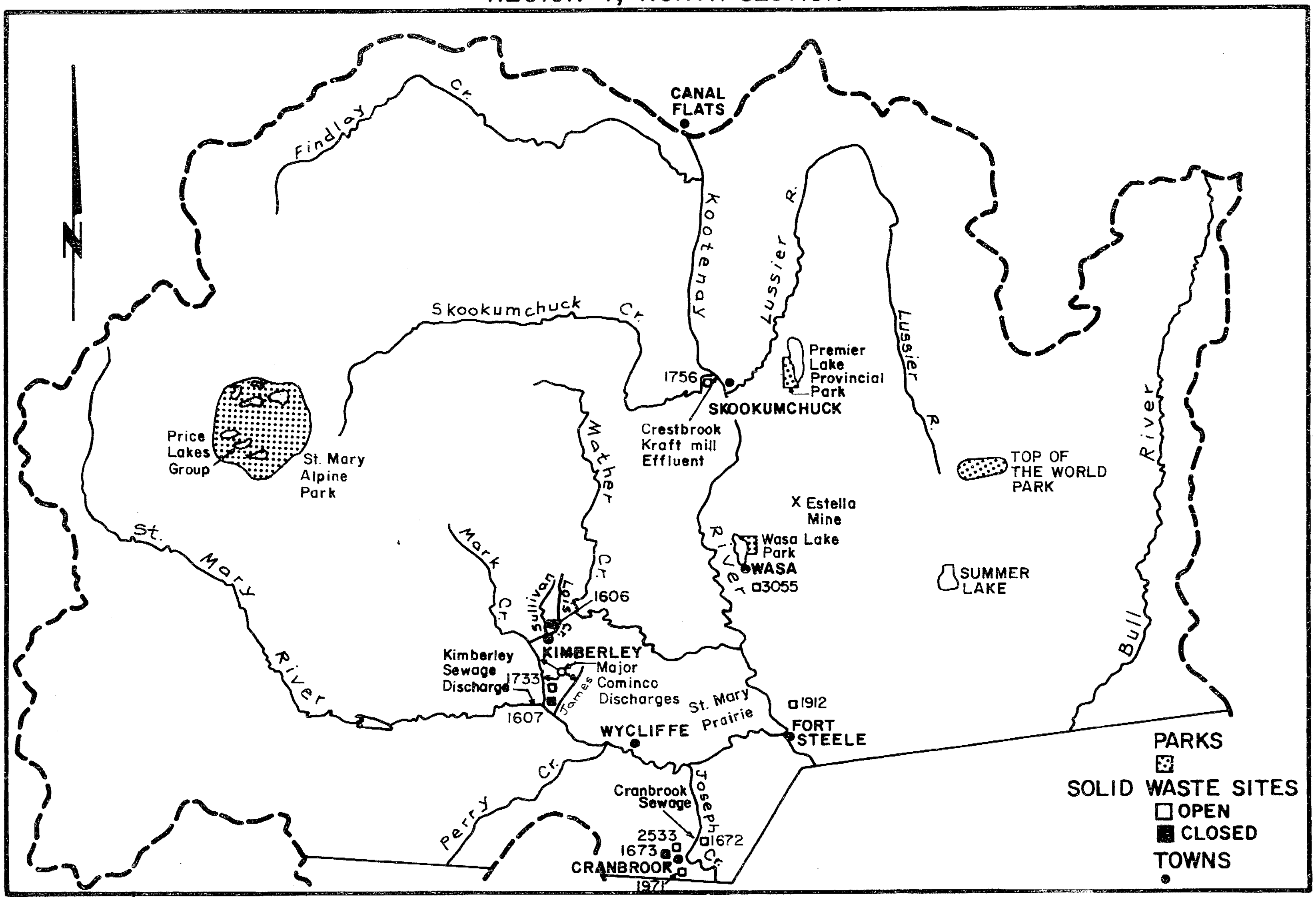


FIGURE 4-3
REGION 4, SOUTH SECTION

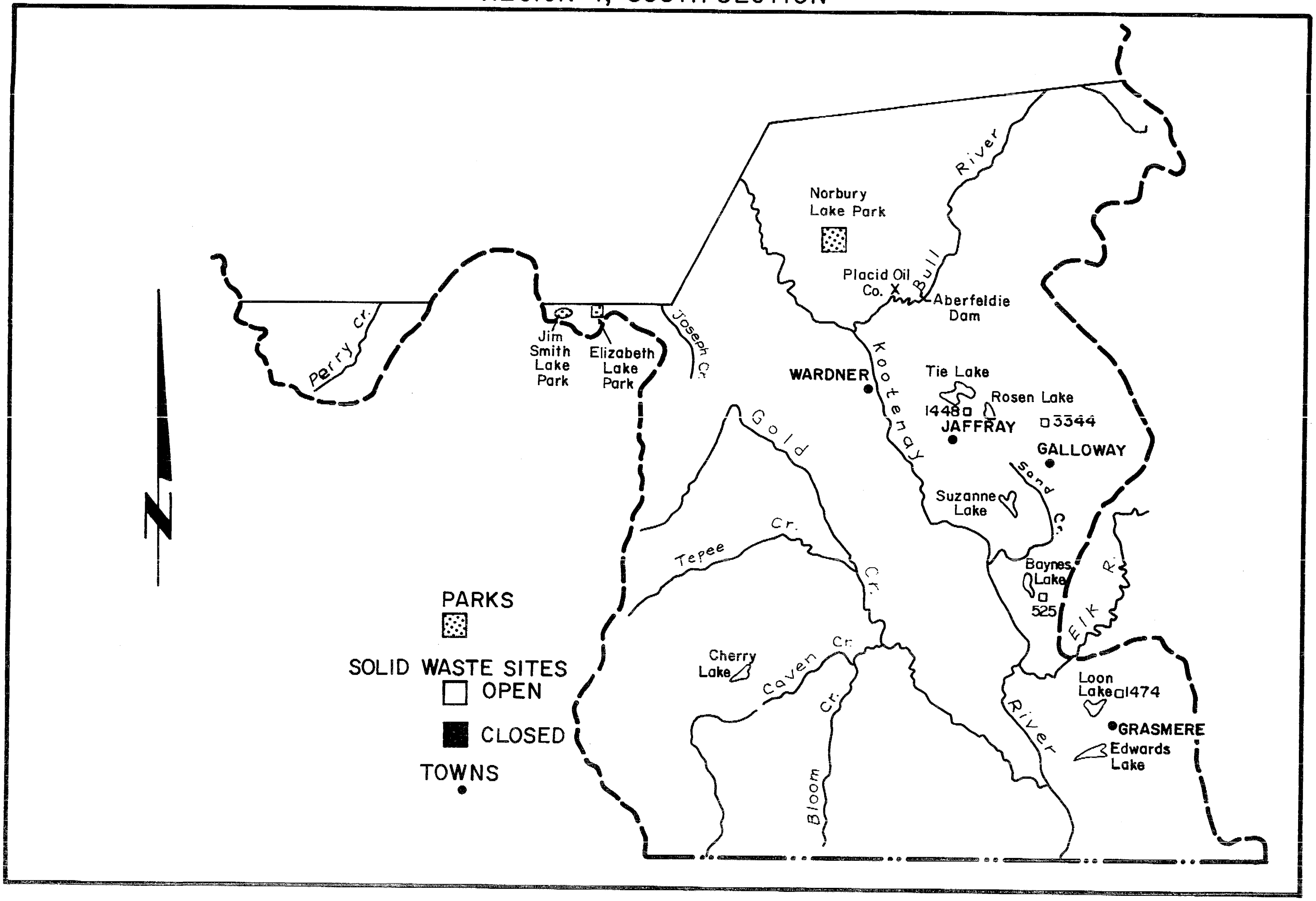


FIGURE 4-4
CRESTBROOK FOREST INDUSTRIES LTD.
SIMPLIFIED FLOW DIAGRAM OF THE PULPING AND BROWN STOCK WASHING PROCESSES

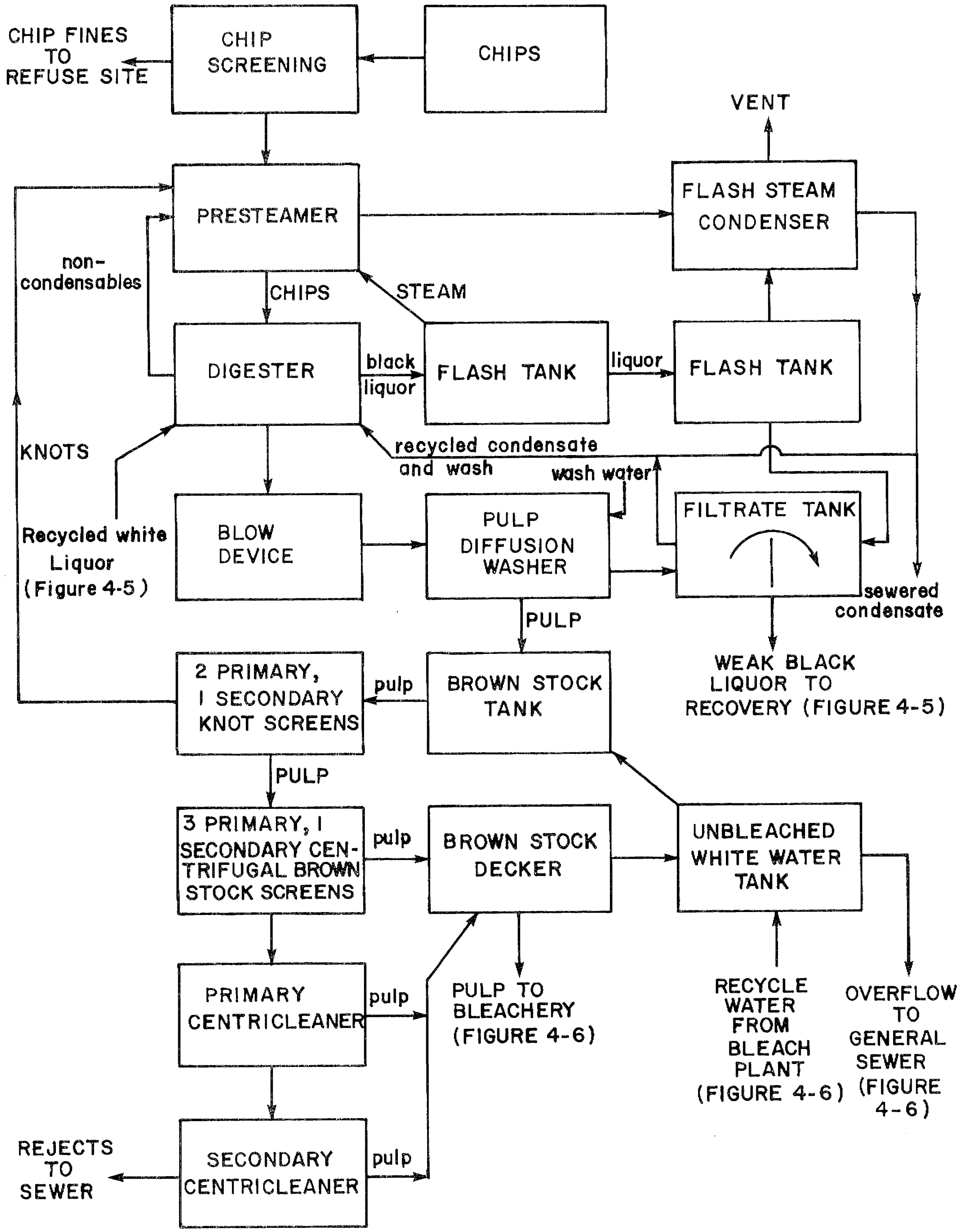


FIGURE 4-5
CRESTBROOK FOREST INDUSTRIES LTD.
SIMPLIFIED FLOW DIAGRAM OF THE RECOVERY PROCESS

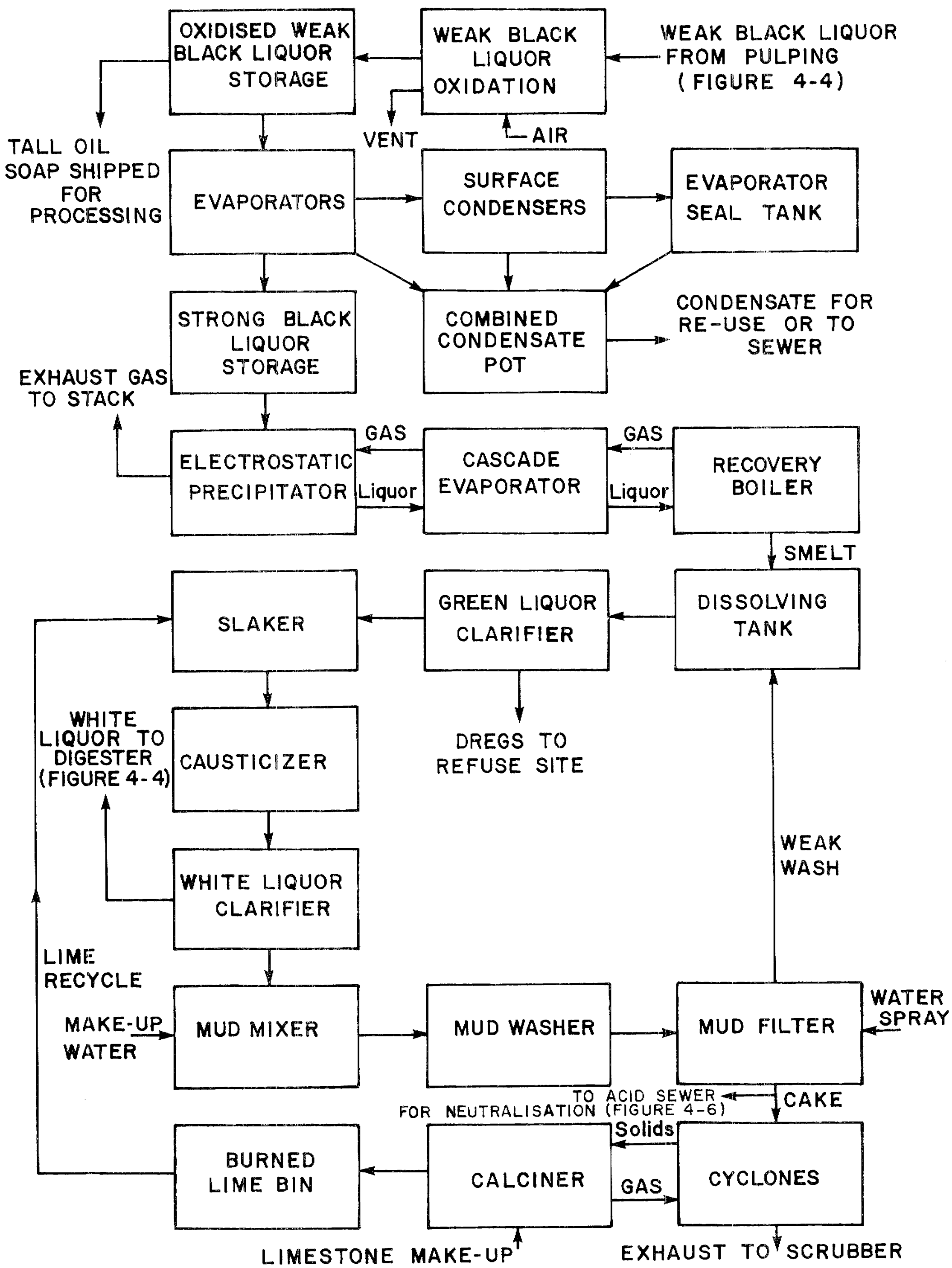


FIGURE 4-6
CRESTBROOK FOREST INDUSTRIES LTD.
SIMPLIFIED FLOW DIAGRAM OF THE BLEACHING, SHEET FORMATION AND EFFLUENT TREATMENT PROCESSES

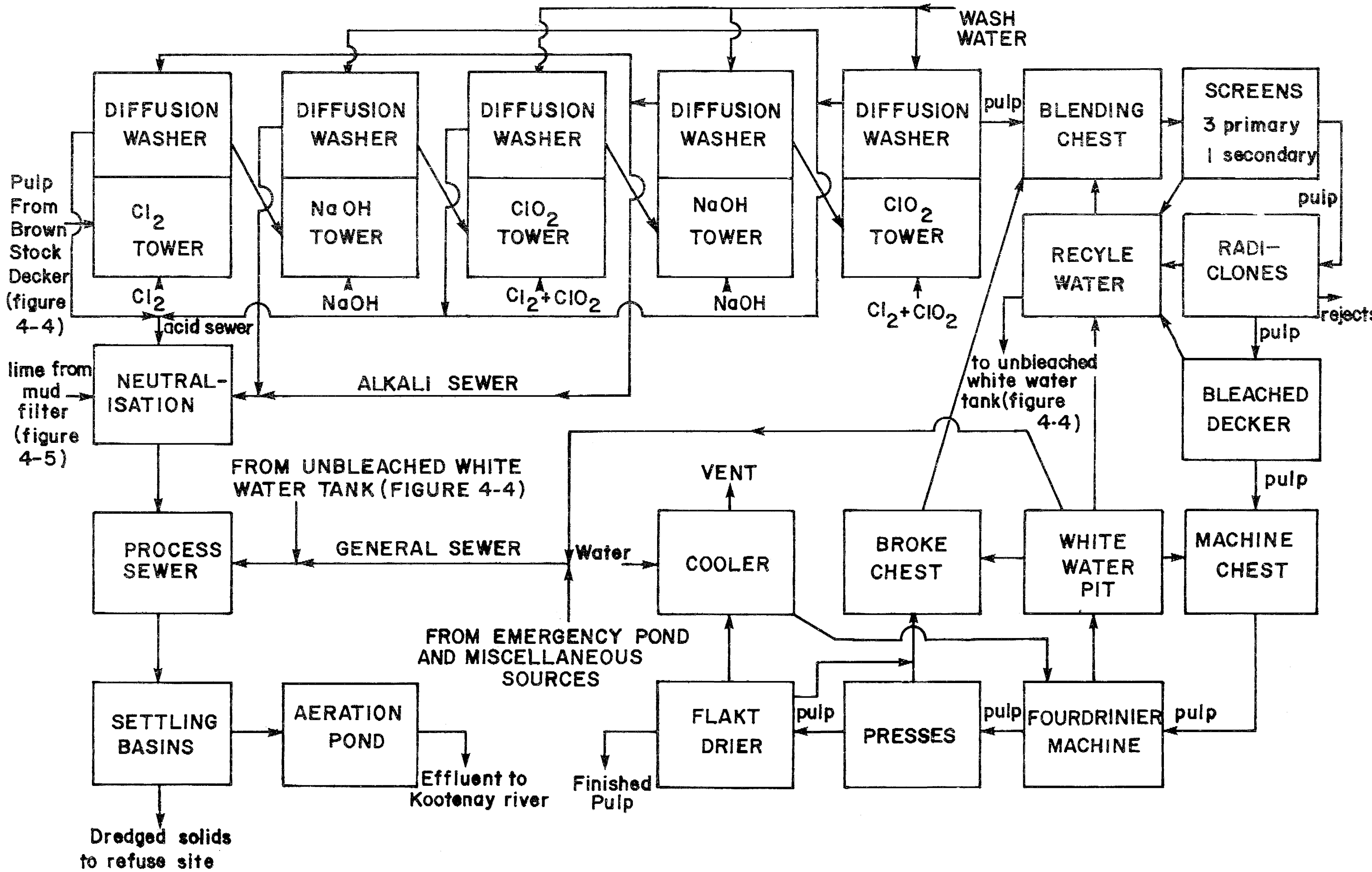


FIGURE 4-7

DIAGRAMMATIC PRESENTATION OF COMINCO LTD. OPERATIONS

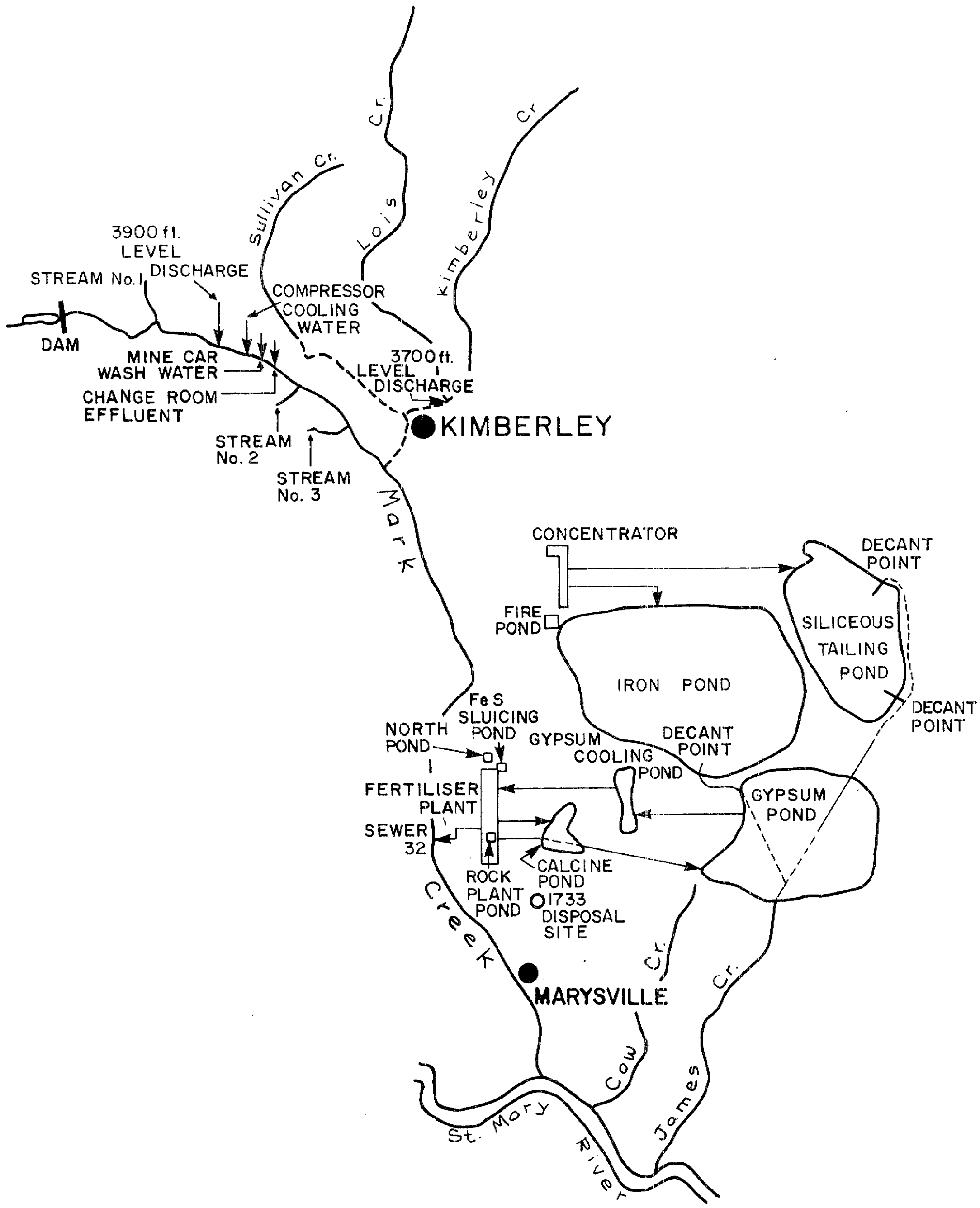


FIGURE 4-8
COMINCO LTD.
SIMPLIFIED FLOW DIAGRAM OF THE SULLIVAN CONCENTRATOR
SINK AND FLOAT CIRCUIT

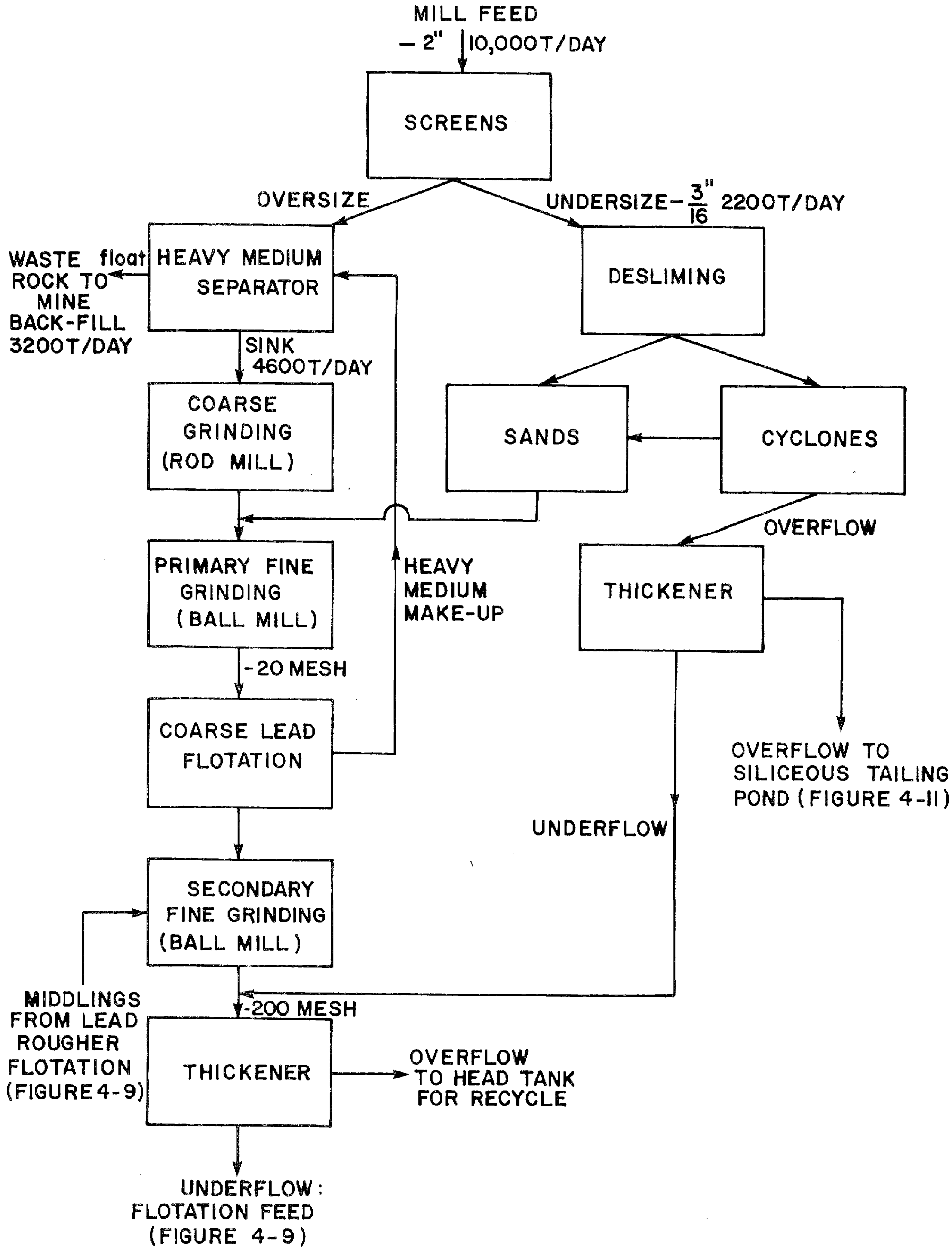


FIGURE 4-9
COMINCO LTD.
SIMPLIFIED FLOW DIAGRAM OF THE SULLIVAN CONCENTRATOR
LEAD CIRCUIT

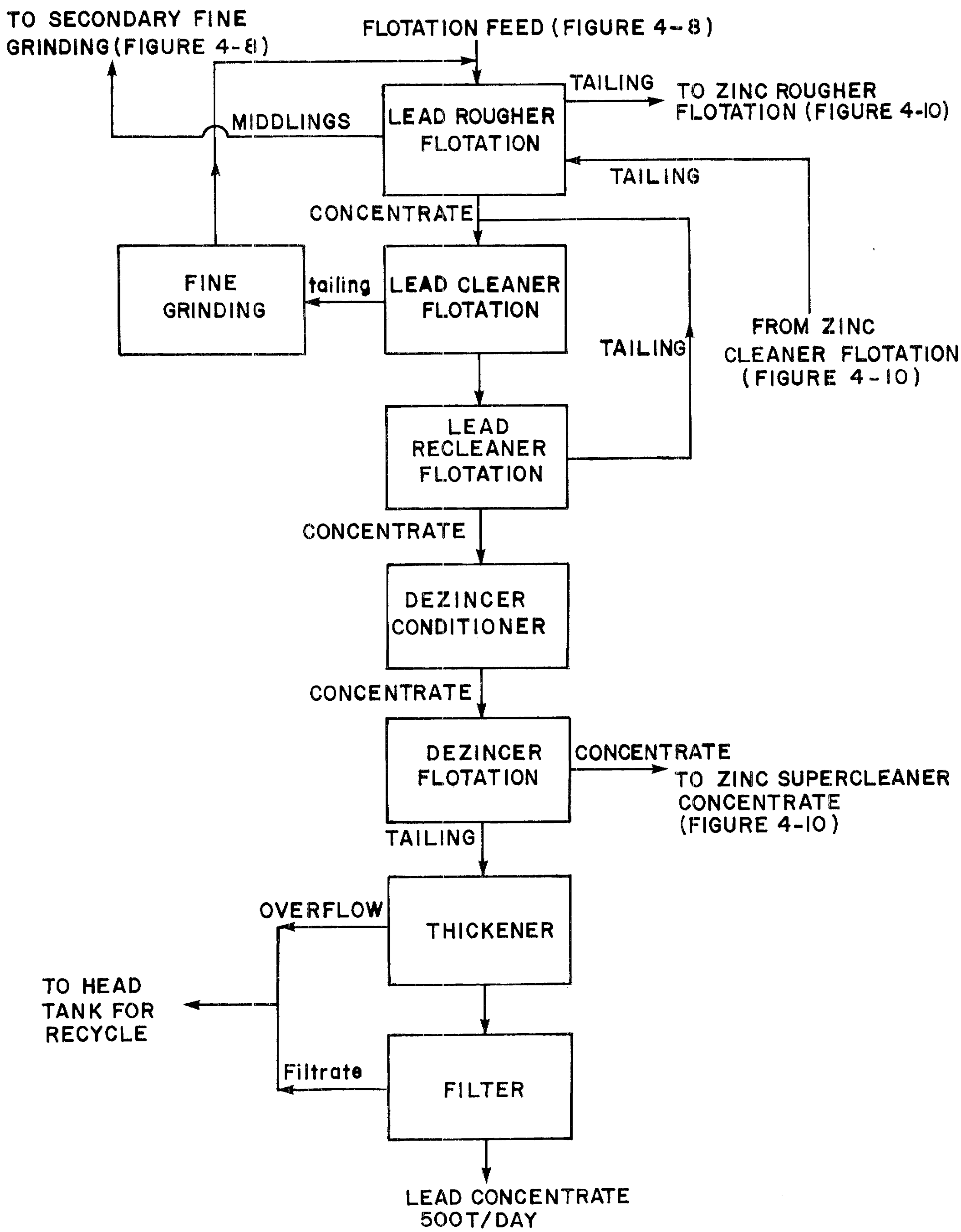


FIGURE 4-10
COMINCO LTD.
SIMPLIFIED FLOW DIAGRAM OF THE SULLIVAN CONCENTRATOR
ZINC CIRCUIT

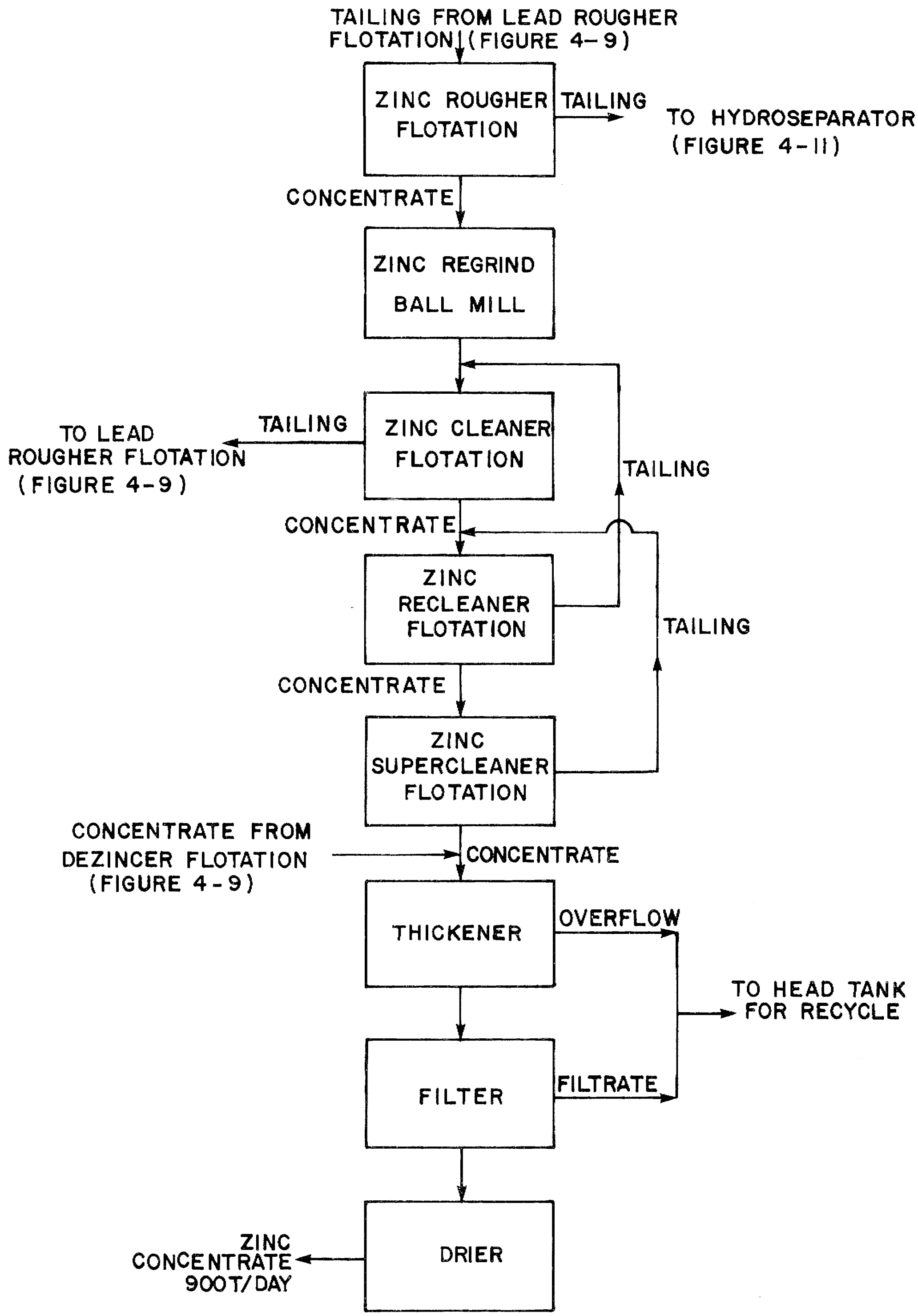


FIGURE 4-11
COMINCO LTD.
SIMPLIFIED FLOW DIAGRAM OF THE SULLIVAN CONCENTRATOR
IRON AND TIN CIRCUITS

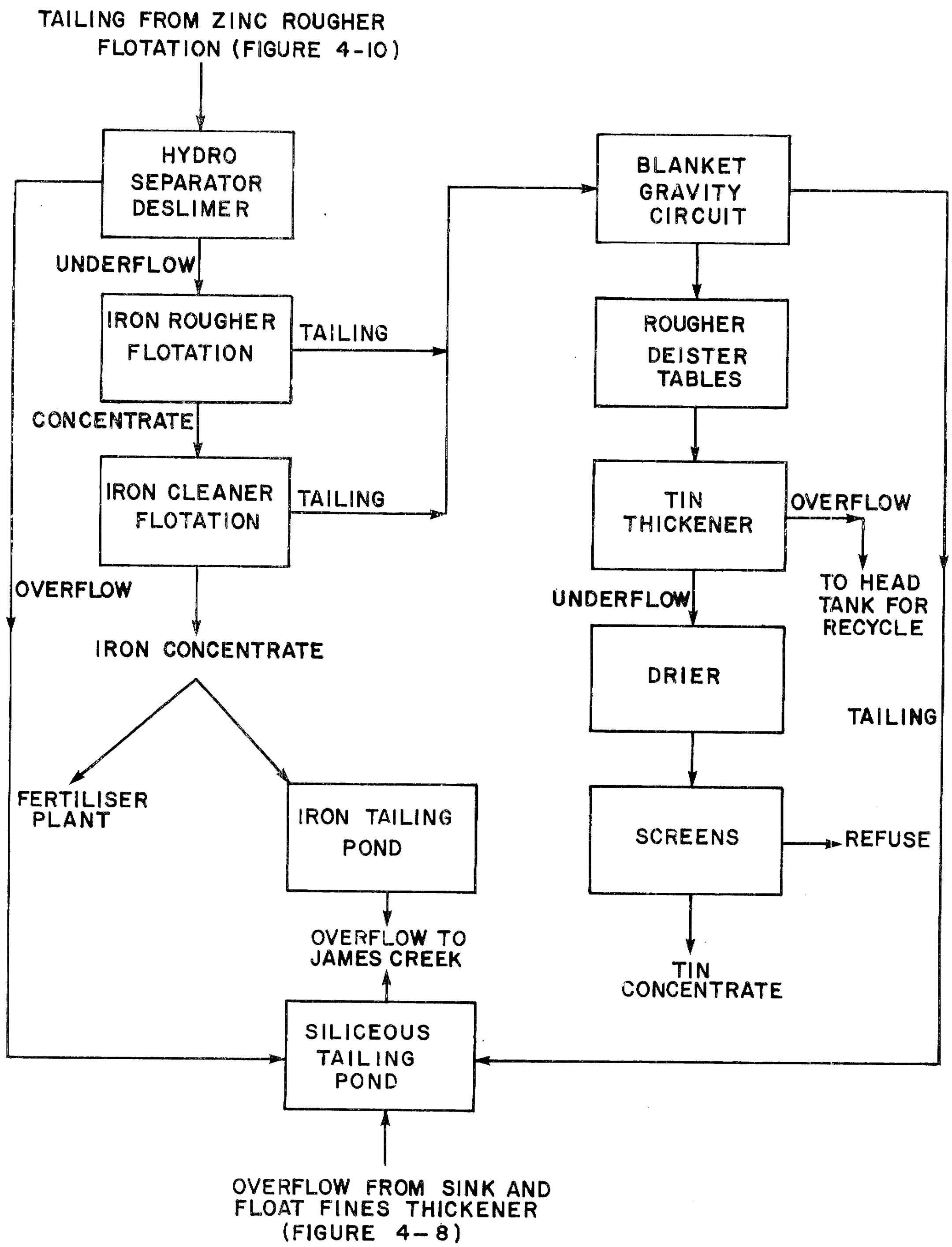


FIGURE 4-12
COMINCO LTD.
SIMPLIFIED FLOW DIAGRAM OF THE IRON SULPHIDE ROASTING AND SULPHURIC ACID PLANT

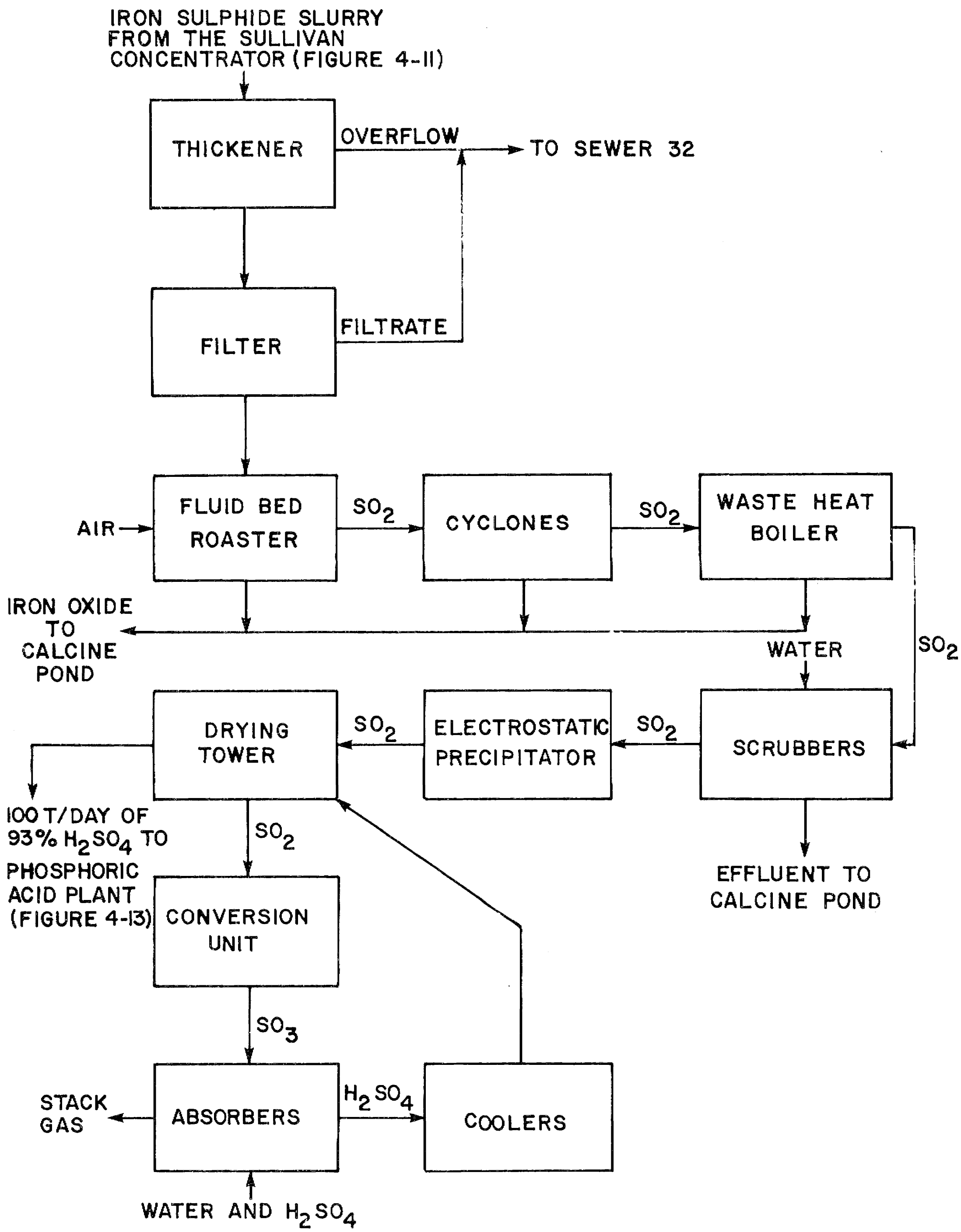


FIGURE 4-13
COMINCO LTD.
SIMPLIFIED FLOW DIAGRAM OF THE PHOSPHORIC ACID PLANT

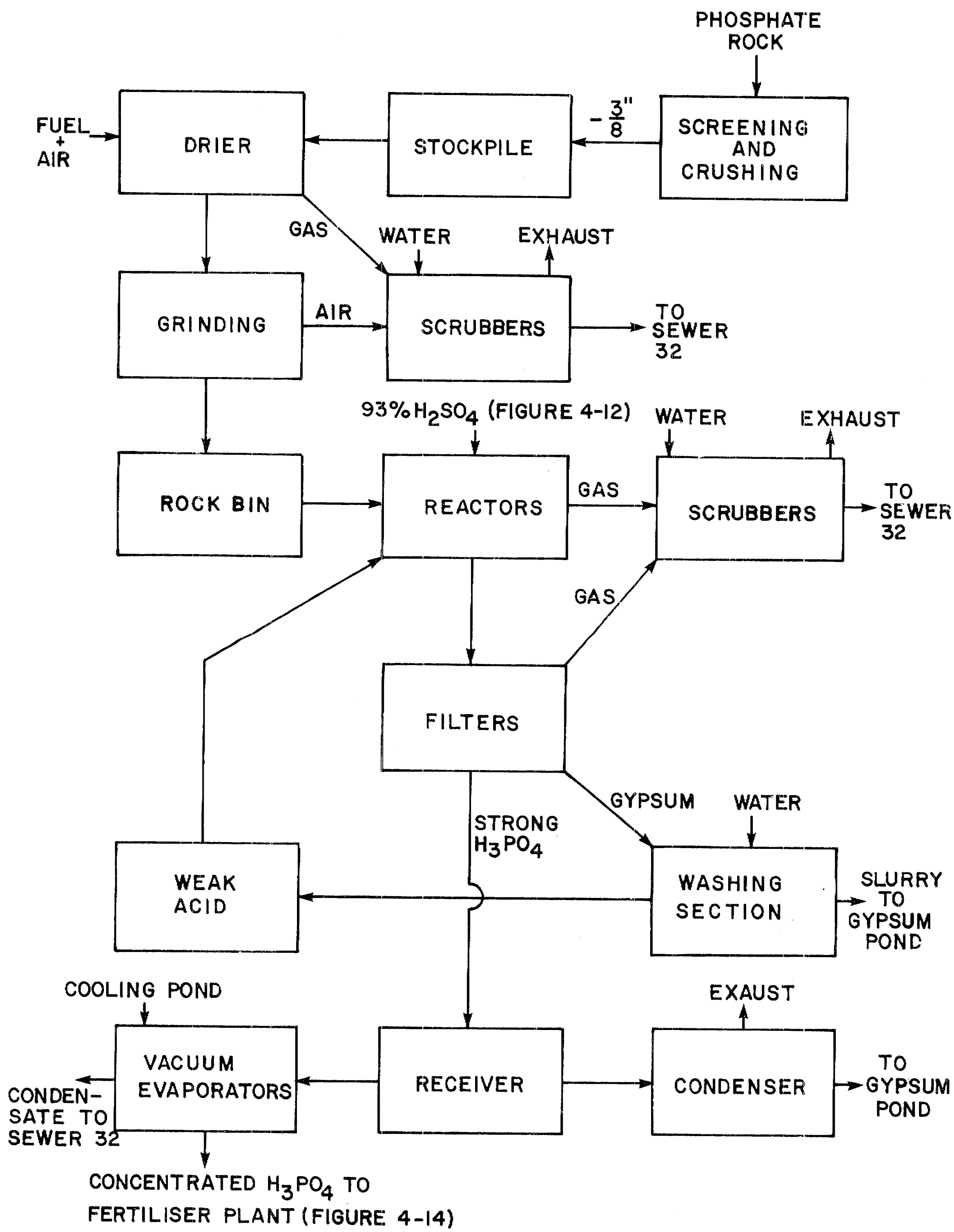


FIGURE 4-14
COMINCO LTD.
SIMPLIFIED FLOW DIAGRAM OF THE FERTILIZER PLANT

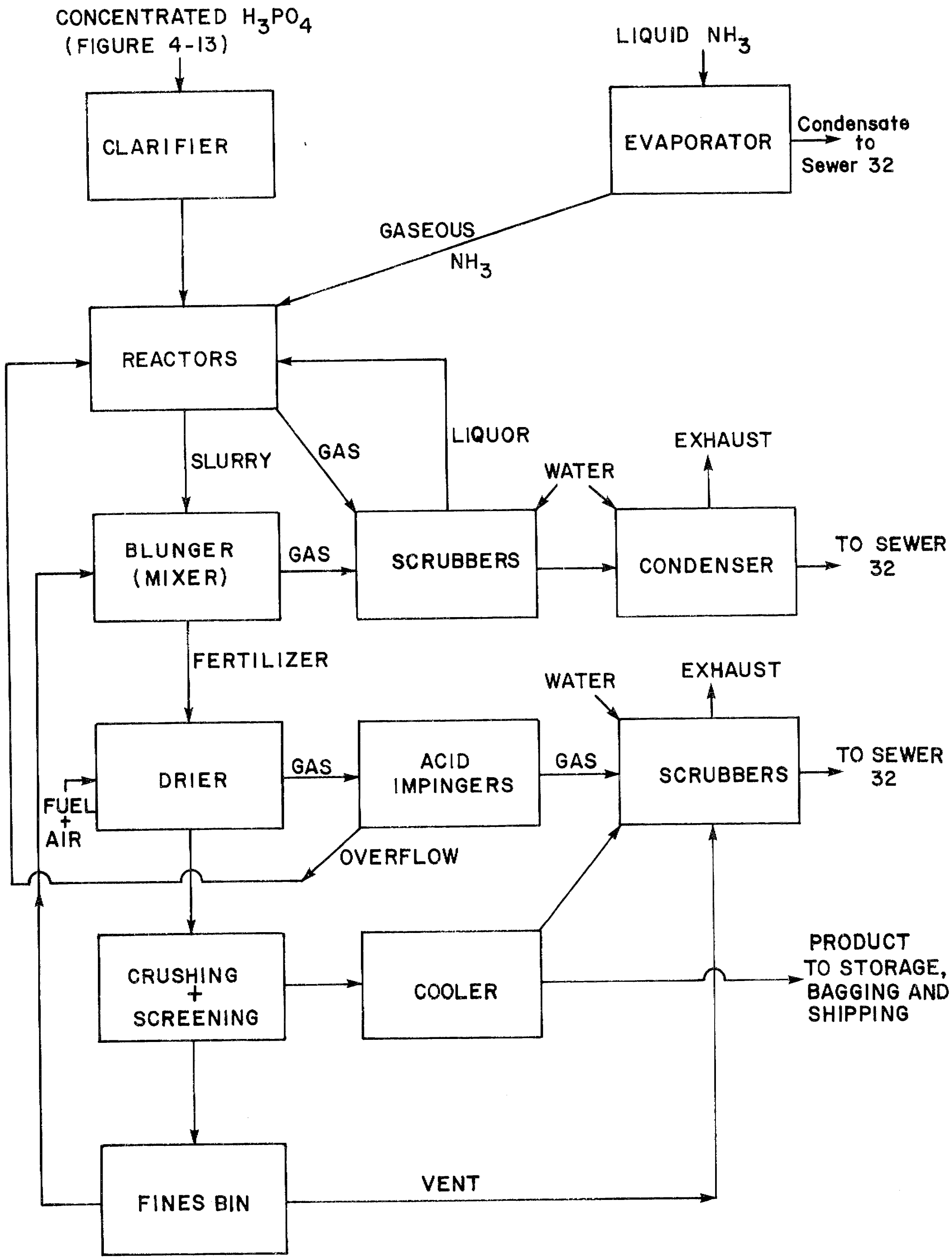
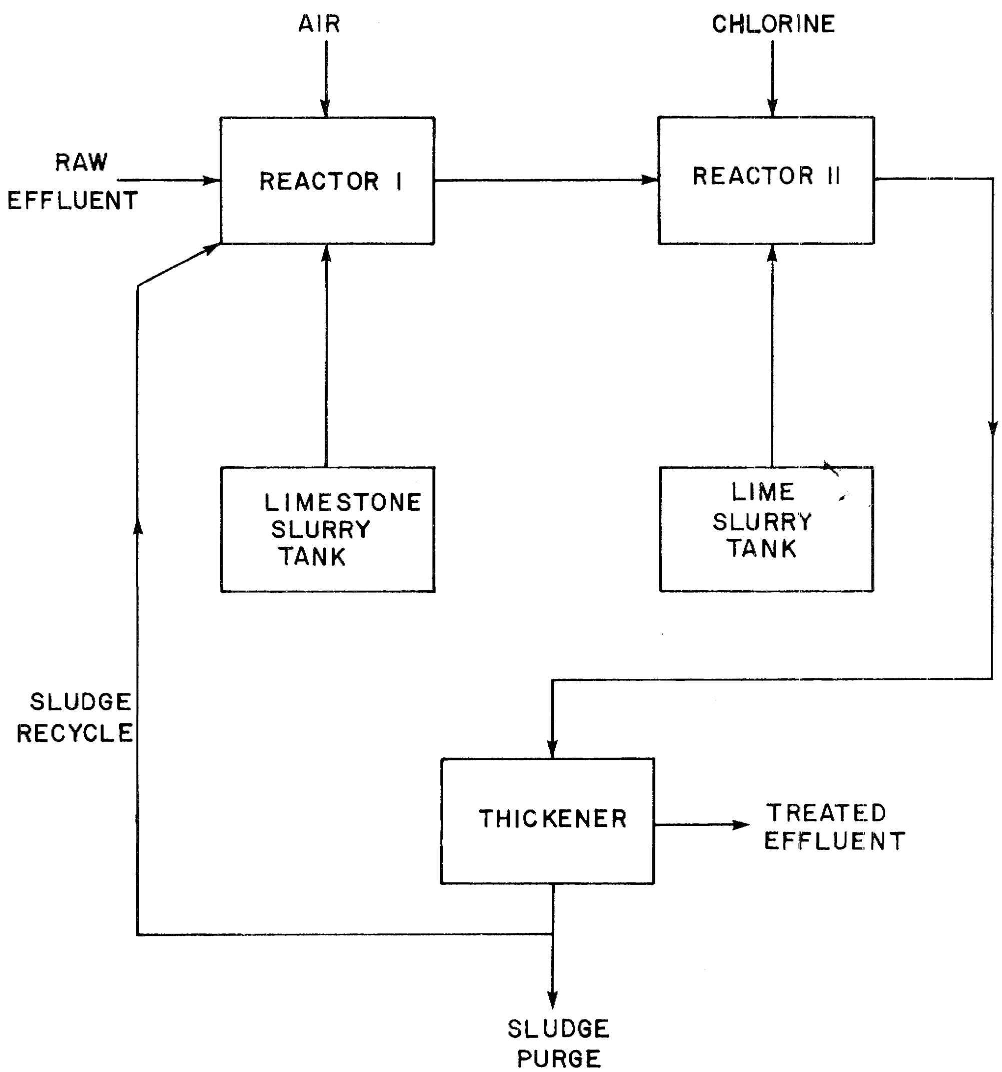


FIGURE 4-15
COMINCO LTD.
SIMPLIFIED FLOW DIAGRAM OF PROPOSED MINE EFFLUENT TREATMENT PROCESS



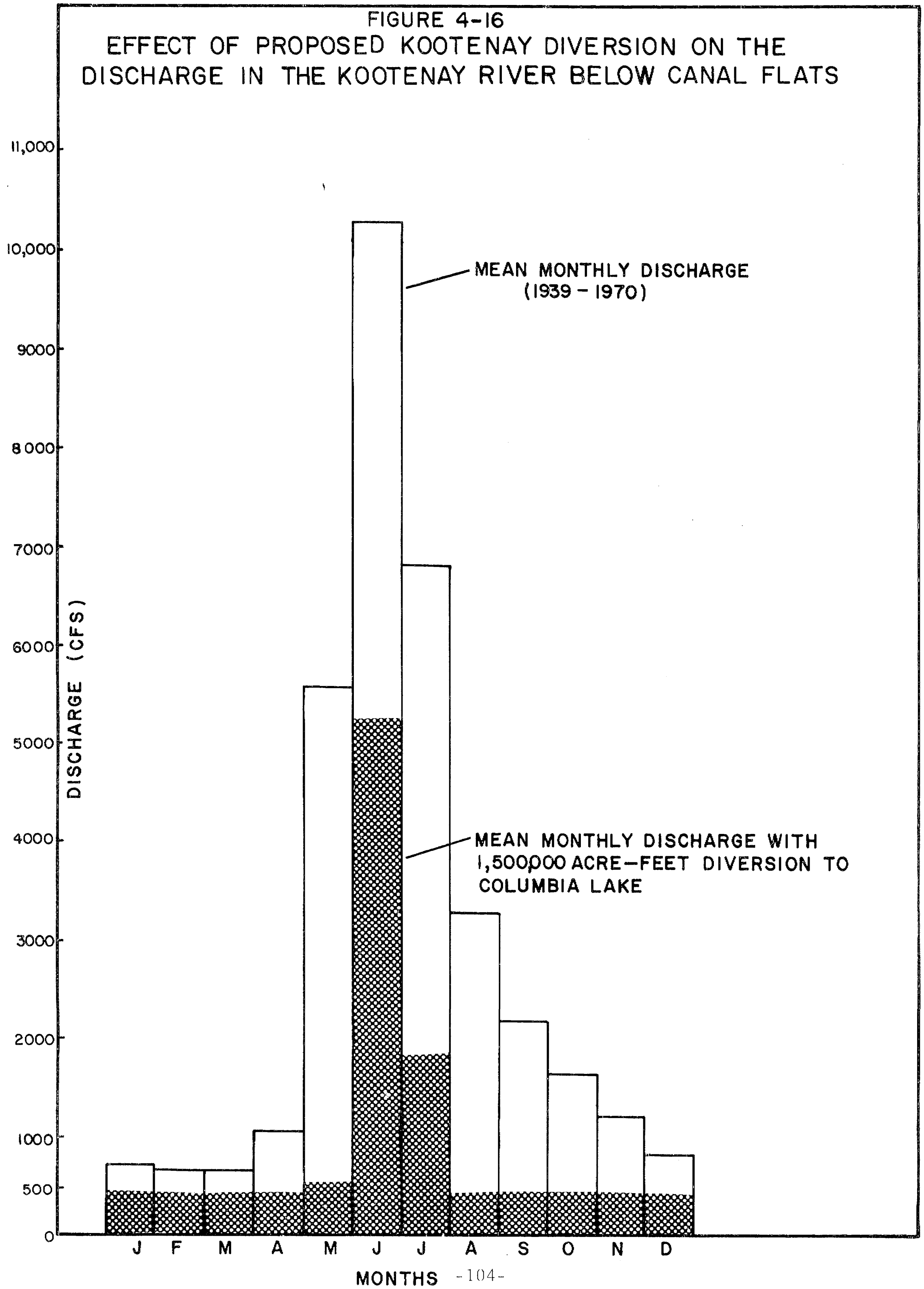


FIGURE 4-16
EFFECT OF PROPOSED KOOTENAY DIVERSION ON THE DISCHARGE IN THE KOOTENAY RIVER BELOW CANAL FLATS
11,000
10,000
9000
8000
7000
6000
5000
4000
3000
2000
1000
500
0
DISCHARGE (CFS)
MEAN MONTHLY DISCHARGE (1939 - 1970)
MEAN MONTHLY DISCHARGE WITH 1,500,000 ACRE-FEET DIVERSION TO COLUMBIA LAKE
J F M A M J J A S O N D
MONTHS

FIGURE 4-17
REGION 4, NORTH SECTION–LOCATION OF SAMPLING SITES

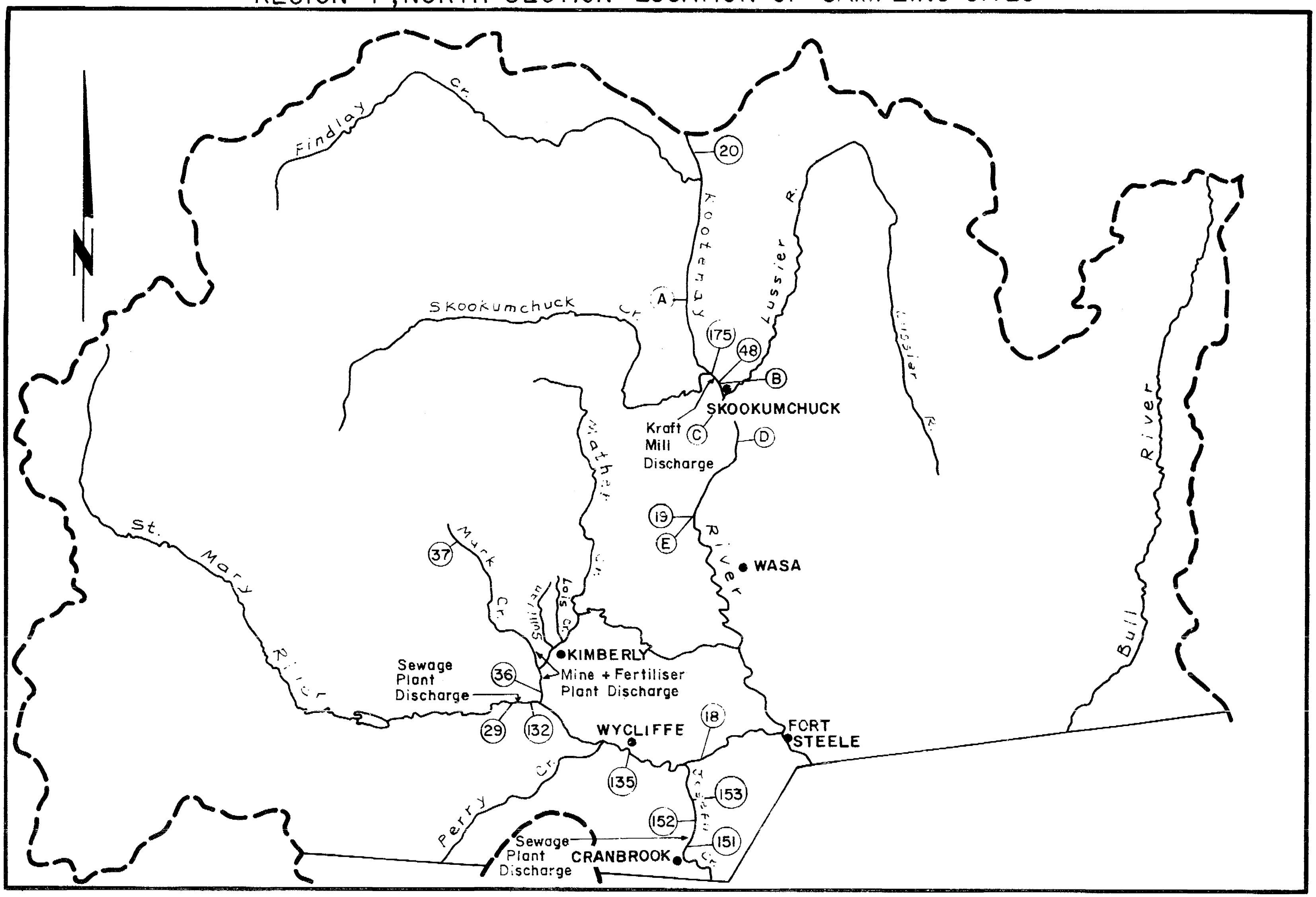


FIGURE 4-18
REGION 4, SOUTH SECTION-LOCATION OF SAMPLING SITES

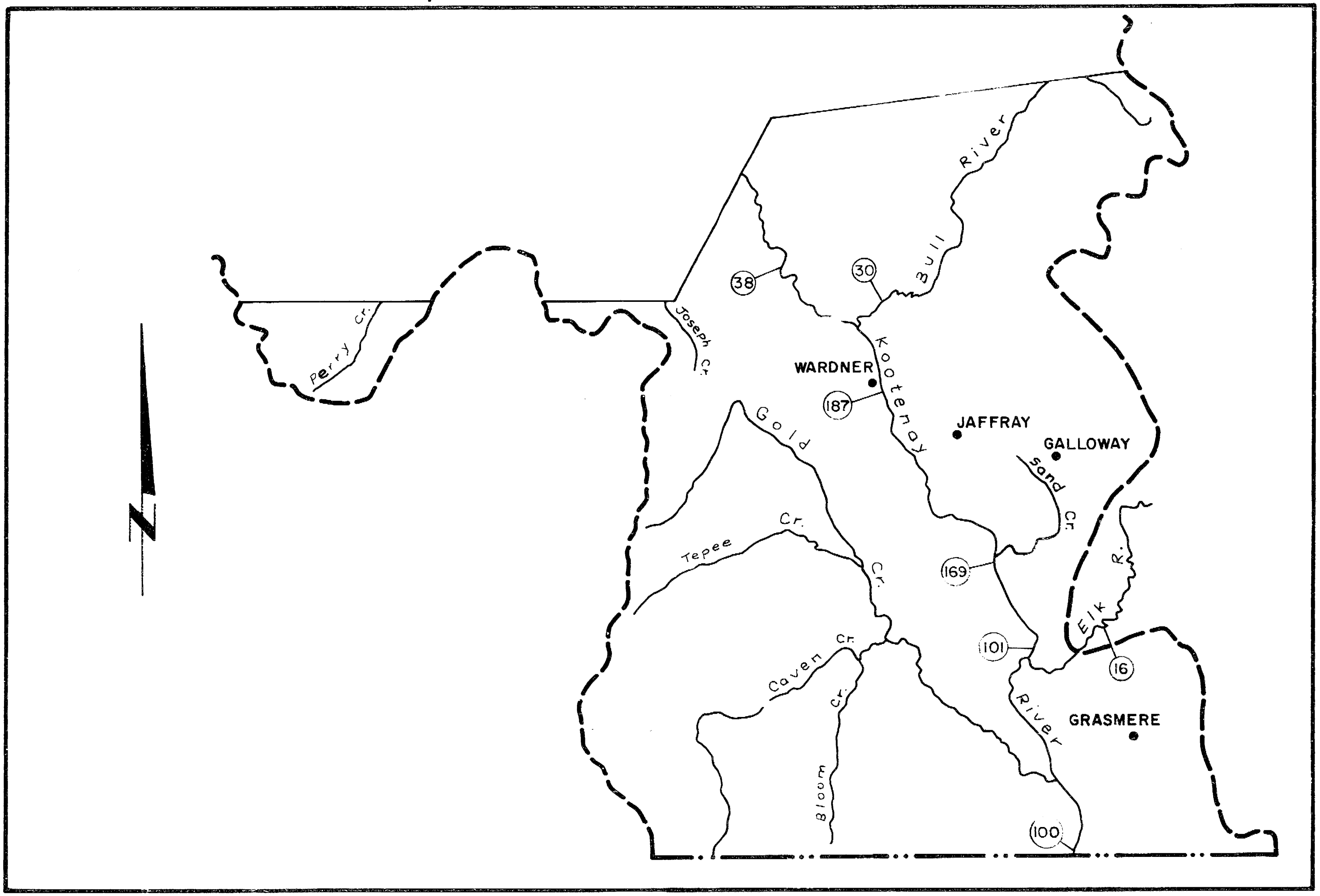
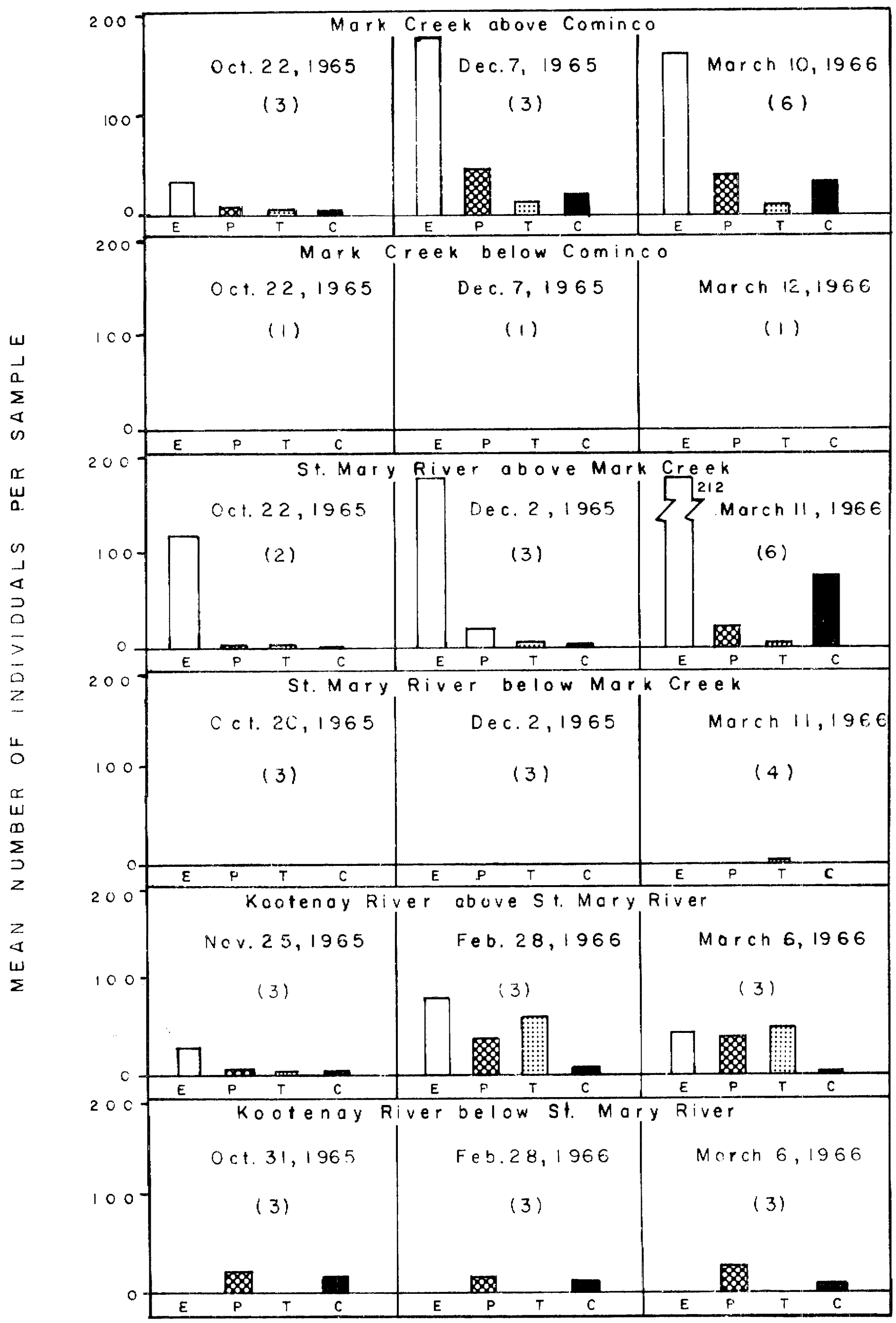
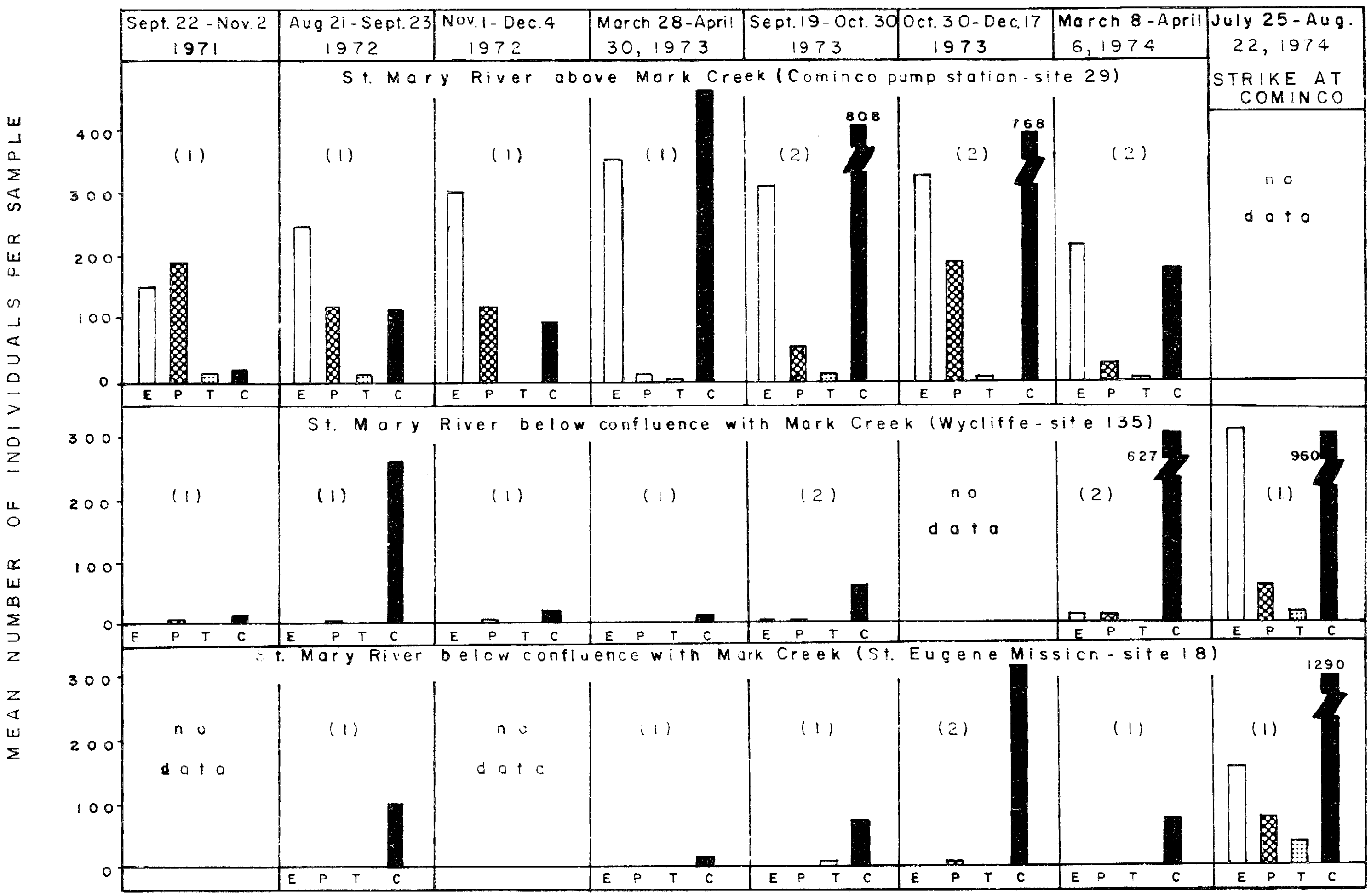


FIGURE 4-19
INVERTEBRATE DATA FOR MARK CREEK, ST. MARY RIVER AND KOOTENAY RIVER, COLLECTED 1965-1966



NOTE: E = Ephemeroptera, P = Plecoptera, T = Trichoptera, C = Chironomidae
number of samplers used is in brackets

FIGURE 4-20
INVERTEBRATE DATA FOR ST. MARY RIVER, COLLECTED 1971-1974



NOTE: E=Ephemeroptera, P=Plecoptera, T=Trichoptera, C=Chironomidae
number of samplers used is in brackets

FIGURE 4-21

PERIPHYTON DATA FROM KOOTENAY RIVER AND TRIBUTARIES, MARCH 1972 TO DEC. 1974

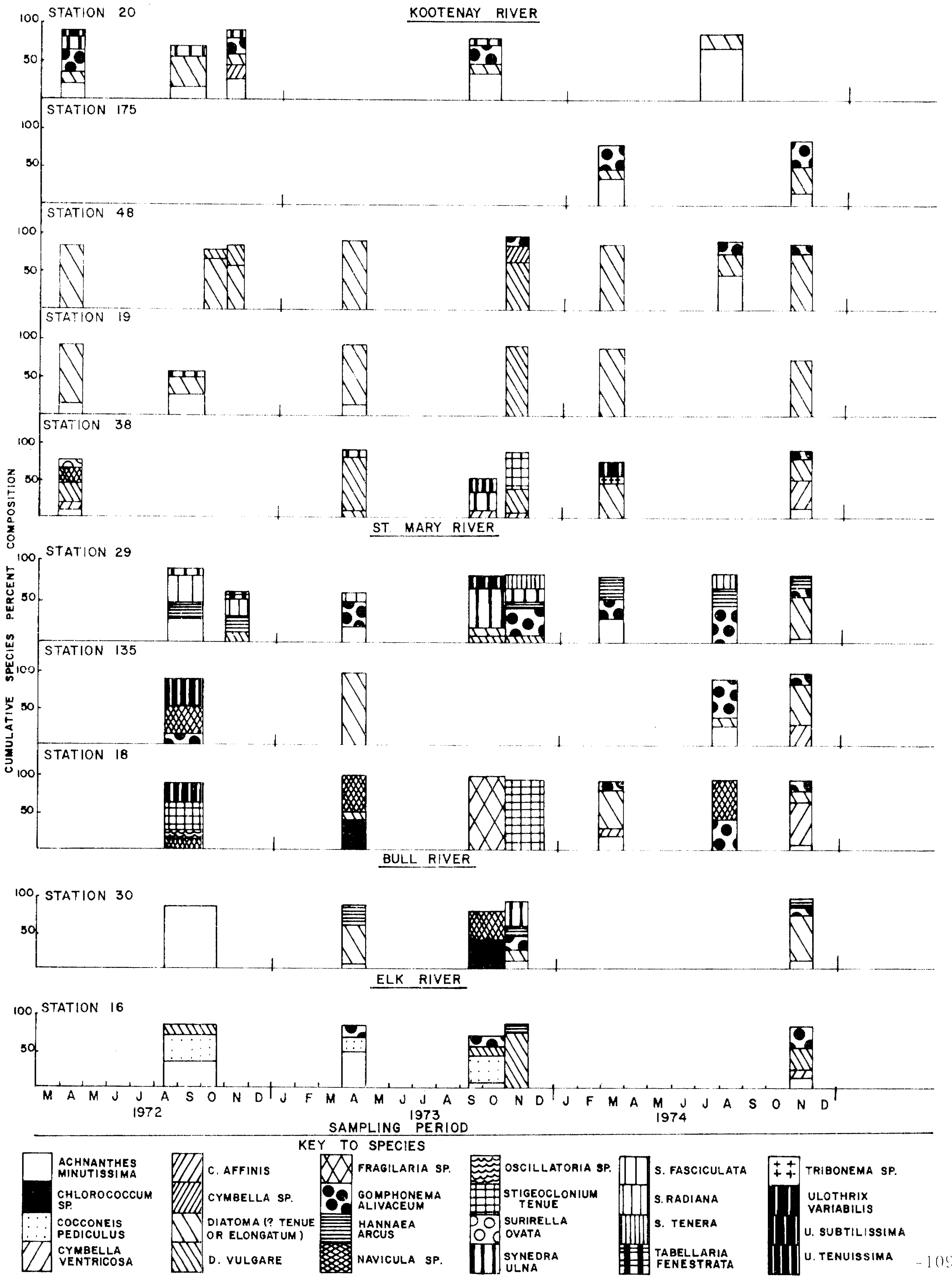
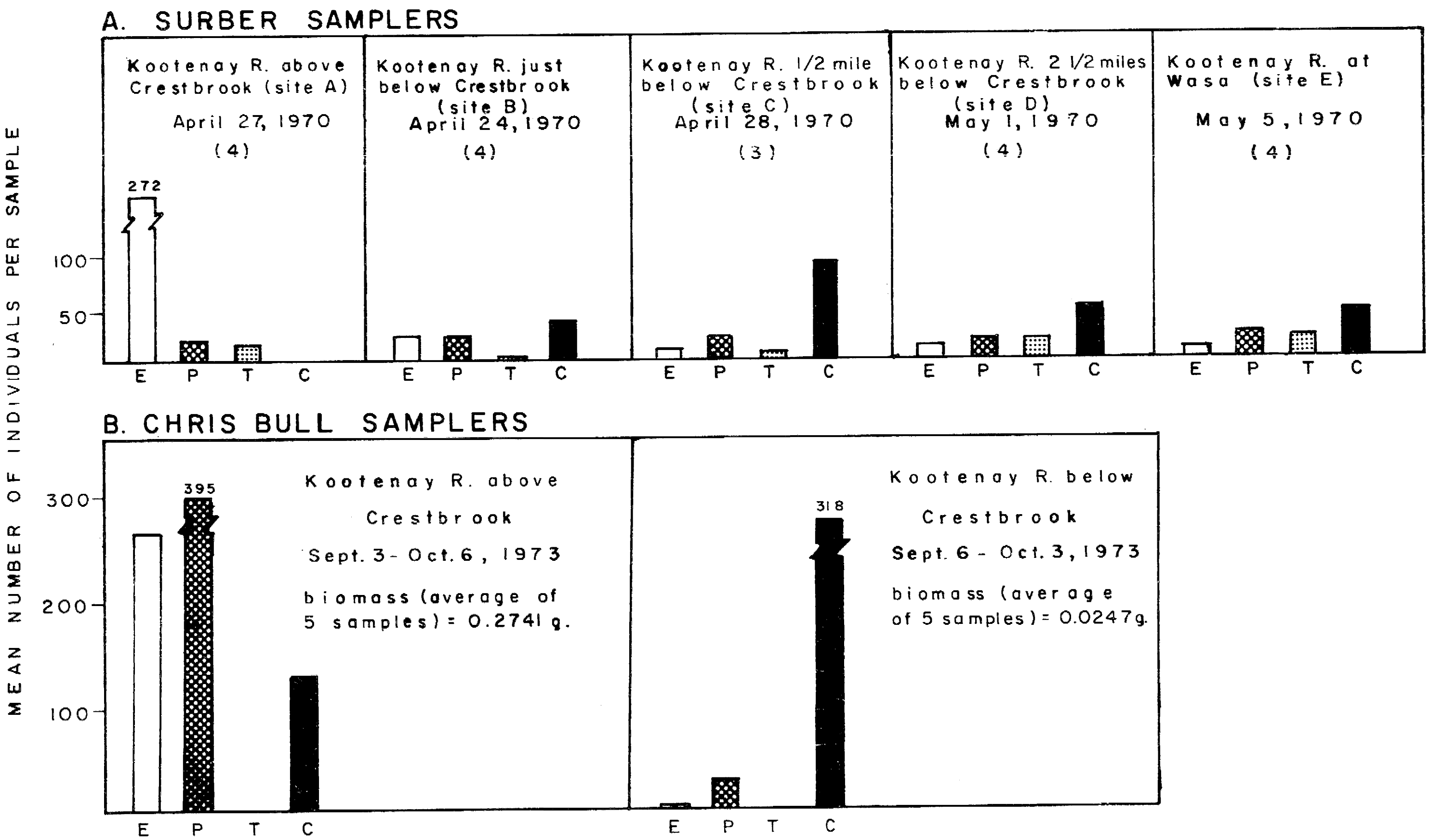


FIGURE 4-22

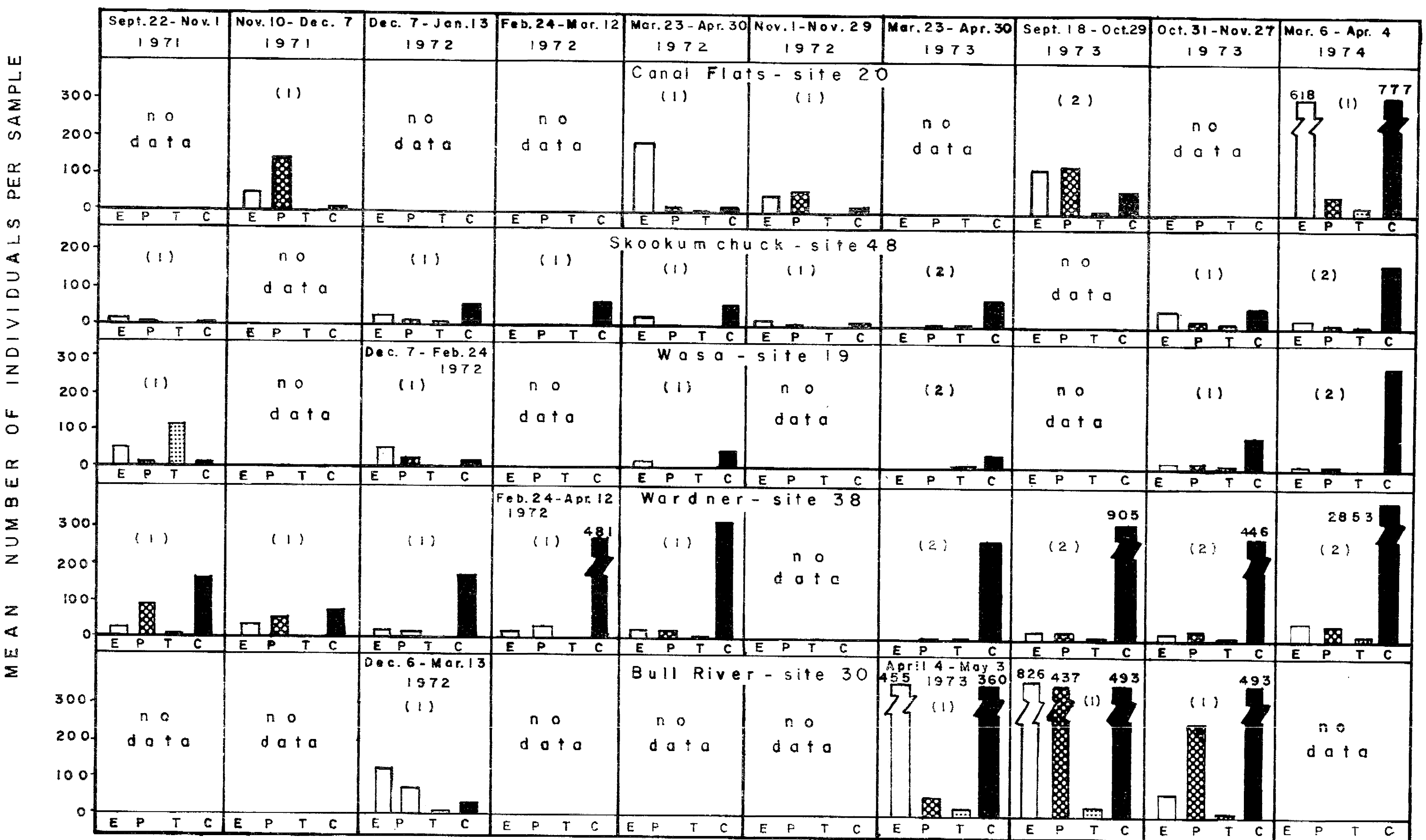
INVERTEBRATE DATA FOR KOOTENAY RIVER, COLLECTED 1970-1973



NOTE: E = Ephemeroptera, P = Plecoptera, T = Trichoptera, C = Chironomidae
number of samplers used is in brackets

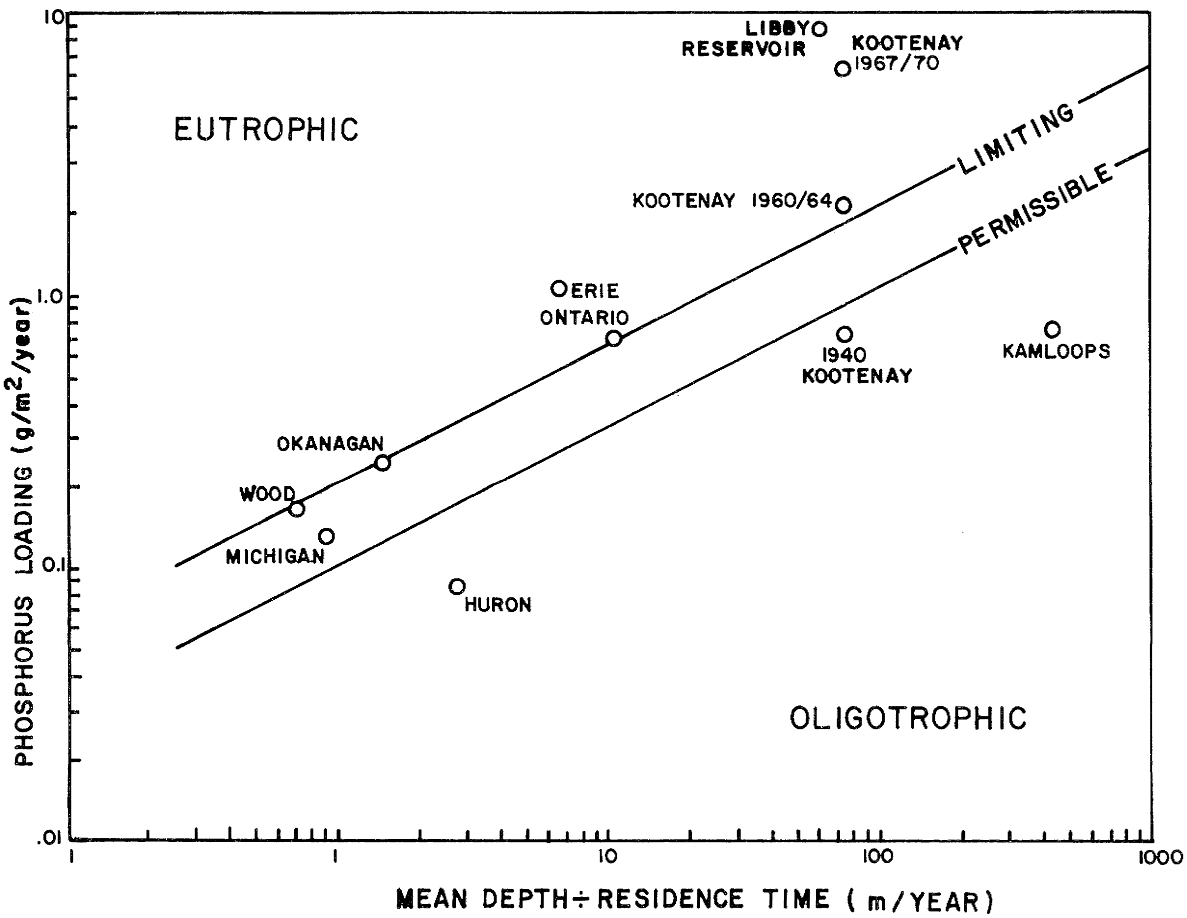
FIGURE 4-23

INVERTEBRATE DATA FOR KOOTENAY RIVER AND BULL RIVER, COLLECTED 1971-1974



NOTE: E= Ephemeroptera, P= Plecoptera, T= Trichoptera, C= Chironomidae
number of samplers used is in brackets

FIGURE 4-24
LOADING OF DISSOLVED PHOSPHORUS AS A FUNCTION OF MEAN DEPTH AND WATER RESIDENCE TIME



NOTE: LIBBY RESERVOIR POINT BASED ON:
PHOSPHORUS LOADING OF 4.3 MILLION LB. / YEAR
MEAN DEPTH OF 36.5 m.
RESIDENCE TIME OF 0.64 YEAR
RESERVOIR AREA OF 46,500 ACRES
CALCULATED FOR THE YEAR 1973

TABLE 4-1

STREAMFLOW SUMMARY FOR REGION 4

Stream	Drainage Area mi^2	Mean Annual Discharge CFS	Maximum Daily Discharge Recorded CFS	Minimum Daily Discharge Recorded CFS
Kootenay R. at Canal Flats	2080	3060	29700	310
Kootenay R. at Skookumchuck	2780	4130	31900	470
Kootenay R. at Fort Steele	4350	6410	44000	814
Kootenay R. at Wardner *	5200	7220	64200	840
Kootenay R. at Newgate *	7660	10500	97900	994
St. Mary R. at Wycliffe	922	1860	21600	143
Bull R. near Wardner	578	1170	13300	31
Elk R. near the mouth	1720	2710	33500	206

* Historical interest only. Creation of the Libby Reservoir in 1972 has flooded this portion of the Kootenay River.

TABLE 4-2

DISTRIBUTION OF GROUNDWATER WELLS IN REGION 4[13]

Location	Number of Wells
Cranbrook Area	240
Kimberley Area	44
Hanbury	33
Wasa	25
Wardner	22
Wycliffe	18
Baynes Lake	17
Jaffray	14
Skookumchuck	12
Ta Ta Creek	11
Wanklyn	9
Galloway	9
Fort Steele	9
Bull River	7
Waldo	7
Sand Creek Area	5
Roosville	5
Colavalli	1
Total	488

TABLE 4-3

SUMMARY OF WATER LICENCES IN

REGION 4 [69]

Source	No. Of Licences	Quantity	Purpose	Owner	Location	Comments
FERNIE WATER DISTRICT - TOBACCO PLAINS PRECINCT						
Bowman Cr.	2	200 AF/Y*	irrigation		L.16, SL.8 Grasmere area	80 acres irrigated fully recorded
Conner Cr.	1	62 AF/Y	irrigation		S.L. 31 Grasmere	15.5 acres irrigated
Edwards Lake	1	500 AF/Y	irrigation		D.L. 355 Grasmere	200 acres irrigated
Flag Cr.	7	292 AF/Y 1,000 GPD**	irrigation domestic		S.L.'s 41 & 24 Grasmere area	192 acres irrigated fully recorded
Kootenay R.	1	300 AF/Y	irrigation		L's 123, 358 6,398 & 4,821 Dorr Area	120 acres irrigated
Maquire Cr.	5	776 AF/Y 3,500 GPD	irrigation domestic		D.L. 361 Grasmere area	310 acres irrigated fully recorded
Miller Cr.	3	294 AF/Y 1,500 GPD	irrigation domestic		Grasmere area	118 acres irrigated

* AF/Y: acre-feet per year
** GPD: imperial gallons per day

All lots are located in the Kootenay Land District unless otherwise noted.

TABLE 4-3 Continued

SUMMARY OF WATER LICENCES IN REGION 4

Source	No. Of Licences	Quantity	Purpose	Owner	Location	Comments
Phillips Cr.	10	1,070 AF/Y 1,500 GPD	irrigation domestic		S.L. 23 Roosville area	442 acres irrigated
Rainbow Cr.	3	540,000 GPD 212.5 AF/Y	power irrigation	McDonald Ranch & Lumber Co.	S.L. 20 Roosville area	85 acres irrigated
Red Canyon Cr.	6	374 AF/Y 3,000 GPD	irrigation domestic		Grasmere area	157 acres irrigated
Scherf Cr.	1	375 AF/Y 1,500 GPD	irrigation domestic		L. 7012 Grasmere	150 acres irrigated
Unnamed Cr.	1	62.5 AF/Y	irrigation		S.L.8 Roosville area	25 acres irrigated
Willie Phillips Cr.	1	414 AF/Y 14,500 GPD	irrigation domestic		D.L. 489 Grasmere area	197 acres irrigated (Reserve Creek also used)
FERNIE WATER DISTRICT - ROCK CREEK PRECINCT						
Barr Sloughs	1	50 AF/Y	irrigation		L.6206 Jaffray area	20 acres irrigated
Burton Cr.	1	28 AF/Y	irrigation		L.B. of D.L. 4590	11 acres irrigated
Caithness Cr.	2	20,000 GPD 30 AF/Y	industrial irrigation		Caithness areas	mobile home manufacturing 12 acres irrigated
Disney Brook	2	160 AF/Y 500 GPD	irrigation domestic		L. 6206 Jaffray area	64 acres irrigated

TABLE 4-3 Continued

SUMMARY OF WATER LICENCES IN REGION 4

Source	No. Of Licences	Quantity	Purpose	Owner	Location	Comments
George Cr.	1	17.5 AF/Y	irrigation		L. 6206, S.L. 3 Jaffray area	7 acres irrigated
Gurney Lake	1	48 AF/Y	irrigation		L. 132 Krag area	16 acres irrigated
Howard Cr.	1	17 AF/Y	irrigation		S.L. 1	7 acres irrigated
Kikomun Cr.	1	250 AF/Y	irrigation		L. 6357 Galloway	62 acres irrigated
Little Sand Cr.	11	253 AF/Y	irrigation		Jaffray area	119 acres irrigated
Sand Cr.	10 1	536 AF/Y 13 AF/Y	irrigation industrial	 Galloway Lumber	Galloway	196 acres irrigated log pond
Stone Cr.	1	17 AF/Y	irrigation		S.L. 1	7 acres irrigated
Supply Cr.	3	493 AF/Y	irrigation		K'a 3008 6671 & S.L.13	147 acres irrigated
Surveyors Cr.	2	132 AF/Y 500 GPD	irrigation domestic		Baynes Lake area	53 acres irrigated
Verna Cr.	2	120 AF/Y 1,000 GPD	irrigation domestic		S.L. 3, L. 6206 Jaffray area	48 acres irrigated
FERNIE WATER DISTRICT - WASA PRECINCT						
Lewis Cr.	11 1	1,162 AF/Y 15,500 GPD 540,000 GPD	irrigation domestic power		D.L. 2069 Wasa area	603 acres irrigated (estimated)

TABLE 4-3 Continued

SUMMARY OF WATER LICENCES IN REGION 4

Source	No. of Licences	Quantity	Purposes	Owner	Location	Comments
Tracy Cr.	3	183 AF/Y	irrigation		D.L.'s 1,266 & 2,898	203 acres irrigated
Wasa Cr.	1	100 AF/Y	irrigation		Wasa area	40 acres irrigated
Wolf Cr.	10	1171 AF/Y 4,000 GPD	irrigation domestic		D.L. 14 & area	492 acres irrigated
FERNIE WATER DISTRICT -- FORT STEELE PRECINCT						
Brewery Cr.	1	50 AF/Y	irrigation		D.L. 12985	20 acres irrigated
Doyle Cr.	2	49 AF/Y 1000 GPD	irrigation domestic		L.'s 6188,284	23 acres irrigated
Estella Sp.	1	100,000 GPD	industrial	Giant Mascot Mines	L.'s 6855,6856, 6412	mining & milling
Fennessy Br.	1	36 AF/Y	irrigation		S.L. 35	12 acres irrigated
Gertrude Br.	1	20 AF/Y	irrigation		L. 6118 Ft. Steele area	8 acres irrigated
Herbert Cr.	1	35 AF/Y	irrigation		L. 8845	14 acres irrigated
Kerrigan Cr.	1	66.5 AF/Y	irrigation		L. 3040	26.5 acres irrigated
Khartoum Cr.	1	50 AF/Y	irrigation		L. 39 Ft. Steele area	12 acres irrigated
Lakit Cr.	4	284 AF/Y 2000 GPD	irrigation domestic		L. 3040, S.L.15 of D.L. 332	140 acres irrigated

TABLE 4-3 Continued

SUMMARY OF WATER LICENSES IN REGION 4

Source	No. Of Licences	Quantity	Purposes	Owner	Location	Comments
Levitt Cr.	1	30 AF/Y	irrigation		L. 39 Ft. Steele area	20 acres irrigated
Mallard Br.	2	24.5 AF/Y	irrigation		L. 6118 Ft. Steele area	10 acres irrigated
Quirk Cr. & Sunk Cr.	6	271 AF/Y 2000 GPD	irrigation domestic		L.'s 1021, 6118, Ft. Steele area	108 acres irrigated
Tracy Lake	1	1000 GPD 2000 GPD	industrial domestic	Giant Mascot Mines	L.'s 6412, & 6855	mining (cooling)
Wild Horse River	5	400 AF/Y 207,000 GPD	irrigation domestic		L. 51 Ft. Steele	130 acres irrigated
FERNIE WATER DISTRICT -- SHEEP CREEK PRECINCT						
Bickell Br.	1	58 AF/Y	irrigation		L. 265	23 acres irrigated
Brad Cr.	1	75 AF/Y	irrigation		L. 6257	30 acres irrigated
Diorite Cr.	6	282 AF/Y 5000 GPD 1,080,000 GPD	irrigation domestic power		L.'s 8846,271 335. Skookumchuck area	125 acres irrigated
Lussier R.	8	650 AF/Y 2500 GPD	irrigation domestic		L.'s 6117,6257, 8757,265,271, 335. Skookumchuck area	269 acres irrigated
Spring Br.	5	8 AF/Y 21,700 GPD	irrigation domestic		L. 265	8 acres irrigated

TABLE 4-3 Continued

SUMMARY OF WATER LICENCES IN REGION 4

Source	No. Of Licences	Quantity	Purposes	Owner	Location	Comments
FERNIE WATER DISTRICT -- BULL RIVER PRECINCT						
Bower Sp.	1	65 AF/Y 500 GPD	irrigation domestic		S.L.'s 1 & 2 of L. 313	26 acres irrigated
Bull R.	2 1 1	$1.9X10^8$ GPD 250,000 GPD 31 AF/Y	Power industrial irrigation	B.C. Hydro Placid Oil Emerald Land Co.	Aberfeldie Dam S.L.18 of L.4590 L. 10278	issued in 1910 & 1920 mining 12 acres irrigated
Goggs Cr.	3	25 AF/Y 3000 GPD	irrigation domestic		L. 310	17 acres irrigated
Horseshoe Cr.	3	210 AF/Y 1000 GPD	irrigation domestic		L. 311	60 acres irrigated
Kootenay R.	2	212.5 AF/Y	irrigation		L.'s 37 & 38	250 acres irrigated
Little Bull Creek	4	1879 AF/Y 5000 GPD	irrigation domestic		S.L. 14 of D.L. 313 D.L. 106, S.L. 2 of D.L. 13 L. 805	780 acres irrigated
Lost Cr.	5	826.5 AF/Y 1000 GPD 16,200,000 GPD	irrigation domestic land improvement		L. 311, 312, 6029	315 acres irrigated
Mause Cr.	7	658.5 AF/Y 1500 GPD	irrigation domestic		L.'s 780, 4834, 310, 3002,10305	276 acres irrigated fully recorded

TABLE 4-3 Continued

SUMMARY OF WATER LICENCES IN REGION 4

Source	No. Of Licences	Quantity	Purposes	Owner	Location	Comments
Moore Brook	1	50 AF/Y 500 GPD	irrigation domestic		L. 15 of L. 313	43 acres irrigated
Norbury Cr.	13	1355 AF/Y 3500 GPD 10,800,000 GPD	irrigation domestic fish culture	Dept. of Public Works	Bull River Fish Hatchery	508 acres irrigated fully recorded
Norm Cr.	1	50 AF/Y 500 GPD	irrigation domestic		L. 15 of L. 313	20 acres irrigated
Peckham Cr.	1	50 AF/Y	irrigation		L. 805, S.L. 33	20 acres irrigated
Peter Brook	2	99 AF/Y 500 GPD	irrigation domestic		L.'s 8 & 9 of L. 313	40 acres irrigated
Pinto & Comfort Br.	1	150 AF/Y	irrigation		L. 676	60 acres irrigated
CRANBROOK WATER DISTRICT -- CHERRY CREEK PRECINCT						
Bechtel Cr.	1	26.5 AF/Y	irrigation		L. 706	11 acres irrigated
Kootenay R.	1	2000 GPD	domestic	Dept. of Hwys.	L. 334 (Ta Ta Creek area)	
Mather Cr.	24	1903 AF/Y 14,500 GPD	irrigation domestic		Kimberley area: L.'s 771, 1235, 339, 655, 656, 7660, 14833, 11074, 15488, 710, 11077, 11034, 711, 12722.	726 acres irrigated

TABLE 4-3 Continued

SUMMARY OF WATER LICENCES IN REGION 4

Source	No. Of Licences	Quantity	Purposes	Owner	Location	Comments
Reed Cr.	2	200 AF/Y	conservation & storage	Fish & Wildlife Branch		
Ta Ta Cr.	11	341 AF/Y 3000 GPD	irrigation domestic		Ta Ta Creek L.'s 6574, 9818, 9817, 12952, 12953, 12956,	142 acres irrigated possible water shortage
Wait Cr.	3	753 AF/Y 4000 GPD	irrigation domestic		L.'s 7660 & 14833 Kimberley area	301 acres irrigated
CRANBROOK WATER DISTRICT -- CRANBROOK PRECINCT						
Angus Cr.	1	40 AF/Y 500 GPD	irrigation domestic		L.'s 2310 & 5801	20 acres irrigated
Arnold Cr.	2	116 AF/Y	irrigation		L. 677, 6204, 7759	63 acres irrigated
Birkenham Cr.	1	19 AF/Y	irrigation		L.'s 25 & 26 of L. 3556	7.5 acres irrigated
Delmer Sp.	2	50 AF/Y	irrigation		D.L. 27 & 28	18 acres irrigated
Doran Cr.	2	58 AF/Y	irrigation		L. 4686, 7103	25 acres irrigated
Hillbarr Cr.	3	190 AF/Y 4,860,000 GPD	irrigation power		D.L. 3553 & 3056	95 acres irrigated
Hospital Cr.	1	25.4 AF/Y	irrigation		Cranbrook L. 29	10 acres irrigated
Horie Br.	1	18 AF/Y	irrigation		D.L. 32	7 acres irrigated

TABLE 4-3 Continued

SUMMARY OF WATER LICENCES IN REGION 4

Source	No. Of Licences	Quantity	Purposes	Owner	Location	Comments
Jim Smith Cr. & Lake	10	27.5 AF/Y 8000 GPD	irrigation domestic		L.'s 31, 4, 5249, 30, 3575, 5801	12 acres irrigated Jim Smith Cr. fully recorded
Joseph Cr.	5	186 AF/Y 4,860,000 GPD	irrigation power		Cranbrook L.'s 27, 3, 1158, 3556, 3558	120 acres irrigated fully recorded
Kootenay R.	1	200 AF/Y 1000 GPD	irrigation domestic		D.L. 7663	100 acres irrigated
New Lake & Dickson Cr.	1	80 AF/Y	irrigation		L. 5248	32 acres irrigated
St. Mary Br.	2	350 AF/Y	irrigation		D.L. 28	140 acres irrigated
Unnamed Cr.	1	25 AF/Y	irrigation		L. 10353	10 acres irrigated
CRANBROOK WATER DISTRICT -- GOLD CREEK PRECINCT						
Englishman Cr.	1	400 AF/Y	irrigation		L. 10348	100 acres irrigated
Gardiner Cr.	1	24 AF/Y	irrigation		D.L. 328 Newgate area	16 acres irrigated
Gold Cr.	5	900 AF/Y 8,077,000 GPD	irrigation domestic	City of Cranbrook	L.'s 3709, 14030, 8282, 9493	380 acres irrigated fully recorded-diverted to Joseph Cr. upstream of Cranbrook
Linklater Cr.	19	1268 AF/Y 3000 GPD	irrigation domestic		Newgate area L.'s 326, 327, 328	563 acres irrigated

TABLE 4-3 Continued

SUMMARY OF WATER LICENCES IN REGION 4

Source	No. Of Licences	Quantity	Purpose	Owner	Location	Comments
CRANBROOK WATER DISTRICT -- SKOOKUMCHUCK PRECINCT						
Copper Cr.	1	37.5 AF/Y 500 GPD	irrigation domestic		L.1 & S.L. 44 of L. 4596	14.5 acres irrigated
Deer Cr.		40 AF/Y 1000 GPD	irrigation domestic		S.L. 52 of L. 4596	16 acres irrigated
Emily Cr.	1	90 AF/Y 500 GPD	irrigation domestic		D.L. 42	36 acres irrigated
Kootenay R.	1	5,400,000 GPD	industrial	Crestbrook Forest Industries	L. 6021	pulp & paper mill
Lavington Cr.	1	89 AF/Y	irrigation		D.L. 5515	36 acres irrigated
Skookumchuck Cr.	4	552.5 AF/Y 500 35,100,000 GPD	irrigation domestic industrial	 Crestbrook Forest Industries	L.6616, 13085, 13086,& 13083 L. 6021	169 acres irrigated pulp & paper mill
Spencer Cr.	1	49 AF/Y 1000 GPD	irrigation domestic		D.L. 5515	25 acres irrigated
Tamarac Cr.	1	25 AF/Y			L. 3707	10 acres irrigated

TABLE 4-3 Continued

SUMMARY OF WATER LICENCES IN REGION 4

Source	No. Of Licences	Quantity	Purpose	Owner	Location	Comments
CRANBROOK WATER DISTRICT -- ST. MARY PRECINCT						
Booth Cr.	3	76 AF/Y 1000 GPD	irrigation domestic		L.'s 6164, 15702, 7320, 6320	37 acres irrigated fully recorded
Eimer Cr.	1	300,000 GPD	domestic	City of Kimberley		waterworks
Hodge Cr. or Ander Cr.	1	29 AF/Y 500 GPD	irrigation domestic		L. 6439	11.5 acres irrigated
Lockspring Cr.	2	640,000 GPD	domestic	City of Kimberley		waterworks possible water shortage
Lois (Estmere), Hope Ben & Kimberley Cr.	1 1	200,000 GPD 50,000 GPD	industrial domestic	Cominco Meadowbrook Wwks. Dist.		 waterworks
Luke Cr. & Tributaries	4	331.5 AF/Y 3500 GPD	irrigation domestic		L.'s 1203, 1204, 12739, 12737, 12738	133 acres irrigated
Mark Cr.	1 2 1 1 2	13,500,000 GPD 265,000 GPD 1,000,000 GPD 5,000,000 GPD 1,195,000 GPD	power domestic industrial industrial domestic	Cominco Cominco Cominco Cominco City of Kimberley	D.L. 2043 (Kimberley area) D.L. 6626	waterworks concentrator waterworks
Mathew Cr.	1 1	75 AF/Y 500 GPD 1,600,000 GPD	irrigation domestic domestic	 City of Kimberley	S.L. 37 of D.L. 4592	30 acres irrigated waterworks
Perry Cr. & Tributaries	4	572 AF/Y 2500 GPD 5,400,000 GPD	irrigation domestic power		L.'s14299,6545, 15137,14298,7035, 15702,15770,6319 Wycliffe area	242 acres irrigated

TABLE 4-3 Continued

SUMMARY OF WATER LICENCES IN REGION 4

Source	No. Of Licences	Quantity	Purpose	Owner	Location	Comments
Reade Lake	1	100 AF/Y 1000 GPD	irrigation domestic		S.L. 2 of L.341	40 acres irrigated
St. Mary R.	1	2688 AF/Y 30,000 GPD	irrigation domestic	Dept. of Indian Af.	St. Mary I.R. (Kootenay #1)	1075 acres irrigated (estimated assuming 2.5 AF/acre)
	1	200,000 GPD	domestic	City of Kimberley		waterworks
	1	50,000 GPD	industrial	B.C. Forest Service	L.1 of Kootenay #1, I.R.	
	4	25,400,000 GPD	industrial	Cominco	L.'s 12945, 6626, 12995	
CRANBROOK WATER DISTRICT -- WARDNER PRECINCT						
Buckeye Br.	1	100 AF/Y	irrigation		L.'s 11766 & 11769	40 acres irrigated
Cameron Cr.	2	65 AF/Y 500 GPD	irrigation domestic		S.L. 13 of L. 331	26 acres irrigated
Chipka Cr.	5	246 AF/Y 1500 GPD	irrigation domestic		L.'s 1968 & 9823 Wardner area	98 acres irrigated fully recorded
Ha Ha Cr. & Edith Cr.	11	675 AF/Y 7500 GPD	irrigation domestic		Wardner area	342 acres irrigated fully recorded
Howell Br.	1	50 AF/Y	irrigation		D.L. 11766	25 acres irrigated
Krys Cr.	1	40 AF/Y	irrigation		L.'s 2710 & 11489	16 acres irrigated

TABLE 4-3 Continued

SUMMARY OF WATER LICENCES IN REGION 4

Source	No. Of Licences	Quantity	Purpose	Owner	Location	Comments
Plumbob Cr.	1	150 AF/Y	irrigation		D.L. 121	60 acres irrigated
Radar Lake & Ballard Swamp	1	100 AF/Y	irrigation		L. 1967	40 acres irrigated possible shortage
Thos Cr.	1	76 AF/Y 500 GPD	irrigation domestic		S.L.'s 13 & 14 of L. 331	30 acres irrigated

Minor sources of water supply for domestic and irrigation purposes in Region 4 which are smaller than those previously listed include: Bed Brook, Horan Davis Lake, Slee Brook, Village Creek, Tie Lake, Damstrom Brook, Rosen Lake Creek, William Lake, Mott Brook, Warden Brook, Saugum Creek, Pape Creek, George Brook, Cain Brook, Burntridge Creek, Douglas Creek, Berg Brook, Gustavas Creek, Blake Brook, Pollen Brook, Scott Creek, Claydon Slough, Ski Slough, Mayook Creek, Chester Brook, Little Pool Creek, Archibald Brook, Black Bear Creek, Resort Creek, Denver Creek, Hriswald Creek, Clifford Brook, Rebecca Brook, Kootenay River, Pennock Creek, and numerous springs.

TABLE 4-4

POPULATIONS OF THE SETTLEMENTS IN REGION 4 [12,14]

Settlement	1971 population
Cranbrook	12,000
Kimberley	7,643
Wasa	355
Jaffray	193
Wardner	149
Galloway	114
Ta Ta Creek	83
Grasmere	74
Skookumchuck	74
Fort Steele	53
Wycliffe	50
Roosville	31
Bull River	27
Newgate	19

TABLE 4-5

LOCATION OF FISH SPECIES IN LAKES OF REGION 4

Fish species	Lake (nearest town) or park	
Rainbow trout	Echo (Wasa) Edith (Wardner) Edwards (Grasmere) Garbutt (Wardner) Grundy (Wasa) Horseshoe (Fort Steele) Jim Smith (Cranbrook) Loon (Grasmere) New (Cranbrook) Peckham (Fort Steele)	Premier (Skookumchuck) Quartz (Skookumchuck) Rosen (Jaffray) Silver Springs (Elko) St. Mary (Kimberley) Surveyors (Elko) Suzanne (Elko) Tamarack (Skookumchuck) Wapiti (Wardner)
Eastern brook trout	Baynes (Elko) Bronze (Wasa) Campbell (Wasa) Echo (Wasa)	Mayook (Wardner) Premier (Skookumchuck) Surveyors (Elko) Wapiti (Wardner)
Yellowstone cutthroat trout	Cherry (Waldo) Cooper (Cranbrook) Fish (Top of the World)	McNair (Skookumchuck) Rosen (Jaffray) St. Mary (Kimberley)
Dolly Varden char	Fish (Top of the World) St. Mary (Kimberley) Surveyors (Elko)	
Kamloops trout	North Star (Jaffray)	
Small mouth bass	Tie (Jaffray)	
Large mouth bass	Wasa (Wasa)	

TABLE 4-6

SUMMARY OF POLLUTION CONTROL BRANCH PERMITS AND APPLICATIONS FOR EFFLUENT DISCHARGE

Pollution Control Application and Permit Holder for Effluent Discharge	Permit or application Number	Waste Discharge Flow (IGPD)	Discharge to	Comments
City of Kimberley	PE 148	1,135,000	St. Mary R.	Typical municipal effluent primary treatment and chlorination. Permit allows BOD_5 of 130 mg/l suspended solids of 130 mg/l.
Crestbrook Forest Industries, Skookumchuk	PE 188	40,000	Skookumchuk Cr.	Domestic effluent from oxidation ditch treatment.
Cominco Ltd., Kimberley	PE 189	13,100,000	St. Mary R. via James Cr., Mark Creek and Kimberley Creek, and to tailing ponds	Mine water, effluent from fertilizer operations and overflow from tailing ponds. All discharges to meet level A or B by the end of 1977.
Crestbrook Forest Industries, Skookumchuk	PE 240	15,000,000	Kootenay R.	Bleached Kraft pulp mill effluent treated in aerated lagoons.
B.C. Ranch & B. Ranch, Wasa	PE 298	2,400	Ground	Typical laundromat effluent.
City of Cranbrook	PE 4148	3,000,000	To land	Municipal effluent to be spray irrigated on land after aeration and settling.
E.C. & D Millar Holdings Ltd., Cranbrook	PE 1646	20,000	Joseph Cr.	Domestic effluent, secondary treatment with chlorination.
Scanlan's Excavating Ltd., Cranbrook	PE 1963	5,000	Ground	Septic tank sludge.
Louis Salvador and Son Ltd. Cranbrook	PE 2161	501,000	Ground	Gravel wash water.
Kenneth McLean, Wycliffe	PE 2364	1,000	Ground	Typical laundromat effluent.
Federal Fisheries Service, Bull River	PE 2375	5,530,000	Bull R. via Norbury Cr.	Trout hatchery.
O.K. Ready Mix Ltd., Cranbrook	PE 3062	1,000	Ground	Washwater from cement and gravel washing.

TABLE 4-6 Continued

SUMMARY OF POLLUTION CONTROL BRANCH PERMITS AND APPLICATIONS FOR EFFLUENT DISCHARGE

Pollution Control Application and Permit Holder for Effluent Discharge	Permit or application Number	Waste Discharge Flow (IGPD)	Discharge to	Comments
Crestbrook Forest Ind., Skookumchuk	PE 3400	15	Ground	Boiler Biowdown.
R.W. Hoare and R.B. Ross, Cranbrook	AE 3757	20,000	Ground	Domestic effluent after aeration.
Robert Steinrigler, Jaffrey	AE 3758	2,000	Ground	Septic tank pumpout.
B.C. Govt., St. Eugene Mission	AE 3909	8,125	Ground	Domestic effluent from septic tank.

TABLE 4-7

DETAILS OF POLLUTION CONTROL PERMIT PE-240, ISSUED TO CRESTBROOK FOREST INDUSTRIES LTD.

Date Permit Issued	August 12, 1968
Expiry Date:	August 12, 1975
Point of Effluent Discharge:	Kootenay River
Major Pollution Control Works:	Settling Basins, Aeration Basin, Submerged Outfall With Diffuser Section

Permit conditions applicable to effluent unless otherwise shown	Average limit	Maximum limit
BOD_5	60 mg/1	80 mg/1 at exit from aeration basin
Chlorine residual		0.1 mg/1
Effluent flow rate	15,000,000 GPD	19,400 GPM
Mercaptans		0.1 mg/1
Oxygen, dissolved (river)		Not to be lowered by more than 0.5 mg/1
pH	6.5 - 8.5	
Resin soaps		1.0 mg/1
Solids, settleable		2.5 mg/1
suspended	60 mg/1	
total	1000 mg/1	
Sulfides		0.1 mg/1
Temperature		125° F
Toxicity		65% effluent in river water must cause no mortality to fish in 96 hour test period
Turbidity (river)		Must not be increased by more than 5 JTU
Colour, taste, odour (river)		Must not be objectionable

TABLE 4-8

CRESTBROOK FOREST INDUSTRIES LTD.

AVERAGED EFFLUENT SAMPLING RESULTS OBTAINED BY THE COMPANY

Sampling Date	Effluent Flow - Million GPD	Production Rate: Air Dried Tons/ Day	Load: lb/Air Dried Ton of Pulp		Bio-Assay Result % Survival in 65% Effluent for 96 hrs.
			BOD_5	Suspended Solids	
Jan. 1973	10.0	351	21	21	100
Feb.	10.2	363	21	12	100
March	10.0	343	31	13	30
April	9.0	338	35	18	
May	10.5	383	24	20	100
June	9.8	386	29	18	0
July	11.4	391	23	17	20
Aug.	11.1	382	20	21	40
Sept.	9.4	323	29	25	0
Oct.	9.7	374	37	20	0
Nov.	9.2	378	31	23	0
Dec.	7.6	351	25	19	0
Jan. 1974	9.2	291	26	21	0
Feb.	12.3	419	31	31	100
March	13.1	392	24	22	100
April	12.8	377	11	17	100
May	10.4	356	22	16	
June	11.2	393	28	28	100
July	11.9	335	22	27	60
Aug.	12.6	404	22	30	100
Sept.	10.0	356	8	22	90
Oct.	10.2	398	9	13	100
Nov.	9.3	392	10	16	100
Dec.	8.7	363	12	12	80

TABLE 4-9

CRESTBROOK FOREST INDUSTRIES LTD.

SUMMARY OF EFFLUENT SAMPLING RESULTS OBTAINED BY

THE POLLUTION CONTROL BRANCH

	1972			1973			1974			Limits of Permit PE-240
	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	
Colour, true APHA units				2000	1000	1460	1600	1000	1390	
Oxygen demand, biological (BOD_5) mg/1	144	120	133	125	31	77	89	17	49	60
pH	7.5	6.5	6.9	7.7	6.8	7.1	8.0	7.1	7.4	6.5 to 8.5
Resin acid soaps mg/1				4.2	0.6	1.8	1.2	<0.5	0.8	1.0
Solids, suspended mg/1	112	48	75	151	70	103	173	43	122	60
Solids, total mg/1	1660	1426	1560	1896	1126	1560	1846	1302	1545	1000
Sulfides mg/1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.1
Temperature °F	80	64	73	84	48	68	81	57	70	<125

TABLE 4-10

CRESTBROOK FOREST INDUSTRIES LTD.

DESCRIPTION OF MAJOR REFUSE SITES

	Site A	Site B
Pollution Control Branch Application or Permit number	PR 1756-0	AR 1756-1 and 2
Location	pulp mill	pulp mill
Status and level of operation	in operation at Level B	closed
Quantity and type of refuse	5 cu yd/day office garbage, waste pulp and shop wastes	1700 cu yd/day for 21 days per year of lime mud & pulp fibre from settling pond 240 cu yd/day for 365 days per year of wood chip fines
Depth to groundwater table	90 ft.	0
Underlying soils	gravel	river silt
Surface runoff or flooding	none	Site on flood plain of Kootenay River, subject to flooding
Distance to surface water	2100 ft. to Kootenay River	800 ft. to Kootenay River
Distance to wells	2000 ft. to pulp mill wells	2250 ft. to pulp mill wells
Mean annual precipitation/ Average annual potential evapotranspiration	16/22	16/22
Potential for adverse effects	groundwater: nil surface water: nil	groundwater: nil surface water: negligible
Area of site	1/3 acre	15-20 acres

TABLE 4-11

CRESTBROOK FOREST INDUSTRIES LTD.

ANALYSIS OF LEACHATE FROM SOLID WASTE DISPOSAL SITE B

Parameter	Value
alkalinity, total	1686 mg/1
carbon, total organic	458 mg/1
chloride, dissolved	225 mg/1
colour, apparent	1300 units
colour, true	500 units
conductance, specific	3510 µmhos/cm
nitrogen, total kjeldahl	5 mg/1
oxygen demand, biological	28 mg/1
oxygen demand, chemical	1020 mg/1
oxygen, dissolved	2.6 mg/1
pH	7.6
phenol	1.99 mg/1
phosphate, total	4.42 mg/1
resin acid soaps	0.7 mg/1
solids, suspended	89 mg/1
solids, total	3104 mg/1
surfactants	<0.03 mg/1
tannins and lignins	87 mg/1

TABLE 4-12

COMINCO LIMITED

SUMMARY OF AMENDED PERMIT PE-189, FOR THE SULLIVAN MINE, CONCENTRATOR AND FERTILIZER OPERATIONS

ISSUED OCTOBER 9, 1975

Description \ Discharge under Permit	Sewer 32	Decant from Siliceous Pond	Decant from Iron Pond	Mine drainage: 3900 ft. portal & surface streams. Mine domestic wastes & shower water	Mine drainage: 3700 ft. portal	Sulphuric acid and roaster plant effluents	Effluent entering gypsum pond
Discharge point	Mark Creek	James Creek	James Creek	Mark Creek	Kimberley Creek	Calcine pond-no net discharge from pond	Gypsum pond-no net discharge from pond
Effective date	Dec.31, 1977	Dec.31, 1977	Dec.31, 1977	Dec.31, 1977	Dec.31, 1977	Aug.31, 1976	Sept.30, 1975
Effluent flow	Daily maximum: 6,000,000 GPD	Annual average: 1,200,000 GPD Daily maximum: 6,000,000 GPD	Annual average: 600,000 GPD Daily maximum: 3,000,000 GPD	Annual average: 1,500,000 GPD Daily maximum: 3,000,000 GPD	Daily maximum: 300,000 GPD	Daily maximum: 1,000,000 GPD	Daily maximum: 2,500,000 GPD
Effluent Characteristics	As diss. 0.05 mg/1 CN tot. 0.10 mg/1 F diss. 2.50 mg/1 Fe diss. 0.30 mg/1 NH_3-N 0.50 mg/1 Oil & Grease 15 mg/1 Pb diss. 0.05 mg/1 pH 6.5-8.5	Al diss. 1.00 mg/1 As diss. 0.25 mg/1 CN tot. 0.50 mg/1 Cu diss. 0.30 mg/1 F diss. 5.00 mg/1 Fe diss. 1.00 mg/1 Mn diss. 0.50 mg/1 NH_3-N 0.50 mg/1	Al diss. 1.00 mg/1 As diss. 0.25 mg/1 CN tot. 0.50 mg/1 Cu diss. 0.30 mg/1 F diss. 5.00 mg/1 Fe diss. 1.00 mg/1 Mn diss. 0.50 mg/1 NH_3-N 0.50 mg/1	Al diss. 1.00 mg/1 As diss. 0.25 mg/1 Cu diss. 0.30 mg/1 F diss. 5.00 mg/1 Fe diss. 1.00 mg/1 Mn diss. 0.50 mg/1 NH_3-N 1.00 mg/1 Pb diss. 0.10 mg/1	Fe diss. 1.00 mg/1 Pb diss. 0.10 mg/1 pH 6.5-9.5 Suspended solids 150 mg/1 Zn diss. 2.00 mg/1	to be monitored	Typical gypsum and process water from a phosphoric acid plant

TABLE 4-12 Continued

COMINCO LIMITED

SUMMARY OF AMENDED PERMIT PE-189, FOR THE SULLIVAN MINE, CONCENTRATOR AND FERTILIZER OPERATIONS

ISSUED OCTOBER 9, 1975

Discharge Under Permit / Description	Sewer 32	Decant From Siliceous Pond	Decant From Iron Pond	Mine Drainage: 3900 ft. portal & Surface Streams. Mine Domestic Wastes and Shower Water	Mine Drainage: 3700 ft. portal	Sulphuric Acid and Roaster Plant Effluents	Effluent Entering Gypsum Pond
Effluent Characteristics	PO_4-P 2.00 mg/1 Suspended Solids 50 mg/1 Zn diss. 0.5 mg/1	Pb diss. 0.10 mg/1 pH 6.5-9.5 PO_4-P 2.00 mg/1 Suspended Solids 150 mg/1 Zn diss. 2.00 mg/1	Pb diss. 0.10 mg/1 pH 6.5-9.5 PO_4-P 2.00 mg/1 Suspended Solids 150 mg/1 Zn diss. 2.00 mg/1	pH 6.5-9.5 Suspended Solids 150 mg/1 Zn diss. 2.00			
Works	Phosphate rock plant ponds, iron sulphide sluicing water pond, sewer 32 outfall, flow measurement.	Siliceous tailing pond, emergency tailing pond, treatment plant for pond overflow, flow measurement.	Iron tailing pond, runoff diversion ditches, treatment plant for pond overflow.	Mine effluent treatment plant, outfall, flow measurement.	Mine ditches, pumps, collection and diversion facilities, flow measurement.	Calcine pond, North pond for emergency use, calcine dewatering facility, flow measurement.	Gypsum ponds, recycle cooling pond, pond recycle, pond seepage collection and return, flow measurement.

TABLE 4-13

COMINCO LIMITED

DATA ON EFFLUENTS DISCHARGED FROM THE SULLIVAN MINE

Parameters \ Data Source	3900 ft. Portal Discharge			Surface Streams			Mine Car Shop AE 189	Change Room Showers AE 189	3700 ft. Portal Discharge AE 189	Total Loading to Mark Creek AE 189
	Cominco Registration May 1970	AE 189 Aug 1973	Poll. Cont. Br. Sample Feb. 1973	Stream No. 1 AE 189	Stream No. 2 AE 189	Stream No. 3 AE 189				
Arsenic tot. mg/l	0.12		0.105							
diss. mg/l	0.002	0.08	0.008	0.004	0.21	0.0005	0.027	0.006	0.002	0.7 lb/day
Cadmium tot. mg/l			0.063							
diss. mg/l			0.050	0.01	0.01	0.36	0.01	0.01		
Calcium diss. mg/l			· 236							
Chromium tot. mg/l			<0.005							
diss. mg/l			<0.005							
Copper diss. mg/l		0.2	0.09							
Cyanide tot. mg/l		0.08	<0.01							
Flow, average IGPD	806,000	805,000	1,940,000	36,000	7,200	360,000	7,000	12,600	224,640	1,450,000
Fluoride diss. mg/l		5.6	2.4							
Iron tot. mg/l	305		219							
diss.mg/l	112	275	150	3.5	115	115	2.5	0.75	1.5	2640 lb/day
Lead tot. mg/l	4.3		4.2							
diss. mg/l	4.7	3.2	2.4	0.25	0.25	0.5	0.25	0.25	1.0	30 lb/day
Magnesium diss mg/l			260							

TABLE 4-13 Continued

COMINCO LIMITED

DATA ON EFFLUENTS DISCHARGED FROM THE SULLIVAN MINE

Parameters / Data Source	3900 Ft. Portal Discharge			Surface Streams			Mine Car Shop AE 189	Change Room Showers AE 189	3700 ft. Portal Discharge AE 189	Loading to Mark Creek AE 189
	Cominco Registration May 1970	AE 189 Aug.1973	Poll. Cont. Br. Sample Feb. 1973	Stream No. 1 AE 189	Stream No. 2 AE 189	Stream No. 3 AE 189				
Manganese tot. mg/l			25							
diss. mg/l			25							
Nitrogen, ammonia mg/l		4.1	0.05							33 lb/day
Oxygen demand mg/l		45								
pH	2.5-3.2	2.5-3.6	3.4	6.5-8.0	2.7-3.2	2.7-7.1	6.5-7.5	6.5-7.5	7.5-7.8	
Solids diss. mg/l	3463	5760	3660							
susp. mg/l	524	470	214	20	44	22	69	69	10	3900 lb/day
tot. mg/l	3987	6230	3874	110	714	3282	129	344	595	
Sulphate diss. mg/l		1135	2204	8	120	209	4	2	91	10,000 lb/day
Temperature ^{o}F		40-48		32-50	32-50	32-50	35-45	35-70	40-50	
Zinc tot. mg/l	125		55							
diss. mg/l	63	115	51	0.53	12.5	226	0.29	0.41	1.9	1700 lb/day

Notes on abbreviations: AE 189 refers to application for Pollution Control Permit of Aug. 1973

diss. = dissolved

tot. = total

susp. = suspended

TABLE 4-14

COMINCO LIMITED

YEARLY AVERAGE CONCENTRATIONS AND LOADINGS OF CONTAMINANTS IN JAMES CREEK

(COMBINED OVERFLOWS FROM THE IRON, SILICEOUS AND GYPSUM TAILING PONDS)

Data Source / Parameters	Cominco Data										Pollution Control Branch Sample Feb. 1973
	1970		1971		1972		1973		1974		
	mg/1	Tons/day	mg/1	Tons/day	mg/1	Tons/day	mg/1	Tons/day	mg/1	Tons/day	mg/1
Arsenic total											0.11
dissolved											0.10
Copper total											0.13
dissolved											0.11
Flow million GPD	6.6		5.8		4.1		3.6		3.7		
Fluoride	84	2.7	111	3.4	135	3.4	232	5.0	237	8.6	
Iron total	161	5.5	205	6.2	174	3.5	200	4.3	221	5.9	215
Lead total	1.2	0.04	1.3	0.04	1.7	0.04	2.3	0.05	1.0	0.03	2.3
Phosphorus dissolved			39.5	0.6	73.7	1.6	100.9	2.2	111	4.1	
total	57.7	1.9	65.5	1.9	57.7	1.2	109.6	2.4	116	4.5	
Solids dissolved	3236	107	3304	95	3464	70	4665	84	4276	143	
suspended	83	1.9	83	2.3	85	1.8	79	2.0	85	3.1	
total	3343	109	3387	98	3549	72	4744	86	4486	146	
Sulphate sulphur	642	21	639	18	651	13	728	19	748	25	
Zinc total	22.6	0.7	14.2	0.4	10.1	0.2	9.0	0.2	12.0	0.3	

TABLE 4-15

COMINCO LIMITED

ANALYSIS OF EFFLUENT FROM THE FERTILIZER PLANT (SEWERS 31 and 32)

OBTAINED BY THE POLLUTION CONTROL BRANCH

Sample Point & Date / Parameter	Sewer 31				Sewer 32, before combining with Sewer 31		Sewer 32 after combining with Sewer 31		
	Sept. 13/73	Sept. 26/73	Feb. 12-15/73		Feb. 12-15/73		Sept. 13/73		Sept. 26/73
	mg/l	mg/l	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l
Aluminum total			3.2-23.0	74-530			10-13.8	900-1260	
dissolved			1.6-19.0	37-440			1-1.8	92-165	
Antimony total			<0.01	<0.2			<0.01	<0.9	
dissolved			<0.01	<0.2			<0.01	<0.9	
Arsenic total	0.72		0.048-0.3	1-7	0.096-0.19	6.6-13.7	0.02	1.8	
dissolved	0.007		0.048-0.3	1-7	0.031-0.038	2.1-2.6	0.015	1.4	
Boron dissolved	<0.1		<0.1	<2	<0.1	<7	<0.1	<9	
Cadmium total	<0.0001	0.02	0.01-0.03	0.2-0.7	0.0028-0.02	0.2-1.4	0.001	0.09	0.013
dissolved	<0.0001	<0.0005	0.01-0.03	0.2-0.7	0.0005-0.0017	0.03-0.1	0.0006	0.05	0.005
Calcium dissolved	8.7	87.5	24.2-130	560-3000	12.5-17.9	860-1230	14	1280	23.5
Chromium total	<0.005	<0.005	<0.005-0.13	<0.1-3.0	<0.005-0.69	0.3-47	<0.005	<0.5	
dissolved	<0.005	<0.005	<0.005-0.1	<0.1-2.3	<0.005	<0.3	<0.005	<0.5	
Copper total	0.13	0.11	0.04-0.19	0.9-4.4	0.003-0.01	0.2-0.7	0.003	0.3	0.03
dissolved	<0.001	<0.01	<0.01-0.02	<0.2-0.5	<0.01	<0.7	<0.01	<0.9	
Cyanide dissolved	<0.01	<0.01	<0.01 0.02	<0.2-0.5	<0.01	<0.7	<0.01	<0.9	
Flow	2,300,000 GPD		2,300,000 GPD		6,850,000 GPD		9,160,000 GPD		
Fluoride dissolved	<0.1	0.18	138-144	3200-3300	57.5-175	3900-12,000	100	9200	240
Iron total	180	80	44-113	1000-2600	19.1-28.5	1300-1900	5.4	500	41
dissolved	0.13	<0.04	5.7-34	130-780	1.4-1.6	96-110	0.65	60	3.5
Lead total	2.3	3.3	1.6-2.6	37-60	0.04-0.082	2.7-5.6	0.013	1.2	0.7
dissolved	0.036	0.013	0.6-1.8	14-41	<0.001-0.003	0.07-0.2			

TABLE 4-15 Continued

COMINCO LIMITED

ANALYSIS OF EFFLUENT FROM THE FERTILIZER PLANT (SEWERS 31 AND 32)

OBTAINED BY THE POLLUTION CONTROL BRANCH

Parameter \ Sample Point and Date	Sewer 31				Sewer 32, before combining with Sewer 31		Sewer 32 after combining with Sewer 31		
	Sept. 13/73	Sept. 26/73	Feb. 12-15/73		Feb. 12-15/73		Sept. 13/73		Sept. 26/73
	mg/l	mg/l	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l
Magnesium dissolved	2	5.3	7.5-8.3	170-190	203-280	13900-19200	1.93	180	2.7
Manganese total	0.23	0.35	0.44-1.0	10-23	0.09-0.11	6.2-7.5	0.03	2.8	0.21
dissolved	0.01	0.04	0.34-0.72	8-17	0.03-0.05	2.0-3.4	0.02	1.8	0.11
	µg/l		µg/l		µg/l		µg/l		
Mercury total	<0.05		0.67-0.91	0.015-0.020	2.1-2.6	0.14-0.18	0.27	0.025	
dissolved	<0.05		<0.05-0.34	0.001-0.008	0.09-0.21	0.006-0.014	<0.05	<0.005	
	mg/l		mg/l		mg/l		mg/l		
Molybdenum total	<0.0005		0.006-0.026	0.1-0.6	0.018-0.029	1.2-2.0	0.0043	0.4	
dissolved	<0.0005		0.0049-0.0055	0.11-0.13	0.0018-0.005	0.1-0.3	0.002	0.2	
Nickel total	0.02		0.01-0.09	0.2-2.1	0.05	3.4	<0.01	<0.9	
dissolved	<0.01		0.01-0.08	0.2-1.9	<0.01-0.01	<0.7-0.7	<0.01	<0.9	
Nitrogen Ammonia			0.32-1.0	7.4-23.0	2	140			
Nitrate + Nitrite			0.31-1.13	7.0-26.0	0.34-0.53	23-36			
Organic			6-14	140-320	2	140			
Total			4.4-15.5	100-360	4.4-38.5	300-2600			
Oil and Grease			<1.0-5.4	<23-124	<1.0-2.2	70-150			
Oxygen demand, chemical			66-122	1500-2800	<10				
pH	8.0	8.5	2.3-2.9		3.5-4.2		3.83		2.9

TABLE 4-15 Continued

COMINCO LIMITED

ANALYSIS OF EFFLUENT FROM THE FERTILIZER PLANT (SEWERS 31 AND 32)

OBTAINED BY THE POLLUTION CONTROL BRANCH

Sample Point and Date / Parameter	Sewer 31				Sewer 32, before combining with Sewer 31		Sewer 32 after combining with Sewer 31		
	Sept. 13/73	Sept. 26/73	Feb. 12-15/73		Feb. 12-15/73		Sept. 13/73		Sept. 26/73
	mg/l	mg/l	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l
Phenol			0.133-0.272	3.0-6.3	<0.002	<0.14			
Phosphorus ortho	0.018		56-513	1290-11800	6.7-29.0	460-2000	9.85	900	
Phosphorus total	0.048		58-530	1340-12190	49.5-88.2	3400-6000	17.4	1600	
Solids total	235		760-3074	17500-70700	680-1050	46000-72000	302	2800	
Solids dissolved	185		66-432	1500-9900	496-713	34000-49000	228	21000	
Silica reactive	5.4		107-116	2500-2700	435-122	3000-8300	68	6200	
Sulphate dissolved	9.4		231-365	5300-8400	17-33	1200-2300	16.7	1500	
Zinc total	1.7	1.2	0.6-2.9	14-67	0.2-0.37	14-25	0.08	7	0.58
Zinc dissolved	0.2	0.005	0.22-1.8	5.1-40	0.07-0.12	5-8	0.05	5	0.22
Vanadium dissolved			0.118-1.4	3-32	0.018-0.1	1.2-7			

TABLE 4-16

COMINCO LTD.

DESCRIPTION OF REFUSE SITES

Pollution Control Branch Permit Number	PR-1733-02	PR-1733-01
Location	Marysville	
Status and level of operation	In operation, Level C	In operation, Level A
Quantity and type of refuse	59 cu. yds/day, 5 days/week of fertilizer, scale, paper, wood, metal and glass	50 cu. yds/day, 5 days/week of municipal refuse
Depth to groundwater table	50 ft.	
Underlying soils	stone and gravel: 0-14 ft. stone, gravel & sand: 14-40 ft. stone, gravel & clay: 40-50 ft.	
Surface runoff or flooding	none	
Distance to surface water	50 ft. to Calf Creek 1700 ft. to Mark Creek	
Distance to wells	4000 ft.	
Mean annual precipitation/ Average annual potential evapotranspiration	15/22	
Potential for adverse effects	groundwater: nil, surface water: nil. Permit requires permittee to install monitoring wells.	
Comments	Calf Creek is at a higher elevation than site.	

TABLE 4-17

DESCRIPTION OF MISCELLANEOUS INDUSTRIAL REFUSE SITES

Pollution Control Branch Permit No.	PR 2553-01,02,03	PR-1971	PR-3344
Operator and Location	Crestbrook Forest Industries Ltd., Cranbrook	Silver Ridge Sawmills(1968) Ltd.,Cranbrook	Galloway Lumber, Galloway
Status & Level of Operation	Site in operation, Level B	Site in operation, Level B	Site in operation, Level C
Depth to Groundwater	70 ft.	6 ft.	30 ft.
Underlying Soils	gravelly clay	gravel, old fill, clay, sand.	very rocky, clay loam
Surface Runoff or Flooding	none	none	none
Distance to Surface Water	1500 ft.	225 ft. (Elizabeth Lake)	2500 ft.
Distance to Wells	700 ft.	1000 ft.	2500 ft.
Mean Annual Precipitation/ Average Annual Potential Evapotranspiration	17/22	17/22	16/22
Potential for Adverse Effects	Groundwater:nil Surface water:nil	Groundwater: negligible Surface water: negligible	Groundwater:nil Surface water:nil
Comments		Elizabeth Lake is a marsh	

TABLE 4-18

DATA TAKEN FROM POLLUTION CONTROL PERMITS FOR MUNICIPAL EFFLUENTS

Description \ Municipality	City of Cranbrook		City of Kimberley	
Permit No.	PE-346	PE-4148	PE-148	Amended PE-148
Date of Issue	June 8, 1970	August 14, 1975	December 9, 1965	April 5, 1972
Date of Expiry	Superseded by PE-4148 on Dec. 31, 1976		December 9, 1970	July 1, 1973
Date of Implementation		December 31, 1976		
Effluent Flow Rate	1,250,000 GPD	3,000,000 GPD from treatment plant to storage lagoon. 6,000,000 GPD from storage lag on between May 1 and Sept. 30	5.8 CFS (3,100,000 GPD)	1,135,000 GPD
Effluent Characteristics	BOD_5 30 mg/1 suspended solids 60 mg/1	to storage lagoon: BOD_5 60 mg/1 suspended solids 100 mg/1	BOD_5 and suspended solids 40-50% less than influent. 99% Kill of bacteria	BOD_5 130 mg/1 suspended solids 130 mg/1
Treatment	Three aerated lagoons	Aerated lagoons, polishing cell, storage lagoon and spray irrigation	Combined primary sedimentation and sludge digestion tanks, chlorination, outfall and diffuser	Same as PE-148
Discharge Point	Joseph Creek	To land in an area 6 miles N.E. of Cranbrook	St. Mary River	St. Mary River

TABLE 4-19

CITY OF CRANBROOK

RESULTS FROM SAMPLING MUNICIPAL EFFLUENT WHEN LAGOONS OPERATED IN PARALLEL WITHOUT AERATION

Sample Location & Parameters (Agency and Sampling Date)		Health Branch									Pollution Control Branch
		June 1966	July 1966	Aug. 1966	Sept. 1966	Jan. 1967	March 1967	May 1967	July 1967	Jan. 1968	Nov. 1968
Effluent	BOD_5 mg/1	25	28	26	30	30	30	45	30	45	64
From	pH	7.5	10.3		7.8	7.5	7.3	8.1	9.3	7.3	6.5
Cell No. 1	Suspended solids mg/1	26	64	64	64	16	20	56	108	20	232
Effluent	BOD_5 mg/1	40	30	16	30	30	35	40	47	55	50
From	pH	8.2	10.2		8.8	7.1	7.9	9.0	9.3	7.3	7.4
Cell No. 2	Suspended solids mg/1	60	56	68	74	24	60	64	66	17	21
Effluent	BOD_5 mg/1	30	26	30	30	35	30	35	50	50	54
From	pH	9.8	10.6		8.2	7.2	7.9	9.1	8.8	7.3	7.4
Cell No.3	Suspended solids mg/1	90	98	74	50	14	48	76	128	26	18

TABLE 4-20

CITY OF CRANBROOK

POLLUTION CONTROL BRANCH SAMPLING OF MUNICIPAL EFFLUENT

WHEN LAGOONS OPERATED IN SERIES WITH AERATION

Parameter \ Sampling Date	April 1972	Feb. 1973	July 1973	Oct. 1973	Feb. 1974	April 1974	May 1974	June 1974	Aug. 1974
Carbon, total organic mg/l	39	39.5	44		23	32	15	36	
Coliform, fecal MPN/100 ml					>240,000		1,300	24,000	23,000
Conductance µmho/cm				570	535	644	588	562	
Hardness mg/l				184		255	211	198	
Oxygen, biological demand mg/l	27	22	23		21	21	17	25	
Oxygen, dissolved mg/l		2.6			0.5				
pH				8.3	7.8		8.4		
Solids, suspended mg/l	47	22	57	58	19	26	16	48	
Solids, total mg/l		342	434	382	322	404	378		420
Temperature °C		2.0	17.0		2.0		15.5		

TABLE 4-21

CITY OF KIMBERLEY

POLLUTION CONTROL BRANCH SAMPLING OF TREATED EFFLUENT

Parameter \ Sampling Date	April 1972	Jan. 1973	July 1973	Oct. 1973	March 1974	June 1974	Sept. 1974
Carbon, total organic mg/l	41	38	46		28	49	35
Chlorine residual mg/l		0.1	0		0.7	0.2	0
Conductance μmho/cm				1030	1050	1340	1460
Oxygen, biological demand mg/l	60	54	57		40	29	67
Oxygen, dissolved mg/l					9.8	9.4	7.1
pH				7.8	7.8	7.5	7.3
Phosphorus, total mg/l				5.06	2.20	2.05	3.62
Solids, suspended mg/l	34	75	75	76	30	26	82
Solids, total mg/l		726	980	890	886	1184	1264
Temperature, °C			12	11	4.5	10	11

TABLE 4-22

DESCRIPTION OF MUNICIPAL REFUSE SITES

	Permit or Application Number				
	PR-3055	PR-1912	PR-1448	PR-525	PR-1474
Operator and Location	East Kootenay Reg. Dist. Wasa	East Kootenay Reg. Dist. Fort Steele	East Kootenay Reg. Dist. Jaffray	East Kootenay Reg. Dist Baynes Lake	East Kootenay Reg. Dist. Grasmere
Status of Site	Open	Open	Open	Open	Open
Level of Operation*	C	C	C	C	C
Refuse Quantity and Type	7 cu. yd/day municipal for 600 people	5 cu. yd/day municipal	2 tons/day municipal	2 tons/day municipal	2 tons/day municipal
Depth to Groundwater Table, ft.	10-13	100		>7	>5
Underlying Soils	sand, sandy clay	glacial till, clay	glacial till with sand, silt & gravel	silt to 3 ft, gravel to 7 ft.	gravel
Surface Runoff or Flooding	none	none	none	runoff diverted	none
Distance to Surface Water, ft.	200 to Lewis Slough, 1000 to Kootenay R.	2500	800 to Little Sand Creek	2000	>1000
Distance to Wells, ft.	3000	2500	none nearby	2000	>1000
MAP/PE **	16/22	16/22	16/22	16/22	15/22
Potential for Adverse Effects: Groundwater	nil	nil	nil	nil	nil
Potential for Adverse Effects: Surface water	nil	nil	nil	nil	nil
Comments	site life 20 years. Well operated				

*As defined in the Operational Guidelines for the Discharge of Refuse on Land, Pollution Control Branch, October 1971.

**Mean annual precipitation/average annual potential evapo-transpiration.

TABLE 4-22 Continued

DESCRIPTION OF MUNICIPAL REFUSE SITES

	Permit or Application Number				
	AR-1607	AR-1606	PR-1733-01	PR-1672	PR-1673
Operator and Location	Kimberley at Marysville	Kimberley at Meadowbrook	Cominco-Kimberley at Marysville	Cranbrook	Cranbrook
Status of Site	Closed	Closed	Open	Open	Closed
Level of Operation*			A	A	A
Refuse Quantity and Type	300 cu.yd/week municipal	40 cu.yd/day municipal	50 cu.yd/day municipal	65 cu.yd/day municipal for 13,000 people	65 cu. yd/ day
Depth to Groundwater Table, ft.	probably 0	probably 0	>50	not a problem	8
Underlying Soils	sandy loam, well drained	sand, gravel and till, well drained	stone, gravel sand and clay	hardpan	sand and gravel
Surface Runoff or Flooding	runoff and flooding problems	runoff and flooding problems	none	runoff diverted	runoff diverted
Distance to Surface	0 - intermittent stream	30 - intermittent stream	50 to Calf Cr., 1700 to Mark Cr.	>2000	>1000
Distance to Wells, ft.			4000	>2000	150
MAP/PE**	15/22	15/22	15/22	17/22	17/22
Potential for Adverse Effects — Groundwater	nil	nil	nil	nil	moderate
Potential for Adverse Effects — Surface water	negligible	negligible	nil	nil	nil
Comments	Closed in '73 Use PR-1733-01	Closed in '73 Use PR-1733-01	Calf Cr. above site		Not in use. Use PR-1672

*As defined in the Operational Guidelines for the Discharge of Refuse on Land, Pollution Control Branch, October 1971.

**Mean annual precipitation/average annual potential evapo-transpiration

TABLE 4-23

NUTRIENT CONTRIBUTION TO THE KOOTENAY RIVER

FROM FERTILIZED, IRRIGATED CROPLAND AND LIVESTOCK

		Bull River	Joseph Creek	St. Mary River	Mathew Creek	Lussier River	Kootenay River			Wolfe Creek	Grasmere Valley	Fort Steele	Sand Creek	Linklater Creek	Totals
							Canal Flats to Fort Steele	Fort Steele to Wardner	Wardner to U.S. Border						
Farms reporting cropland		11	20	26	4	7	17	8	21	2	17	19	10	8	170
Cropland area - acres		1350	1035	1330	350	810	1615	650	1750	240	1730	1600	900	860	14,390
Irrigated land area - acres		1982	470	1672	1030	455	1510	370	1305	492	2110	870	520	1000	13,786
Calculated nutrient contribution to the river from irrigated cropland	N. lb/year	13,300	3100	11,200	6900	3000	10,100	2500	8700	3300	14,100	5800	3500	6700	92,300
	P. lb/year	340	80	280	170	80	260	60	220	80	360	150	90	170	2400
Number of head of cattle		900	920	700	300	700	1200	550	1700	200	1600	1300	800	800	11,670
Calculated nutrient contribution to the river from cattle	N. lb/year	8600	8800	6700	2900	6700	11,500	5300	16,300	1900	15,300	12,500	7700	7700	111,900
	P. lb/year	180	180	140	60	140	240	110	340	40	320	260	160	160	2,330
Total nutrient contribution to the river from cropland and cattle	N. lb/year	21,900	11,900	17,900	9800	9800	21,600	7800	25,000	5200	29,400	18,300	11,200	14,400	204,000
	P. lb/year	520	260	420	230	230	500	170	560	120	680	410	250	330	4700

TABLE 4-24

CALCULATED NUTRIENT LOADINGS AND CONCENTRATIONS IN

THE KOOTENAY RIVER DUE TO AGRICULTURAL OPERATIONS

Location \ Parameter	Nitrogen			Phosphorus		
	Loading lb/day	Concentration mg/l		Loading lb/day	Concentration mg/l	
		Low flow	High flow		Low flow	High flow
Lussier River	65			1.5		
Wolfe Creek	35			1.0		
Kootenay R. (Canal Flats to Fort Steele)	145			3.0		
Mathew Creek	65			1.5		
Total: Kootenay River above St. Mary Confluence	310	0.03	0.006	7.0	0.0006	0.0001
Joseph Creek	80			2.0		
St. Mary River	120			3.0		
Fort Steele	120			3.0		
Total: St. Mary River	320	0.06	0.012	8.0	0.0015	0.0003
Total: Kootenay River below St. Mary River Confluence	630	0.04	0.008	15.0	0.0009	0.0002
Bull River	150			3.5		
Kootenay River (Fort Steele to Wardner)	50			1.0		
Kootenay River (Wardner to U.S. Border)	170			4.0		
Sand Creek	75			2.0		
Grasmere Valley	200			4.5		
Linklater Creek	100			2.0		
Total: Kootenay River entering Lake Koocanusa	1375	0.064	0.013	32	0.0015	0.0003
Kootenay River flow above St. Mary River Confluence:	low flow: 2000 CFS, high flow: 10,000 CFS					
St. Mary River flow:	low flow: 1000 CFS, high flow: 5000 CFS					
Kootenay River flow entering Lake Koocanusa:	low flow: 4000 CFS, high flow: 20,000 CFS					

TABLE 4-25

STATISTICS ON THE LIBBY PROJECT [8,10,36]

DAM

Height: 370 feet (above streambed), 420 feet (above bedrock)

Length: 3055 feet (crest length)

Spillway Capacity: 145,000 CFS at elevation 2459 feet

Spillway Height: 322 feet

Spillway Type: Gate controlled with stilling basin (2-48 feet X 59 feet tainter gates)

Depth of Downstream Pool: 60 feet

Special Feature: Selective withdrawl structure (to be completed in 1975)

POWER INSTALLATION

Ultimate: 8 units at 105 MW: 840 MW

Initial: 4 units at 105 MW: 420 MW (by March, 1976)

Head: 341 feet

RESERVOIR

	Normal Full Pool	Minimum Pool
Total Reservoir length:	92 miles	42 miles
Elevation:	2459 feet	2287 feet
Storage Capacity	5,850,000 ac.ft.	885,000 ac. ft.
Surface Area (total):	46,500 acres	15,000 acres
Surface Area (U.S.):	28,850 acres	15,000 acres
Surface Area (Canada):	17,650 acres	0 acres
Depth at International Boundary:	155 feet	0 feet

TABLE 4-26

DRAWDOWN STATISTICS FOR THE LIBBY RESERVOIR[36]

Month	Pool Elevation in Feet		
	Wet Year	Median Year	Dry Year
July 1	2459	2446	2400
Aug. 1	2459	2459	2419
Sept. 1	2459	2459	2426
Oct. 1	2459	2459	2418
Nov. 1	2459	2459	2400
Dec. 1	2459	2453	2383
Jan. 1	2440	2438	2344
Feb. 1	2432	2409	2295
Mar. 1	2415	2377	2287
Apr. 1	2403	2342	2287
May 1	2410	2350	2287
June 1	2436	2392	2340

TABLE 4-27

SUMMARY OF POLLUTION CONTROL BRANCH WATER QUALITY DATA FOR KOOTENAY RIVER AND TRIBUTARIES FROM 1969 TO 1974

Site Location		Kootenay River at Canal Flats	Kootenay River at Skookum-chuck	Kootenay River at Wasa	St. Mary River	Kootenay River below St. Mary River	Bull River	Lake Koocanusa	Lake Koocanusa	Elk River	Lake Koocanusa	Max. permissible limit for drinking water (37)
Parameter / Site No.		20	48	19	18	38	30	169	101	16	100	
Arsenic, total mg/l	L	0.005		0.005	0.007	0.005	0.005	0.005	0.005	0.004	0.005	0.05
	H	0.005		0.005	0.005	0.005	0.005	0.005	0.005	0.004	0.005	
Coliform, fecal MPN/100 ml	L	2.0	2500	1000	750	40		5.0	20.0		3.5	nil
	H	2.0	50	50	50	100		5.0	30.0		3.5	
Colour, true relative units	L	5	35	25	5	12	5	5	5	5	5	15
	H	5	10	7	5	5	5	8	10	8	8	
Conductivity, specific μmho/cm	L	375	450	400	250	350	335	275	275	300	200	
	H	250	250	250	200	250	290	250	225	300	200	
Copper, total mg/l	L	0.001		0.001	0.004	0.002	0.001	0.001	0.001	0.001	0.002	1.0
	H	0.001		0.001	0.007	0.002	0.001	0.001	0.001	0.001	0.001	
Flow-1000 CFS	L	1.0	1.5*	1.5	1.0	3.0	0.5			1.0	4.0*	
	H	5.0	7.5*	10.0	5.0	15	2.5			5.0	20*	
Fluoride, dissolved mg/l	L	0.15		0.10	7.0	3.0	0.12	0.3		0.15		1.5
	H	0.15		0.10	1.0	1.0	0.10	0.3		0.15		
Iron, total mg/l	L	0.05		0.08	4.0	0.80		0.15	0.17	0.18	0.3	0.3
	H	0.05		0.08	3.0	0.60		0.15	0.17	0.18	0.3	
Lead, total mg/l	L	0.003		0.002	0.07	0.004	0.003	0.001	0.001	0.003	0.001	0.05
	H	0.003		0.002	0.02	0.004	0.003	0.001	0.001	0.003	0.001	
Manganese total mg/l	L	0.01		0.02	0.2	0.05	0.01	0.02	0.01	0.01	0.01	0.05
	H	0.01		0.01	0.1	0.02	0.01	0.02	0.01	0.01	0.01	

Note: L = low flow regime, H = high flow regime, * = estimated flow

TABLE 4-27 Continued

SUMMARY OF POLLUTION CONTROL BRANCH WATER QUALITY DATA FOR KOOTENAY RIVER AND TRIBUTARIES

FROM 1969 TO 1974

Site Location			Kootenay River at Canal Flats	Kootenay River at Skookum-chuck	Kootenay River at Wasa	St. Mary River	Kootenay River be-low St. Mary R.	Bull River	Lake Koocanusa	Lake Koocanusa	Elk River	Lake Koocanusa	Max. permissible limit for drink-ing water (37)
Parameter / Site No.			20	48	19	18	38	30	169	101	16	100	
Mercury, dissolved µg/l		L			0.05	0.15	0.05						
		H			0.05	0.10	0.05						
Nitrogen mg/l	ammonia	L	0.02	0.01	0.05	0.50	0.3	0.02	0.01	0.02	0.04	0.02	0.5
		H	0.02	0.03	0.10	0.20	0.05	0.02	0.01	0.02	0.01	0.03	
	nitrate	L	0.13	0.10	0.10	0.20	0.15	0.08	0.03	0.02	0.08	0.02	10.0
		H	0.13	0.05	0.12	0.10	0.10	0.08	0.03	0.02	0.08	0.05	
	organic	L	0.03	0.08	0.08	0.3	0.13	0.03	0.08	0.11	0.07	0.07	
		H	0.03	0.08	0.08	0.1	0.13	0.02	0.04	0.11	0.07	0.07	
pH		L	8.0	8.0	8.0	7.1	8.0	8.3	8.5	8.5	8.5	8.5	6.5-8.3
		H	8.0	8.0	8.0	7.1	8.0	8.2	8.5	8.5	8.0	8.5	
Phenol mg/l		L	0.002	0.004	0.004	0.004	0.005	0.002			0.005		0.002
		H	0.002	0.004	0.004	0.002	0.005	0.002			0.005		
Phosphorus mg/l	dissolved	L	0.003	0.003	0.003	2.0	0.5	0.003	0.01	0.01	0.007	0.04	0.2
		H	0.003	0.003	0.003	1.0	0.25	0.003	0.01	0.01	0.006	0.04	
	total	L	0.006	0.05	0.01	4.0	0.75	0.004	0.01	0.05	0.025	0.06	
		H	0.006	0.05	0.01	1.0	0.25	0.003	0.01	0.20	0.075	0.06	
Solids mg/l	dissolved	L	200	250	250	150	200	210	175	150	175	130	1000
		H	150	200	150	50	100	190	150	125	150	130	
	total	L	250	250	240	200	215	210			225		
		H	300	250	240	100	215	190			180		

Note: L = low flow regime, H = high flow regime.

TABLE 4-27 Continued

SUMMARY OF POLLUTION CONTROL BRANCH WATER QUALITY DATA FOR KOOTENAY RIVER AND TRIBUTARIES

FROM 1969 TO 1974

Site Location		Kootenay River at Canal Flats	Kootenay River at Skookum-chuck	Kootenay River at Wasa	St. Mary River	Kootenay River be-low St. Mary R.	Bull River	Lake Koocanusa	Lake Koocanusa	Elk River	Lake Koocanusa	Max. permissible limit for drink-ing Water (37)
Site No. / Parameter		20	48	19	18	38	30	169	101	16	100	
Tannins and lignins mg/l	L	0.10	1.0	1.0								
	H	0.10	0.5	0.5								
Turbidity J.T.U.	L	10	4	4	15	5	3	3	10	4	4	5
	H	40	10	15	15	10	3	3	10	20	10	
Zinc, total mg/l	L	0.005		0.005	0.3	0.08	0.005	0.006	0.005	0.005	0.008	5
	H	0.005		0.005	0.1	0.05	0.005	0.006	0.005	0.025	0.008	

Note: L = low flow regime, H = high flow regime.

TABLE 4-28

SUMMARY OF SELECTED TOXICITY DATA FOR FRESHWATER AQUATIC ORGANISMS[(a)]

See Last Page For Definitions.

	Lethal Toxicity Data		Sublethal Toxicity Data	Remarks
	Fish	Invertebrates		
Arsenic	low: 1.1 mg/l, toxic to Stizostedium (walleye) in 2 days (40) high: 60 mg/l, toxic to minnows in 16 hours (40)	4.3 mg/l, toxic to crabs in 11 days (38)	1.73 mg/l, withstood generally by fish food organisms (38)	Toxicity varies with valence state: $As^{3+} > As^{5+}$ (38) Cumulative poison (38)
Cadmium	low: 0.008 - 0.01 mg/l, 7 day LC50, hard water, Salmo gairdneri (rainbow trout) high: 73.5 mg/l, 96 hour LC50, hard water, Pimephales (fathead minnow)	0.005 mg/l, 3 week LC50, soft water, Daphnia (water flea) 25.0 mg/l, 96 hour LC50, saline water, Mytilus (mussel)	0.0005 mg/l, reproductive impairment, Daphnia (water flea)	toxicity varies with temperature and salinity. Toxicity varies with hardness (b) LCd = 11.5 H-150 (H<100) = 20 H - 1000(H>100)
Chromium (trivalent)	low: 1.2 mg/l incipient lethal level (c), soft water, Gasterosteus (threespine stickleback) high: 76 mg/l, 96 hour LC50, hardwater, Salmo gaidneri (rainbow trout)	0.01 mg/l, 48 hour LC50, Daphnia (water flea) 32.0 mg/l, 7 day LC50, softwater, Hydropsyche (caddisfly) and Acroneuria (stonefly)	0.33 mg/l, 16% reproductive impairment (d), soft water, Daphnia (water flea)	toxicity varies with hardness
Chromium (hexavalent)	low: 17.6 mg/l, 96 hour LC50, softwater, Pimephales (fathead minnow) high: 133 mg/l, 96 hour LC50, hardwater, Lepomis (bluegill)	0.05 mg/l, 48 hour LC50, Daphnia (water flea)	0.1 mg/l, decreased viability Cyprinus (carp), Daphnia (water flea) and Paramecium (protozoan)	toxicity varies with pH and hardness greater variability in toxicity with hexavalent compounds

TABLE 4-28 Continued

SUMMARY OF SELECTED TOXICITY DATA FOR FRESHWATER AQUATIC ORGANISMS[(a)]

	Lethal Toxicity Data		Sublethal Toxicity Data	Remarks
	Fish	Invertebrates		
Copper	low: 0.015 mg/1 incipient lethal level (c), soft water, *Gasterosteus* (threespine stickleback) high: 10.2 mg/1, interpolated 96 hour LC50, hardwater, *Lepomis* (bluegill)	0.008 mg/1, incipient lethal level (c), soft water Gammarus (scud) 32.0 mg/1, 2 week LC50, softwater, *Hydropsche* (caddisfly)	0.0046 mg/1 affected completion of *Gammerus* (scud) life cycle.	toxicity varies with chemical form and chelation. Toxicity varies with hardness (6). LCu = 2.02 H + 7.87 (H<53) = 1.56 H + 32.2 (H>53)
Fluoride	low: 2.3 mg/1-7.3 mg/1, 10 day LC50, soft water, *Salmo gairdneri* (rainbow trout) high: 925 mg/1, 96 hour LC50, turbid water, *Gambusia* (mosquitofish)		1.5 mg/1 affected hatching of fish eggs	toxicity varies with hardness and chloride levels
Iron	low: 0.1 mg/1, lethal to certain fish in 24 hours high: 10,000 mg/1, lethal to *Tinca* (tench) after 1 week	0.32 mg/1, 96 hour LC50, soft water, *Ephemeralla* (may fly) 16.0 mg/1, 96 hour LC50, soft water, *Acroneuria* (stonefly) and *Hydropsyche* (caddisfly)	0.52 mg/1 killed *Coregonus* (arctic cisco) spawn	Dissolved and suspended iron toxicity Toxicity varies with pH, hardness, dissolved oxygen, and chelation $Fe(OH)_3$ more toxic at low concentration
Lead	low: 0.1 mg/1 incipient lethal level (c), soft water, *Gasterosteus* (threespine stickleback) high: 432 mg/1, 96 hour LC50 hard water, *Pimephales* (fathead minnow)	0.3 mg/1, 3 week LC50, soft water, *Daphnia* (water flea) 64.0 mg/1, 2 week LC50, softwater, *Acroneuria* (stonefly)	0.03 mg/1, 16% reproductive impairment (d), soft water, *Daphnia* (water flea)	low solubility, toxicity varies with pH and chelation Toxicity varies with hardness (b) LPb = 17.9 H + 585 (H<27) = 10.2 H + 790 (H>27)

TABLE 4-28 Continued

SUMMARY OF SELECTED TOXICITY DATA FOR FRESHWATER AQUATIC ORGANISMS[a]

	Lethal Toxicity Data		Sublethal Toxicity Data	Remarks
	Fish	Invertebrates		
Managanese	low: 12 mg/l, lethal to Fundulus (killifish) in 6 days (38) high: 7850 mg/l, lethal to Orizias in 24 hours (38)	0.005 mg/l, toxic to some algae, stimulates others (40)	6.9 mg/l, eff ~t on acetylcholinesterase in shinerperch (38)	Permanganates are much more toxic than manganates (40) Antagonistic towards nickel toxicity (38)
Mercury	low: 0.001 mg/l, lethal to Esox (pike) in one season high: 0.3 mg/l, 96 hour incipient lethal level (c), Cyprinus (carp)	0.013 mg/l, 3 week LC50, softwater, Daphnia (water flea) 2.0 mg/l, 96 hour LC50, soft water, Acroneuria (stonefly), Ephemeralla (mayfly), Hydropsyche (caddisfly)	0.001 mg/l decreased algal growth and photosynthesis	methyl mercury accumulates in aquatic biota via the water or the food chain Toxicity not affected by hardness
Nitrogen (ammonia)	low: 0.2 mg/l un-ionized NH_3, lethal level (c) Salmo gairdneri fry (rainbow trout fry) high: 2.0 mg/l un-ionized NH_3, toxic level for Cyprinus (carp) and Tinca (tench)	0.66 mg/l un-ionized NH_3, 48 hour LC50, Daphnia (water flea)		Un-ionized ammonia is the toxic entity, therefore toxicity increases with increased pH Toxicity depends on temperature, dissolved oxygen and alkalinity
Nitrogen (nitrite nitrate)			Stimulates growth of plankton and aquatic weeds - Critical concentration below which algal blooms not troublesome 0.3 mg/l (40)	

TABLE 4-28 Continued

SUMMARY OF SELECTED TOXICITY DATA FOR FRESHWATER AQUATIC ORGANISMS[(a)]

	Lethal Toxicity Data		Sublethal Toxicity Data	Remarks
	Fish	Invertebrates		
pH (acid)	low: pH 6.2, incipient lethal level (c), salmonids high: pH 4.2, 8 day LC50, Salmo gairdneri (rainbow trout) and Rutilus (roach)	pH 6.6 50% emergence of Isogenus (stonefly) pH 2.45, 30 day LC50 Brachycentrus (caddisfly)	pH 5.0, possible reproduction impairment	pH dependent upon buffering capacity Toxicity varies with acclimation Effects toxicity of other poisons Lethal amounts of CO_2 may be liberated Basic nutrients unavailable to plants at pH <6.5 and pH >8.5.
pH (alkali)	low: pH 9.2, incipient lethal level (c), salmonids high: pH 10.8, incipient lethal level (c), Cyprinus (carp)			
Phenol	low: 0.079 mg/l, lethal to minnows in 30 minutes high: 44.5 mg/l, 48 hour LC50, Carassius (gold fish)	1.0 mg/l, incipient lethal level (c), Mytilus (mussel) 150 mg/l, incipient lethal level (c), Cyclops (copepod)	1.0 mg/l, 20% reduction in growth of Salmo gairdneri (rainbow trout)and possible avoidance reaction at 0.1 mg/l	Toxicity varies with temperature, dissolved oxygen and hardness. With Cl_2 very toxic chlorinated phenols may be formed 1-10 mg/l taints fish flesh
Phosphorus	1090 mg/l of Na tripolyphosphate and Na pyrophosphate lethal to fishes	126 mg/l Na phosphate 96 hour LC50, Daphnia (water flea)	0.01 mg/l soluble ortho phosphate associated with algal blooms. 0.005 mg/l inhibited growth of the algae: Uroglena and Dinobryon 1.78 mg/l inhibited growth of the algae: Pediastrum, Staurestrum and Nitzschia (higher levels are probably toxic)	Algal blooms may reduce dissolved oxygen below critical level
Zinc	low: 0.3 mg/l incipient lethal level (c), soft water, Gasterosteus (threespine stickleback) high: 40.9 mg/l, interpolated 96 hour LC50, hard water, Lepomis (bluegill)	0.1 mg/l, 48 hour LC50, unfed Daphnia (water flea) 32.0 mg/l, 2 week LC50, soft water, Acroneuria (stonefly) and Hydropsyche (caddisfly)	0.0056 mg/l, soft water avoidance reaction in Salmo gairdneri (rainbow trout)	Toxicity varies with chemical form and pH. Toxicity varies with hardness (b) LZn = 19.5 H + 291 (H<46) = 10.2 H + 710 (H>46)

NOTES TO TABLE 4-28

LC50 : concentration which results in 50% mortality (or 50% survival) within a specified time period, for example 96 hour LC50.

Lethal : causing death

Sublethal : below the level which directly causes death

a. All data taken from Clarke (39) except where indicated
b. The hardness formulae adjust toxicity for various levels of hardness. LX is the lethal threshold for metal X in µg/l. H is total hardness as mg/l $CaCO_3$. Formulae for cadmium are based on 48 hour LC50, not on lethal threshold.
c. Incipient lethal level is the concentration at which increased mortality is observed.
d. 16% reproductive impairment means the total number of young produced is 16% less than that of controls.

TABLE 4-29

AVERAGE CONCENTRATIONS OF CERTAIN PARAMETERS WHICH DO NOT ADVERSELY AFFECT WATER QUALITY IN THE KOOTENAY RIVER (FROM POLLUTION CONTROL BRANCH DATA COLLECTED 1969 - 1974)

Parameters \ Site Nos.	20	38	Recommended Drinking Water Standard (37)
Alkalinity, total mg/l	130	96	
Calcium mg/l	45	37	200
Carbon, organic mg/l	3.6	5.0	
Chloride mg/l	6.4	6.9	250
Hardness, total mg/l	167	140	180
Magnesium mg/l	14	12	150
Nitrate nitrogen mg/l	0.005	0.006	10
Potassium, dissolved mg/l	0.5	0.8	
Silica, reactive mg/l	4.5	6.5	
Sodium, dissolved mg/l	4.9	5.8	
Sulphate mg/l	38	42	500

TABLE 4-30

AN ESTIMATE OF THE INFLUENCE OF THE SKOOKUMCHUK PULP MILL DISCHARGE ON THE KOOTENAY RIVER

	Loading from pulp mill as a percent of total loading in the Kootenay River, immediately downstream from the discharge $(\frac{B}{C})100\%$		Difference in loadings between site 48 and a point immediately downstream from the discharge, as a percent of loadings at site 48 $(\frac{D-C}{D})100\%$	
	Low flow	High flow	Low flow	High flow
Coliforms	>90	>90	-25	-90
Colour	90	65	0	0
Phenols	75	40	-25	90
Phosphorus, total	70	35	260	700
Tannins and lignins	>90	>90	-25	-90

Explanatory Diagram

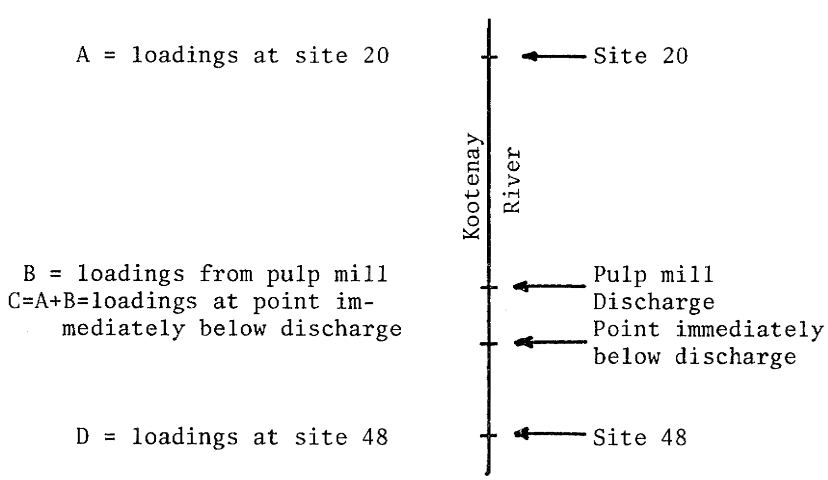


TABLE 4-31

SUMMARY OF POLLUTION CONTROL BRANCH WATER QUALITY DATA FOR ST. MARY RIVER AND MARK CREEK FROM 1970 TO 1974

Site Location		St. Mary River	Mark Creek	Mark Creek	St. Mary River	St. Mary River	Maximum Permissible Limit For Drinking Water (37)
Parameter / Site Number		29	37	36	135	18	
Alkali, total mg/1	L H	14-40	20-40 5-15	<10	to 24	to 50	
Arsenic, dissolved mg/1	L H	<0.005	<0.005	0.005-0.05	to 0.08 <0.001	0.01-0.04 <0.01	0.05
Calcium, total mg/1	L H	10 5-8	10-14 2-6	60-80 0-50	25-40 5-20	30-50 <30	200
Carbon, organic mg/1		2-8			1-5		
Chloride, dissolved	L H	<0.5	<0.5	1-5 few 5-12	1-3 <1	4-5 <2	250
Chromium, total mg/1					<0.005	<0.005	0.05
Coliform, fecal MPN/100 ml	L H	<2			<2 single value	750 50	nil
Copper, total mg/1					<0.007	<0.007	1.0
Flow, mean monthly range CFS		200-6000	2-60	2-60	300-7000	300-7000	
Fluoride, dissolved mg/1	L H	<0.15	0.12	100-150 10-60	15-20 0-10	10-15 <5	1.5
Iron, dissolved mg/1	L H	<0.01	0.4-0.5 0.05-0.25	10-23 1-10	4-10 0.5-3	2-5 <1	0.3

Note: L = low flow period, H = high flow period.

TABLE 4-31 Continued

SUMMARY OF POLLUTION CONTROL BRANCH WATER QUALITY DATA FOR ST. MARY RIVER AND MARK CREEK FROM 1970 TO 1974

Site Location		St. Mary River	Mark Creek	Mark Creek	St. Mary River	St. Mary River	Maximum Permissible Limit for Drinking Water (37)
Parameter / Site Number		29	37	36	135	18	
Lead, dissolved mg/l	L H	0.001-0.005	0.001-0.016 in 1973, <0.003 in 1972/74	0.001-0.18 in 1973, 0.1-0.2 in 1972/74	to 0.12 <0.02	0.003 few to 0.01	0.05
Manganese, dissolved mg/l	L H	<0.01	0.15-0.2 0.01-0.15	1.0-25 0.2-1.0	0.2-0.4 0.05-0.2	0.2-0.4 0.03-0.2	0.05
Molybdenum, total mg/l	L H	<0.0005	<0.0005	0.001-0.002	0.001 <0.0005	0.001 <0.0005	
Nitrogen: ammonia mg/l		0.001-0.013	0.005, few: 0.06-0.18	0.02-0.13 in summer	<0.8 March to 0.8	<0.5 March to 0.14	0.5
Nitrogen: nitrate + nitrite mg/l	L H	0.1-0.15 0.003-0.01	0.005-0.008 <0.004	0.1-1.5 0.01-0.02	0.2-0.35 <0.2	0.2-0.5 <0.1	10
Nitrogen: organic mg/l	L H	0.001-0.016	0.01-0.14	0.5-0.9 0.1-0.3	0.3-0.4 <0.2	0.3-0.6 <0.2	
pH	L H	6.8-7.5	6.8-8.0	2.3-4.0 6.7	3.5-6.5 6.5-7.5	6.0-7.5	6.5-8.3
Phosphorus: dissolved mg/l	L H	<0.005	<0.003	5-12 0-4	5-9 <2	1-8 <0.5	0.2 as $(PO_4)^{\equiv}$
Phosphorus: total mg/l	L H	0.001-0.01	<0.25 0.9 in Sept./74	8-30 0.1-8	0.1-12 30-40 in Feb/74	0.1-10	

Note: L = low flow period, H = high flow period.

TABLE 4-31 Continued

SUMMARY OF POLLUTION CONTROL BRANCH WATER QUALITY DATA FOR ST. MARY RIVER AND MARK CREEK FROM 1970 TO 1974

Site Location		St. Mary River	Mark Creek	Mark Creek	St. Mary River	St. Mary River	Maximum Permissible Limit for Drinking Water (37)
Parameter / Site Number		29	37	36	135	18	
Solids, dissolved mg/1	L	50	50-90	500-1200	150-270	200-300	1000
	H	<40	20-50	100-500	<100	<150	
Turbidity - J.T.U.	L	<30	1-50	5-10	1-25	5-15	5
	H			2-5		15-30	
Zinc, dissolved mg/1	L	0.02	0.4-0.9	7.5-10	0.3-0.6	0.05-0.9	5
	H		0.05-0.2	1.0-5.0	0.05-0.2		

Note: L = low flow period, H = high flow period.

Data for other parameters were examined. The values were judged to be relatively insignificant and hence were not included in the Table. The parameters included: oil and grease, total solids, suspended solids, temperature, dissolved oxygen, conductivity, cyanide, hardness, phenol, COD, silica, sulphate, surfactants, tannin and lignin, sulphide, boron, cadmium, magnesium, nickel, potassium, sodium, aluminum, antimony and vanadium.

TABLE 4-32

SUMMARY OF POLLUTION CONTROL BRANCH WATER QUALITY DATA

FOR JOSEPH CREEK FROM 1970 - 1974

Parameters \ Site No.			151	152	153	Maximum Permissible Limit For Drinking Water (37)
Coliform, fecal MPN/100 ml.			130-540	540-2400	14-2400	<50
Flow, mean monthly range CFS			1-20	1-20	1-20	
Nitrogen mg/1	nitrate + nitrite	L	0.15-0.7	0.2-1.0	1.0-2.0	10
		H			0.1-0.5	
	organic		0.15-0.35	0.5-1.4	0.5-1.7	
Oxygen, dissolved mg/1			8-12	4-12	2.5-11	
pH			8.0-8.5	7.5-8.0	7.5-8.0	6.5-8.3
Phos phorus mg/1	dissolved	L	0.005-0.003	2-4	2-3.5	
		H		0.2-1	0.2-1	
	total	L	0.001-0.01	2-4.5	2-4	0.2 as $(PO_4)^{\equiv}$
		H		0.2-1.2	0.2-1.5	
Solids mg/1	dissolved		120-250	150-300	150-350	1000
	total		170-270	200-350	200-350	
Specific conductance μmho/cm			200-400	200-480	200-580	

Note: L = low flow period, H = high flow period.

TABLE 4-33

SUMMARY OF POLLUTION CONTROL BRANCH DATA FOR JAMES CREEK, INCLUDING LOADINGS CALCULATED FROM THE DATA.

Parameter	Range of average daily concentration - mg/1		Range of average daily load lb/day	
	1973	1974	1973	1974
Arsenic	0.2-7.0	0.2-1.0	20-400	20-100
Fluoride	100-300	200-400	4000-20,000	10,000-100,000
Iron	150-300	150-300	4000-20,000	4000-20,000
Lead, total	1-6	0.5-1.5	20-200	20-100
pH	2.4-3.5	2.4-3.0		
Phosphorus, total	70-200	100-250	2000-6000	2000-14,000
Solids, dissolved	3000-5000	4000-5000	100,000-200,000	200,000-600,000
Sulphate	600-800	700-900	20,000-60,000	40,000-80,000
Zinc, total	2-16	2-16	20-200	20-100

Note: High concentration and high load may not occur at the same time due to seasonal variations in the creek flow.

TABLE 4-34

MAXIMUM PERCENT INCREASE IN CONCENTRATION OF CERTAIN PARAMETERS IN THE ST. MARY RIVER BETWEEN SITE 29, ABOVE KIMBERLEY, AND SITE 135 AT WYCLIFFE, DURING LOW FLOW 1970 - 1973

	Concentration Range at Site 29	Concentration Range at Site 135	Maximum increase as a percent of concentration at Site 29
Arsenic, mg/1	<0.005	<0.005 Aug, Sept/73 to 0.1	
Fluoride, mg/1	<0.15	10-20	10,000
Iron, dissolved, mg/1	<0.01	3-10	100,000
Lead, dissolved, mg/1	<0.005	0.02	400
Manganese, dissolved, mg/1	<0.01	0.05-0.4	4000
Mercury, dissolved, μg/1	<0.005	1973: to 0.4 1974: < 0.005	10,000 0
Nitrogen, total, mg/1	0.01-0.1	0.01-0.3	300
pH	6.8-7.5	3.8-7.5	
Phosphorus, dissolved, mg/1	<0.005	1-9	100,000
Silica, reactive, mg/1	5-7	5-25	500
Solids, dissolved, mg/1	50-100	50-270	300
Sulphate, mg/1	5-10	10-120	1000
Zinc, dissolved, mg/1	0.02	0.3-0.6	3000

TABLE 4-35

CONCENTRATION AND LOADING DATA FOR MARK CREEK AND DISCHARGES TO MARK CREEK

Sample Location	Upper Mark Creek, Site 37		Sewer 32(a)		Main Mine Drainage		Mine Change Room Showers		Mine Car Shop		Surface Stream No. 1		Surface Stream No. 2		Surface Stream No. 3		Mine Water 3700ft. level	
Data Source	Poll.Cont. Br.		Cominco		Cominco		Cominco		Cominco		Cominco		Cominco		Cominco		Cominco	
Flow-average CFS	2-60		1.2		0.15		0.02		0.001		0.07		0.001		0.07		0.4	
pH	6.8-7.5		3.0-4.0		2.5-3.6		6.5-7.5		6.5-7.5		6.5-8.0		2.7-3.2		2.7-7.0		7.5-7.8	
	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day
Arsenic	<0.005	<2	0.06	0.4	0.1	0.08	0.006	-	0.027	-	0.004	-	0.21	-	0.005	-	0.002	-
Cadmium	?	?	?	?	0.1	0.08	0.01	-	0.01	-	0.01	-	?	?	?	?	?	?
Copper	?	?	0.04	6	0.20	0.15	-	-	-	-	?	?	?	?	?	?	?	?
Cyanide	?	?	0.17	1	0.08	0.06	-	-	-	-	?	?	?	?	?	?	?	?
Fluoride	<0.1	<32	23.4	150	5.6	4.5	-	-	-	-	?	?	?	?	?	?	?	?
Iron, dissolved	<0.08	<25	6.6	42	300	240	0.25	-	2.5	-	3.5	-	115	0.6	115	43	?	?
Lead, dissolved	<0.005	<2	0.52	3.3	3.2	2.5	0.25	-	0.25	-	0.25	-	0.25	-	0.5	0.2	1.0	2
Manganese, dissolved	<0.01	<4	?	?	50	40	-	-	-	-	?	?	?	?	?	?	?	?
Phosphorus, total	<0.001	-	54.2	345	?	?	-	-	-	-	?	?	?	?	?	?	?	?
Solids, dissolved	<50	<1600	?	?	4000	3000	-	-	?	?	?	?	?	?	?	?	?	?
Zinc, dissolved	<0.2	<60	0.52	3	100	80	0.41	-	0.29	-	0.53	-	12.5	-	226	84	1.9	4

Note: ? = unknown
- = negligible amount

TABLE 4-35 Continued

CONCENTRATION AND LOADING DATA FOR MARK CREEK AND DISCHARGES TO MARK CREEK

	Total load to Mark Creek calculated from known discharges = A lb/day	Load in Mark Creek calculated from Poll. Cont. Br. analyses at site 36		Load in Mark Creek at site 36, not accounted for by known discharges, expressed as approx. percent of load in creek $= \frac{(B-A)}{B} 100$
		mg/l	B lb/day	
Arsenic	<3	0.05-0.5	0.5-2	0
Cadimum	<0.1	?	?	?
Copper	7	?	?	?
Cyanide	1	?	?	?
Fluoride	190	50-100	1000-1500	80
Iron, dissolved	400	5-20	200-4000	0-80
Lead, dissolved	8	0.1	25	60
Manganese, dissolved	45	0.2-2.0	5-20	
Phosphorus, total	350	2-10	100-6000	0-90
Solids, dissolved	<4600	300-1000	10,000-100,000	50-95
Zinc, dissolved	230	1-10	100-300	0

Note: ? = unknown

TABLE 4-36

CONCENTRATION AND LOADING DATA FOR ST. MARY RIVER AND ITS TRIBUTARIES

Sample Location	St. Mary River site 29		Discharge from Kimberley Sewage Treatment Plant		Discharge from Mark Creek, from analyses at site 36		Discharge from James Creek (Table 4-33)		Discharge from Joseph Creek	
Data Source	Pollution Control Branch		Pollution Control Branch		Pollution Control Branch		Pollution Control Branch		Pollution Control Branch	
Flow CFS	300-600		2.4		2-60				1-30	
	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day
Arsenic	<0.005	<150	<0.005	-	0.005-0.05	0.5-2	0.2-7.0	20 -400	-	-
Fluoride	0.15	<500	0.6	3	50-100	1000-1500	100-400	400-100,000	0.1	-
Iron, dissolved	0.005	150	0.2	1	5-20	200-4000	150-300	4000-20,000	-	-
Lead, dissolved	0.001-0.003	<20	0.008	-	0.1	25	0.5-6.0	20-200	-	-
Manganese, dissolved	<0.01	<300	-	-	0.2-2.0	5-20	?	?	-	-
Mercury, dissolved	<0.001	<25	-	-	?	?	?	?	-	-
Nitrogen, total	0.01-0.1	<300	15	80	0.2-2.0	20-60	?	?	0.8-5	25-120
Phosphorus, total	0.001-0.01	< 30	3	15	2-10	100-6000	70-250	2000-14000	0.2-4	20-30
Solids, dissolved	30-50	80,000-900,000	1000	5000	300-1000	10,000-100,000	3000-5000	10,000-600,000	200-300	1600-30,000
Zinc, dissolved	<0.01	<300	3	16	1.0-10.0	100-300	2-16	20-200	-	-

Note: ? = unknown, - = negligible amount

TABLE 4-36 Continued

CONCENTRATION AND LOADING DATA FOR ST. MARY RIVER AND ITS TRIBUTARIES

	Total Load to St. Mary River calculated from known discharges = A lb/day	Loads from known discharges, expressed as a percent of total calculated load A					Load in St. Mary River calculated from Pollution Control Branch analyses at site 18		Load in St. Mary River at Site 18, not accounted for by known discharges, expressed as approx. percent of load in River $=(\frac{B-A}{B})\ 100$
		Upper St. Mary Riv. Site 29	Kimberley Sewage Treatment Plant	Mark Creek	James Creek	Joseph Creek	mg/l	B lb/day	
Arsenic	20-550	< 25	-	-	> 75	-	0.001-0.05	30-100	-80
Fluoride	5000-100,000	< 10	-	< 20	> 80	-	1-7	500-4000	-99
Iron, dissolved	5000-25,000	< 3	-	< 10	> 80	-	1-4	2000-3000	-80
Lead, dissolved	50-250	< 10	-	< 20	> 70	-	0.003-0.01	< 500	< 50
Manganese, dissolved	?	?	-	?	?	-	0.1-0.2	1000-3000	?
Mercury, dissolved	?	?	-	?	?	-	< 0.005	< 25	?
Nitrogen, total	< 600	?	-	?	?	?	0.2-1.0	5000	> 90
Phosphorus, total	2000-20,000	-	-	< 30	> 70	-	1-4	25,000	0
Solids, dissolved	200,000-1,800,000	30-50	-	< 5	30-50	< 5	100-300	500,000-5,000,000	60
Zinc, dissolved	<800	< 30	-	>30	> 20	-	0.1-0.3	1600-2100	>50

TABLE 4-37

SUMMARY OF RECOMMENDED RECEIVING WATER SAMPLING FOR PHASE II

Location	Mark Creek				Kimberley Creek				St. Mary River				Kootenay River							
	Above Cominco	Chapman Camp	Marysville	Lois Creek	Above 3700 ft. Portal	Below 3700 ft. Portal	Cow Creek at Highway 95A	James Creek at Highway 95A	Control Site	Above Cow and James Creeks	Wycliffe	St. Eugene Mission	Upstream From Pulp Mill	Downstream From Pulp Mill	Wasa	Upstream From St. Mary River	Picture Valley	Libby Reservoir		
Parameter / Site No.	37	N 13	36	N 21	N 22	N 34	214	213	29	N 14	135	18	175	48	19	N 25	38	169	101	100
Arsenic, total	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Boron, dissolved							√	√												
Cadmium, total	√		√				√	√												
Coliform													√	√	√	√	√	√	√	√
Colour, TAC													√	√	√	√	√	√	√	√
Cyanide, dissolved							√	√												
Flow estimate				√	√	√	√	√							√					
Fluoride	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Iron dissolved	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√
Iron total							√	√												
Hardness	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√
Lead, dissolved	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√
Manganese, dissolved	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√
Mercury, total							√	√												
Molybdenum, total							√	√												

TABLE 4-37 Continued

SUMMARY OF RECOMMENDED RECEIVING WATER SAMPLING FOR PHASE II

Location	Mark Creek				Kimberley Creek				St. Mary River				Kootenay River							
	Above Cominco	Chapman Camp	Marysville	Lois Creek	Above 3700 ft. Portal	Below 3700 ft. Portal	Cow Creek at Highway 95A	James Creek at Highway 95A	Control Site	Above Cow and James Creeks	Wycliffe	St. Eugene Mission	Upstream From Pulp Mill	Downstream From Pulp Mill	Wasa	Upstream From St. Mary River	Picture Valley	Libby Reservoir		
Parameter / Site No.	37	N 13	36	N 21	N 22	N 34	214	213	29	N 14	135	18	175	48	19	N 25	38	169	101	100
Nickel, dissolved							√	√												
Nitrogen, total							√	√												
pH	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√
Phenol							√	√												
Phosphorus dissolved	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√
Phosphorus total	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√
Sediment	√		√					√	√			√					√	√	√	√
Solids dissolved								√												
Solids total	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√
Specific Conductance	√	√	√	√	√	√	√													
Turbidity													√	√	√	√	√	√	√	√
Tannin & lignin													√	√		√	√	√	√	√
Temperature	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√
Zinc, total	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√

Notes: Sampling frequency monthly initially.
Sites prefixed N are new W.I.B. sites. All other sites are P.C.B. sites.

TABLE 4-38

LOADING DATA, EXPRESSED IN PERCENTAGES, FOR THE KOOTENAY RIVER BETWEEN ST. MARY RIVER CONFLUENCE AND THE INTERNATIONAL BORDER

	Loading from St. Mary River as a percent of loadings from Kootenay River at site 19(A lb/day) and St. Mary River at site 18 (B lb/day) $= (\frac{B}{A + B})\ 100\%$		Percent difference between the loadings at site 19 (A lb/day) + site 18 (B lb/day) and the loading at site 38 (C lb/day) downstream from St. Mary River. $= (\frac{A + B - C}{A + B})\ 100\%$		Difference between loading entering Lake Koocanusa (Bull River, site 30 + Elk River, site 16 + Kootenay River, site 169) and loading leaving Lake Koocanusa at the border (site 100), as a percent of loading entering the lake.	
	Low flow	High flow	Low flow	High flow	Low flow	High flow
Colour, true	10	25	15	20	45	5
Copper	70	80	0	35	-45	35
Fluoride	>90	85	-25	-150	85	65
Iron	>90	>90	55	25	55	25
Lead	>90	85	75	25	45	5
Manganese	85	85	35	50	70	35
Mercury	65	50	35	25	--	--
Nitrogen, ammonia	85	50	-55	65	90	10
Nitrogen, organic	70	40	10	-50	35	25
Phosphorus, diss.	>90	>90	25	25	85	75
Phosphorus, total	>90	>90	55	25	90	65
Zinc	>90	90	20	-35	85	75

TABLE 4-39

DISSOLVED GAS VALUES MEASURED IN THE LOWER KOOTENAY RIVER

Site	Agency	Date	Total dissolved gas as % saturation
Wardner Bridge	U.S.	June 13/72	102.2
	P.C.B.	July 27/72	103.7
	P.C.B.	July 20/73	101.5
	P.C.B.	Nov. 1/73	100.4
	P.C.B.	June 19/74	100.4

% Saturation	Approximate potential effects
100 - 110	Satisfactory. Possible sub-lethal effects.
110 - 120	Borderline. Increased likelihood of sub-lethal effects. Some mortality, especially in shallow waters
120 - 140	Unsatisfactory. Increased likelihood of significant mortality, especially if water shallower than 3 meters.
>140	Critical. High probability of extensive fish mortalities.

TABLE 4-40

ANALYSIS OF SEDIMENT SAMPLES COLLECTED BY THE POLLUTION CONTROL BRANCH IN 1973

Parameter \ Sample Location	St. Mary River						Kootenay River		Lake Koocanusa	Goat River
	St. Mary Lake	0.6 mile above Mark Creek	Site 29 just above Mark Creek	Site 135 at Wycliffe	8 miles below Wycliffe	At confluence with Kootenay River	At Fort Steele	Site 38 at Wardner		
Cadmium µg/g	0.93	<0.25	1.34	4.71	20.7	3.51	2.11	6.20	8.3 16.2	4.05
Calcium mg/g	1.46	2.63	1.84	2.54	14.3	2.25	11.1	84.8	12.25	3.94
carbon mg/g carbohydrate				4.74					3.63	
carbon mg/g inorganic				<0.3					4.54	
carbon mg/g organic	3.65	11.4	1.80	4.80	65.5	2.17	12.2	22.1	22.0	55.5
Copper µg/g	18.6	23.8	16.5	38.7	261	21.5	28.9	64.9	14.2	35.6
Iron mg/g	13.9	18.1	13.9		179	15.1	0.137	30.1		323
Lead µg/g	12.1 18.9	29.0	11.9	179	3040	85.9 54.6	116 158	329	12.1	20.2
Magnesium mg/g	2.39	4.89	2.86	2.71	2.78	2.74	6.63	19.6	5.95	1.03
Manganese mg/g	0.592	0.221	0.203		1.74	0.289	0.295	0.823		10.10
Nitrogen (Kjeldahl) mg/g	0.354	0.60	0.161	0.450	9.14	0.195	0.901	2.40	1.20	4.01
Phosphorus mg/g hydrolyzable	0.269	0.508	0.283	4.21	61.2	1.144	1.19	4.81	4.60	1.86
Phosphorus mg/g organic				<0.008					0.037	
Zinc µg/g	34.5	52.4	28.8	492	4590	198	273	1000	42.4	43.7

Results reported on a dry weight basis.

TABLE 4-41

NUMBER OF INSECTS COLLECTED AT LOCATIONS

IN THE ST. MARY RIVER[46]

Location	Date	Species				
		Ephemeroptera	Plecoptera	Trichoptera	Diptera	Other
Camp Stone	Aug. 1969	6	7	3	0	0
3-4 miles upstream from	Oct. 1969	67	9	2	10	0
Mark Creek confluence	Nov. 1969	85	7	1	20	0
	Aug. 1969	0	0	2	0	0
Wycliffe	Oct. 1969	0	0	1	0	0
	Nov. 1969	0	0	2	0	0

TABLE 4-42

SUMMARY OF IN SITU FISH CAGING EXPERIMENTS IN THE ST. MARY RIVER

Data Source	Species	Location	Starting Date	No. of Fish	Sampling Time	No. of Live Fish	% Survival	Comments
Sinclair[45]	Rainbow Trout Fry	St. Mary's River immed. above confluence with Mark Creek	Sept. 29, 1965	18	20 days	18	100	Fish in good condition.
		St. Mary's River - 10 miles below confluence with Mark Cr. (Wycliffe)	Sept. 29, 1965	26	20 days	0	0	84% surviving after 24 hours; 0% after 48 hours.
Whately[49]	Rainbow Trout Fry	St. Mary's River immed. above confluence with Mark Creek	August 23, 1969	10	48 hrs.	7	70	loss thought due to shock
		St. Mary's River 10 miles below confluence with Mark Creek.	August 23, 1969	10	48 hrs.	0	0	no healthy fish after 24 hrs.
Pollution Control Branch[50]	Rainbow Trout Fingerlings	St. Mary's River above confluence with Mark Creek (site 29)	August 15, 1973	26	96 hrs.	26	100	also checked at 24, 48 and 72 hours.
		St. Mary's River near Wycliffe (site 135)	August 15, 1973	19	24 hrs. 48 hrs. 72 hrs. 96 hrs.	19 18 12 9	100 94.7 73 47.5	remaining fish in poor condition.
Pollution Control Branch[50]	Rainbow Trout	St. Mary's River above confluence with Mark Creek (site 29)	July 23, 1974 (during strike)	20	99 3/4 hrs.	20	100	
		St. Mary's River at confluence with Mark Creek	July 23, 1974 (during strike)	20	50 hrs.	0	0	all fish dead for some time; little St. Mary's River water going through cage
		St. Mary's River at Wycliffe (site 135)	July 23, 1974 (during strike)	20	96 hrs.	20	100	fish sluggish after 48 hrs. but O.K. at end.
		St. Mary's River 7.3 miles below site 135	July 23, 1974 (during strike)	20	95 1/3 hrs.	11	55	death possibly due to Joseph Creek influence

TABLE 4-43

DATA FOR JAMES CREEK COLLECTED BY COMINCO BEFORE AND

AFTER THE STRIKE AT COMINCO OPERATIONS

Date / Parameter	June 12-19 1974	June 19-26 1974	July 1- Nov. 6 1974 Strike Period	Nov. 6-13 1974	Nov. 13-20 1974	Nov. 20-27 1974	Nov. 27- Dec. 4 1974
Flow, daily average GPM	2808	3426		826	890	1818	2061
Fluoride, mg/l	190	-		18	15	20	175
Phosphate, dissolved mg/l	273	382		42	6	-	269
Phosphate, total mg/l	276	385		52	30	31	360
Zinc, dissolved mg/l	14.4	13.5		4.4	4.1	20.5	21.1

TABLE 4-44

NUMBERS OF INSECTS COLLECTED AT LOCATIONS IN THE KOOTENAY RIVER PRIOR TO OPERATION OF CRESTBROOK FOREST INDUSTRIES LTD. PULP MILL[46]

Location	Date	No. of Samples	Species Ephemeroptera	Plecoptera	Trichoptera	Diptera	Other
Canal Flats	April '67	1	30	10	0	8	0
	Oct. '67	1	68	3	0	1	3
	Nov. '67	1	42	4	0	0	0
"	March '68	1	130	21	2	82	4
	Sept. '68	1	19	5	1	18	0
	Nov. '68	1	35	10	0	51	12
	Dec. '68	1	0	0	0	0	1
Skookumchuck	March '67	2	18	8	2	15	4
	April '67	2	44	50	3	30	1
	Oct. '67	2	63	8	1	6	0
	Nov. '67	3	53	6	1	1	0
	Dec. '67	2	132	13	1	21	2
"	March '68	2	81	3	1	38	1
	April '68	2	315	16	8	0	0
	Nov. '68	2	26	40	0	22	0
	Dec. '68	2	40	4	1	33	0
Wasa	March '67	1	48	57	13	0	0
	Nov. '67	1	0	0	3	1	0
"	May '68	1	35	3	0	45	0
	Aug. '68	1	10	13	0	0	0
	Sept. '68	1	7	6	1	50	0
	Nov. '68	1	13	6	1	15	0
Fort Steele	March '67	1	2	22	1	9	0
	Oct. '67	1	12	22	0	122	0
East Bank	Nov. '67	1	5	1	2	1	0
	Dec. '67	1	16	12	4	14	168
Fort Steele	March '67	1	1	3	0	0	0
	Oct. '67	1	2	1	0	17	0
West Bank	Nov. '67	1	6	3	0	1	3
	Dec. '67	1	3	10	3	1	0
"	April '68	1	2	3	0	34	1
	Sept. '68	1	11	5	0	2	0
	Dec. '68	1	32	2	0	20	0

TABLE 4-45

NUMBER OF INSECTS COLLECTED AT LOCATIONS IN THE KOOTENAY RIVER DURING OPERATION OF CRESTBROOK FOREST INDUSTRIES LTD. PULP MILL (46)

Location	Date	Species				
		Ephemeroptera	Plecoptera	Trichoptera	Diptera	Other
		Chris Bull Samplers - Each Value From One Sample				
Canal Flats	Oct. 1969	54	1	1	10	1
Skookumchuck	Oct. 1969	82	1	1	27	1
	Oct. 1969	65	15	0	0	1
Wasa	Aug. 1969	9	5	0	0	0
Fort Steele West Bank	Oct. 1969	4	30	0	70	0
Wardner	Aug. 1969	28	1	7	10	0
	Aug. 1969	27	0	12	20	0
	Nov. 1969	3	62	0	0	1
		Surber Samplers - Each Value is a Mean of 10 Samples				
Above the Pulp Mill	1969	40	20	6	160	6
Below the Pulp Mill		7	2	2	255	1

TABLE 4-46

PERCENT COMPOSITION OF ORGANISMS IN THE STOMACHS OF WHITEFISH[46]

	Kootenay River Near Waldo March 1968 60 Adults	Lower Bull River March 1968 20 Adults	Lower Bull River August 1967 17 Fry
Ephemeroptera	1%	2%	21%
Plecoptera	59%	35%	4%
Trichoptera	12%	4%	
Diptera	28%	2%	73%
Whitefish Eggs		57%	
Other			2%

Not known whether percent by weight, volume or number

TABLE 4-47

PERIPHYTON DATA OBTAINED IN 1972 AND 1973

FROM THE KOOTENAY RIVER[48]

Site No.	Date	Number of cells/mm^2	Biomass µg/mm^2
20	22 Mar. - 19 Apr. '72	120	0.03
48	22 Mar. - 19 Apr. '72	3385	0.55
19	23 Mar. - 20 Apr. '72	8735	0.92
38	23 Mar. - 20 Apr. '72	6585	4.60
48	28 Mar. - 30 Apr. '73	3515	0.4
19	28 Mar. - 30 Apr. '73	14090	1.44
38	28 Mar. - 03 May '73	9975	9.73
20	21 Aug. - 28 Sept. '72	120	0.02
19	21 Aug. - 28 Sept. '72	1860	0.24
20	01 Nov. - 24 Nov. '72	40	0.01
48	01 Nov. - 24 Nov. '72	210	0.10
20	18 Sept. - 24 Oct. '73	2.3	0.06
38	19 Sept. - 24 Oct. '73	15520	5.35
48	31 Oct. - 27 Nov. '73	3	0.003
19	31 Oct. - 27 Nov. '73	133	0.15
38	31 Oct. - 27 Nov. '73	400	0.37
		Average Values From All Samples	
20		141	0.036
48		2058	0.407
19		6207	0.687
38		6576	4.082

TABLE 4-48

SUMMARY OF IN SITU FISH CAGING EXPERIMENTS IN THE KOOTENAY RIVER

Data Source	Species	Location	Starting Date	Number Of Fish	Sampling Time	Number Of Live Fish	% Survival	Comments
Sinclair[45]	Rainbow Trout Fry	Kootenay R. 20 miles above confluence with St. Mary R. (Wasa)	29 Sept. 1965	18	18 days	18	100	also checked after 24, 48, 96 hours and 10 days
		Kootenay R. 30 miles below confluence with St. Mary R. (Wardner)	"	30	"	30	100	"
Whatley[49]	Rainbow Trout Fry	Kootenay R. 20 miles above confluence with St. Mary R. (Wasa)	Aug. 23, 1969	10	48 hrs.	6	60	loss thought due to shock
		Kootenay R. 30 miles below confluence with St. Mary R. (Wardner)	"	10	48 hrs.	10	100	fish also checked after 24 hrs
Pollution Control Branch (50)	Rainbow Trout Fry	Kootenay R., east side ¼ mile below confluence with St. Mary R. (out of St. Mary Flow)	May 15, 1973	21	96 hrs.	21	100	
		Kootenay R., west side ½ mile below confluence with St. Mary R., partially mixed with St. Mary R. water	"	20	96 hrs.	20	100	water level rose 3 ft. during the test period; silt loads also heavy. Flow increased from 5350 CFS to 22,600 CFS at Fort Steele

TABLE 4-49

SUMMARY OF PRODUCTIVITY DATA FOR THE LIBBY RESERVOIR, 1973-1974 [48]

Parameters / Location	Phytoplankton Data		Zooplankton Data Organisms/cm^2 of Lake Surface	Chlorophyll a Data mg/m^3	Carbon-14 Uptake Rate mgC/m^2/day
	Mean Biomass mg/m^3	Cell Numbers cells/ml			
Libby Reservoir station 100	40.1 (1973)	95.3 (1973)	18.8 (1973	1.17 (from surface to depth of 20 m.)	39-510
Libby Reservoir station 101	110.9 (1974)	158.7 (1974)	21.3 (1974)		53-476
Libby Reservoir station 169					64-510
Lake Superior[66]			43 (oligotrophic)		
Lake Huron[63,66]	offshore: 900 (oligotrophic)		167 (oligotrophic)	1.70 (oligotrophic)	offshore: 147-698 (oligotrophic)
Lake Ontario[63]	offshore: 2600 (mesotrophic)				offshore: 58-1443 (mesotrophic)
Lake Erie[66]			400 (eutrophic)		
Lake Erie, West Basin[63]	5300 (eutrophic)			8.9 (eutrophic)	30-4760 (eutrophic)
Kalamalka Lake[64]		700 (oligotrophic)			
Okanagan Lake[64,65]		1500 (oligotrophic)	101-188 (oligotrophic)		
Skaha Lake[64]		3700 (meso-eutrophic)			
Wood Lake[64]		7900 (eutrophic)			