# Engineering Report On Feasibilty Study Of A Proposed Trout Rearing And Processing Operation At Grand Cache, Alberta

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THE PROVINCE OF ALBERTA

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# ENGINEERING REPORT ON FEASIBILITY STUDY OF A PROPOSED TROUT REARING AND PROCESSING OPERATION AT GRANDE CACHE, ALBERTA

OCTOBER 1976

W. L. WARDROP & ASSOCIATES LTD.
ENGINEERING CONSULTANTS

ABSTRACT

This Study was carried out to determine the potential for intensive culture of rainbow trout at Grande Cache, Alberta, using water from the Smoky River heated by condenser discharge from the H. R. Milner Generating Station.

Except for seasonal high sediment loads which can be corrected by use of a settling basin, the Smoky River has an adequate flow of water with good characteristics for growing rainbow trout.

If it were operated as a baseload plant at a minimum 59% of rated capacity, waste heat from the H. R. Milner Station would be sufficient to raise 1.3 million kg. of rainbow trout annually.

Market projections indicate that by the time full production is achieved, the product could be absorbed by the urban population of Alberta.

Despite the basic biological and engineering feasibility of large scale intensive aquiculture, detailed information is lacking in both aspects and in the interface between them. Still in need of elucidation are size, conformation, construction materials, and operating procedures for raceways; loading densities, water flow rates, and supplies of food and fingerlings. Because a precise economic evaluation is not possible at this time, due to these factors, our best projections indicate that domestic rainbow trout would suffer a wholesale price disadvantage of between $0.50 - $1.15 per kg. compared to the Japanese product.

It is recommended that a pilot study be undertaken to evaluate the technical problems and variables associated with intensive aquiculture. Until this is done, a realistic evaluation of full-scale commercial rearing of rainbow trout is not possible.

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## INTRODUCTION

Intensive large scale aquiculture has not been attempted in Canada. In Western Canada, rainbow trout culture has been widely practised by planting fingerlings in winter-kill lakes in the spring and harvesting the fish in the fall. Extensive culture does not show commercial promise because of summer-kill, the seasonal nature of the production and the logistics of collecting and marketing the product.

Groundwater in the region is limited in supply and is ususally 4*C. or colder; the plentiful surface waters range in temperature from 1°C. or lower in winter to 20°C. or higher in summer. The use of low grade waste heat from industrial processes to maintain water temperatures in the range needed for fish culture is attractive since it would make 15°C. water available for 12 months of the year rather than 2 - 4 months, without incurring the large fuel costs otherwise required. This economy could make the difference between a viable and an uneconomic undertaking.

Previous studies for the Alberta Department of Agriculture (1 & 2)* have indicated a potential for intensive aquiculture in Alberta using waste heat.

The Province of Alberta engaged Ferguson, Harrison and Associates to analyze the feasibility of using waste heat from the H. R. Milner Power Generating Station at Grande Cache, Alberta to heat Smoky River water for the production of 1.3 million kilograms (2.5 million lbs.) per year of rainbow trout for human consumption.

This Project has been taken over by W. L. Wardrop & Associates Ltd. with the approval of the Province of Alberta at the request of Mr. R. W. Ferguson as a result of the untimely death of Mr. D. Harrison.

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* Numbers in parentheses refer to list of references.

The present report presents a re-examination of the technical and commercial factors involved in rearing rainbow trout on a year-round basis using waste heat from the H. R. Milner Power Generating Station and water from the Smoky River.

The production objective used for this analysis is 0.96 million kg. (2.1 million lbs.) of dressed rainbow trout. To achieve this goal depending on fish size and waste rates 1.14 - 1.36 million kg (2.5 - 3.0 million lbs.) live weight must be produced.

## REARING RAINBOW TROUT

### General Background

Aquiculture has been practised for at least 4,000 years, mainly in the warmer areas of Asia and the Mediterranean, although moats and other bodies of water were stocked with fish during the feudal era in Europe[3]. Historically, aquiculture has been a low intensity, labour intensive cottage industry producing fish for local consumption.

Commercial intensive aquiculture, producing fish for national or international markets, is a more recent phenomenon. Some successes have been obtained, generally as a result of favorable local conditions such as in the Snake River, Idaho operation or in Japan where both labor and trash fish for food are plentiful. Experimental, intensive, commercial undertakings in North America have not yet succeeded in providing significant amounts of fish for human consumption. Economics of these operations are a closely guarded industrial secret.

To be successful, aquiculture requires water, a commercially desirable species of fish, knowledge of how to propagate, and rear it, a supply of suitable food at an economic price and in Northern latitudes, an economical source of heat for raising water temperatures.

Canada has large supplies of freshwater that could be warmed by low grade waste heat. Rainbow trout is the species of choice at present, since it is desirable for human food, and as a result of years of culture semi-domesticated strains have been developed. More is known about propagation, feeding and culture of rainbow trout than perhaps for any other suitable fish species. Rainbow trout are hardy and can tolerate or adapt to a wide range of conditions.

## Water Requirements for Rainbow Trout Culture

### 1. Chemical Composition

Table 1 shows water criteria that are most generally accepted as suitable for rearing rainbow trout. Water with grossly higher total dissolved solids and widely variable mineral contents and ratios have been used successfully to grow rainbow trout[4]. Water with extreme chemical characteristics may not be suitable for intensive rainbow trout culture although seawater and seawater-freshwater blends were used to culture rainbow trout in the Sea-Pool facility near Halifax.

### 2. Toxic Substances

Very low levels of a number of chemicals can produce, with time, chronic toxicity leading to unthriftiness, poor health and death. The same chemicals at higher concentrations can result in death in a very short time. Table 2 lists some major toxic substances often found in water supplies. The low ranges will cause either acute or chronic toxicity while the high ranges generally produce death in a short time. Levels below those in Table 2 can also cause chronic toxicity. For example continuous exposure to 0.002 mg/l of sulfide ion produces toxic symptoms in rainbow trout. Generally, hard water (300 mg/l) reduces toxic effects compared to soft water (100 mg/l).

TABLE 1: DESIRABLE WATER QUALITY CRITERIA FOR THE OPTIMUM GROWTH OF RAINBOW TROUT

| | |
|---|---|
| PH | 7.0- 8.0 |
| Alkalinity | L 250 mg/litre |
| Colour | L 3 T.C.U.* |
| Carbon Dioxide | L 10 mg/litre |
| Dissolved Oxygen | 7 - 8 mg/litre |
| Conductivity | L 1.0 x $10^{-6}$ mho |
| Total Dissolved Solid | L 250 mg/litre |
| $Ca^{++}$ | 4 - 150 mg/litre |
| $Mg^{++}$ | 5 - 10 mg/litre |
| $Na^{+}$ | 1 - 5 mg/litre |

* T.C.U. -- True Colour Unit

L Less than

TABLE 2: LETHAL LIMITS FOR TOXIC SOLUTES

| | |
|---|---|
| Non-ionized ammonia | 0.3 - 0.5 mg/litre |
| Sulphide | 0.5 - 0.2 mg/litre |
| Chlorine | 0.01 - 0.08 mg/litre |
| Chloramine | 0.01 - 0.08 mg/litre |
| Copper | 0.03 - 0.04 mg/litre |
| Zinc | 0.5 - 2.8 mg/litre |
| Chromium | 2.5 - 1.0 mg/litre |
| Packaged Detergents -- soft water | 41 - 85 mg/litre |
| -- hard water | 15 - 97 mg/litre |

3. Suspended Solids

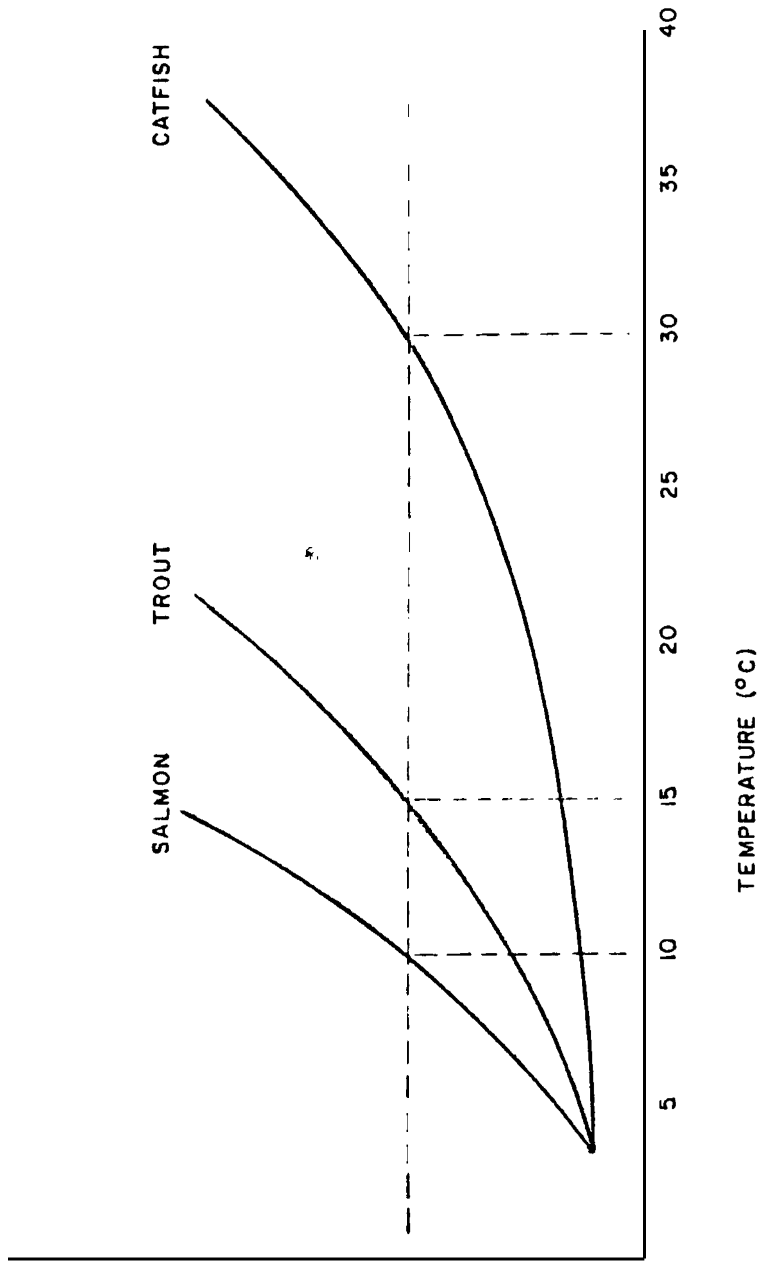
Fingerling rainbow trout are very susceptible to suspended solids. Exposure to fine silt results in mass mortalities in a few hours. Larger trout can withstand moderate loads of silt for a short period but gill fouling and abrasion results in stress that requires some time for recovery. Quantitative data does not exist for the effects of load, particle size and composition on rainbow trout of various ages.

4. Oxygen

The concentration required for rainbow trout is generally given as 8 mg/l which is near the saturation point of oxygen in water in the preferred 13 - 18°C. temperature range for growth. Lower concentrations can be tolerated for a short time especially if the oxygen demand by the fish is low (fish are relatively inactive and not digesting food). The only safe practise is to maintain oxygen levels near saturation values at all times since increased oxygen requirements resulting from bursts of activity or from digestion of food could reduce oxygen tension below the borderline levels of 5 - 6 mg/l. Supplementary aeration is necessary if stressing water flow velocities are to be avoided. Supplementary aeration provides a measure of protection against gas bubble disease. This condition results from nitrogen supersaturation of water arising from pumping operations or from raising water temperatures without subsequent turbulence.

5. Water Temperature

The temperature of the water is another important parameter in commercial aquiculture because it determines the rate of growth. The optimum range of temperature for maximum growth of salmonids is 13 - 18°C. (5) For rainbow trout, the optimum growth temperature is approximately 15°C. Figure 1 shows the relationship of water temperature to metabolic rate for salmon, trout, and catfish. When the temperature of the water is outside the optimum range, the rate of growth is reduced.




**PERCENT OF THE METABOLIC RATE AT STANDARD ENVIRONMENTAL TEMPERATURE**

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RELATIONSHIP OF WATER TEMPERATURE TO METABOLIC RATE FOR SALMON, TROUT, AND CATFISH

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| | | |
|---|---|---|
| DESIGNED BY F. C. | DRAWN BY D. R. D. | DRAWING NO |
| CHECKED BY [illegible] | DATE FEB. 1976 | 74700-01 FIG. 1 |

At high temperatures, the growth rate is reduced because of an increased requirement for food to maintain basal metabolism relative to growth. At low temperatures, the metabolic processes are too slow for commercial aquiculture to be economical.

Rainbow trout are sensitive to sudden temperature change, 1 - 2°C. per hour being considered completely safe, 5°C. stressing and 10°C. severely stressing to lethal. These effects can be lessened if the fish are in a good physical state (optimum nutrition, exercise, pH, oxygen, tension). Even mild temperature shifts can increase the susceptibility of trout to infectious disease agents if the shifts are frequent. Growth and efficiency of food conversion are reduced from stress induced by sudden temperature shifts even within the preferred 13 - 18°C. temperature range.

## 6. Water Flow Rates and Loading Densities

Water flows have been generally based on calculations relating temperature and oxygen content(6) of the water to loading densities and the consistent oxygen demand and production of toxic waste products. Widely divergent results are achieved from these calculations. Another method(7) calculates the tank volume replacement time needed to supply oxygen and flush wastes. Using these methods or graphs developed from them leads to higher water flows and lower loading densities (0.02 - 0.04 kg/1) than can be attained.

Studies by Gillespie and Scott(8) indicate that the calculations noted above yield a water use 5 - 6 times that required to flush out wastes and greater than required to maintain adequate oxygen levels. Practical experience(9) confirms these calculations in that reduction of flows by a factor of 4 - 5 results in oxygen levels 5 ppm or higher at the outflow.

Loading densities can be increased (up to 0.12 to 0.24 kg/1) over those calculated above if supplementary aeration is provided.

No data is available on desirable water flow rates for trout of various sizes; however, Scott and Gillespie[10] reared rainbow trout from 12 to 160 gm size in a flow rate of 56.7 lpm, i.e. in a 1,600 litre tank, with no signs of over or under exercising and an even fish distribution in the tank. Water velocities can vary widely for a given size of rainbow trout but flows based on the generally accepted criteria discussed above overwork the fish sometimes to the extent that they cannot maintain themselves against the current flow.

Unnecessarily high water flow rates cause food consumed being devoted to muscular energy output instead of weight gain.

Water conservation may be necessary at some aquiculture sites. Savings achieved by reducing capital costs of water delivery and discharge systems, and the capital and operating costs for supplementary heating and cooling systems should more than compensate for the cost of an artifical aeration system. Standby aeration is usually installed in fish culture stations for emergency use. Therefore, expansion to a full time system is all that would be required.

## CULTURE CONDITIONS

### GENERAL

### 1. Diseases

Good cultural practices (nutrition, oxygen relations, temperature) lessen the possibility of fish becoming diseased as well as the severity of the outbreak should a disease agent enter the culture facility.

Stocking should be carried out only with fingerlings that have undergone testing for infectious diseases of salmonids[11] and declared free of the disease symptoms and its causative agent.

Waterborne diseases can enter a fish culture unit and may not be detected until an epizootic is underway. Control or cure is expensive and most of the therapeutic agents are either of limited effect or are banned for use in fish for human consumption.

The best water source for fish culture is true groundwater which contains few, if any, bacteria. Next best is surface water taken close to source and which harbors no fish at least no salmonid fish. Water of this type will possibly contain low grade pathogens such as the agent of columnaris disease. Below $15^{o}C.$ these and most other fish diseases are of little consequence, as the temperature rises susceptibility to disease increases.

Above $18^{o}C.$ if a causitive organism is present severe disease problems can be expected.

Surface waters containing resident populations of salmonids are not desirable sources since these fish may harbour serious disease agents and release them into the water supply. Most waters containing salmonids have been subject to introductions from hatcheries which until recently paid no attention to fish diseases.

2. Feed and Feeding Rates

Knowledge of fish nutrition is very limited, the standard reference(12) makes very extensive reference to studies on nutrition of domestic animals to fill in large information gaps. There is no sound information on the differing nutrient requirements for fry fingerlings and production fish. Empirical formulas have been established but manufacturers have been forced by pressures of price and availability to substitute constituents and bring the formulation to a standard nutritional level by addition of basic nutrients.

Both the quantity and quality of fish feed has been variable in the last few years. Oscillations in the price and availability of basic plant and animal proteins resulted from agricultural crop failures and disappearance of herring and anchoveta from the fishing grounds. Fish culture must compete with the well established poultry and livestock industry for basic food ingredients.

Quality of fish foods vary between suppliers and within one supplier with time as evidenced by mortality rates, growth rates, vigor and the appearance of nutritional disease[13].

Unbalanced rations (especially high carbohydrate content) can result in large amounts of visceral fat in the fish. This fat is removed in processing as non-saleable weight gain and food conversion.

Appropriate tonnages of fish food may be available on long-term contracts. It is doubtful whether sufficient food of standard and reliable formulation could be guaranteed at a reasonably firm price. Long-term or even annual contracts would be advisable only if the feed were tested in feed trials and found satisfactory and if the manufacturer could guarantee ingredients (quality) as well as volume, delivery schedule and price.

Costs of feed in 1975 ranged from $500 to $700 per metric ton on a volume purchase basis. Lower priced food may be expensive in terms of mortalities, weight gain and conversion efficiency. At an average price of $0.55/kg ($500/ton) and conversion rates of 1.1:1[3] or 1.5:1 and 2:1[13] food would contribute $0.60, $0.83 and $1.10/kg of fish flesh respectively.

Feeding rates suggested by manufacturers are reliable except for 5 cm - 10 cm fingerlings in which case 10% less should be used. Experience has shown that large food wastage occurs at recommended feeding rates[9].

Enhanced consumption and food conversion are achieved if the daily ration is fed over an 8 - 10 hour period. If hand feeding is used, five feeding times at equal intervals over 8-hours is adequate. With automatic feeders, the distribution should be in small equal amounts over an 8 - 10 hour period[9].

## INTENSIVE AQUACULTURE

### 1. Rationale for Intensive Rearing of Rainbow Trout

Aquiculture is predicated on a number of factors; some of which are soundly based on fact and some are more speculative in nature.

-- Rainbow trout are a desirable form of high quality animal protein for human consumption.
-- A large potential market exists for cultured rainbow trout.
-- Food conversion efficiency is higher for fish than for agricultural animals.
-- Available animal protein for human consumption is declining, especially fish protein as a result of over exploitation of natural stocks.
-- Intensive aquiculture is both technically feasible and economically profitable.
-- A large supply of suitable fish food is available at economically attractive prices.
-- A supply of fingerlings is available for raising to a size that is marketable.
-- Infectious and physiological diseases can be controlled.

The high quality of trout protein, its desirability as human food and the efficiency of food conversion by fish are well established facts.

The other factors are reasonably valid for small scale, moderate intensity culture aimed at markets in a geographically restricted range. Projection to large scale intensive culture aimed at national or international markets is a dubious proposition at present.

2. Methods of Culture

Extensive Culture

Historically fish have been reared in ponds at low stocking densities feeding on natural food, on artifical rations or on a combination of natural and artificial food. "Pot-hole" aquiculture as practised on the Prairies is typical extensive culture using natural food. This method entails low capital costs, is labor intensive and does not lend itself to production of fish of specific sizes year-round to meet the market. Harvesting is labor intensive and leads to volume production in the fall of the year, disease and predator control is virtually impossible and summer-kill from anoxia is a frequent and erratic event. Logistics of processing and marketing fish produced this way make extensive culture largely suited to small operations and local markets.

Cage Culture

Rearing fish in cages has been successful in Japan (14) where labor is relatively cheap and abundant "trash" fish (sandlaunce, anchovy, saury and small horse mackerel) are available for feed. Cage culture in the Prairies using rainbow trout has not shown promising results. While harvesting is facilitated, cage culture without added food has the disadvantages of extensive culture along with poor growth rates. Feeding artificial food adds to the costs without noticeably improving growth (16).

Intensive Culture

In North America, analysis has indicated (17) that intensive culture using artificial feeds is the only economically practical approach to fish culture. The following sections are based on acceptance of the facts that high density capital - intensive low labour cultivation of fish using heated water is the only approach to rearing rainbow trout for a national market at the present time.

Unless the design of raceways and the operating procedures maximize the benefits of intensive culture, the economic feasibility is destroyed.

## 3. Raceway Construction and Design

### Poured Concrete

Concrete has been the most widely used material for fish rearing in recent years in North America. It offers the advantages of strength, durability, has a smooth non-abrading surface that allows easy cleaning and disinfection and readily lends itself to achieving the desired design conformations. Rough surfaces will cause lesions on the trout that will become infected with fungus or bacteria. Concrete construction has been relatively inexpensive in most places when its long life is considered.

### Epoxy-Fiberglass

This material has been widely used in parts of Europe where concrete is expensive. Increasing use in North America has been inhibited by cost increases in the last three years. Fibreglass-epoxy has all the advantages of concrete and because of its lightness can be fabricated in a central plant and transported to site for assembly and installation. Its sanitary properties are superior to concrete. Present costs make it unattractive.

### Earthen Raceways

Compacted soil raceways or dugouts have been used in the past where low density non-intensive rearing has generally prevailed. These units are rapidly being phased out mainly because of the inability to control infectious diseases of fish in earthen construction.

Compacted soil raceways will not maintain the desirable conformation required for intensive aquiculture.

Plastic-lined Soil

Compacted soil with an overlay of heavy flexible polyethylene or vinyl plastic have been used for swimming pools, sewage lagoons and fish culture. If local soil has suitable mechanical properties, construction of this type has attractive cost advantages.

Disadvantages include the difficulty of building and maintaining a desired design conformation under the impact of operations involved in fish culture. Puncture or tearing of the liner is highly likely with destabilization of the structure resulting from water seepage.

Block Construction

Concrete "cinder block" should be considered as an alternative where poured concrete is expensive. If the surface of the walls are smoothed by a coat of parging and the holes in the blocks filled with a grout, most of the advantages of poured concrete can be obtained with the exception of extreme durability. Depending on local labour conditions, considerable cost savings could be achieved.

4. Raceway Design and Operation

Open or Enclosed Raceways

Open raceways are probably unsuitable for intensive aquiculture in most regions of Canada.

In the winter as temperatures reach -20°C., the extreme heat loss from the water will produce lower temperatures than desired and a temperature gradient along the raceway. These conditions result in slower growth, decreased food conversion efficiency, and make the fish more susceptible to disease from temperature stress. Below -15°C., the tendency of trout to rise to the surface during feeding will produce frozen dorsal fins resulting in reduced marketability because of their appearance and result in open lesions susceptible to infection.

Ice fog resulting from the temperature differential ($15^{o}C.$ water, $15^{o}C.$ air) will result in reduced visibility hampering operations. Icing conditions will interfere with the operation of mechanical equipment such as automatic feeders and create personnel hazards. Ice fog will be increased by the necessity for aeration of the raceways under conditions of intensive culture.

In the summer, small trout especially will be subject predation from birds. Fish of all sizes will be subject to predation by mink or other animals. In time, both classes of predators could increase to the point where serious economic loss would result.

Light construction may suffice to overcome most of these problems. Plastic greenhouses have been developed which could be adequate. They are relatively inexpensive, sturdy and allow natural light to enter. Enclosing the raceways in any structure will impose size constraints on the raceway design.

The economic loss from open raceways as well as the cost of various types of enclosure and their ability to withstand snowloads and wind should be the subject of controlled investigation in an experimental pilot feasibility study.

## Raceway Design

Size constraints imposed by enclosure will probably be met by restraints imposed by other conditions necessary for efficient rearing of rainbow trout. The raceway design proposed by Scott (18) for an intensive aquiculture pilot feasibility study has many excellent features but is too small for commerical use and has some complexities that may make it unwieldy. The basic design could be doubled in length for commercial use and still maintain its basic useful features. Two raceways would fit inside the suggested greenhouse module.

Eighty raceways, 25 M. long, 2.5 M. wide and 1.3 M. deep would be capable of producing 1.36 million kg of rainbow trout per year with a loading density of 0.21 kg/1 (17,000 kg/raceway) at a water flow of 1,825 lpm (400 IGPM) per raceway using supplementary aeration.

V-bottom construction and a drop of 0.3 M. (1 foot) from inlet to outlet will provide a large degree of self-cleaning. A drawing of the proposed raceway design is shown in Figure 2.

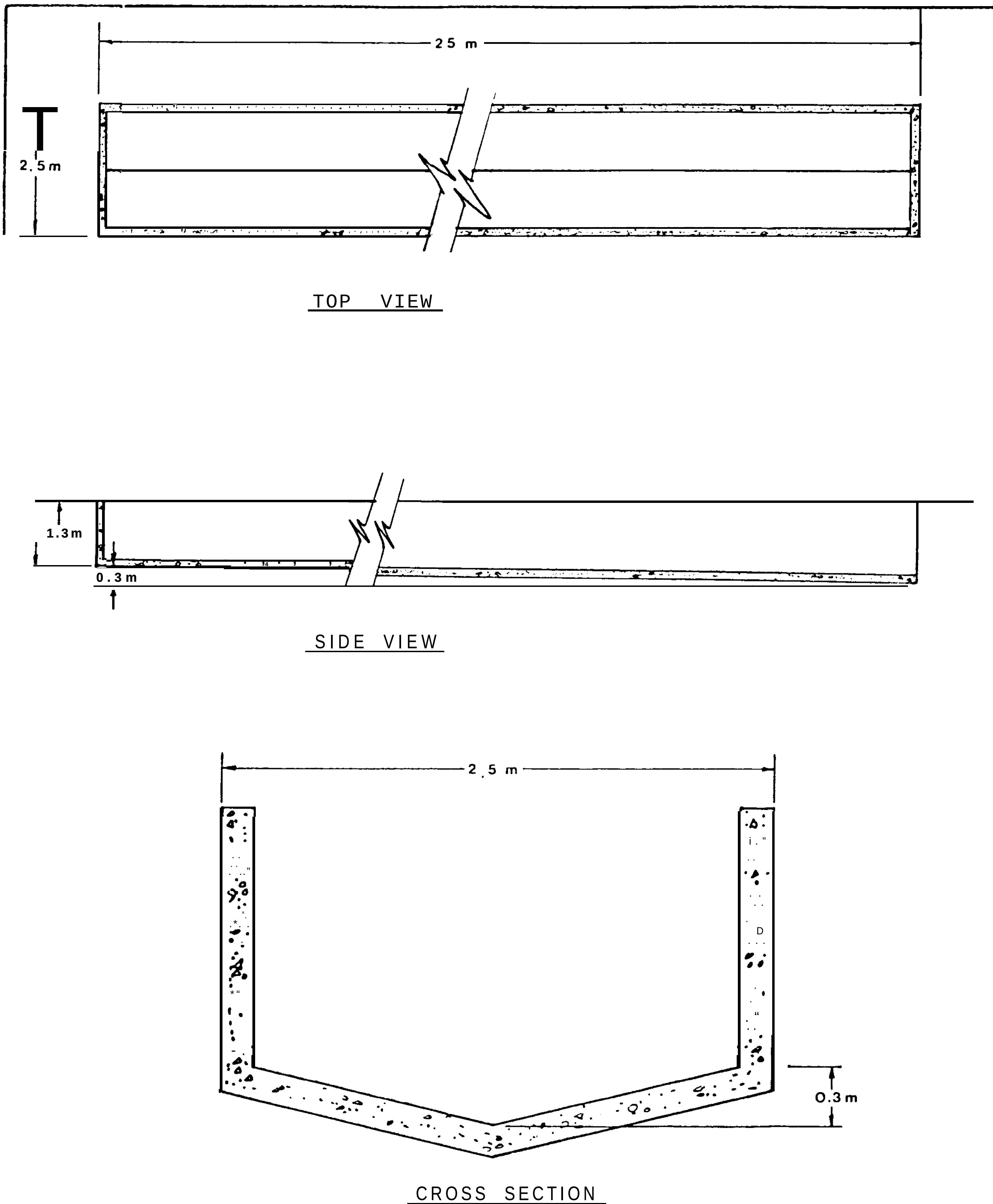
## Feeding

Raceway dimensions should allow automatic feeding devices to cover most of the surface area with the discharged food. Uneven food distribution would cause the fish to crowd into one area of the tank causing physiological stress. During the feeding frenzy under crowded conditions, some of the food could be lost to the bottom of the tank and the amount of food obtained by different fish would vary. Poor food consumption patterns combined with reduced assimilation from physiological stress will raise unit food costs and decrease growth rates.

## Water Velocity

Proper water velocity in the raceway will promote an even distribution of fish throughout the water volume. The importance of this has been discussed in preceding sections.

Without supplemental aeration, a raceway 25 M. long would require approximately 13,638 lpm (3,000 IGPM) per 3 $m^2$ of cross-section to maintain adequate oxygen levels. The other parameters would be adequately controlled but water velocity would be too high. With aeration, adequate growth conditions could be maintained, at the range of fish densities discussed below, with flows of 1,825 lpm (400 IGPM) per 3$m^2$ cross-section.

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NORTHERN DEVELOPMENT BRANCH
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PROPOSED RACEWAY DESIGN

| | | |
|---|---|---|
| DESIGNED BY D. G. DRAWN BY D. R. D. | DRAWING NO | |
| CHECKED BY | DATE APR. 1976 | 74 700-01 | Fig. 2 |

Labour Intensive Operations

Some supplementary hand cleaning of tanks is required and raceways must not be so wide or deep that brushing down the sides and bottom becomes unwieldy and time consuming. Two to three meters is an appropriate width and 1 to 1.5 meters an appropriate depth.

Random sampling of the fish by dipnet to check on weight gain and size distribution must be undertaken periodically; therefore, all parts of the raceway should be readily accessible to dipnet sampling.

These dimensions also allow observation of the fish to determine if infectious disease has occurred or if their behaviour shows stress conditions.

To meet market size requirements, the fish must be size graded every few weeks. Dimensions which are too great makes this operation difficult since the fish must be removed, sorted and replaced in their size groups either in separate raceways or in pens within a raceway.

Restriction in raceway dimensions and provisions for subdivisions into cages facilitate harvesting. The fish can be herded into one section; the water level drawn down and the fish harvested by dipnet.

5. Growing the Fish

Loading Densities

Calculations of fish densities possible for intensive fish culture vary widely. Guthrie, Prowse and Scott (3) project that 220 $kg/m^3$ (0.22 kg/1) as a feasible density. Generally, loading densities used or projected have been much lower. (0.03 kg/1 in the Lornevine study) (19). Scott and Gillespie (lo) reared rainbow trout from 11 gm to 165 gm at densities of 0.45 kg/1 with no significant mortalities and good weight gain. This loading was achieved under experimental conditions under close supervision in a water reuse system and demonstrates what is possible, not what may be practical, in larger units. 'High densities in the order of 0.2 kg/1 seem indicated if intensive aquaculture is to be commercially viable.

## Fingerling Supply

Ideally fingerlings should be available in uniform supply over 12 months of the year. Rainbow trout spawn in the spring or in the fall over a period of a few months in each case. There is an oscillation in egg production and thus in fingerling supply that can be partially damped by controlling the temperatures used for hatching and rearing and by reducing the feeding rate for fry and fingerlings.

More significant is the inadequate supply of healthy certified fingerlings sufficient to supply even one major rainbow trout culture facility in Western Canada. The supply within the region is virtually nil. Dependence on imports of fingerlings from the United States is hazardous, both in terms of quality and quantity. "Pot-hole" aquiculture for the three Prairie Provinces used about 2.3 million fingerlings in 1974 and almost 3 million (estimated) in 1975. These demands were met with difficulty. Often smaller fingerlings than desired were imported; some showing signs of nutritional inadequacy. Their disease background was dubious,

Until there is a broodstock and fingerling industry in the region, any large scale rainbow trout facility is in a position of vulnerability to supply failure.

Uniform supply of "seed stock" throughout the year (as is available to the poultry industry) awaits development of research leads on the effects of manipulating water temperature and light cycles to control time of spawning.

## THE SMOKY RIVER

The Smoky River was first discovered by Alexander Mackenzie on his journey to the Pacific in 1792 and was so named because of the shouldering coal beds along the river banks. It is a major tributary of the Peace River and rises in the Rocky Mountains where they constitute the Alberta-British Columbia boundary, a few miles North of Mount Robson. Its North-easterly course travels 245 miles reaching the Peace near the Town of Peace River. Some 40 miles from its mouth, it is joined by the Little Smoky River which is 185 miles long coming from the South. Further upstream, about 20 miles directly to the East of Grande Prairie, it is also joined by the Wapiti River. A location plan is shown in Figure 3.

### 1) Water Volume

The Smoky River at Grande Cache is a potential source of water supply for trout farming. Appendix I shows the daily discharges from 1969 to 1973. The minimum during these 6 years was 295 cubic feet per second (cfs) on January 15th and 16th, 1970. Appendix I also shows the monthly and annual mean discharge of the River on record since 1915 as well as the extreme discharges on record since 1916.

These records show that the Smoky River would be capable of providing the 145,344 lpm (38,400 USGPM ≑ 85 cfs) required for a potential trout farming operation at Grande Cache.

### 2) Water Chemistry

The chemistry and characteristics of the Smoky River at various stations along the River are available on record from the Water Quality Branch of Environment Canada. Appendix B shows some of the characteristics of the Smoky River at a station upstream of the McIntyre Porcupine Mines for selected dates in the period from 1969 to 1975.


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LOCATION PLAN

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Examination of the chemical data shows that the water of the Smoky River is suitable for the rearing of rainbow trout. The majority of the parameters are within either the optimal or the acceptable limit ranges for trout growth. The pH sometimes tends to the high end of the range but is within the acceptable limits and not far enough outside the optimal range to cause concern.

The colour and turbidity of the Smoky River tend to be high during the months of May, June and July. These factors are associated with spring run-off of melting ice and snow, and rainfall. The high turbidity and colour values, however, are seasonal and can be corrected. Otherwise the water of the Smoky is good for trout farming.

## THE H. R. MILNER POWER GENERATING STATION

The H. R. Milner Power Generating Station, owned by Alberta Power, is situated about 17.6 km (11 miles) North of the Town of Grande Cache on the shore of the Smoky River adjacent to the McIntyre Porcupine Mines.

This station is a 150 Megawatt coal-fired thermal power plant. The boilers consume approximately 82 metric tons of coal per hour when operating at full capacity. The heat generated is used to produce high pressure steam which drives a generator connected turbine to produce electricity.

### 1. Waste Heat Generation

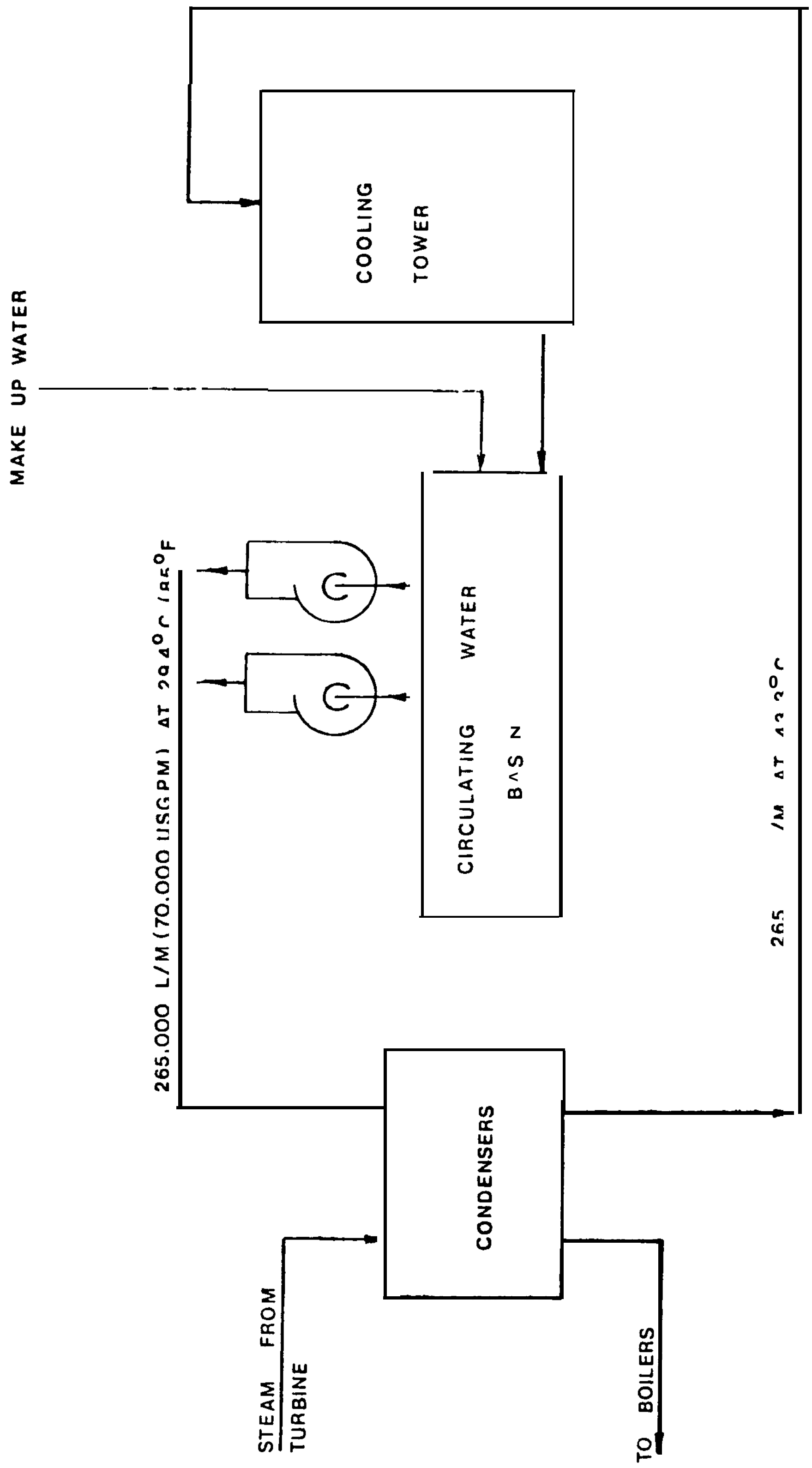
The turbine exhaust steam which is discharged at 43.2°C. and 3.5 mm Hg absolute pressure is condensed for recycling to the boilers. Approximately 265,000 lpm (70,000 USGPM) of cooling water is pumped through the condenser when the plant is operating at full capacity. The cooling water is drawn from a recirculating water basin at 29.4°C. and leaves the condensers at 43.3°C. Upon leaving the condenser, the water is passed through a cooling tower arrangement where the water is cooled prior to being fed back to the water basin thus completing the cooling cycle. A schematic of the cooling cycle is shown in Figure 4.

The cooling tower is a FLUOR Model 470-1-6711 unit consisting of 4 cells. One, two, three or all four cells can be used at any one time and each cell requires 33,119 lpm (8,750 USGPM) of flow at 29.4°C. to prevent freezing.

The level of heat loss and the eff'luent temperature of the water leaving the cooling tower is controlled by the operation of pumps and fans. There are three pumps for regulating the flow of cooling water from the basin to the condenser. These pumps are manually controlled. There are also 4 fans for the cooling tower, each having two speeds. These fans are also controlled manually. The combination of these pumps and fans at different speeds allows substantial variability in regulating the flow and temperature of the cooling water from the condensers.

2. Using the H. R. Milner Plant Waste Heat for Trout Farming

To raise $1.134 \times 10^6$ kg (2.5 million pounds) of rainbow trout a year to market size at Grande Cache, 145,344 lpm (38,400 USGPM) of Smoky River water is required. To heat this quantity of water from a winter- river temperature of 0°C. to 15°C., $2.18 \times 10^6$ Kcal/min. ($8.64 \times 10^6$ BTU/rein.) of heat energy will be required. This represents 59.2% of the maximum heat rejection of $3.684 \times 10^6$ Kcal/min. through the condensers by the power plant when running at full capacity. However, the H. R. Milner Power Generating Station is not a baseload plant and rarely runs at full capacity. Even baseload plants do not run at full capacity. The majority of them operate at 80% to 85% of design capacity. Therefore, the engineering of any proposed trout rearing facility at Grande Cache must incorporate the different operating conditions of the power plant into the design.




NORTHERN DEVELOPMENT BRANCH
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COOLING CYCLE SCHEMATIC AT H.R. MILNER POWER GENERATING STATION

| | | |
|---|---|---|
| DESIGNED BY F.C. | DRAWN BY D. R.D. | DRAWING NO |
| CHECKED BY | DATE FEB 1976 | 74700-01 FIG. 4 |

To utilize the heat from the power plant, a heat exchanger can be installed downstream of the existing condensers to extract heat from the cooling water effluent from the condensers. , By varying the flows, the temperature of the different streams can be kept constant. This is desirable since it is necessary to keep the temperature of the water to the rearing facility constant at the optimum growth temperature.

a. Power plant operating at or above 59.2% capacity

When the H. R. Milner Power Generating Station is operating at 59.2% capacity, 156,880 lpm (41,440 USGPM) of cooling water pass through the condensers. The temperature rises 13.89°C. to a leaving water temperature of 43.33°C. This represents the amount of heat energy required to heat 145,344 lpm (38,400 USGPM) of Smoky River water from 0°C. to 15°C. After passing through the heat exchanger, the cooling water temperature drops to 29.4°C. This water would not require any further cooling before being stored in the circulating water basin. Therefore, the existing cooling tower would be by-passed.

When the plant operates above 59.2% of design capacity, the cooling water effluent from the condenser would exceed 156,880 lpm. Since the maximum requirement of the trout rearing facility is 156,880 lpm, cooling is required prior to storage in the circulating water basin. Until the plant operates at or over 71.69% capacity (at which time, effluent from the condenser would be 190,000 lpm (50,190 USGPM), the flow to be cooled would be less than 33,119 lpm (8,750 USGPM). This flow is too low for the existing cooling tower to be used because of potential freezing problems. Under this condition, when the power plant is operating at between 59.2% and 71.69% capacity, a new cooling tower system which can handle a minimum of 4,542 lpm (1,200 USGPM) and a maximum of 33,119 lpm (8,750 USGPM), would be required. When the flow to be cooled reaches 4,542 lpm (1,200 USGPM), the new cooling tower would be used. When the flow increases to 33,119 lpm (8,750 USGPM), at which time the power plant is operating at 71.69% capacity, the existing cooling tower could be used with one cell operating. When the flow increases further by increments of 33,119 lpm (8,750 USGPM), additional cells of the existing cooling tower could be put into operation. A schematic is shown in Figure 5.

b. Power plant operating at less than 59.2% capacity

When the H. R. Milner Power Generating Station operates at less than 59.2% capacity, the cooling water effluent from the condensers would be less than 156,880 lpm (41,440 USGPM), which is required for the trout rearing facility. There would be insufficient waste heat from the power plant cooling system for the trout rearing facility if this condition occurred during the winter months. Additional heat is required.

Since the proposed trout rearing facility at Grande Cache will require 59.2% of the total available waste heat from the H. R. Milner Power Generating Station, any shut-down or considerable reduction in operation during the winter months without additional heat will be disastrous.

Figure 6 shows the monthly percentage output of the H. R. Milner Power Generating Station for the climatic year 1974 - 1975. This chart is typical of the Milner Station, being a non-baseload plant. During this climatic year, the Station operated at an average of 37.5% output with a maximum of only 46.8% in December 1974. This is much less than the 59.2% minimum required for a trout farming facility to be economical at Grande Cache, Alberta. Under present operating conditions, supplementary heat would be required year round. Moreover, the Milner Station shuts down once annually for a period of up to one month for maintenance. This usually occurs in the summer, but can occur at any time during the period from May to November*. Should the shut down occur during the cold winter months, the trout-rearing facility would have to be maintained by another heat source.

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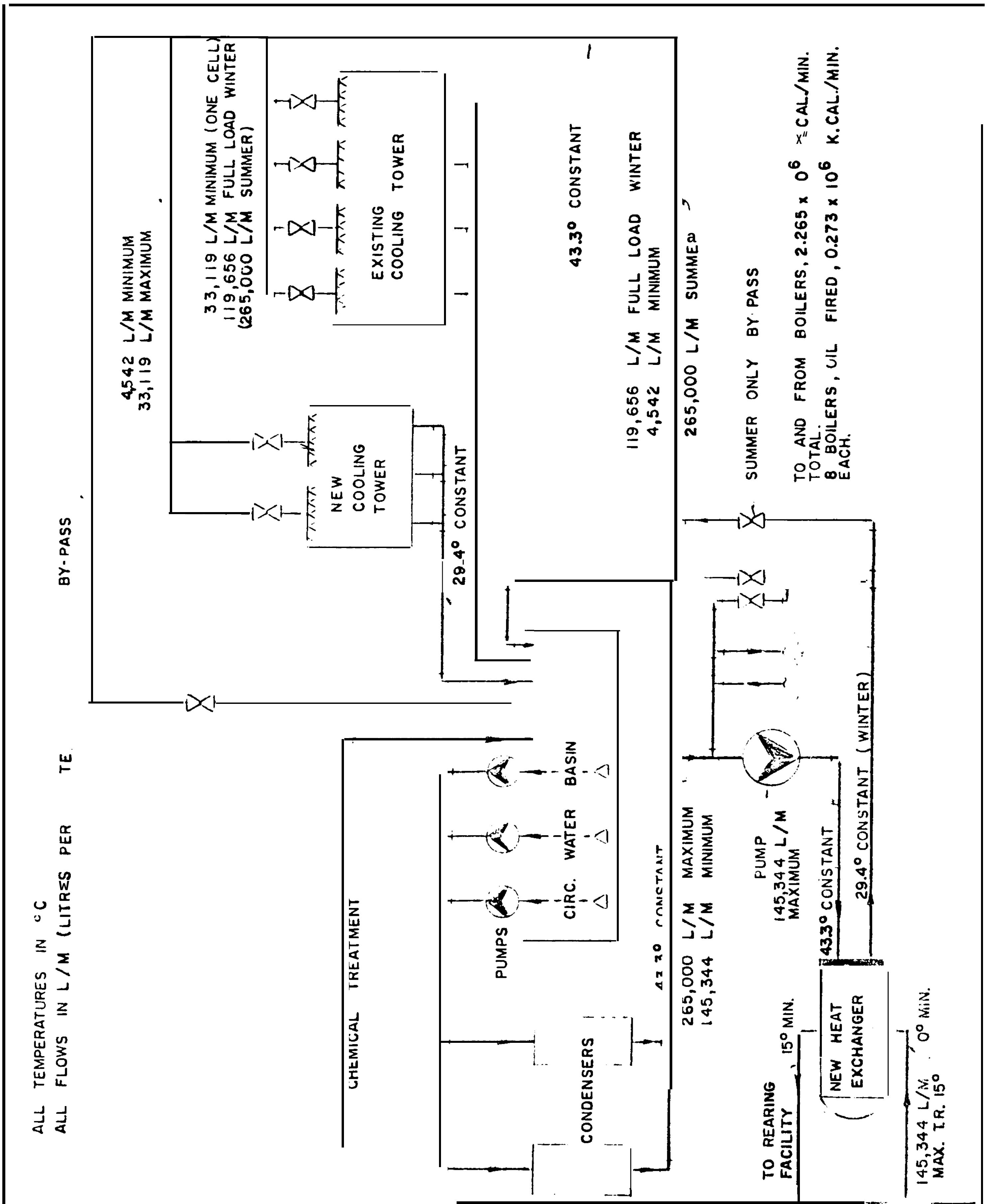
* Personal communication with G. H. Mead, Senior Project Engineer, Alberta Power Limited, Edmonton, Alberta.




NORTHERN DEVELOPMENT BRANCH
GOVERNMENT OF ALBERTA

W. L. WARDROP & ASSOCIATES LTD.
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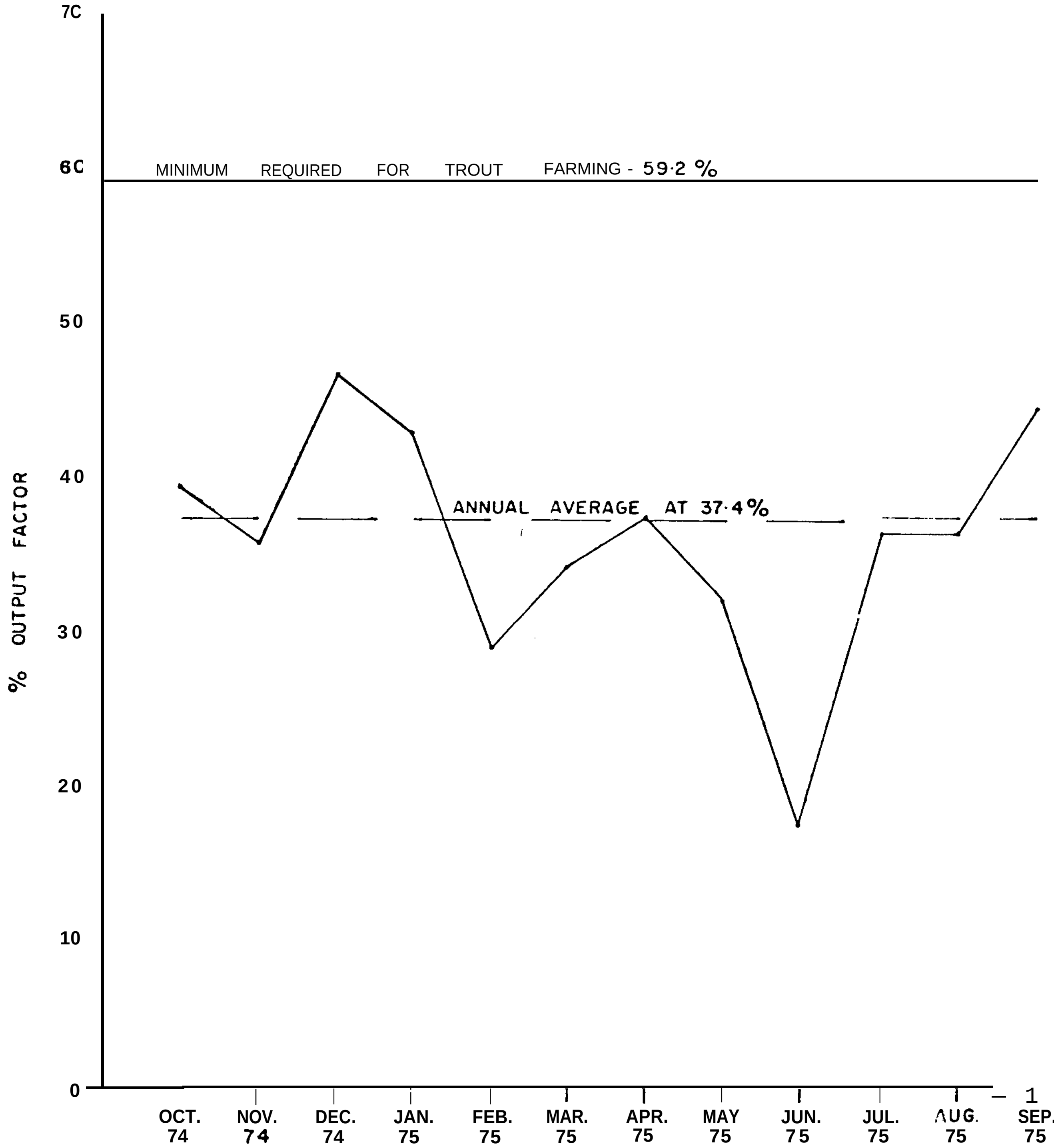
FLOW SCHEMATIC FOR USING WASTE HEAT FROM H.R. MILNER POWER PLANT FOR TROUT FARMING

| | | |
|---|---|---|
| DESIGNED BY S.K. | DRAWN BY D.R.D. | DRAWING NO |
| CHECKED BY F.C. | DATE FEB. 1976 | 7470001 FIG. 5 |




NORTHERN DEVELOPMENT BRANCH
GOVERNMENT OF ALBERTA

W. L WARDROP S ASSOCIATES LTD
ENGINEERING CONSULTANTS

H. R. MILNER POWER GENERATING STATION
% OUTPUT FOR 1974-1975

| | | |
|---|---|---|
| DESIGNED BY F. C. | DRAWN BY J. B. | DRAWING NO |
| CHECKED BY | DATE FEB 1976 | 74700-01 FIG. 6 |

Smoky River water can be heated to a temperature suitable for trout farming by the combustion of a fess"il fuel such as coal, oil and natural gas. In this case, the farming of trout will be a primary heat user. There are several advantages to this approach. It gives the trout rearing operation a high degree of independence in terms of site selection. Also, the reliability of the source of heat would not be contingent upon the continuity of another industry.

To bring 145,344 lpm (38,400 USGPM) of water to trout rearing temperature, 2.18 x $10^6$ Kcal/min. (8.64 x $10^6$ BTU/rein.) would be required. This energy can be provided by a fuel burning boiler. The boiler would be used to heat a certain quantity of water which would in turn heat 145,344 lpm (38,400 USGPM) of Smoky River water to 15°C. by a heat exchanger. Of the three most common types of fuel, oil and gas are the most desirable because the capital cost for a gas or oil-fired boiler is less expensive than a coal -fired, boiler. However, oil and gas are more expensive than coal.

Discussion with the utility company that supplies natural gas to the proposed trout rearing site revealed that the existing pipeline that delivers natural gas to the area may not have sufficient capacity for a full-scale trout rearing facility. To obtain an estimate of the cost of natural gas supply at the proposed site, the utility supplier will have to carry out a study of the cost for a pipeline expansion. Such a study is beyond the scope of free information from the utility company. In any event, the well head price of natural gas in Alberta doubled earlier this year from $0.01 to $0.02 per cubic meter ($0.28 to $0.56 per thousand cubic feet). Assuming the consumer price of natural gas to be $0.35 per cubic meter ($1.00 per thousand cubic feet) at the site, the cost of natural gas alone is 2.778 million dollars per year. This estimate is based on heating Smoky River from 0° to 15 C. for 8 months of the year. In addition, the capital cost of just the gas-fired boiler itself to provide 2.18 x $10^6$ Kcal/min. is in the neighborhood of 2 million dollars. Therefore, it is obvious that the heating of Smoky River water to trout raising temperature by the direct combustion of natural gas is not economical. Furthermore, continuing increases in the price of natural gas and the uncertainty of its long-term supply make it unsuitable for use in a permanent boiler operation at Grande Cache.

Oil-fired boilers are comparable in price to gas-fired boilers. The most inexpensive grade is Number 6 heavy fuel oil. This fuel has some potential for future price stability. A bulk quantity delivered price to Grande Cache of $0.059 per litre ($0.27/gallon) can be negotiated. Even at this price, the annual heavy fuel oil cost alone for a boiler operation to heat Smoky River for trout farming is estimated to be 6.3 million dollars. The economics of using Number 6 heavy fuel oil is even worse than that of natural gas.

There"is an advantage in considering the use of coal because of the presence of the McIntyre Porcupine Mines at Grande Cache. The McIntyre Mine produces various grades of coal for export. The operation also produces a substantial amount of substandard secondary reject coal. This coal is a potential source of cheap fuel for a boiler operation to heat Smoky River water to trout rearing temperature.

However, an investigation of the coal situation in the Grande Cache area reveals some less encouraging facts. McIntyre has not been able to achieve its original production expectations. Consequently, all the reject coal produced is taken up by the H. R. Milner Power Generating Station. This means that there will not be any surplus supply of reject coal for a boiler operation for trout farming. Supplies have to be brought into the Grande Cache area from the Edson-Hinton region. Surveying of coal mining companies operating in this region cast considerable doubt as to the availability of reject coal supplies with less than 50% ash content in volumes of $1.36 \times 10^8$ kg (150,000 tons) to $1.814 \times 10^8$ kg (200,000 tons) a year, (depending on the ash content) which will be required to heat 145,344 lpm (38,400 USGPM) of Smoky River water for trout farming.

Apart from doubtful supplies, the transportation, handling, and storage of reject coal will add substantial operating costs to the operation. It is estimated that an additional cost of $11.57/1,000 kg ($10.50/ton) will be required. On the basis of 1.36 x $10^8$ kg (150,000 tons) of reject coal a year for the annual production of 1.14 x $10^6$ kg (2.5 million pounds) of trout, the operating cost for the handling of coal ALONE represents $1.39/kg ($0.63/lb.) of trout produced. When one considers the wholesale price of dressed frozen packaged rainbow trout from Japan at $2.50/kg[19] ($1.14/lb.), the use of coal for a boiler operation for trout farming is not economical.

## POLLUTION CONTROL

Water pollution has become one of the major concerns of our highly industrialized society. The deterioration of the quality of most surface waters has reached a point where it poses a threat to many of our everyday activities. It is estimated that while the human population doubles every 35 years, the rate of increase of water pollution multiplies six times in the same period[20].

### Waste Sources and Characteristics

The operation of a trout rearing and processing facility will undoubtedly produce a large quantity of contaminated water. The effluent from the raceway system does not require any high degree of treatment other than solids separation. The waste in the once-through type raceway system is mainly metabolic and food wastes. Upon dilution by the flow, these wastes do not constitute any great pollution concern under normal operation. Should disease be detected in the system, however, disinfection of the effluent will be required.

Other wastewaters in the facility are sanitary wastewater from washrooms and process wastewater from the fish processing area. The major activity in this particular processing plant includes only scaling, eviscerating, washing and packaging of the rainbow trout for freezing before marketing. It does not involve any filleting nor further processing of the fish for by-products. Therefore, the process wastewater will contain mainly fish blood, scales, offal, particulate, dissolved fish solids and some oily scum.

The quantity of wastewater and the BOD loading vary tremendously depending on the type of fish processed, processing procedures and the size and packaging habits of individual plants. Flows of 8.35 litre to 125.18 litre per kg of fish processed have been reported. For the type of processing activity as discussed for Grande Cache, a wastewater flow of 25.04 l/kg (3,000 gal./1000 lbs.) of fish processed per day is believed to be reasonable.

BOD concentration of fish processing plant effluents varies to a much larger extent than the wastewater flow. It reflects very much the operating habits of the plant as well as pollution consciousness of the people in charge. Nemerow[21] quoted a BOD concentration of 3,000 mg/l to 6,000 mg/l for the type of fish -processing plant effluent as discussed for Grande Cache while Environment Canada studies[22] reported a range of approximately 30 to 2,000 mg/l. The discrepancy probably lies in the fact that the high number quoted by Nemerow is for the total effluent which may include offal and scales while the low number as reported by Environment Canada studies is for effluents that do not include offal, scales and large solid particles. Good housekeeping and proper waste management will reduce the wastewater volume and loading substantially. In such cases, a BOD concentration of 1,000 mg/l is reasonable.

The proposed trout rearing facility at Grande Cache, when operated efficiently and up to capacity, can produce 1.134 x $10^6$ kg (25 million pounds] of-fish a year. This represents approximately 4,727 kg (10,400 pounds) per working day, assuming 240 working days a year. Assuming 20% of trout produced can be sold fresh and 50% over-harvesting because of uncontrollable circumstances, a treatment facility has to be designed to provide treatment far the wastewater from the processing of 3,782 to 7,091 kg of rainbow trout a day. With the flow and strength estimated at 25.04 l/kg (3,000 gallons/1,000 pounds) of fish processed and 1,000 mg/l of BOD, a treatment facility has to be able to handle 90,850 to 170,344 litre/day and 90.85 to 170.34 kg of BOD per day.

Discharge Regulations

Currently in Canada, the Federal Department of the Environment has established Federal Fish Processing Operations Liquid Effluent Guidelines to regulate the discharge of fish processing wastewater. Under these guidelines, all contaminated process water should be treated for solids removal and the solids removal facilities should produce an effluent similar in quality to that produced by 25 mesh screening of the contaminated process water.

In the Province of Alberta, there is no specific regulations governing the industrial discharge of fish processing wastewater. However, it is anticipated that a licence to operate such a trout rearing and processing facility will not be issued under the Clean Water Act unless satisfactory treatment is provided for the effluent from the processing plant.

Treatment

It has been found through research and s well documented in the 1 terature that fish processing plant effluent is amenable to biological treatment. Preliminary investigation indicates that the most economical treatment is a package treatment plant of the extended aeration variety. Estimated capital cost for an extended aeration package plant to handle a flow of 170,344 l/day and a BOD oading of 170.34 kg/day is $110,000.

## ECONOMIC ANALYSIS

### Markets and Marketability

A mass market for rainbow trout requires a steady supply of fish twelve months of the year. The fish should be in a size range of 350 - 500 gms dressed weight (10 - 16 oz.) for individual portions served in homes or restaurants. The major outlet would be for fresh dressed and iced fish for over the counter sales. Frozen packaged fish would have to compete with the imported products mainly from Japan currently $6.00/kg ($3.00/lb.) at the retail level. Prices quoted generally range from $4 - $8 per kilogram ($z - $4/lb.) with frozen fish bringing the lower price. There is a restricted demand for larger trout (2 - 4 kg) used fresh in restaurants or occasionally in homes. A very minor but high priced market is in specialty restaurants where the customer selects a live fish from a tank for dinner.

At the lowest retail price range $6.00/kg ($3.00/lb.) rainbow trout rate as a luxury food compared to other protein sources despite the lower waste ratio for fish. The capability of the market to absorb aquiculture products at this price is questionable as is the ability of an aquaculture industry to raise fish to sell at that price.

Several recent studies have projected production costs as follows: $2.50/kg (operating costs only); $2.20- $6.60/kg; $2.75 /kg[19]. In all analyses economy of large-scale, intensive culture were invoked, but in all cases several cost components were omitted. At present $6.00/kg retail prices total production costs would have to be $3.00/kg or less. It is impossible to predict or assess whether or not unit production costs can meet this figure until an intensive culture operation is undertaken.

## Market Potential

Total market potential is difficult to estimate but some information exists that allows reasonable projections.

### Fresh Fish

Canadian fish consumption is about 4.5 kg/year/capita (10 - 11 lbs.) but consumption on the Prairies is closer to 2.25 kg (5 lbs.). A steady supply of fresh, high quality fish at an attractive price, as exists on both coasts where fish consumption is high should bring the regional consumption to the national level or higher. Most of all of the increase could be captured by rainbow trout.

"Pot-hole" farmers have found a ready and unsaturated market on a local basis for their fish. A large scale aquiculture unit would require mass marketing aimed at urban centres to absorb its production.

Assuming a mass market for Alberta of 1,000,000 - 1,250,000 people in the Edmonton-Calgary corridor and sales of 2.25 kg/capita a market potential of 2.25 - 2.8 million kg (5 - 6 million pounds) seems reasonable. Development of a stable market this size would require the modern handling and merchandising methods typical of the food industry. Failure to maintain quality or supply, as has been traditional with the fishing industry, would inhibit the rate of market development and its final size.

Increasing the market in Alberta beyond this projection is speculative and might be possible only if other fish species were cultured.

Depending on supply, price, transportation costs and competition from other intensive aquiculture ventures, a regional or central Canadian market several times the projected size could be available for fresh trout.

Frozen Rainbow Trout

Freezing and packaging rainbow trout makes national and international sales possible. Frozen fish bring a lower price than fresh trout and the added costs of freezing and packaging will lower profit margins. As for fresh fish, quality and regular availability are important but also the product must compete in price with imports in the Canadian market and with domestic production in the United States market.

Using production not absorbed by the fresh market as a result of fluctuations in demand will not lead to a stable market for frozen fish. Devoting a minimum percentage of monthly production to the frozen product as well as using any surplus from the fresh trout demand will be necessary.

Subject to the same price and competition provisions as for fresh trout, there is no reason a domestic frozen trout industry could not capture the present market estimated at 0.68 million kg or 1.5 million lbs.[25] from the imported product. With time, this market could also be expanded.

Exports to the United States are hazardous to predict but successful marketing in that country will depend to a greater extent than the Canadian market on regular delivery of large volumes at a competitive price.

Exports will not be worth considering until production, processing, marketing and shipping problems have been solved on a regional and national basis.

Cost Estimates

Capital and operating cost estimates are listed in Tables 3 and 4. "The cost estimates are based on pricing from equipment suppliers and estimated installation cost at Grande Cache. These estimates are very preliminary and should not be used for budgetary purposes. They are presented to indicate the economic feasibility of the venture. These costs also do not include the following: engineering, land purchases, trucks and small handling equipment, covers or housing for raceways, stand-by chlorination for effluent, supplementary fuel, and maintenance and repair.

The estimated capital cost for stand-by boilers is for boiler equipment tosupply 50% of the total heat energy required. The total required energy of $2.18 \times 10^6$ kcal/min. is the maximum for the trout rearing facility. It is estimated that by staging the operation and overharvesting when the power plant is shut down, the trout rearing facility can survive with only 50% of the total heat requirement.

A preliminary site plan is shown in Figure 7 and a preliminary processing plant layout is shown in Figure 8.

TABLE 3

CAPITAL COST ESTIMATES

| | Concrete | Lined Earther |
|---|---|---|
| 80 raceways | $ 800,000 | $ 200,000 |
| 80 raceway inlet sections | 8,000 | |
| 80 raceway outlet sections | 10,000 | |
| 80 raceway outlet screens | 2,000 | |
| Inlet and outlet ditches | 20,000 | |
| Aeration equipment | 60,000 | |
| Effluent settling basin | 45,000 | |
| New small cooling tower | 80,000 | |
| Plate type heat exchangers (6) | 200,000 | |
| Heat exchanger housing | 110,000 | |
| Intake | 65,000 | |
| River Pumphouse | 1,000,000 | |
| Water supply piping | 300,000 | |
| Influent settling basin | 45,000 | |
| Control and instrumentation | 300,000 | |
| Modification to existing cooling system | 30,000 | |
| Stand-by boilers (50% requirement) | 800,000 | |
| Package Wastewater Treatment Plant | 110,000 | |
| Processing Plant: | | |
| Building | 100,000 | |
| Mechanical | 30,000 | |
| Quick freezer | 20,000 | |
| Ice maker | 20,000 | |
| Conveying system | 10,000 | |
| Miscellaneous equipment | 30,000 | |
| | $4,195,000 | $4,195,000 |
| Savings if lined earthen raceways to be used | | 600,000 |
| | $4,195,000 | $3,595,000 |
| Amortization @ 10% over 20 years | $ 492,745 | $ 422,269 |

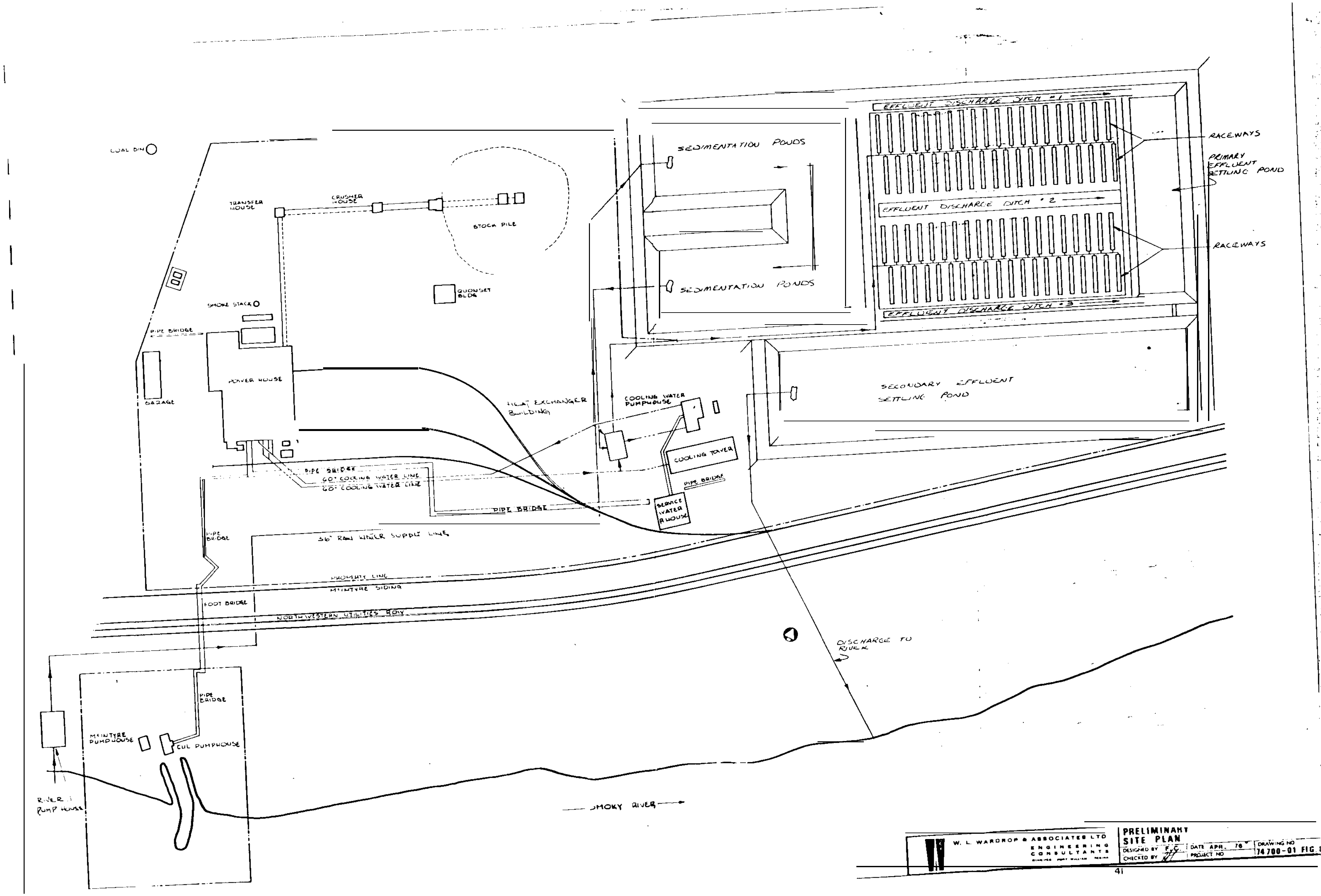
TABLE 4

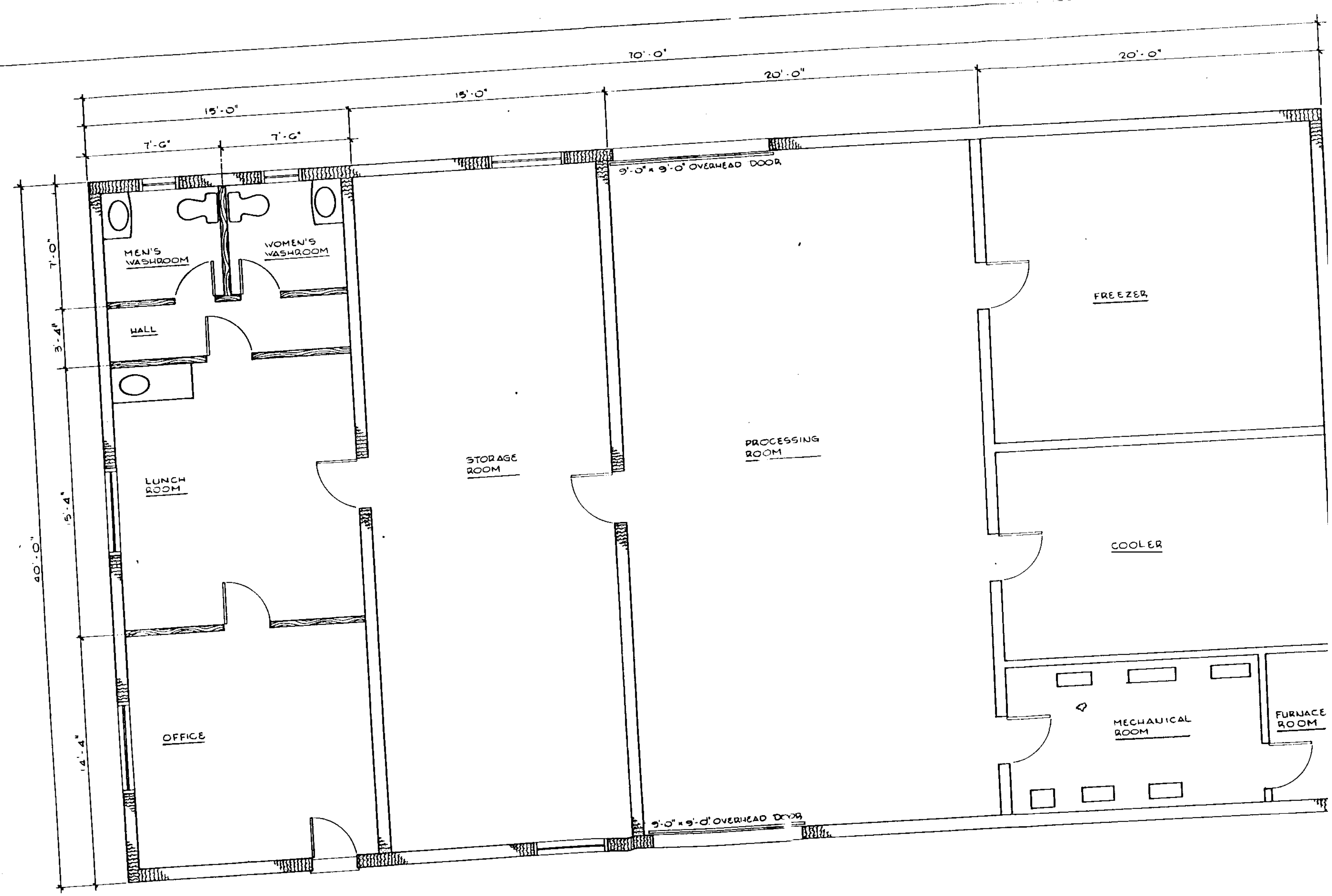
OPERATING COST ESTIMATES

| | Concrete | Lined Earthen |
|---|---|---|
| 3 million fingerlings | $ 240,000 | |
| Feed:<br>Assuming medium conversion of 1.5 kg food/kg fish<br>i.e. $1.869 \times 10^6$ kg at $552/1,000 kg | 1,031,688 | |
| Labour | 400,000 | |
| Transportation | 100,000 | |
| Utilities | 25,000 | |
| Packaging | 210,000 | |
| | $2,006,688 | $2,006,688 |
| Amortization | 492,745 | 422,269 |
| Total Annual Cost of Operation | $2,499,433 | $2,428,957 |
| Based on 0.96 million kg (2.1 million lbs.) of saleable rainbow trout product | | |
| Production Cost | $2.61/kg | $2.54/kg |
| Assuming 20% profit wholesale price | $3.14/kg | $3.05/kg |

COST ESTIMATES DO NOT INCLUDE:

- -- engineering;
- -- land purchases;
- -- trucks and small handling equipment;
- -- covers or housing for raceways;
- -- stand-by chlorination for effluent;
- -- stand-by or supplementary fuel; and
- -- maintenance and repair.


COAL BIN
TRANSFER HOUSE
CRUSHER HOUSE
STOCK PILE
QUONSET BLDG
SMOKE STACK
PIPE BRIDGE
GARAGE
POWER HOUSE
HEAT EXCHANGER BUILDING
COOLING WATER PUMPHOUSE
COOLING TOWER
PIPE BRIDGE
SERVICE WATER P. HOUSE
PIPE BRIDGE
60" COOLING WATER LINE
60" COOLING WATER LINE
PIPE BRIDGE
PIPE BRIDGE
36" RAW WATER SUPPLY LINE
PROPERTY LINE
McINTYRE SIDING
FOOT BRIDGE
NORTHWESTERN UTILITIES R.O.W.
SEDIMENTATION PONDS
SEDIMENTATION PONDS
EFFLUENT DISCHARGE DITCH #1
EFFLUENT DISCHARGE DITCH #2
EFFLUENT DISCHARGE DITCH #3
RACEWAYS
PRIMARY EFFLUENT SETTLING POND
RACEWAYS
SECONDARY EFFLUENT SETTLING POND
DISCHARGE TO RIVER
PIPE BRIDGE
McINTYRE PUMPHOUSE
CUL PUMPHOUSE
RIVER PUMP HOUSE
SMOKY RIVER
W. L. WARDROP & ASSOCIATES LTD
ENGINEERING CONSULTANTS
PRELIMINARY SITE PLAN
DESIGNED BY F.C.
CHECKED BY
DATE APR. 76
PROJECT NO
DRAWING NO 74700-01 FIG 1




FLOOR PLAN

SCALE: 1/8" = 1'-0"

| | | |
|---|---|---|
| W. L. WARDROP & ASSOCIATES LTD. ENGINEERING CONSULTANTS | PRELIMINARY PROCESSING PLANT LAYOUT | |
| DESIGNED BY F.C. | DATE APRIL 78 | DRAWING NO. 74 700 - 01 FI |
| CHECKED BY | PROJECT NO. | |

### Cost Analysis

The cost estimates indicate a production cost of $2.61/kg ($3.14/kg wholesale) if concrete raceways are used. Savings by using plastic lined earthen raceways will reduce the costs to $2.54/kg (production) and $3.05 (wholesale). However, this price cannot compete with frozen products from Japan at a wholesale price of $2.50/kg. If waste heat is available in sufficient quantities at all times, elimination of boilers, the new cooling tower and some extra controls and instrumentation would further reduce the production cost by $0.13/kg. This would bring the costs down to $2.48/kg (production) and $2.92/kg (wholesale) for concrete raceways. Even if these reductions were practical and considering the non-costed items in the analysis, a production cost of $2.48/kg still would not be competitive against imports without some form of government tariff protection. Superior quality and regularity of supply might overcome the price disadvantage. This possibility will have to be examined by careful market analysis to determine its validity and the effect of a premium price in market potential.

## GENERAL SUMMARY AND DISCUSSION

### The H. R. Milner Site

No significant economic benefit would be obtained from siting an intensive aquiculture facility adjacent to the H. R. Milner Generating Station.

It is clear that a thermal generating station such as the H. R. Milner Plant which responds to demands for electricity offers only marginal benefits to trout culture since large units for standby heat must be installed with associated high fuel costs. Although the cost of standby facilities has been included in our capital estimates, the cost of fuel

Alberta Power Limited has stated that an aquiculture facility adjacent to H. R. Milner or other generating stations would be acceptable as long as it did not increase the costs of producing electricity or interfere with operation of the thermal plant. Costs of modifying an electric generating station so that waste heat can be used to raise trout can be quite readily assessed. Operation of the two associated industries would require close co-operation in terms of changes of heat output resulting from emergencies or base demand loads. Whether or not such co-operation could be regarded as interference with smooth operation of a thermal electric generating station is open to interpretation. A pilot aquiculture study could assess the realities of the dependence of aquiculture on another industry as well as the more specific aquiculture related problems.

The Smoky River

The Smoky River has adequate supplies of water suitable for raising rainbow trout on a large scale provided facilities are incorporated to remove high sediment loads occuring during periods of high runoff.

It is not known what scale of production is needed for an economically viable trout rearing venture, this factor determines the water flows required. For example, the Smoky River can supply enough water to raise 0.96 million kg. of rainbow trout. At the historic minimum flow of the Smoky River about 30% of the water would be required for rearing the projected amount of trout. Diversion of flows in excess of 30% may not be desirable.

Technical Problems

A poured concrete raceway with a sloped V-bottom is recommended in this report. Enclosure in a stable building is also recommended. The cost of enclosure of the concrete raceways has not been included in the estimates.

Systematic studies of raceway design for intensive aquiculture have not been undertaken. Our recommendations are based upon the best information available in the literature. Proper design can achieve good fish distribution in the water volume, self-cleaning features and easy manipulation of the fish.

It is possible that proper design could eliminate high heat loss and damage to fish resulting from very low winter temperatures. Elimination of the need to enclose raceways would enhance the economics of rearing rainbow trout in Alberta.

The analysis of construction materials was based on experience factors but it is possible that a comparison through use would show epoxy-fibreglass, parged slump concrete, concrete block or plastic-lined soil construction to have advantages over poured concrete when initial costs, operating costs, and durability are taken into consideration.

Market Potential and Economic Evaluation

There is market potential in Alberta sufficient to absorb the production of 0.96 million kg per year of rainbow trout envisaged in this report. If an attractive price and a steady supply of high quality product could be realized, a much larger market in Alberta and in the Prairie region is possible.

It is quite clear from the analysis in this Report, as well as from previous studies, that it is impossible to assess accurately the costs associated with an intensive commercial aquiculture industry either in the Province of Alberta or in Canada. Reference to apparently successful ventures in other countries are irrelevant to the climatic features, social structure and economic-financial situation in Canada. The basic biological features are understood but their interaction with technical and engineering realities to result in a sound commerical venture is not.

Cost estimates in this study which, as in others, omit some components that cannot be evaluated, indicate a price advantage of \$0.50 - \$1.15/kg for frozen rainbow trout imported from Japan over a domestic product.

Other analyses have projected favorable to very unfavorable production costs in Canada, sometimes both, when some dubious economies of scale are invoked. This diversity of projected costs points out the lack of information essential to a commerical trout raising venture. Invoking economics of scale when base costs are uncertain is unrealistic.

To attempt even a small scale commercial venture would be an extremely high risk undertaking and failure would inhibit further attempts at aquiculture. The loss of several million dollars in the Sea-Pool undertaking near Halifax is a case in point.

## The Need for a Pilot Study

A pilot feasibility study written off against research and development budgets of one or more government agencies or of a private company is essential.

Siting of a pilot project should be in reference to an eventual commercial undertaking and should be on a site suitable for such. The site should be representative of those potentially available in Alberta in terms of water availability, chemistry, sediment, the availability of waste heat and of a market. Direct transfer of information and technology from the pilot plant to a commerical undertaking as it built up would be facilitated by proper siting of the feasibility study.

It is impossible to analyze with any certainty the technical and commercial possibilities of aquiculture in Western Canada because neither precise basic data are available nor are facts concerning regional costs. Even if this information were available, intensive aquiculture has some high risks associated with it since compared to intensive agriculture there is no base that has built up over a period of time. Specifically, a broodstock-egg-fingerli ng industry does not exist in the region nor does a regional domestic supply of fish food. There is a ready market for about 3,000,000 rainbow trout fingerlings in the region for use in pot-hole aquiculture. This demand provides a base for fingerling production that could be expanded for a large scale intensive aquiculture industry. Establishment of a fingerling industry would provide the stimulus and the market for a domestic fish food industry.

Specifically, a pilot study should address itself to these major problems:

- -- What are water heating costs and what are the economic benefits of using waste heat?
- -- The need for enclosed vs open raceways?
- -- The most efficient size and design of raceways?
- -- What loading densities are possible in commercial practise?
- -- What are the unit labour requirements?
- -- What are the growth rates and conversion efficiencies under commercial conditions and with different available feeds?
- -- What, if any, price premium will fresh fish command on the local market?
- -- What is the present size of the local market and how much can it be expanded?

## CONCLUSION AND RECOMMENDATIONS

An intensive aquiculture facility at Grande Cache, Alberta using water from the Smoky River and waste heat from the H. R. Milner Power Generating Station is technically possible but economically not feasible. Grande Cache is, therefore, not a suitable site for a commercial intensive aquiculture industry. Only multiple-unit baseload thermal or nuclear power plants are capable of satisfying the waste heat requirement of such a facility. This study also indicates that 0.96 million kg (2.1 million pounds) may not be a profitable production volume, within the accuracy of the cost estimates, because of low priced imports from Japan. The per unit weight production cost can be reduced by increasing the production volume and reducing the prices of feed and fingerling stock. Therefore, it appears that the success of an intensive aquiculture facility will be increased by simultaneously establishing a brood-stock hatchery and fish feed manufacturing facilities.

W. L. Wardrop & Associates Ltd. recommends the following:

1. A priority be established for aquiculture in the Province of Alberta.
2. Preliminary investigations be carried out for potential sites.
3. Carry out pilot plant feasibility study to obtain critical operating data.

PROFESSIONAL ENGINEER ALBERTA
F. C. K. CHAN

F. C. K. Chan, P.Eng.

D. C. Gillespie, Ph.D.

THE ASSOCIATION OF
PROFESSIONAL ENGINEERS
OF ALBERTA
PERMIT NUMBER
P 940
W. L. WARDROP &
ASSOCIATES LTD.

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TAB

HISTORICAL S

SMOKY RI

Monthly and Annual Mean Discharges in Cubic Fee

| Year | Jan. | Feb. | Mar. | April | May | Jun |
|---|---|---|---|---|---|---|
| 1915 | ---- | ---- | ---- | ----- | ----- | 309 |
| 1916 | 1180 | 1700 | 1860 | 6960 | 15700 | 277 |
| 1917 | 1530 | 1300 | 1120 | 9850 | 53200 | 444 |
| 1918 | 3200 | 2010 | 1470 | 11000 | 19800 | 395 |
| 1919 | 1470 | 823 | 829 | 6580 | 11000 | 400 |
| 1920 | 2360 | 1680 | 1520 | 4590 | 66800 | 593 |
| 1921 | 2030 | 1610 | 2570 | 17400 | 37200 | 377 |
| 1922 | ---- | ---- | ---- | ----- | ----- | 256 |
| 1955 | ---- | ---- | ---- | ----- | 20800 | 547 |
| 1956 | 1040 | 974 | 994 | 19600 | 24400 | 349 |
| 1957 | 1240 | 847 | 1050 | 12800 | 36500 | 230 |
| 1958 | 5590 | 1700 | 1370 | 14800 | 31900 | 299 |
| 1959 | 1260 | 1030 | 1330 | 6000 | 21400 | 351 |
| 1960 | 2110 | 1520 | 2990 | 12000 | 30300 | 587 |
| 1961 | 1650 | 1060 | 1210 | 3060 | 17000 | 227 |
| 1962 | 1100 | 1680 | 775 | 20000 | 35300 | 332 |
| 1963 | 2180 | 1910 | 2420 | 25500 | 44000 | 349 |
| 1964 | 1620 | 1740 | 1280 | 6490 | 31400 | 527 |
| 1965 | 2250 | 1870 | 2290 | 29400 | 42300 | 509 |
| 1966 | 2130 | 1850 | 2080 | 23300 | 44000 | 308 |
| 1967 | 2290 | 2080 | 1730 | 5470 | 45300 | 619 |
| 1968 | 1780 | 2040 | 2990 | 5360 | 25700 | 402 |
| 1969 | 1270 | 1100 | 1120 | 16600 | 24600 | 214 |
| 1970 | 1360 | -1-250 | 1720 | 13200 | 18700 | 272 |
| Mean: | 1940 | 1510 | 1650 | 12900 | 31700 | 382 |

Source: Historical Streamflow Summary: Albert
Directorate, Department of the Environment

TABLE 1A

HISTORICAL STREAMFLOW SUMMARY

SMOKY RIVER: TO 1970

Annual Extremes of Discharge in CFS and Annual Total Discharge in AC-FT:

| Year | Maximum Instantaneous Discharge | Maximum Daily Discharge | Minimum Daily Discharge |
|---|---|---|---|
| 1916 | --- | 98,000 cfs, July 5 | 1,030 cfs, Jan. 26 |
| 1917 | --- | 92,400 cfs, May 22 | 1,030 cfs, Feb. 19 |
| 1918 | --- | 60,800 cfs, July 14 | 1,320 cfs, Mar. 5 |
| 1919 | --- | 103,000 cfs, June 12 | 670 cfs, Feb. 8 |
| 1920 | --- | 110,000 cfs, May 9 | 1,150 cfs, Mar. 22 |
| 1955 | 163,000 cfs, June 2 | --- | --- |
| 1956 | 77,500 cfs, June 13 | 75,900 cfs, June 13 | 494 cfs, Dec. 12 |
| 1957 | 67,700 cfs, Aug. 13 | 65,200 cfs, Aug. 13 | 714 cfs, Feb. 2 |
| 1958 | 90,600 cfs, June 30 | 81,200 cfs, June 30 | 1,040 cfs, Dec. 10 |
| 1959 | 68,800 cfs, June 28 | 65,500 cfs, June 28 | 857 cfs, Feb. 13 |
| 1960 | 178,000 cfs, June 23 | 156,000 cfs, June 23 | 1,080 cfs, Feb. 9 |
| 1961 | 50,300 cfs, July 2 | 45,200 cfs, July 3 | 726 cfs, Dec. 26 |
| 1962 | 87,000 cfs, July 20 | 79,400 cfs, July 20 | 610 cfs, Mar. 8 |
| 1963 | --- | 71,100 cfs, Apr. 29 | 1,230 cfs, Dec. 28 |
| 1964 | 115,000 cfs, Aug. 3 | 108,000 cfs, Aug. 4 | 1,050 cfs, Mar. 24 |
| 1965 | 195,000 cfs, July 10 | 184,000 cfs, July 10 | 1,340 cfs, Dec. 31 |
| 1966 | 86,100 cfs, May 12 | 81,200 cfs, May 12 | 1,170 cfs, Feb. 15 |
| 1967 | --- | 77,600 cfs, June 3 | 1,190 cfs, Dec. 27 |
| 1968 | 86,100 cfs, June 14 | 83,800 cfs, June 14 | 1,370 cfs, Jan. 16 |
| 1969 | 39,800 cfs, Apr. 30 | 39,000 cfs, Apr. 30 | 886 cfs, Jan. 29 |
| 1970 | 54,700 cfs, June 5 | 51,400 cfs, June 5 | 1,010 cfs, Mar. 9 |

| Year | Total Discharge: AC-FT | Year | Total Discharge: AC-FT | Year | Total Discharge: AC-FT |
|---|---|---|---|---|---|
| 1916 | 7.45 million | 1956 | 7.63 million | 1961 | 5.61 million |
| 1917 | 9.7 " | 1957 | 10.0 " | 1962 | 9.8 " |
| 1918 | 8.97 " | 1958 | 7.71 " | 1963 | 9.48 " |
| 1919 | 7.57 " | 1959 | 8.21 " | 1964 | 1305 " |
| 1920 | 14.0 " | 1960 | 10.1 " | 1965 | 15.0 " |
| 1966 | 10.9 " | | | | |
| 1967 | 10.0 " | | | | |
| 1968 | 8.5 " | | | | |
| 1969 | 7.34 " | | | | |
| 1970 | 5.75 " | | | | |

Source: Historical Streamflow Summary to 1970: Alberta, Water Survey of Canada Inland Water Directorate, Dept. of the Environment, Ottawa, Canada.

TABLE 2

SMOKY RIVER ABOVE HELL'S CREEK

DISCHARGE IN CFS FOR JANUARY

| Day | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|
| 1 | 544 | 405 | 408 | 585 | 640 |
| 2 | 543 | 395 | 400 | 570 | 630 |
| 3 | 542 | 385 | 390 | 560 | 615 |
| 4 | 541 | 380 | 375 | 550 | 605 |
| 5 | 540 | 370 | 365 | 540 | 595 |
| 6 | 540 | 362 | 360 | 530 | 585 |
| 7 | 539 | 360 | 354 | 520 | 575 |
| 8 | 539 | 350 | 350 | 510 | 570 |
| 9 | 538 | 340 | 345 | 500 | 558 |
| 10 | 532 | 330 | 342 | 490 | 545 |
| 11 | 531 | 325 | 339 | 484 | 540 |
| 12 | 530 | 315 | 338 | 480 | 530 |
| 13 | 528 | 305 | 338 | 470 | 525 |
| 14 | 527 | 300 | 338 | 465 | 520 |
| 15 | 525 | 295 | 338 | 465 | 515 |
| 16 | 524 | 295 | 333 | 465 | 510 |
| 17 | 522 | 300 | 335 | 465 | 510 |
| 18 | 521 | 305 | 340 | 465 | 505 |
| 19 | 520 | 340 | 346 | 465 | 500 |
| 20 | 518 | 420 | 360 | 465 | 495 |
| 21 | 517 | 455 | 364 | 465 | 495 |
| 22 | 516 | 475 | 373 | 465 | 490 |
| 23 | 509 | 485 | 379 | 465 | 485 |
| 24 | 503 | 490 | 388 | 467 | 480 |
| 25 | 501 | 500 | 394 | 468 | 470 |
| 26 | 500 | 505 | 405 | 469 | 470 |
| 27 | 498 | 510 | 420 | 470 | 465 |
| 28 | 496 | 515 | 434 | 471 | 460 |
| 29 | 494 | 515 | 450 | 472 | 455 |
| 30 | 492 | 520 | 468 | 474 | 455 |
| 31 | 490 | 515 | 485 | 475 | 450 |

Source: Historical Streamflow Summary to 1973: Alberta, Water Survey of Canada, Inland Water Directorate, Dept. of the Environment, Ottawa, Canada.

TABLE 3

SMOKY RIVER ABOVE HELL'S CREEK

DISCHARGE IN CFS FOR FEBRUARY

| Day | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|
| 1 | 489 | 530 | 505 | 473 | 445 |
| 2 | 488 | 535 | 525 | 474 | 440 |
| 3 | 487 | 537 | 534 | 470 | 435 |
| 4 | 486 | 530 | 537 | 463 | 430 |
| 5 | 486 | 520 | 540 | 460 | 425 |
| 6 | 485 | 515 | 542 | 455 | 421 |
| 7 | 484 | 505 | 543 | 454 | 415 |
| 8 | 483 | 500 | 545 | 445 | 410 |
| 9 | 482 | 490 | 546 | 433 | 406 |
| 10 | 481 | 480 | 549 | 430 | 403 |
| 11 | 480 | 475 | 550 | 425 | 400 |
| 12 | 480 | 465 | 551 | 424 | 400 |
| 13 | 479 | 455 | 552 | 410 | 398 |
| 14 | 478 | 445 | 553 | 405 | 397 |
| 15 | 477 | 440 | 553 | 400 | 390 |
| 16 | 476 | 430 | 552 | 400 | 385 |
| 17 | 475 | 420 | 551 | 395 | 380 |
| 18 | 474 | 415 | 550 | 393 | 380 |
| 19 | 472 | 420 | 544 | 396 | 380 |
| 20 | 470 | 425 | 538 | 385 | 380 |
| 21 | 468 | 430 | 522 | 384 | 380 |
| 22 | 468 | 435 | 510 | 382 | 380 |
| 23 | 466 | 435 | 503 | 380 | 383 |
| 24 | 466 | 430 | 490 | 380 | 385 |
| 25 | 464 | 425 | 485 | 380 | 395 |
| 26 | 464 | 420 | 478 | 378 | 405 |
| 27 | 462 | 400 | 472 | 376 | 418 |
| 28 | 462 | 395 | 465 | 375 | 420 |
| 29 | | | | 375 | |

Source: Historical Streamflow Summary to 1973: Alberta, Water Survey of Canada, Inland Water Directorate. Dept. of the Environment, Ottawa, Canada.

TABLE 4

SMOKY RIVER ABOVE HELL'S CREEK

DISCHARGE IN CFS FOR MARCH

| Day | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|
| 1 | 460 | 370 | 450 | 372 | 425 |
| 2 | 460 | 360 | 442 | 370 | 430 |
| 3 | 460 | 350 | 435 | 370 | 430 |
| 4 | 460 | 350 | 430 | 368 | 430 |
| 5 | 460 | 350 | 428 | 367 | 430 |
| 6 | 460 | 355 | 428 | 367 | 427 |
| 7 | 460 | 355 | 428 | 368 | 425 |
| 8 | 460 | 355 | 428 | 373 | 424 |
| 9 | 460 | 355 | 432 | 380 | 422 |
| 10 | 460 | 360 | 438 | 390 | 421 |
| 11 | 464 | 360 | 442 | 395 | 421 |
| 12 | 468 | 365 | 444 | 405 | 420 |
| 13 | 472 | 365 | 449 | 428 | 420 |
| 14 | 476 | 380 | 453 | 431 | 420 |
| 15 | 480 | 390 | 459 | 440 | 420 |
| 16 | 484 | 395 | 461 | 440 | 420 |
| 17 | 488 | 400 | 460 | 450 | 418 |
| 18 | 492 | 400 | 459 | 455 | 418 |
| 19 | 496 | 405 | 453 | 460 | 417 |
| 20 | 500 | 410 | 450 | 460 | 417 |
| 21 | 508 | 410 | 447 | 462 | 416 |
| 22 | 510 | 410 | 443 | 462 | 415 |
| 23 | 524 | 410 | 442 | 462 | 413 |
| 24 | 532 | 415 | 441 | 462 | 411 |
| 25 | 540 | 415 | 440 | 462 | 409 |
| 26 | 550 | 420 | 440 | 462 | 407 |
| 27 | 560 | 420 | 440 | 462 | 405 |
| 28 | 570 | 420 | 440 | 462 | 407 |
| 29 | 580 | 420 | 440 | 462 | 409 |
| 30 | 590 | 420 | 440 | 462 | 411 |
| 31 | 600 | 420 | 441 | 462 | 413 |

Source: Historical Streamflow Summary to 1973: Alberta, Water Survey of Canada, Inland Water Directorate, Dept. of the Environment, Ottawa, Canada.

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TABLE 5

SMOKY RIVER ABOVE HELL'S CREEK

DISCHARGE IN CFS FOR APRIL

| Day | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|
| 1 | 640 | 420 | 443 | 462 | 415 |
| 2 | 710 | 420 | 447 | 462 | 416 |
| 3 | 800 | 425 | 449 | 462 | 417 |
| 4 | 8170 | 425 | 452 | 462 | 418 |
| 5 | 970 | 425 | 455 | 462 | 420 13R |
| 6 | 1070 | 425 | 460 | 462 | 423 |
| 7 | 1170 | 425 | 460 | 462 | 426 |
| 8 | 1190 | 428 BR | 461 | 462 | 429 |
| 9 | 1200 | 465 | 463 | 462 | 432 |
| 10 | 1210 | 510 | 463 | 462 | 435 |
| 11 | 1220 | 494 | 463 | 462 | 434 |
| 12 | 1230 BR | 475 | 464 | 462 | 432 |
| 13 | 1230 | 516 | 464 | 464 BR | 447 |
| 14 | 1230 | 500 | 465 | 474 | 452 |
| 15 | 1230 | 507 | 465 | 450 | 460 |
| 16 | 1210 | 517 | 466 | 403 | 465 |
| 17 | 1200 | 545 | 467 | 392 | 470 |
| 18 | 1170 | 572 | 468 | 438 | 480 |
| 19 | 1130 | 576 | 469 | 451 | 485 |
| 20 | 1100 | 592 | 470 BR | 458 | 495 |
| 21 | 1070 | 603 | 557 | 428 | 505 |
| 22 | 1040 | 640 | 559 | 402 | 510 |
| 23 | 1020 | 662 | 719 | 371 | 520 |
| 24 | 990 | 655 | 808 | 428 | 530 |
| 25 | 980 | 616 | 920 | 509 | 540 |
| 26 | 970 | 602 | 1090 | 518 | 555 |
| 27 | 970 | 609 | 1200 | 573 | 662 |
| 28 | 980 | 617 | 1290 | 822 | 647 |
| 29 | 1140 | 646 | 1480 | 939 | 612 |
| 30 | 1240 | 677 | 1500 | 837 | 589 |

BR = Break up of ice cover

Source: Historical Streamflow Summary to 1973: Alberta, Water Survey of Canada, Inland Water Directorate, Dept. of the Environment, Ottawa, Canada.

TABLE 6

SMOKY RIVER ABOVE HELL'S CREEK

DISCHARGE IN CFS FOR MAY

| Day | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|
| 1 | 1370 | 1540 | 743 | 1550 | 833 | 647 |
| 2 | 1310 | 1780 | 994 | 1800 | 867 | 792 |
| 3 | 1240 | 2090 | 1190 | 2150 | 963 | 980 |
| 4 | 1270 | 1910 | 1220 | 2760 | 985 | 1180 |
| 5 | 1490 | 1700 | 1490 | 3470 | 979 | 1280 |
| 6 | 1420 | 1610 | 1470 | 3640 | 928 | 1460 |
| 7 | 1310 | 1560 | 1480 | 3920 | 958 | 1560 |
| 8 | 1320 | 1680 | 1530 | 4830 | 998 | 1450 |
| 9 | 1490 | 2170 | 1550 | 4300 | 1290 | 1360 |
| 10 | 1660 | 3120 | 1640 | 3690 | 1880 | 1270 |
| 11 | 2030 | 4840 | 1570 | 3970 | 2210 | 1230 |
| 12 | 2780 | 6030 | 1450 | 5860 | 3040 | 1320 |
| 13 | 2590 | 5960 | 1380 | 8410 | 5210 | 1630 |
| 14 | 2260 | 5910 | 1250 | 7280 | 7470 | 2510 |
| 15 | 2220 | 4540 | 1340 | 5310 | 6970 | 4020 |
| 16 | 2530 | 3710 | 2140 | 4260 | 5810 | 6900 |
| 17 | 3650 | 3470 | 3620 | 3530 | 5360 | 9820 |
| 18 | 5040 | 3600 | 2880 | 3200 | 3120 | 10600 |
| 19 | 6580 | 3730 | 2350 | 3300 | 4730 | 9440 |
| 20 | 8090 | 3710 | 2160 | 3650 | 5870 | 8100 |
| 21 | 10100 | 4290 | 2470 | 3990 | 9150 | 6340 |
| 22 | 9940 | 5040 | 3320 | 4830 | 11900 | 5680 |
| 23 | 9100 | 6770 | 4490 | 8550 | 11000 | 6030 |
| 24 | 8920 | 9090 | 4000 | 7650 | 8860 | 6950 |
| 25 | 9130 | 11000 | 4390 | 8300 | 7540 | 9610 |
| 26 | 8890 | 10000 | 7600 | 8410 | 7270 | 7580 |
| 27 | 7980 | 8030 | 6220 | 9060 | 8320 | 6130 |
| 28 | 7720 | 6300 | 4560 | 8240 | 10000 | 5520 |
| 29 | 7870 | 5410 | 3610 | 8170 | 12900 | 5480 |
| 30 | 7640 | 5130 | 3370 | 8150 | 15800 | 5920 |
| 31 | 7240 | 4000 | 3680 | 9360 | 18700 | 7190 |

Source: Historical Streamflow Summary to 1973: Alberta, Water Survey of Canada. Inland Water Directorate, Dept. of the Environment, Ottawa, Canada.

TABLE 8

SMOKY RIVER ABOVE HELL'S CREEK

DISCHARGE IN CFS FOR JULY

| Day | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|
| 1 | 7020 | 6090 | 6780 | 5540 | 8050 | 6710 |
| 2 | 6330 | 5760 | 6360 | 5480 | 6740 | 6290 |
| 3 | 4570 | 5890 | 6520 | 5000 | 6420 | 6340 |
| 4 | 3000 | 5470 | 8020 | 4530 | 6700 | 7650 |
| 5 | 3000 | 5310 | 8640 | 4520 | 7570 | 8980 |
| 6 | 3000 | 5770 | 7840 | 5790 | 8280 | 7490 |
| 7 | 3000 | 5480 | 7320 | 8040 | 8380 | 6280 |
| 8 | 3000 | 5620 | 7940 | 8780 | 8460 | 5520 |
| 9 | 3000 | 6010 | 7420 | 9680 | 8390 | 5180 |
| 10 | 3000 | 6090 | 6820 | 10800 | 7400 | 5240 |
| 11 | 3000 | 7140 | 6650 | 12900 | 6470 | 6600 |
| 12 | 3000 | 6740 | 6080 | 11800 | 6090 | 5490 |
| 13 | 3000 | 5460 | 5470 | 10900 | 6280 | 4930 |
| 14 | 5800 | 4710 | 5150 | 11000 | 7180 | 5490 |
| 15 | 7000 | 4130 | 5250 | 11700 | 6990 | 6770 |
| 16 | 7430 | 3730 | 5520 | 10800 | 6960 | 6950 |
| 17 | 6740 | 3630 | 6180 | 9400 | 6800 | 5940 |
| 18 | 6360 | 3510 | 6280 | 9380 | 6990 | 5530 |
| 19 | 6540 | 3550 | 6250 | 9690 | 6570 | 5410 |
| 20 | 6950 | 3780 | 6020 | 9910 | 5940 | 5900 |
| 21 | 7450 | 4120 | 5630 | 9870 | 5870 | 6660 |
| 22 | 7910 | 3960 | 5030 | 9790 | 5990 | 6610 |
| 23 | 7590 | 4160 | 4560 | 10000 | 6340 | 6350 |
| 24 | 7020 | 4390 | 4830 | 10400 | 6720 | 5710 |
| 25 | 6860 | 5790 | 4240 | 8510 | 6660 | 5020 |
| 26 | 7270 | 5100 | 3790 | 7440 | 6890 | 4350 |
| 27 | 7670 | 5180 | 4300 | 7460 | 6560 | 5120 |
| 28 | 6780 | 6990 | 4630 | 7810 | 6510 | 5730 |
| 29 | 6260 | 8570 | 4610 | 7430 | 7180 | 5280 |
| 30 | 7030 | 7320 | 3980 | 7400 | 6220 | 5460 |
| 31 | 8150 | 6470 | 3800 | 7620 | 5760 | 5510 |

Source: Historical Streamflow Summary to 1973: Alberta, Water Survey of Canada, Inland Water Directorate, Dept. of the Environment, Ottawa, Canada.

TABLE 9

SMOKY RIVER ABOVE HELL'S CREEK

DISCHARGE IN CFS FOR AUGUST

| Day | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|
| 1 | 8400 | 6130 | 3890 | 7610 | 5950 | 5700 |
| 2 | 7570 | 5610 | 3930 | 7740 | 5660 | 5670 |
| 3 | 7140 | 5180 | 4450 | 7770 | 5430 | 5490 |
| 4 | 7060 | 4800 | 5110 | 7120 | 5380 | 5280 |
| 5 | 8270 | 12400 | 5290 | 6740 | 5850 | 5890 |
| 6 | 8590 | 13400 | 5280 | 6820 | 6320 | 6300 |
| 7 | 7220 | 9920 | 5390 | 6720 | 7340 | 5380 |
| 8 | 6250 | 8710 | 4770 | 6560 | 7640 | 4970 |
| 9 | 5490 | 8530 | 3820 | 6100 | 8190 | 5080 |
| 10 | 5130 | 10300 | 3530 | 6180 | 7580 | 5110 |
| 11 | 5490 | 9850 | 3960 | 6360 | 6790 | 4680 |
| 12 | 6200 | 8180 | 4000 | 6390 | 5770 | 4490 |
| 13 | 5660 | 7290 | 4840 | 6020 | 4980 | 4430 |
| 14 | 5460 | 6570 | 4130 | 5540 | 4500 | 4410 |
| 15 | 5310 | 6630 | 3530 | 5040 | 4490 | 4200 |
| 16 | 5220 | 6960 | 3930 | 4320 | 4500 | 4040 |
| 17 | 5370 | 5500 | 3260 | 3990 | 4970 | 4270 |
| 18 | 5450 | 5040 | 2620 | 3880 | 4520 | 3820 |
| 19 | 4910 | 6060 | 2480 | 3870 | 4400 | 3040 |
| 20 | 4750 | 5590 | 2640 | 4390 | 4380 | 2770 |
| 21 | 5110 | 5930 | 3040 | 4640 | 4420 | 2590 |
| 22 | 5140 | 5950 | 3340 | 4990 | 4610 | 2500 |
| 23 | 4810 | 5050 | 3770 | 4520 | 4570 | 2550 |
| 24 | 4710 | 4830 | 3830 | 3760 | 4400 | 2510 |
| 25 | 4760 | 6000 | 3860 | 3830 | 4350 | 2450 |
| 26 | 4890 | 5250 | 3730 | 3540 | 4290 | 2320 |
| 27 | 4740 | 5230 | 3170 | 3320 | 4210 | 2250 |
| 28 | 4200 | 4940 | 3150 | 3320 | 4180 | 2120 |
| 29 | 3970 | 4370 | 2910 | 3400 | 4340 | 2070 |
| 30 | 3860 | 4030 | 2670 | 3500 | 4000 | 1950 |
| 31 | 3760 | 3690 | 2780 | 3880 | 3990 | 1810 |

Source: Historical Streamflow Summary to 1973: Alberta, Water Survey of Canada. Inland Water Directorate, Dept. of the Environment, Ottawa, Canada,

TABLE 10

SMOKY RIVER ABOVE HELL'S CREEK

DISCHARGE IN CFS FOR SEPTEMBER

| Day | 1968 | 1969 | 1970 | 1971 | 1973 |
|---|---|---|---|---|---|
| 1 | 4000 | 3530 | 3050 | 3720 | 1720 |
| 2 | 4010 | 3790 | 3220 | 2990 | 1630 |
| 3 | 3590 | 4390 | 2930 | 2600 | 1730 |
| 4 | 3290 | 4140 | 2820 | 2370 | 1850 |
| 5 | 3400 | 3120 | 2350 | 2490 | 1890 |
| 6 | 4890 | 3560 | 2230 | 3280 | 2140 |
| 7 | 6110 | 3200 | 1990 | 2620 | 2610 |
| 8 | 5070 | 3140 | 1770 | 2640 | 2530 |
| 9 | 4520 | 3250 | 1620 | 4060 | 2690 |
| 10 | 4430 | 3290 | 1560 | 3140 | 3540 |
| 11 | 5010 | 3520 | 1500 | 4190 | 3520 |
| 12 | 6510 | 3810 | 1360 | 4020 | 3890 |
| 13 | 5630 | 5240 | 1320 | 3670 | 3350 |
| 14 | 4830 | 5260 | 1300 | 3170 | 2700 |
| 15 | 4490 | 4160 | 1280 | 2860 | 2370 |
| 16 | 4010 | 3580 | 1260 | 2570 | 2140 |
| 17 | 4210 | 3290 | 1240 | 2350 | 2020 |
| 18 | 4130 | 3200 | 1310 | 2290 | 1870 |
| 19 | 3610 | 3370 | 1500 | 2660 | 1770 |
| 20 | 3290 | 3270 | 1460 | 3170 | 1710 |
| 21 | 2980 | 3280 | 1410 | 2720 | 1720 |
| 22 | 2840 | 3120 | 1440 | 2550 | 1700 |
| 23 | 3170 | 2980 | 1650 | 2470 | 1670 |
| 24 | 2850 | 3060 | 1470 | 2880 | 1650 |
| 25 | 3020 | 2990 | 1350 | 3810 | 1570 |
| 26 | 3010 | 2980 | 1440 | 3370 | 1470 |
| 27 | 3080 | 2790 | 1900 | 2920 | 1830 |
| 28 | 3020 | 2940 | 1920 | 2670 | 2850 |
| 29 | 2810 | 2830 | 1950 | 2480 | 6240 |
| 30 | 2830 | 2760 | 1940 | 2280 | 6040 |

Source: Historical Streamflow Summary to .1973: Alberta, Water Survey of Canada, Inland Water Directorate, Dept. of the Environment, Ottawa, Canada.

TABLE 11

SMOKY RIVER ABOVE HELL'S CREEK

DISCHARGE IN CFS FOR OCTOBER

| Day | 1968 | 1969 | 1970 | 1971 | 1973 |
|---|---|---|---|---|---|
| 1 | 2740 | 2820 | 1880 | 2130 | 4510 |
| 2 | 2540 | 2900 | 1810 | 2060 | 3580 |
| 3 | 2410 | 2830 | 1780 | 2210 | 3100 |
| 4 | 2330 | 2620 | 1850 | 3290 | 2820 |
| 5 | 2250 | 2560 | 2240 | 3380 | 2860 |
| 6 | 2140 | 2670 | 1810 | 3790 | 2480 |
| 7 | 2050 | 2620 | 1560 ICE | 4780 | 2330 |
| 8 | 1970 | 2650 | 1570 | 3970 | 2090 |
| 9 | 1800 | 2800 | 1520 | 3500 | 2050 |
| 10 | 1800 | 2500 | 1480 | 3180 | 1940 |
| 11 | 1770 | 2450 | 1450 | 2970 | 1850 |
| 12 | 1720 | 2300 | 1400 | 2870 | 1820 |
| 13 | 1630 | 2200 | 1370 | 3030 | 1730 |
| 14 | 1580 | 2190 | 1320 | 2730 | 1620 |
| 15 | 1570 | 2050 | 1290 | 2420 | 1470 |
| 16 | 1480 | 1970 | 1260 | 2100 | 1610 |
| 17 | 1480 | 1900 | 1220 | 2070 | 1530 |
| 18 | 1500 | 1880 | 1180 | 2000 | 1860 |
| 19 | 1450 | 1920 | 1140 | 1860 | 2080 |
| 20 | 1410 | 1950 | 1100 | 1830 | 2490 |
| 21 | 1370 | 2000 | 1080 | 1690 | 2300 |
| 22 | 1360 | 2070 | 1060 | 1630 | 2160 |
| 23 | 1300 | 2270 | 1040 | 1570 | 1970 |
| 24 | 1550 | 1960 | 1020 | 1480 | 1870 |
| 25 | 1640 | 1720 | 1000 | 1500 | 1800 |
| 26 | 1630 | 1600 | 950 | 1420 | 1700 |
| 27 | 1470 | 1610 | 920 | 1230 | 1650 |
| 28 | 1460 | 1890 | 880 | 993 | 2250 |
| 29 | 1650 | 1820 | 850 | 1240 | 2730 |
| 30 | 1640 | 1770 | 740 | 1340 | 2330 |
| 31 | 1640 | 1730 | 730 | 1290 | 2050 |

Source: Historical Streamflow Summary to 1973: Alberta, Water Survey of Canada, Inland Water Directorate, Dept. of the Environment., Ottawa, Canada,

TABLE 12

SMOKY RIVER ABOVE HELL'S CREEK

DISCHARGE IN CFS FOR NOVEMBER

| Day | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|
| 1 | 1630 | 1730 | 700 | 1250 | 1820 | 1920 |
| 2 | 1620 | 1710 | 660 | 1220 | 2780 | 1590 |
| 3 | 1600 | 1780 | 640 | 1210 | 1880 | 1150 ICE |
| 4 | 1590 | 1770 | 609 | 1170 | 1810 | 990 |
| 5 | 1580 | 1700 | 500 | 981 | 1500 | 775 |
| 6 | 1560 | 1630 | 640 | 1120 ICE | 1060 | 750 |
| 7 | 1540 | 1620 | 760 | 1100 | 900 | 730 |
| 8 | 1520 | 1560 | 740 | 1090 | 940 | 710 |
| 9 | 1500 | 1560 | 710 | 1090 | 1430 | 700 |
| 10 | 1470 ICE | 1510 | 690 | 1080 B R | 1370 | 700 |
| 11 | 1420 | 1480 | 660 | 1070 | 1360 | 690 |
| 12 | 1360 | 985 ICE | 650 | 1010 | 1210 ICE | 690 |
| 13 | 1300 | 975 | 620 | 962 | 980 | 660 |
| 14 | 1230 | 960 | 610 | 988 | 873 | 680 |
| 15 | 1170 | 950 | 600 | 924 | 541 | 685 |
| 16 | 1120 | 950 | 580 | 917 | 603 | 685 |
| 17 | 1060 | 945 | 570 | 926 | 643 | 685 |
| 18 | 1020 | 945 | 560 | 902 | 670 | 685 |
| 19 | 940 | 940 | 550 | 1150 | 683 | 685 |
| 20 | 940 | 940 | 540 | 1900 | 667 | 690 |
| 21 | 920 | 925 | 530 | 1590 | 540 | 690 |
| 22 | 900 | 910 | 520 | 1350 | 470 | 695 |
| 23 | 880 | 890 | 510 | 1200 | 510 | 700 |
| 24 | 850 | 875 | 490 | 1140 | 530 | 705 |
| 25 | 830 | 860 | 480 | 1100 | 540 | 715 |
| 26 | 800 | 845 | 480 | 947 | 545 | 720 |
| 27 | 770 | 830 | 470 | 996 | 555 | 725 |
| 28 | 750 | 820 | 470 | 1110 | 560 | 735 |
| 29 | 730 | 805 | 460 | 1010 | 570 | 745 |
| 30 | 710 | 790 | 460 | 852 | 580 | 750 |

Source: Historical Streamflow Summary to 1973: Alberta, Water Survey of Canada, Inland Water Directorate, Dept. of the Environment, Ottawa, Canada.

TABLE 13

SMOKY RIVER ABOVE HELL'S CREEK

DISCHARGE IN CFS FOR DECEMBER

| Day | 1968 | 1969 | 1970 | 1971 | | 1972 | 1973 |
|---|---|---|---|---|---|---|---|
| 1 | 690 | 750 | 450 | 750 | | 540 | 780 |
| 2 | 680 | 685 | 450 | 917 | | 520 | 770 |
| 3 | 670 | 615 | 440 | 955 | | 540 | 780 |
| 4 | 660 | 550 | 440 | 857 | | 570 | 798 |
| 5 | 650 | 480 | 430 | 860 | | 560 | 810 |
| 6 | 640 | 440 | 420 | 800 | ICE | 550 | 820 |
| 7 | 630 | 400 | 420 | 780 | | 565 | 830 |
| 8 | 630 | 355 | 420 | 760 | | 580 | 830 |
| 9 | 620 | 315 | 430 | 760 | | 600 | 830 |
| 10 | 620 | 300 | 430 | 750 | | 625 | 830 |
| 11 | 620 | 300 | 430 | 750 | | 640 | 825 |
| 12 | 610 | 300 | 440 | 740 | | 661 | 825 |
| 13 | 600 | 300 | 430 | 730 | | 670 | 825 |
| 14 | 600 | 300 | 400 | 720 | | 680 | 815 |
| 15 | 590 | 300 | 382 | 710 | | 685 | 805 |
| 16 | 590 | 310 | 380 | 700 | | 690 | 800 |
| 17 | 590 | 320 | 370 | 720 | | 665 | 790 |
| 18 | 580 | 330 | 370 | 740 | | 660 | 780 |
| 19 | 580 | 340 | 360 | 760 | | 680 | 770 |
| 20 | 580 | 350 | 350 | 780 | | 690 | 760 |
| 21 | 570 | 365 | 340 | 790 | | 710 | 750 |
| 22 | 570 | 380 | 350 | 770 | | 720 | 740 |
| 23 | 560 | 390 | 350 | 750 | | 720 | 730 |
| 24 | 560 | 405 | 360 | 730 | | 730 | 720 |
| 25 | 560 | 420 | 370 | 710 | | 750 | 705 |
| 26 | 560 | 420 | 380 | 690 | | 740 | 695 |
| 27 | 550 | 420 | 380 | 670 | | 730 | 685 |
| 28 | 550 | 420 | 390 | 650 | | 730 | 675 |
| 29 | 550 | 420 | 400 | 630 | | 720 | 665 |
| 30 | 545 | 415 | 410 | 610 | | 710 | 655 |
| 31 | 545 | 410 | 410 | 600 | | 700 | 645 |

Source: Historical Streamflow Summary to 1973: Alberta. Water Survey of Canada, Inland Water Directorate. Dept. of the Environment, Ottawa, Canada.

APPENDIX

STATION 00AL07GA0001 LATITUDE 53D 57M LONGITUDE 119D 0M

SMOKY RIVER ABOVE HELLS CREEK, ALBERTA

| SAMPLE DATE D M Y | TIME MST H M | 02061S TEMP. WATER DEG.C. | 02041S SPECIFIC CONDUCT. US/CM | 10301S PH PH UNITS | 08101S OXYGEN DISSOLVED DO O2 MG/L | 02061L TEMP. WATER DEG.C. | 02041L SPECIFIC CONDUCT. US/CM | 02073L TURBIDITY JTU | 10301L PH PH UNITS |
|---|---|---|---|---|---|---|---|---|---|
| 27 5 70 | | 3.3 | | | | 2 3 . 2 | 184 | 45.0 | 9.0 |
| 3 11 70 | | 0.6 | | | | 23.6 | 455 | 2.0 | 8.! |
| 24 11 70 | | 0.6 | | | | 22.3 | 491 | 10.0 | 9.2 |
| 15 12 70 | | 0.6 | | | | 22.2 | 421 | 0.9 | 7.7 |
| 5 1 71 | | 0.0 | | | | 23.? | 464 | 5.8 | 8.? |
| 2 .2 71 | | 0.0 | | | | 22.7 | 458 | 17.0 | 7.8 |
| 23 2 71 | | 0.6 | | | | 2?.4 | 520 | 2.3 | 8.0 |
| 16 3 71 | | 0.6 | | | | 23.5 | 525 | 1.5 | 8.2 |
| 6 4 71 | | | | | | ?2.2 | 51? | 1.0 | 8.? |
| 1 6 71 | | | | | | 20.4 | 173 | 38.0 | 8.0 |
| 22 6 71 | | 8.9 | | | | 22.0 | 180 | 27.0 | 8.? |
| 29 6 71 | 19 20 | 9.5 | | | | | | | |
| 14 7 71 | | 8.9 | | | | | | | |
| 21 7 71 | | 10.6 | | | | 23,3 | 185 | 46.0 | 9.? |
| 24 7 71 | | | | | | 23.7 | 227 | 27.0 | 8.2 |
| 26 7 71 | | 13.9 | | | | | | | |
| 17 8 71 | | 8.9 | | | | | | | |
| 21 9 71 | | 5.6 | | | | 23.5 | 254 | 4.5 | 8.! |
| 26 10 71 | | 1.1 | | | | ?3.2 | 240 | 2.6 | 8.? |
| 23 11 71 | | | | | | 7?.4 | 315 | 3.9 | 7.9 |
| 11 1 72 | | 0,6 | | | | 2 3 , 9 | 478 | 2.5 | 8.2 |
| 2 2 72 | | 0.6 | | | | 23.5 | 528 | 1.? | 8.? |
| 23 2 72 | | 0.6 | | | | 23.8 | 527 | 1.! | 9.1 |
| 14 4 72 | | 0.6 | | | | 23.2 | 49 | 3.3 | 7.4 |
| 3 5 72 | | | | | | 24.7 | 426 | 20.0 | 8.2 |
| 6 6 72 | | 6.1 | | | | 24.9 | 168 | 57, ) | 9.2 |
| 18 7 72 | | 8.9 | | | | 23.? | 212 | 24.? | 8.? |
| 28 8 72 | | 12.0 | | | | 22.2 | 27! | 260) | 9.1 |
| 27 9 72 | | 1.1 | | | | 22.? | 350 | 2.1 | 7.8 |
| 31 10 72 | | 1.1 | | | | 22.? | 355 | 2.? | 8.1 |
| 12 12 72 | | 0.6 | | | | 23.5 | 604 | 17.) | 8.0 |
| 5 1 73 | | 1.0 | | | | 26.0 | 510 | ?.1 | 8.2 |
| 2 2 73 | | 0.6 | | | | 24.- | 501 | 1.8 | 8.1 |
| 27 2 73 | | 0.6 | | | | 22.? | 525 | 1.? | 9.0 |
| 26 4 73 | | | | | | 24.5 | 510 | 5.6 | 8.3 |
| 12 6 73 | | | | | | 24.? | 240 | 7.3 | 8.3 |
| 26 6 73 | | | | | | 24.? | 175 | 82.0 | 8.2 |
| 24 7 73 | | | | | | 26.8 | 185 | 37.0 | 8.2 |
| 21 8 73 | | 7.8 | | | | 23.2 | 247 | 6.0 | 2.? |
| 28 8 73 | 1010 | 9.0 | 280 | 8.3 | | 2?.? | | | |

STATION 00 AL07GA0001 LATITUDE 530 57M LONGITUDE 119D 0M

| SAMPLE DATE D M Y | TIME H M | 02061S TEMP. WATER DEG.C. | 02041S SPECIFIC CONDUCT. US/CM | 10301S PH PH UNITS | 08101S OXYGEN DISSOLVED DO O2 MG/L | 02061L TEMP. WATER DEG.C. | 02041L SPECIFIC CONDUCT. US/CM | 02073L TURBIDITY JTU | 10301L PH PH UNITS |
|---|---|---|---|---|---|---|---|---|---|
| 25 9 73 | | 6.2 | | | | 22.7 | 298 | 1.5 | 8.3 |
| 8 1 74 | | 0.0 | | | | 16.6 | 491 | 0.7 | 7.9 |
| 12 1 74 | 12 30 | 0.9 | 536 | 8.4 | | 20.4 | 510 | 4.8 | 8.0 |
| 30 1 74 | | 0.0 | | | | 23.5 | 500 | 1.8 | 8.0 |
| 19 2 74 | | | | | | 19.8 | 517 | 2.9 | 8.0 |
| 1 5 74 | | | | | | 22.0 | 315 | 130. | 8.1 |
| 14 5 74 | | 4.0 | | | | 21.2 | 219 | 8.0 | 8.1 |
| 30 5 74 | 12 12 | 8.5 | 202 | 8.1 | 9.6 | 22.7 | 261 | 6.5 | 7.8 |
| 15 9 74 | 11 15 | 11.0 | 240 | 8.2 | 10.2 | 19.8 | 225 | 9.3 | 8.3 |
| 20 10 74 | 11 24 | 5.0 | 200 | 7.5 | 10.6 | 20.8 | 204 | 6.0 | 7.0 |
| 30 1 75 | 17 15 | 0.0 | 346 | 8.5 | 12.1 | 19.9 | 455 | 0.5 | 7.9 |

TION 00AL07GA0001 LAT TUDE 53° 57M LONGITUDE 119D

ELLS CREEK, ALBERTA

| 02011L COLOUR APPARENT REL. UNITS | 10602L HARDNESS TOTAL (CALCD.) CACO3 MG/L | 10603L HARDNESS TOTAL CACO3 MG/L | 10451L RESIDUE FILTERABLE MG/L | 10551L RESIDUE FIXED FILTERABLE MG/L | 10401L RESIDUE NONFILTR. MG/L | 10501L RESIDUE FIXED NONFILTR. MG/L | 10151L ALKALINITY PHENOL-PHTHALEIN CACO3 MG/L |
|---|---|---|---|---|---|---|---|
| 20 | | 99.3 | | | 78 | 68 | 0 |
| L5 | | 218. | | | | | 0 |
| L5 | | 269. | | | 19 | 17 | 0 |
| L5 | | 225. | | | 21 | | 0 |
| 5 | | 230. | | | 23 | 15 | 0 |
| 10 | | 243. | | | 21 | 21 | 0 |
| L5 | | 273. | | | 11 | | 0 |
| L5 | | 282. | | | | | 0 |
| 5 | | 261. | | | | | 0 |
| 15 | | 92.4 | | | 100 | 79 | 0 |
| 10 | | 85.7 | | | 37 | 24 | 0 |
| 5 | | 87.2 | | | 61 | 56 | 0 |
| 5 | | 113. | | | 18 | 14 | 0 |
| 5 | | 125. | | | 7 | 4 | 0 |
| L5 | | 167. | | | | | 0 |
| L5 | | 157. | | | 4 | 2 | 0 |
| L5 | | 231. | | | | | 0 |
| L5 | | 262. | | | | | 0 |
| L5 | | 278. | | | | | 0 |
| 5 | | | | | | | 0 |
| 20 | | 210. | | | 11 | 7 | 0 |
| 40 | | 78.4 | | | 128 | 112 | 0 |
| 20 | | 99.5 | | | 27 | 20 | 0 |
| 5 | | 109. | | | 24 | 30 | 0 |
| L5 | | 171. | | | | | 0 |
| L5 | | 176. | | | | | 0 |
| 5 | | 246. | | | 30 | 34 | 0 |
| L5 | | 268. | | | | | 0 |
| L5 | | 272. | | | | | 0 |
| 5 | | 292. | | | | | 0 |
| 8 | | 259. | | | 4 | 2 | 0 |
| 10 | | 116. | | | 2 | 11 | 0 |
| 70 | | 80.8 | | | 179 | 158 | 0 |
| 5 | | 92.0 | | | | | 0 |
| 10 | | 124. | | | | | 0 |
| 15 | | 331. | | | | | 0 |
| 5 | | 158. | | | | | |
| L5 | | 249. | | | | | |
| 10 | | 328. | | | | | |
| L5 | | 257 | | | | | |

STATION 00AL07GA0001 LATITUDE 530 57M LONGITUDE 1190 9M

| SAMPLE DATE / TIME MST D M Y H M | 02011L COLOUR APPARENT REL. UNITS | 10602L HARDNESS TOTAL (CALCD.) CACO3 MG/L | 10603L HARDNESS TOTAL CACO3 MG/L | 10451L RESIDUE FILTERABLE MG/L | 10551L RESIDUE FIXED FILTERABLE MG/L | 10401L RESIDUE NONFILTR. MG/L | 10501L RESIDUE FIXED NONFILTR. MG/L | 10151L ALKALINITY PHENOL-PHTHALEIN CACO3 MG/L |
|---|---|---|---|---|---|---|---|---|
| 19 2 74 | L5 | | 267. | | | | | 0 |
| 1 5 74 | 40 | | 157. | | | 32 | | 0 |
| 14 5 74 | 30 | | 157. | | | 5 | 5 | 0 |
| 30 5 74 12 10 | 30 | | 131. | | | | | 0 |
| 15 8 74 11 15 | 5 | | 109. | | | | | 0 |
| 20 10 74 11 24 | L5 | | 101. | | | | | 0 |
| 30 1 75 17 15 | L5 | | 262. | | | | | 0 |

- 1

STATION 00AL07GA0001 LATITUDE 53° 57M LONGITUDE 119D 0M

SMOKY RIVER ABOVE HELLS CREEK, ALBERTA

| SAMPLE DATE TIME MST (D M Y H M) | 20101L CALCIUM DISSOLVED CA MG/L | 12102L MAGNESIUM DISSOLVED MG MG/L | 12101L MAGNESIUM DISSOLVED (CALCD.) MG MG/L | 11103L SODIUM DISSOLVED NA MG/L | 17203L CHLORIDE DISSOLVED CL MG/L | 16303L SULPHATE DISSOLVED SO4 MG/L | 06201L BICARBONT. (CALCD.) HCO3 MG/L | 00201L TOTAL DISSOLVED SOLIDS (CALCD.) MG/L |
|---|---|---|---|---|---|---|---|---|
| 27 5 70 | 25.2 | | 6.6 | 1.4 | 0.3 | 24.2 | 78 | 99 |
| 3 11 70 | 60.2 | | 16.4 | 3.5 | 0.6 | 97.2 | 145 | 253 |
| 24 11 70 | 71.1 | | 22.2 | 4.3 | 1.1 | 154. | 135 | 324 |
| 15 12 70 | 59.7 | | 18.4 | 3.2 | 1.3 | 127. | 119 | 272 |
| 5 1 71 | 59.6 | | 19.7 | 3.3 | 1.3 | 135. | 109 | 276 |
| 2 2 71 | 65.0 | | 19.6 | 2.9 | 1.2 | 140. | 120 | 292 |
| 23 2 71 | 75.3 | | 20.6 | 3.2 | 1.6 | 147. | 152 | 327 |
| 16 3 71 | 76.1 | | 22.3 | 3.8 | 1.1 | 151. | 154 | 334 |
| 6 4 71 | 70.6 | | 20.6 | 3.5 | 1.0 | 142. | 145 | 312 |
| 1 6 71 | 23.4 | | 5.8 | 1.2 | 0.5 | 18.5 | 76 | 99 |
| 22 6 71 | 24.0 | | 6.3 | 1.0 | 0.1 | 21.8 | 76 | 93 |
| 21 7 71 | 24.7 | | 6.2 | 1.0 | 0.3 | 21.1 | 81 | 95 |
| 24 7 71 | 32.0 | | 8.0 | 1.2 | 0.3 | 37.0 | 90 | 125 |
| 21 9 71 | 37.1 | | 7.9 | 1.4 | 0.3 | 47.5 | 94 | 143 |
| 26 10 71 | 45.3 | | 13.1 | 1.9 | 0.7 | 71.7 | 121 | 196 |
| 23 11 71 | 41.3 | | 13.1 | 2.1 | 0.7 | 73.4 | 101 | 194 |
| 11 1 72 | 66.8 | | 15.6 | 2.9 | 0.9 | 124. | 130 | 278 |
| 2 2 72 | 72.5 | | 19.7 | 3.4 | 1.4 | 140. | 150 | 315 |
| 23 2 72 | 81.9 | | 17.8 | 3.5 | 1.4 | 144. | 160 | 332 |
| 14 4 72 | | | | | | | | |
| 3 5 72 | 61.2 | | 13.9 | 3.6 | 1.4 | 89.8 | 149 | 247 |
| 6 6 72 | 22.8 | | 5.2 | 0.7 | 0.3 | 17.3 | 75 | 85 |
| 18 7 72 | 30.7 | | 5.5 | 1.4 | 0.5 | 30.8 | 85 | 112 |
| 28 8 72 | 32.5 | | 6.8 | 1.0 | 0.3 | 36.2 | 85 | 121 |
| 27 9 72 | 50.2 | | 11.1 | 1.8 | 0.6 | 75.8 | 122 | |
| 31 10 72 | 46.9 | | 14.2 | 2.1 | 0.6 | 73.6 | 122 | 201 |
| 12 12 72 | 96.8 | | 25.3 | 4.2 | 1.2 | 169. | 213 | 407 |
| 5 1 73 | 73.6 | | 20.5 | 3.1 | 1.0 | 132. | 160 | 313 |
| 2 2 73 | 73.4 | | 21.5 | 3.6 | 1.4 | 145. | 159 | 328 |
| 27 2 73 | 81.4 | | 21.6 | 3.6 | 1.4 | 149. | 163 | 342 |
| 26 4 73 | 71.9 | | 19.3 | 3.4 | 1.4 | 118. 041 | 161 | 237 |
| 12 6 73 | 32.6 | | 8.4 | 1.7 | 0.4 | 33.3 | 99 | 127 |
| 26 6 73 | 23.8 | | 5.2 | 0.9 | 0.2 | 20.0 041 | 74 | 99 |
| 24 7 73 | 26.0 | | 6.6 | 0.9 | 0.5 | 27.0 041 | 79 | 102 |
| 21 8 73 | 36.0 | | 8.3 | 1.4 | 0.9 | 45.0 041 | 94 | 141 |
| 28 8 73 10 10 | 38.0 | | 8.8 | 1.4 | 0.9 | 52.0 041 | 98 | 15[illegible] |
| 25 9 73 | 47.0 | | 9.9 | 1.8 | 0.4 | 69.0 041 | 105 | 193 |
| 8 1 74 | 68.0 | | 19.2 | 3.1 | 1.1 | 117. 041 | | 236 |
| [illegible] 74 | 7[illegible] | | | 1 | 1 * | 152. 041 | 201 | 23[illegible] |

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STATION 00AL07GA000I LATIT

| SAMPLE DATE D | M | Y | TIME MST H | M | 20101L CALCIUM DISSOLVED CA MG/L | 12102L MAGNESIUM DISSOLVED MG MG/L | 12101L MAGNESIUM DISSOLVED (CALCD.) MG MG/L |
|---|---|---|---|---|---|---|---|
| 19 | 2 | 74 | | | 69.0 | | 23.0 |
| 1 | 5 | 74 | | | 42.0 | | 12.7 |
| 14 | 5 | 74 | | | 44.0 | | 11.4 |
| 30 | 5 | 74 | 12 | 1) | 34.0 | | 11.2 |
| 15 | 8 | 74 | 11 | 15 | 30.0 | | 8.3 |
| 20 | 10 | 74 | 11 | 24 | 28. | | 7.5 |
| 30 | 1 | 75 | 17 | 15 | 74. | | 18.8 |

STATION 00AL07GA0001 LATITUDE 530 57M LONGITUDE 190 0M

SMOKY RIVER ABOVE HELLS CREEK, ALBERTA

| SAMPLE DATE D M Y | TIME MST H M | 10101L ALKALINITY TOTAL CACO3 MG/L | 09105L FLUORIDE DISSOLVED F MG/L | 19103L POTASSIUM DISSOLVED K MG/L | 14102L SILICA REACTIVE SIO2 MG/L | 06711L CHLORO-PHYLL A MG/L | 26102L IRON DISSOLVED FE MG/L | 26304P IRON EXTRABLE. FE MG/L | 06531P PHENOLIC MATERIAL PHENOL MG/L |
|---|---|---|---|---|---|---|---|---|---|
| 27 5 70 | | 64 | 0.08 | [illegible] | 2.6 | | 0.020 | | |
| 3 11 70 | | 119 | 0.14 | [illegible] | 3.0 | | L.001 | | |
| 24 11 70 | | 111 | | [illegible] | 3.7 | | L.001 | | |
| 15 12 70 | | 97 | 0.13 | [illegible] | 3.0 | | L.001 | | |
| 5 1 71 | | 89 | | [illegible] | 3.2 | | L.001 | | |
| 2 2 71 | | 98 | 0.14 | 0.6 | 3.3 | | L.001 | | |
| 23 2 71 | | 125 | 0.15 | 0.7 | 3.4 | | 0.030 | | |
| 16 3 71 | | 126 | 0.14 | 0.4 | 3.4 | | 0.010 | | |
| 6 4 71 | | 119 | 0.15 | 0.6 | 2.6 | | L.001 | | |
| 1 6 71 | | 63 | L.05 | 0.4 | 1.9 | | 0.010 | | |
| 22 6 71 | | 63 | 0.06 | 0.2 | 2.1 | | 0.010 | | |
| 14 7 71 | | | | | | | | 1.23 | |
| 21 7 71 | | 67 | 0.05 | 0.3 | 1.9 | | L.001 | | |
| 24 7 71 | | 74 | 0.07 | 0.3 | 2.0 | | 0.010 | | |
| 26 7 71 | | | | | | | | 0.98 | |
| 17 8 71 | | | | | | | | 1.15 | |
| 21 9 71 | | 77 | 0.10 | 0.3 | 2.5 | | 0.010 | | |
| 26 10 71 | | 99 | 0.11 | 0.4 | 3.0 | | 0.070 | | |
| 23 11 71 | | 83 | 0.10 | 0.4 | 3.1 | | 0.030 | | |
| 11 1 72 | | 107 | 0.16 | 0.6 | 3.4 | | L.001 | | |
| 2 2 72 | | 123 | 0.17 | 0.7 | 3.6 | | L.001 | | |
| 23 2 72 | | 131 | 0.17 | 0.7 | 3.7 | | L.001 | | |
| 14 4 72 | | 11 | | 0.2 | 0.2 | | L.001 | | |
| 3 5 72 | | 122 | 0.12 | 1.3 | 3.1 | | L.001 | | |
| 6 6 72 | | 62 | 0.06 | 0.3 | 1.7 | | 0.020 | | |
| 18 7 72 | | 69 | 0.07 | 0.3 | 1.6 | | L.001 | | |
| 28 8 72 | | 70 | 0.08 | 0.4 | 2.1 | | L.05 041 | | |
| 27 9 72 | | 100 | 0.12 | 0.5 | | | 0.100 | | |
| 31 10 72 | | 100 | 0.12 | 0.6 | 2.8 | | L.05 041 | | |
| 12 12 72 | | 175 | 0.15 | 0.7 | 4.8 | | L.001 | | |
| 5 1 73 | | 131 | 0.16 | 0.7 | 3.4 | | L.001 | | |
| 2 2 73 | | 130 | 0.12 | 0.9 | 4.0 | | 0.010 | | |
| 27 2 73 | | 134 | 0.16 | 0.8 | 3.7 | | L.001 | | |
| 26 4 73 | | 132 | 0.15 | 0.7 | 3.5 | | L.05 041 | | |
| 12 6 73 | | 80 | | 0.4 | 2.7 | | L.05 041 | | |
| 26 6 73 | | 63 | 0.07 | 0.3 | 2.2 | | L.05 041 | | |
| 24 7 73 | | 64 | 0.07 | 0.2 | 2.0 | | L.05 041 | | |
| 21 8 73 | | 77 | | 0.4 | 2.5 | | L.05 041 | | |
| [illegible] | [illegible] | | | | | | | [illegible] | |

STATION 00AL07GA0001 LATITUDE 53D 57M LONGITUDE 119D 9M

| SAMPLE DATE D M Y | TIME MST H M | 10101L ALKALINITY TOTAL CACO3 MG/L | 09105L FLUORIDE DISSOLVED F MG/L | 19103L POTASSIUM DISSOLVED K MG/L | 14102L SILICA REACT.VE SIO2 MG/L | 06711L CHLORO-PHYLL A MG/L | 26102L IRON DISSOLVED FE MG/L | 26304P IRON EXTRBLE. FE MG/L | 06531P PHENOLIC MATERIAL PHENOL MG/L |
|---|---|---|---|---|---|---|---|---|---|
| 8 1 74 | | 122 | 0.17 | 0.5 | 3.7 | | L.05 04L | | |
| 12 1 74 | 12 30 | 165 | 0.22 | 0.7 | 4.7 | L.001 | | 0.05 | L.002 |
| 30 1 74 | | 126 | 0.17 | 0.7 | 3.6 | | L.05 04L | | |
| 19 2 74 | | 124 | 0.16 | 0.5 | 3.6 | | L.05 04L | | |
| 1 5 74 | | 100 | 0.10 | 0.6 | 3.3 | | L.05 04L | | |
| 14 5 74 | | 104 | 0.11 | 4.0 | 3.4 | | L.05 04L | | |
| 30 5 74 | 12 10 | 94 | 0.07 | 0.5 | 3.0 | L.001 | | 0.19 | 0.0[illegible]4 |
| 15 8 74 | 11 15 | 77 | 0.07 | 0.4 | 2.1 | 0.006 | | 0.22 | |
| 20 10 74 | 11 24 | 67 | L.05 | 0.3 | 2.6 | L.005 | | 0.08 | |
| 30 1 75 | 17 15 | 126 | 0.16 | 0.6 | 3.6 | L.005 | | L.04 | |

STATION 00AL07GA0001 LATITUDE 530 57M LONGITUDE 1190 9M

SMOKY RIVER ABOVE HELLS CREEK, ALBERTA

| SAMPLE DATE TIME MST D M Y H M | 15255L PHOSPHORUS DISSOLVED ORTHO PO4 P MG/L | 15413L PHOSPHORUS TOTAL PHOSPHATE P MG/L | 07108L NITROGEN DISSOLVED NO3 & NO2 N MG/L | 07001L NITROGEN TOTAL KJELDAHL N MG/L | 07602L NITROGEN TOTAL (CALCD.) N MG/L | 06051L CARBON TOTAL INORGANIC C MG/L | 06001L CARBON TOTAL ORGANIC C MG/L | 03301P LITHIUM EXTRBLE. LI MG/L |
|---|---|---|---|---|---|---|---|---|
| 27 5 70 | L.002 57L | | | | | | | |
| 3 11 70 | L.002 59L | | 0.040 05L | | | | | |
| 24 11 70 | L.002 59L | | 0.060 05L | | | | | |
| 15 12 70 | 0.003 59L | | 0.070 05L | | | | | |
| 5 1 71 | L.002 59L | | 0.070 05L | | | | | |
| 2 2 71 | L.002 59L | | 0.070 05L | | | | | |
| 23 2 71 | 0.003 59L | | 0.080 05L | | | | | |
| 16 3 71 | 0.003 59L | | 0.060 05L | | | 26.0 | 4.0 | |
| 6 4 71 | 0.030 | | 0.050 05L | | | 21.0 | L.5 | |
| 1 6 71 | L.002 | 0.098 | L.005 05L | | | 13.0 | 8.0 | |
| 22 6 71 | L.002 | | 0.050 05L | | | 16.0 | 4.0 | |
| 29 6 71 19 20 | | | | | | | | L.005 |
| 14 7 71 | | | | | | | | L.005 |
| 21 7 71 | L.002 | | 0.030 05L | | | 13.0 | 4.0 | |
| 24 7 71 | L.002 | | 0.230 05L | | | 12.0 | 2.0 | |
| 26 7 71 | | | | | | | | L.005 |
| 17 8 71 | | | | | | | | 0.005 |
| 21 9 71 | L.002 | | 0.050 05L | | | 10.0 | 4.0 | |
| 26 10 71 | L.002 | | 0.060 05L | | | 13.0 | 3.0 | |
| 23 11 71 | L.002 | | 0.050 05L | | | 14.0 | 8.0 | |
| 11 1 72 | L.002 | | 0.070 05L | | | 25.0 | L.5 | |
| 2 2 72 | L.002 | | 0.100 05L | | | 27.0 | 2.0 | |
| 23 2 72 | L.002 | | 0.110 05L | | | 20.0 | 10.0 | |
| 14 4 72 | L.002 | | 0.240 05L | | | 3.0 | 4.0 | |
| 3 5 72 | L.002 | | 0.070 05L | | | 19.0 | 8.0 | |
| 6 6 72 | L.002 | | 0.040 05L | | | 1[illegible].0 | 20.0 | |
| 18 7 72 | L.002 | | 0.020 06L | | | 1[illegible].0 | 2.0 | |
| 28 8 72 | L.002 | | 0.320 06L | | | 1[illegible].0 | 4.0 | |
| 27 9 72 | L.002 | | 0.030 06L | | | 1[illegible].0 | 2.0 | |
| 31 10 72 | 0.003 | | 0.030 05L | | | 2[illegible].0 | 4.0 | |
| 12 2 72 | 0.004 | | 0.210 06L | | | | | |
| 5 1 73 | L.002 | | 0.080 06L | | | 25.0 | L.5 | |
| 2 2 73 | L.002 | | 0.070 06L | | | 24.0 | 2.0 | |
| 27 2 73 | L.002 | | 0.060 06L | | | 25.0 | 1.0 | |
| 26 4 73 | L.002 | | 0.040 06L | | | 22.0 | 2.0 | |
| 12 6 73 | L.002 | | 0.020 06L | | | 13.0 | 5.0 | |
| 26 6 73 | L.002 | | 0.120 06L | | | 15.0 | 3.0 | |
| 24 7 73 | L.002 | | 0.160 06L | | | 12.0 | 2.0 | |
| 21 8 73 | L.002 | | | | | 17.0 | 1.0 | |
| 28 8 | | | | | | | | |

STATION 00AL07GA0001 LATITUDE 53D 57M LONGITUDE 119D 0M

| SAMPLE DATE D M Y | TIME MST H M | 15255L PHOSPHORUS DISSOLVED ORTHO PO4 P MG/L | 15413L PHOSPHORUS TOTAL PHOSPHATE P MG/L | 07108L NITROGEN DISSOLVED NO3 & NO2 N MG/L | 07001L NITROGEN TOTAL KJELDAHL N MG/L | 07602L NITROGEN TOTAL (CALCD.) N MG/L | 06051L CARBON TOTAL INORGANIC C MG/L | 06001L CARBON TOTAL ORGANIC C MG/L | 03301P LITHIUM EXTRBLE. LI MG/L |
|---|---|---|---|---|---|---|---|---|---|
| 25 9 73 | | L.002 | | 0.010 06L | | | 16.0 | 2.0 | |
| 8 1 74 | | L.002 | | 0.160 06L | | | 27.0 | 2.0 | |
| 12 1 74 | 12 30 | | 0.011 | 0.080 06L | L.5 | 0.08 | 14.0 | 2.0 | |
| 30 1 74 | | L.002 | | 0.100 06L | | | 20.0 | L.5 | |
| 19 2 74 | | L.002 | | 0.100 06L | | | 18.0 | 2.0 | |
| 1 5 74 | | L.003 | | 0.090 06L | | | 19.0 | 11.0 | |
| 14 5 74 | | L.002 | | 0.230 06L | | | 22.0 | 2.0 | |
| 30 5 74 | 12 10 | | 0.011 | 0.050 06L | L.5 | 0.05 | 17.0 | 4.0 | |
| 15 8 74 | 11 15 | | | 0.020 06L | L.5 | 0.02 | 13.0 | 2.0 | |
| 20 10 74 | 11 24 | | | 0.04 06L | 0.3 | 0.34 | 13. | 2. | |
| 30 1 75 | 17 15 | | | 0.06 06L | 0.5 | 0.56 | 20. | 2. | |

WATER QUALIT

STATION 00AL07GA0001 LATIT

SMOKY RIVER ABOVE HELLS CREEK, ALBERTA

| SAMPLE DATE TIME MST D M Y H M | 25101L MANGANESE DISSOLVED MN MG/L | 25304P MANGANESE EXTRBLE. MN MG/L | 29105L COPPER DISSOLVED CU MG/L |
|---|---|---|---|
| 27 5 70 | | L.01 04L | |
| 3 11 70 | | L.01 04L | 0.001 |
| 24 11 70 | L.01 04L | | L.001 |
| 15 4 71 | L.01 04L | | 0.003 |
| 5 1 71 | L.01 C4L | | L.001 |
| 2 2 71 | L.01 04L | | 0.002 |
| 23 2 71 | L.01 04L | | 0.002 |
| 16 3 71 | 0.01 04L | | 0.001 |
| 6 5 71 | L.01 04L | | L.001 |
| 1 6 71 | L.01 04L | | L.001 |
| 22 6 71 | L.01 04L | | L.001 |
| 29 6 71 19 20 | | 0.02 | |
| 14 7 71 | | 0.04 | |
| 21 7 71 | L.01 04L | | L.001 |
| 24 7 71 | L.01 04L | | L.001 |
| 26 7 71 | | 0.03 | |
| 17 8 71 | | 0.04 | |
| 21 9 71 | L.01 04L | | L.001 |
| 26 10 71 | L.01 04L | | L.001 |
| 23 11 71 | L.01 C4L | | 0.001 |
| 11 1 72 | L.01 C4L | | 0.002 |
| 2 2 72 | L.01 04L | | 0.003 |
| 23 2 72 | L.01 04L | | 0.004 |
| 14 4 72 | L.01 04L | | 0.003 |
| 3 5 72 | L.01 04L | | 0.003 |
| 6 6 72 | L.01 04L | | L.001 |
| 18 7 72 | L.01 04L | | 0.002 |
| 28 8 72 | L.01 04L | | 0.002 |
| 27 9 72 | L.01 04L | | 0.001 |
| 21 10 72 | L.001 05L | | L.001 |
| 12 12 72 | L.01 04L | | L.001 |
| 5 1 73 | | | L.001 |
| 2 2 73 | | | L.001 |
| 27 2 73 | L.01 04L | | 0.001 |
| 26 4 73 | L.01 C14L | | 0.006 |
| 12 6 73 | L.01 04L | | 0.001 |
| 26 6 73 | L.01 04L | | 0.003 |
| 24 7 73 | L.01 04L | | L.001 |
| 21 9 77 | L.01 04L | | L.001 |

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STATION 00 AL07GA0001 LATITU

| SAMPLE DATE D M Y | TIME MST H M | 25191 L MANGANESE DISSOLVED MN MG/L | | 25304P MANGANESE EXTRBLE. MN MG/L | 29105L COPPER DISSOLVED Cu MG/L |
|---|---|---|---|---|---|
| 25 9 73 | | L.01 | 04L | | L.001 |
| 8 1 74 | | L.01 | 04 L | | 0.003 |
| 12 1 74 | 12 30 | | | L.01 | |
| 30 1 74 | | L.01 | 04L | | 0.006 |
| 19 2 74 | | L.01 | 04 L | | 0.002 |
| 1 5 74 | | L.01 | 04L | | 0.007 |
| 14 5 74 | | L.01 | 04 L | | 0.005 |
| 30 5 74 | 12 19 | | | L.01 | |
| 15 8 74 | 11 15 | | | L.01 | |
| 20 10 74 | 11 24 | | | L.010 | |
| 39 1 75 | 17 15 | | | L.010 | |

STATION 00AL07GA0001                LATITUDE 53D 57M        LONGITUDE 119D 9M

SMOKY RIVER ABOVE HELLS CREEK, ALBERTA

| SAMPLE DATE TIME MST (D M Y H M) | 24052L CHROMIUM DISSOLVED CR MG/L | 24302P CHROMIUM EXTRBLE. CR MG/L | 28101L NICKEL DISSOLVED NI MG/L | 28302P NICKEL EXTRBLE. NI MG/L | 27102L COBALT DISSOLVED CO MG/L | 27302P COBALT EXTRBLE. CO MG/L | 42101L MOLYBDENUM DISSOLVED MO MG/L | 42301P MOLYBDENUM EXTRBLE. MO MG/L |
|---|---|---|---|---|---|---|---|---|
| 29 6 71 19 20 | | L.010 | | L.01 01P | | L.01 01P | | L.05 |
| 14 7 71 | | L.010 | | L.01 01P | | L.01 01P | | L.05 |
| 26 7 71 | | L.010 | | L.01 01P | | L.01 01P | | L.05 |
| 17 8 71 | | L.010 | | L.01 01P | | L.01 01P | | L.05 |
| 28 8 73 10 10 | | L.010 | | L.001 | | L.001 | | L.05 |
| 12 1 74 12 30 | | L.010 | | 0.005 | | 0.003 | | L.05 |
| 30 5 74 12 10 | | L.010 | | L.001 | | 0.013 | | [illegible] |
| 15 8 74 11 15 | | L.010 | | 0.011 | | 0.006 | | 0.15 |
| 20 10 74 11 24 | | L.015 | | 0.004 | | 0.003 | | 0.10 |
| 30 1 75 17 15 | | L.015 | | L.002 | | L.002 | | 0.10 |

WATER QUALITY DATA    REQUEST 0038    PAGE 1

STATION 00AL07GA0001    LATITUDE 53D 57M    LONGITUDE 119D 6M

SMOKY RIVER ABOVE HELLS CREEK, ALBERTA

| SAMPLE DATE D M Y | TIME MST H M | 48101L CADMIUM DISSOLVED CD MG/L | 48302P CADMIUM EXTRBLE. CD MG/L | 13101L ALUMINUM DISSOLVED AL MG/L | 13302P ALUMINUM EXTRBLE. AL MG/L | 23301P VANADIUM EXTRBLE. V MG/L | 38301P STRONTIUM EXTRBLE. SR MG/L | 56301P BARIUM EXTRBLE. BA MG/L | 05105L BORON DISSOLVED B MG/L |
|---|---|---|---|---|---|---|---|---|---|
| 29 6 71 | 19 20 | | L.01 01P | | 0.31 | L.05 | 0.20 | L.1 | |
| 14 7 71 | | | L.01 01P | | 1.3 | L.05 | 0.21 | L.1 | |
| 26 7 71 | | | L.01 01P | | 1.4 | L.05 | 0.25 | L.1 | |
| 17 8 71 | | | L.01 01P | | 2.0 | L.05 | 0.20 | L.1 | |
| 28 8 73 | 10 10 | | L.001 | | 0.11 | | 0.40 | L.1 | L.02 |
| 12 1 74 | 12 30 | | L.001 | | L.10 | | 1.05 | L.1 | 0.05 |
| 30 5 74 | 12 10 | | L.001 | | 0.10 | | 0.20 | L.1 | 0.02 |
| 15 8 74 | 11 15 | | 0.003 | | L.10 | | 0.27 | L.1 | 0.05 |
| 20 10 74 | 11 24 | | L.001 | | 0.10 03P | | 0.22 | L.1 | 0.02 |
| 30 1 75 | 17 15 | | L.001 | | 0.01 03P | | 0.07 | L.1 | 0.04 |

STATION 00AL07GA0001 LATITUDE 530 57M LONGITUDE 1190 0M

SMOKY RIVER ABOVE HELLS CREEK, ALBERTA

| SAMPLE DATE TIME MST D M Y H M | 33103L ARSENIC DISSOLVED AS MG/L | 33303P ARSENIC EXTRBLE. AS MG/L | 10711L NTA NITRILOTRI ACETIC AC. H3NTA MG/L | 80311P MERCURY EXTRBLE. HG UG/L | 80111L MERCURY DISSOLVED HG UG/L | 47301P SILVER EXTRBLE. AG MG/L | 47101L SILVER DISSOLVED AG MG/L |
|---|---|---|---|---|---|---|---|
| 27 5 70 | | | | | L.05 | | |
| 29 6 71 19 20 | L.005 | | | L.05 | | L.01 | |
| 14 7 71 | | | | L.05 | | L.01 | |
| 26 7 71 | L.005 | | | 0.08 | | L.01 | |
| 17 8 71 | | | | 0.13 | | L.01 | |
| 28 8 73 10 10 | | | | L.05 | | L.01 | |
| 12 1 74 12 30 | | | | L.05 | | L.01 | |
| 30 5 74 12 10 | | | | L.05 | | L.01 | |
| 15 8 74 11 15 | | | | L.05 | | | |
| 20 10 74 11 24 | | | | L.05 | | | |
| 30 1 75 17 15 | | | | L.05 | | | |

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STATION 00AL07GA0001 LATI

SMOKY RIVER ABOVE HELLS CREEK,ALBERTA

| SAMPLE DATE TIME MST | 18140L ENDRIN | 18520L MCPA | 18161L AROCLOR 1248 (PCB'S) |
|---|---|---|---|
| D M Y H M | UG/L | UG/L | UG/L |
| 29 6 71 19 23 | | | |
| 14 7 71 | | | |
| 26 7 71 | | | |
| 17 8 71 | | | |
| 28 8 73 10 10 | | | L.032 |
| 12 1 74 12 30 | | | L.024 |
| 30 5 74 12 10 | | | L.02 |