Non-Treaty Storage Agreement

Technical Report: Appendices M - O

Bonneville
POWER ADMINISTRATION

March 1990

APPENDIX O

CANADIAN ENVIRONMENTAL REPORT

B.C. HYDRO AND POWER AUTHORITY
COLUMBIA RIVER
RESERVOIR COORDINATION STUDIES

ENVIRONMENTAL IMPACT ASSESSMENT

SUMMARY REPORT

TRITON
Environmental Consultants Ltd.

EXECUTIVE SUMMARY

The British Columbia Hydro and Power Authority (BCHPA) is presently negotiating a reservoir coordination agreement with Bonneville Power Administration (BPA) to utilize the storage of water in reservoirs controlling the Columbia River, beyond that covered under the existing Columbia River Treaty and the existing Non-Treaty Storage Agreement. This summary report has been produced as a background document for public information and discussion on the proposed changes in reservoir operation.

The intent of a new agreement for use of non-treaty storage is to optimize power generation over the whole length of the Columbia River within licence and power transmission restraints. Currently, 2.47 x 10^9 m^3 (2.0 million acre feet (MAF)) of Mica Reservoir non-treaty storage is being utilized under the present Non-Treaty Storage Agreement, which expires in 1993. BCHPA proposes to make an additional 3.71 x 10^9 m^3 (3.0 MAF) of non-treaty storage behind Mica Dam available for use under the proposed new agreement. This water can be used to generate additional hydroelectric energy at both Mica and Revelstoke Dam generation facilities as well as at U.S. facilities along the Columbia River.

This report summarizes the findings of an assessment of the potential environmental impacts of four alternate reservoir operating regimes, including effects on water quality, fish, wildlife, heritage resources, and water-based uses relating to settlements, forestry, agriculture and recreation in the areas adjacent to Mica and Arrow Lakes Reservoirs. Each regime was compared to an associated base case. The comparisons were selected to bound potential impacts and determine the sensitivity of resources to each regime. Actual operation is likely to be a combination of or variation on these basic regimes at different times during the agreement. Each regime utilizes the total non-treaty storage (6.18 x 10^9 m^3 (5.0 MAF)) behind Mica Dam and tests, in order, different assumptions for energy loading scenarios including medium loads and opportunity energy sales (Regime 1), changes in energy production priorities, termed Alternate Resource Order (Regime 1, ARO), more active marketing of energy, termed Alternate Operating Scenario (Regime 1, AOS) and firm energy sales (Regime 2).

Physical data on the alternate reservoir operating regimes were supplied by BCHPA in conjunction with BPA, consisting of statistical distributions of monthly reservoir elevations and outflows from Mica and Arrow Lakes Reservoirs. These data were subsequently put into graph and summary table format by Triton Environmental Consultants Ltd. for use in the comparative analyses. The statistical data were generated by BPA's System Analysis Model (SAM), which simulated operation of the U.S. Pacific Northwest and B.C. power systems on a monthly basis.

Environmental Resources and Resource Uses

Mica Reservoir

Mica Reservoir is licensed to be operated between a minimum elevation of 707 m (2320 ft) and a maximum elevation of 754 m (2475 ft) (an operating range of 47 m (155 ft)). It currently is operated between approximately 735 m (2411 ft) and full pool. The reservoir is a deep, cold, nutrient-poor lake, with low biological productivity. Rainbow trout, kokanee, Dolly Varden char and Mountain whitefish are the most important and abundant sport fish. Due to the steepness of the slopes above the reservoir and in the drawdown zone itself, Mica Reservoir does not provide good habitat for most species of wildlife. Most waterfowl use occurs in the few areas of flat or gently-sloping shoreline around the reservoir.

Forestry is the dominant resource industry in the region and large areas of Crown Land near the reservoir are held under various forest tenures. Valemount and Golden are the major employment, transportation, retailing and service centers for the region. None of the communities in the area utilize the reservoir as a water supply source.

Poor soils, a short growing season and distance to markets severely limit agricultural activity in the Mica Reservoir area. Recreation activity on and around the reservoir is light and confined mainly to the local population, although use has been slowly increasing over the years.

Arrow Lakes Reservoir

The Arrow Lakes Reservoir extends from Revelstoke in the north to Castlegar in the south.

The reservoir presently has a minimum elevation of 420 m (1378 ft) and a normal maximum elevation of 440.1 m (1444 ft), an operating range of 20 m (66 ft).

The Arrow Lakes Reservoir is deep and has fairly low biological productivity, although it is slightly more productive than Mica Reservoir. Rainbow trout, Dolly Varden char and kokanee are the principal sport fish. The Arrow Lakes occupy a deep north-south oriented valley which forms a natural migration route for many birds during spring and fall. The species of importance are primarily waterfowl and other aquatic/wetland species.

The largest communities are Revelstoke at the north end of Upper Arrow Lake, the City of Castlegar at the south end of Lower Arrow Lake, and Nakusp near the Narrows area. None of the communities except Castlegar use the reservoir as a source of water supply.

Forestry sustains most of the labour force in the area. The majority of land surrounding the reservoir is within Tree Farm Licence (TFL) #23 and provides logs to area sawmills. The majority of the logs go to Westar Timber's sawmill just north of Castlegar. The Celgar Pulp and Paper Company operates a water intake just upstream of Hugh Keenleyside Dam which supplies process and drinking water to its pulp mill near Castlegar, the Westar sawmill, and drinking water to Castlegar itself.

At present, there is limited agriculture in the Arrow Lakes area, mostly in the vicinity of Edgewood, Nakusp and Burton.

The Arrow Lakes Reservoir is large, scenic and more accessible than Mica Reservoir, and provides numerous recreation opportunities. Recreational use by both residents and tourists is increasing.

Downstream Area

Flows released from Hugh Keenleyside Dam control Columbia River water levels in the reach upstream of the confluence with the Kootenay River. Flows are greatest during winter in response to downstream water demands and decline to a low in March-April. The river provides resident fish with year-round, mostly open-water habitat with high rearing potential. Rainbow trout, kokanee, Dolly Varden char, whitefish and burbot are

the principal sportfish species. Because the flows are controlled and the spring freshet has been reduced, the river provides relatively stable habitat conditions for aquatic/riparian wildlife although riparian habitats are of limited extent. Relatively small numbers of birds, primarily migrants and wintering birds, utilize the river.

Trail is the largest community downstream of Castlegar and is the location of Cominco's large smelter, refinery and fertilizer complex. Cominco uses water from the river for its smelting and fertilizer complex at Trail and the Village of Warfield (population 1840) and the Tadanac subdivision of Trail also obtain their water from this intake. Effluent from these industrial complexes and from Castlegar's sewage treatment facility is discharged to the Columbia River. The major industrial user of the river, other than as a source of water, is the Westar Timber Corporation, which stores logs on the river prior to transporting them by water into its sawmill.

There is very little active agriculture in the vicinity of the Columbia River.

The river is considered to have moderate recreation capability. At present, there are few developed recreation facilities. The river is mainly used for recreation by regional residents.

Impact Assessment

Physical Effects

Regime 1 (Medium Load) Compared to Base Case (Medium Load)

With Regime 1 (medium load), the average elevation of the Mica Reservoir decreases during all times of the year, and the annual operating range increases by up to 6.4 m (21 ft) compared to the Base Case (medium load).

In the Arrow Lakes Reservoir, the annual average elevation difference between Regime 1 and the Base Case (medium loads) is 0.07 m (0.3 ft). Average elevations range from a decrease of 0.03 m (0.1 ft) in March, to an increase of 0.2 m (0.7 ft) in early April.

Average outflows from Hugh Keenleyside Dam increase in August through December and decrease January through July. With Regime 1, the highest average flow increase (235.7 m^3/s (8322.1 ft^3/s)) occurs in September, while the highest average flow reduction (116.8 m^3/s (4124.5 ft^3/s)) occurs in April.

Regime 1 (ARO) Compared to Base Case (ARO)

Under Regime 1 (ARO), the average elevation of the Mica Reservoir decreases, and its annual operating range increases by up to 6.7 m (22 ft) compared to the Base Case (ARO).

In the Arrow Lakes Reservoir, the annual average elevation difference between Regime 1 (ARO) and the Base Case (ARO) is 0.03 m (0.1 ft). Average changes in elevation range from no change in March, and June through August, to a 0.12 m (0.4 ft) increase in late April. No changes in maximum and minimum elevations will occur.

Average outflows from Hugh Keenleyside Dam generally increase in August through December and decrease in January through July, compared to the Base Case (ARO). With Regime 1 (ARO), the highest flow increase (225 m^3/s (7944.5 ft^3/s)) occurs in September, while the highest flow reduction (123.3 m^3/s (4354.7 ft^3/s)) occurs in late April.

Regime 1 (AOS) Compared to Base Case (AOS)

Under Regime 1 (AOS), the average elevation of Mica Reservoir decreases and its annual operating range increases by up to 7.8 m (25.6 ft) compared to the Base Case (AOS).

In the Arrow Lakes Reservoir, the annual average elevation difference between Regime 1 (AOS) and the Base Case (AOS) is 0.07 m (0.22 ft).

Average outflows from Hugh Keenleyside Dam generally increase in August through December, and decrease in January through July, compared to the Base Case (AOS). With Regime 1 (AOS), the highest average flow increase (215 m^3/s (7591.7 ft^3/s)) occurs in September, while the highest average flow reduction (108.5 m^3/s (3833.1 ft^3/s)) occurs in late April.

Regime 2 (Medium Load) Compared to Base Case (Medium Load)

Under Regime 2 (medium load), the average elevation of the Mica Reservoir decreases at all times of the year, and the annual operating range increases by up to 3.4 m (11.1 ft) compared to the Base Case (medium load).

In the Arrow Lakes Reservoir, the annual average elevation of the reservoir with Regime 2 (medium load) decreases by 0.03 m (0.1 ft) compared to the Base Case (medium load).

Average outflows from Hugh Keenleyside Dam generally increase in August through January, early April and June, and decrease in February, March, late April and May, compared to Base Case (medium load) outflows. Under Regime 2, the highest flow increase (101.0 m^3/s (3565.4 ft^3/s)) occurs in September, while the highest flow reduction (80.4 m^3/s (2839.4 ft^3/s)) occurs in February.

Biological Effects

Water Quality

The only area where water quality is a concern at present is the reach of the Columbia River downstream of Hugh Keenleyside Dam, due mainly to the effects of the Celgar pulp mill effluent. As the Celgar pulp mill near Castlegar will be required to comply with B.C. guidelines for effluent toxicity by 1991, future water quality will be improved compared to what it is today.

Fish and Fish Habitat

Mica Reservoir

The capability to predict the effects of water-level changes on aquatic biota in lower trophic levels is poor, however, changes in plankton production can be expected with implementation of any of the regimes. The generally lower reservoir levels should not adversely affect access to tributaries by spawning fish, except in three rivers. Migration barriers on the Wood and Beaver Rivers and Foster Creek would be exposed at various

times with all regimes. The extent and severity of this potential impact is difficult to assess since the proportion of the total fish population utilizing the three streams for spawning and rearing purposes is not known. However, it is likely that these three streams only contribute between 5 and 10% of the overall fish production of the reservoir.

The current drawdown zone does not provide productive fish habitat. Therefore, it is unlikely that reduced overall reservoir levels will have any effect on the amount of available rearing habitat in the reservoir or its tributaries. Due to the steep-sided slope of the reservoir and the effects of drawdown, shoreline spawning is already extremely limited and would remain so under both base case and alternate regime conditions.

Arrow Lakes Reservoir

For all regimes, the projected Arrow Lakes Reservoir elevations are very similar to the associated base case elevations. Increased entrainment of plankton, benthic invertebrates and fish from the Arrow Lakes during periods of rapid discharge is not expected to significantly affect the biological productivity of fish resources of the Arrow Lakes Reservoir. Overall, there are no anticipated impacts on fish utilizing the Arrow Lakes Reservoir.

Downstream Area

The different regimes will result in elevated outflows during August to December from the Arrow Lakes Reservoir compared to the base cases. There will likely be minor beneficial effects downstream of the Hugh Keenleyside Dam as increased outflows result in increased numbers of juvenile fish and invertebrates from Lower Arrow Lake being entrained over the dam to the downstream area.

Decreased outflows from Hugh Keenleyside Dam during the period January through July would result in small decreases in overall discharge in the Columbia River downstream of the dam which, in turn, could adversely affect important sport fish rearing and/or spawning habitat in the Columbia River below Hugh Keenleyside Dam. Eggs deposited during the high water period may become exposed when late winter - early spring downward fluctuations in water depth occur.

Wildlife Resources

Mica Reservoir

At present, variations in reservoir level, combined with other factors such as steepness of terrain, severely limit production of aquatic/wetland wildlife at Mica Reservoir. Therefore, increased annual ranges in reservoir level due to any of the reservoir operating regimes would have little incremental effect compared to the associated base cases. Generally lower reservoir levels at times when waterfowl, shorebirds and other species are migrating along the Rocky Mountain Trench should have no adverse impact because those birds primarily rest on sandbars and mudflats and such habitats will still be available.

Arrow Lakes Reservoir

With all regimes, differences between Arrow Lake elevations and the associated base case conditions are small. Slight, if any, incremental impacts on wildlife habitat or on waterfowl occurrence will result.

Downstream Area

With the alternate reservoir operating regimes, differences in average monthly outflows from Arrow Lake Reservoir compared to their associated base case flows are slight. Resulting changes in water depth and channel width in the Columbia River will be minor and are expected to have no measurable impact, positive or negative, on wildlife habitats or populations along the river.

Resource Uses

Forestry

Mica Reservoir

The problems forest companies experience with fluctuating reservoir levels, particularly with low levels, during June through October when water-based forestry activities occur on

Mica Reservoir, will be exacerbated if any of the regimes are implemented. As average elevations are substantially lower with Regime 1 (AOS) than with any other proposed operating regime, this regime will generally have the greatest impacts on forest industry activities in the area. With lower elevations, some barge points, log dumps and dewatering sites will require modification by lengthening ramps and skids, which would add to operating and maintenance costs. Some companies may have to delay start-up until July and may have difficulties even then, particularly with Regime 1 (AOS).

Arrow Lakes Reservoir

The very small differences in average reservoir elevations between all the regimes and their associated base cases, coupled with the fact that the range of elevations will not change, will result in slight, if any, impacts on water-based forestry activities, over and above those presently experienced.

Downstream Area

Present problems encountered by Westar in navigation, log storage and mill feeding operations may be exacerbated by the changes in outflows with all regimes. Incremental impacts may occur due to more frequent daily flow changes from the implementation of alternate regimes.

Recreation

Mica Reservoir

The relatively large decreases in reservoir levels during June through September under the different regimes compared to their associated base cases will cause access problems and an unattractive exposed drawdown area which will detract from the recreational appeal of the area. With several years with Regime 1 (medium load and ARO) and in the majority of years studied with Regime 1 (AOS), average June elevations are below the level at which protruding stumps create navigation hazards. The problem would not occur with Regime 2 (medium load).

Under the base cases, all boat launch ramps would be usable only from June through September. With the alternate regimes, none of the existing ramps except for Westar's barge points will be usable in May under average conditions, and several will not be usable during other recreation months, particularly June, in some years. With all alternate regimes and base cases, minimum elevations are generally always too low for use of the boat launch ramps, particularly at the private resorts in the southern half of the reservoir (at Esplanade Bay and Beavermouth Creek) and recreation sites at the northern end.

Sport fish populations may be affected by the alternate regimes, which may compound access and navigation impacts on recreational fishing.

Arrow Lakes Reservoir

The very slight differences in Arrow Lakes elevations between all four alternate regimes and their associated base cases are not expected to affect recreation. No measurable impacts are predicted on sport fish and wildlife, therefore recreational fishing and hunting will not be affected by the change in operating regime.

Downstream Area

With all regimes, the slight changes in median monthly outflows projected compared to the associated base case should not affect recreation facilities as they have been constructed to accommodate changes in flows. However, recreational boaters could experience navigation and access difficulties during prolonged periods of minimum or maximum flows under both alternates and base case.

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1.0 INTRODUCTION

The British Columbia Hydro and Power Authority (BCHPA) is presently negotiating a reservoir coordination agreement with Bonneville Power Administration (BPA) to utilize the storage of water in reservoirs controlling the Columbia River, beyond that covered under the existing Columbia River Treaty and the existing Non-Treaty Storage Agreement. This summary report has been produced as a background document for public information and discussion on the proposed changes in reservoir operation.

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Triton Environmental Consultants Ltd. (formerly Envirocon Pacific Ltd.) was contracted by BCHPA to assess the potential environmental impacts of changes in operation of the Mica and Arrow Lakes Reservoirs as a result of alternative reservoir operating regimes involving the use of non-treaty water storage.

The purpose of this report is to summarize the findings of an assessment of the potential environmental impacts of the alternate regimes, including effects on water quality, fish, wildlife, heritage resources, and water-based uses relating to settlements, forestry, agriculture and recreation. The detailed report is available from BCHPA upon request.

Environmental baseline and resource use information is briefly described in this report and the potential impacts of four alternative reservoir operations compared to associated base cases are discussed. The different regimes are described in Section 2.0.

Increased use of the non-treaty storage under negotiation between BCHPA and BPA would affect water storage in Mica Reservoir, impounded by Mica Dam and, consequently, operation of the Arrow Lakes Reservoir, impounded by Hugh Keenleyside Dam. Therefore, only these reservoirs are considered in this study. As the Revelstoke Canyon Power Project is operated as a run-of-river plant, and no change in its operation is contemplated under the proposed Non-Treaty Storage Agreement, it is not included in this study. Also, as the Revelstoke Reservoir extends almost to the base of Mica Dam, the small reach of the Columbia River below Mica Dam has not been considered in detail. However, the river system downstream of Hugh Keenleyside Dam has been considered in detail. The proposed agreement would not affect operation of projects on the Kootenay River system.

The cumulative effects of the use of additional non-treaty storage on any other energy projects which may be developed on the Columbia River, such as the proposed Murphy Creek project, have not been addressed in this report but will be addressed in other individual project studies.

2.0 DESCRIPTION OF OPERATING REGIMES

Physical data on alternate reservoir operating regimes were supplied by BCHPA in conjunction with BPA, consisting of statistical distributions of monthly reservoir elevations and outflows from Mica and Arrow Lakes Reservoirs. Semi-monthly data were supplied for April and August as the reservoirs reach minimum and maximum levels during these months, respectively, and data on any of the potential changes in the timing of the achievement of these levels were required. These data were subsequently put into graph and summary table format by Triton for use in the comparative analyses. The statistical data were generated by BPA's System Analysis Model (SAM), which simulated operation of the U.S. Pacific Northwest and B.C. power systems on a monthly basis. The SAM model incorporates statistical methods to simulate variations due to uncertainties in regional loads, thermal plant performance and streamflows. For each study case, a 20-year (1989-2008) simulation was run a total of 200 times, each time with a random selection of each variable. The result was 200 data points for each month of the study (240 months) for each parameter of interest (eg. Mica and Arrow elevations and outflows).

The data represent a statistical time series of possible outcomes for each regime in response to changes in both operating conditions and variations in reservoir inflows over the twenty year period. These statistical distributions cover the range of expected variation in each parameter for the assumed operating regime. The impact assessment is based mainly on projected median reservoir levels and outflows averaged over the 20-year study period. However, extreme minima and maxima have also been considered.

The SAM model attempts to simulate the actual operation of the power systems based on simplified decision criteria. The SAM model is intended to provide a reasonable indication of the range of operations expected for the non-treaty storage so that the SAM results can be used to assess the sensitivity of environmental resource impacts to different operating regimes. However, SAM does not predict the actual operation of the non-treaty storage, but rather gives and indication of the probability that the operation will be within certain limits for a particular operating regime.

The SAM studies examined two generic operating regimes: Regime 1 based on using non-treaty storage for opportunity sales, and Regime 2 based on using non-treaty storage as a firm resource. The operation of the non-treaty storage will not necessarily follow either of these generic regimes for the full term of the proposed agreement. Actual operation is likely to be a combination of or variation on these basic regimes at different times during the agreement.

The comparisons made for the assessment are indicated in Table 2.1.

2.1 No Action - Base Case Regime

The Base Case regime assumes that no new agreement is negotiated and that BCHPA continues to operate the reservoirs under the terms of the Columbia River Treaty and the current Non-Treaty Storage Agreement, which expires in 1993. The latter agreement calls for the use of 2.47×10^9 m^3 (2 MAF) of storage behind Mica Dam, divided equally between BCHPA and BPA. Base Case energy production is based on medium or average forecast loads.

TABLE 2.1

Comparisons Made in the Impact Assessment

	No Action		Proposal	Energy Load Scenario
1.	Base Case - 2.47 x 10^9 m^3 (2.0 MAF) of non-Treaty storage used to 1993.	vs.	Regime 1 - 6.18 x 10^9 m^3 (5.0 MAF) of non-Treaty storage used to 2008.	Medium Loads - opportunity sales of energy
2.	Base Case (ARO) - 2.47 x 10^9 m^3 (2.0 MAF) of non-Treaty storage used to 1993.	vs.	Regime 1 (ARO) - 6.18 x 10^9 m^3 (5.0 MAF) of non-Treaty storage used to 2008.	Alternate Resource Order - change in priority of energy production from facilities
3.	Base Case (AOS) - 2.47 x 10^9 m^3 (2.0 MAF) of non-Treaty storage used to 1993.	vs.	Regime 1 (AOS) - 6.18 x 10^9 m^3 (5.0 MAF) of non-Treaty storage used to 2008.	Alternate Operating Scenario for opportunity sales - more active use of non-Treaty storage
4.	Base Case - 2.47 x 10^9 m^3 (2.0 MAF) of non-Treaty storage used to 1993.	vs.	Regime 2 - 6.18 x 10^9 m^3 (5.0 MAF) of non-Treaty storage used to 2008.	Medium Loads - use non-Treaty storage as a firm resource

Cross reference to comparison in BPA's Environmental Assessment:

1. Base Case (ARO) vs. Regime 1 (ARO) is BPA's base case comparison under the "Opportunity Storage" proposal.

2. Base Case (AOS) vs. Regime 1 (AOS) is designated by BPA as the sensitivity comparison under the "Alternative Dispatch Criteria".

3. Base Case vs. Regime 2 is BPA's base case comparison under the "Firm Resource" proposal.

2.2 Non-Treaty Storage Agreement Alternative Operating Regimes

Under the operating regimes described below, the use of non-treaty is assumed to be expanded to 6.18 x 10^9 m^3 (5 MAF) and the period of operation is assumed to extend to 2008.

Regime 1

This regime assumes that the non-treaty storage would be used for opportunity sales by BPA and BCHPA. The intent is to store water in non-treaty storage during high runoff and poor market conditions, and release it at another time for generation to serve higher valued markets. The storage is not reserved to serve firm load, but serving firm load is not precluded. As with the Base Case, energy production is based on medium or average forecast loads.

Alternate Resource Order (ARO)

Current operating strategies for energy production assume that energy will be produced at different plants based on operation priorities. Changes to the priority given energy production at different plants could also affect the reservoir operations. Therefore, the environmental sensitivity of these changes is tested by making a comparison between current operating conditions and an alternate policy. These are designated the Alternate Resource Order (ARO) Base and Regime 1 cases, respectively.

BPA have indicated that the operation priorities under the ARO case are the more likely priorities that would be adopted for operation of U.S. projects.

Alternate Operating Scenario (AOS)

The strategies adopted by BCHPA and BPA for utilizing non-treaty storage to make opportunity sales may result in more active use of non-treaty storage. Therefore, a comparison is made in this report of the environmental consequences of more active and frequent use of non-Treaty storage under the Base Case, No-Action Scenario and Regime 1 to assess the sensitivity of environmental resources.

Regime 2

Under this operating regime, the use of non-treaty storage and term of agreement are the same as in Regime 1. However, the storage is assumed to be used as a firm resource by both BCHPA and BPA for the entire 20 year period to 2008. It is expected that the use of expanded non-treaty storage space would start by using Regime 1 and could potentially change to Regime 2 when additional resources are needed to meet firm load. By studying both alternatives, potential environmental effects can be bounded without specifying the exact time when the change may occur. The decision to use non-treaty storage as a firm resource may be made by either BPA or BCHPA independently of each other.

3.0 PROFILE OF ENVIRONMENTAL RESOURCES AND RESOURCE USES

The Columbia River in Canada flows north along the Rocky Mountain Trench for approximately 314 km (195 miles) to Big Bend where it makes a 180 degree turn around the northern end of the Selkirk Mountains. The river then flows south through the Arrow Lakes and crosses the international border just south of Trail, B.C. (Figure 3.1).

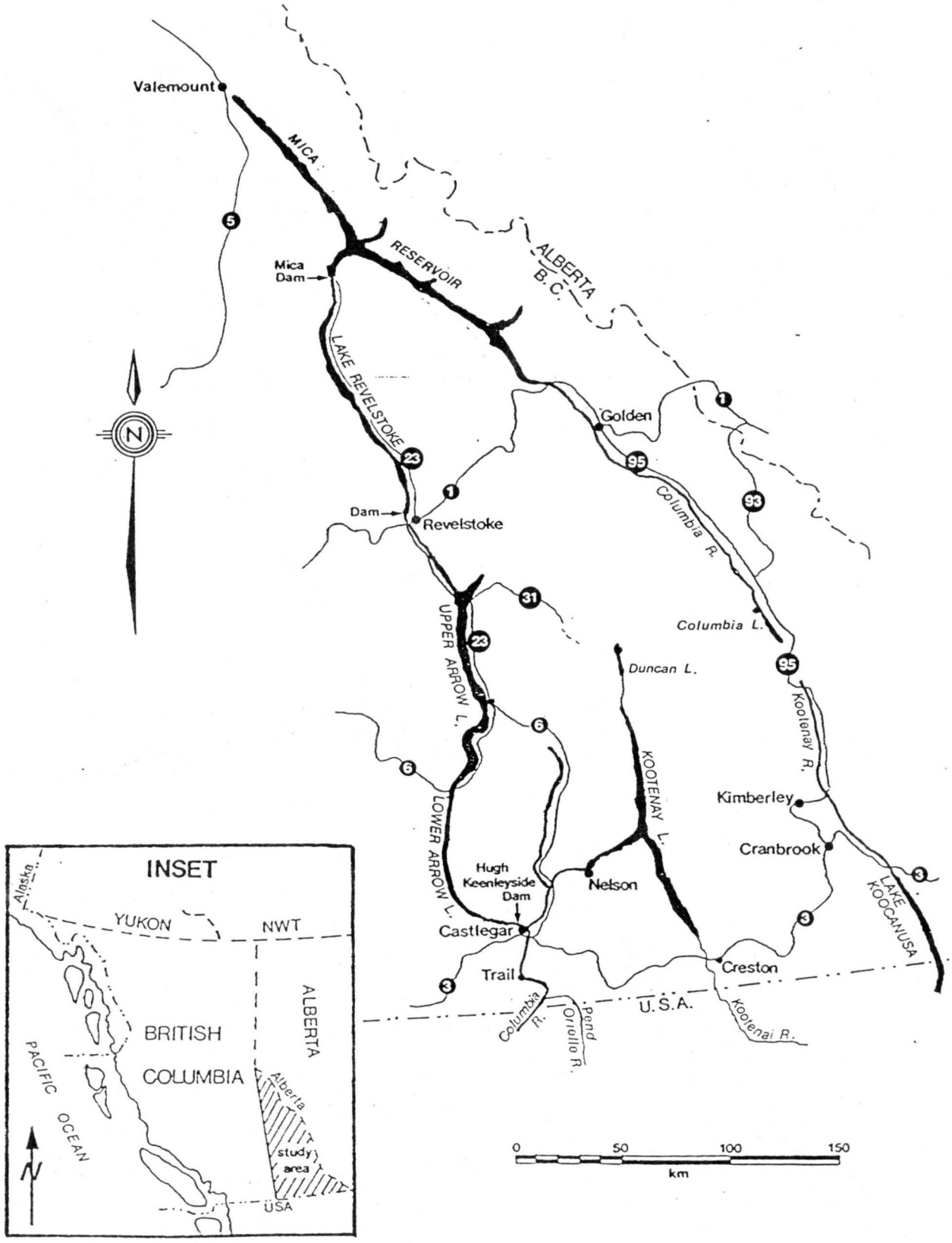
The Columbia system in Canada is controlled by five large dams (one, the Libby Dam, is located in the U.S.), and a number of smaller, run-of river dams. The two largest reservoirs in the system are the Mica Reservoir, impounded by Mica Dam, and the Arrow Lakes Reservoir, behind Hugh Keenleyside Dam. Figures 3.2, 3.3, 3.4, and 3.5 show the Mica Reservoir, Arrow Lakes Reservoir and the Columbia River below the Hugh Keenleyside Dam to the U.S. border.

3.1 Mica Reservoir

Mica Dam, completed in 1973, presently has a generating capacity in the powerhouse of 1736 megawatts (MW) from four generators. There is potential to install two more generators in the powerhouse for a potential total generation capacity of 2604 MW. The reservoir is licensed to be operated between a minimum elevation of 707 m (2320 ft) and a maximum elevation of 754 m (2475 ft) (an operating range of 47 m (155 ft)). It currently is operated between approximately 735 m (2411 ft) and full pool. The reservoir usually

Figure 3.1

Columbia River System



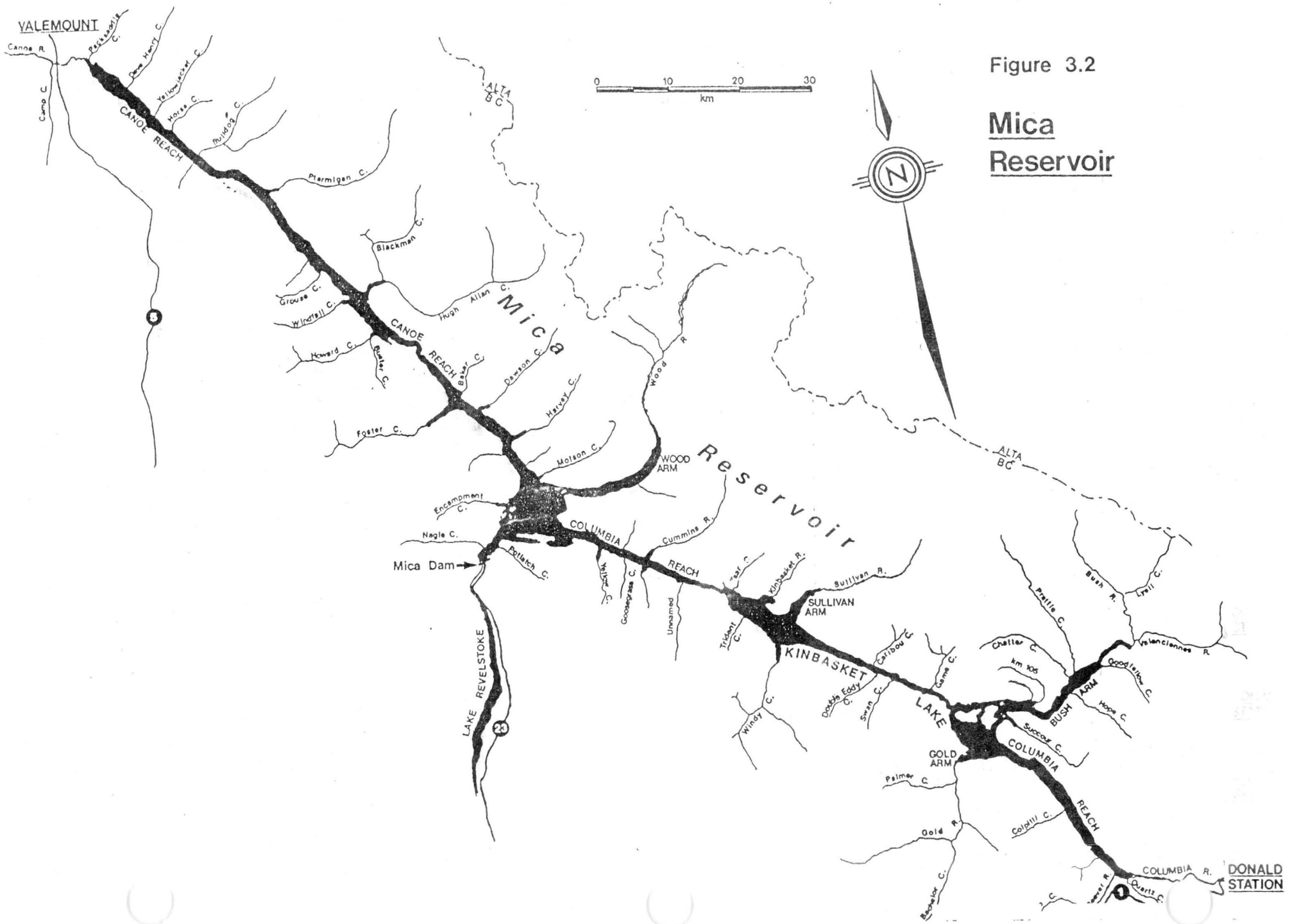


Figure 3.2
Mica Reservoir
VALEMOUNT
Canoe R.
Canoe C.
Parkhouse C.
Dave Henry C.
Yellowjacket C.
Horse C.
Rudolf C.
CANOE REACH
Ptarmigan C.
ALTA BC
0 10 20 30
km
N
Blackman C.
Grouse C.
Windfall C.
Howard C.
Baxter C.
Baker C.
Hugh Allan C.
Mica
Dawson C.
Harvey C.
Foster C.
Molson C.
Wood R.
WOOD ARM
Reservoir
ALTA BC
Encampment C.
Nagle C.
COLUMBIA REACH
Cummins R.
Mica Dam
Pollatch C.
Yellow C.
Goosegrass C.
Unnamed
Trident C.
Kinbasket R.
Sullivan R.
SULLIVAN ARM
KINBASKET LAKE
LAKE REVELSTOKE
Caribou C.
Windy C.
Dowsie Eddy C.
Swan C.
Cume C.
Chatter C.
km 105
Prattle C.
Bush R.
Lyell C.
Valenciennes R.
Goodsir C.
BUSH ARM
Hope C.
Succour C.
COLUMBIA REACH
GOLD ARM
Palmer C.
Gold R.
Colpitt C.
Boulder C.
COLUMBIA R.
Quartz C.
DONALD STATION

Figure 3.3 **Upper Arrow Lake**

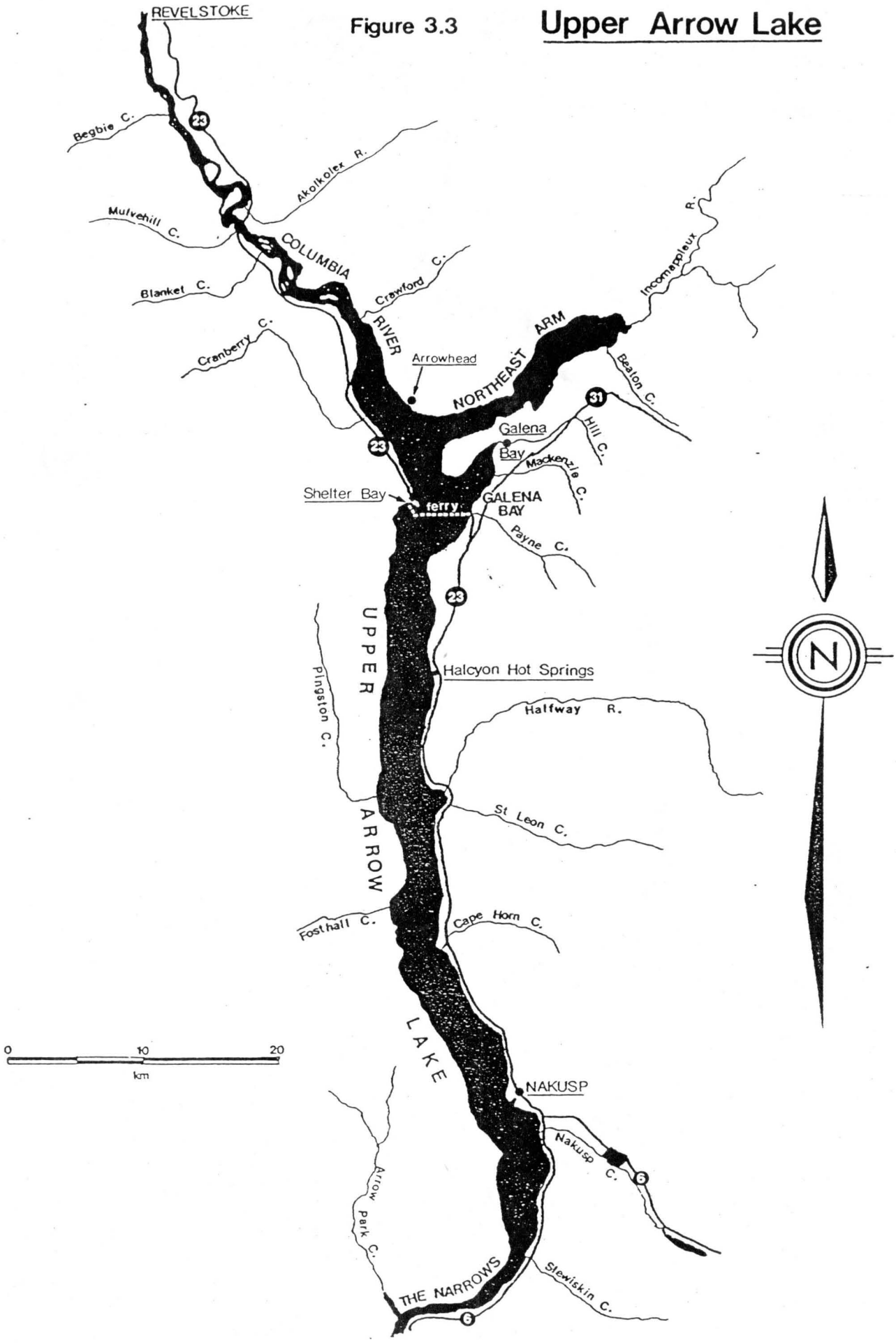
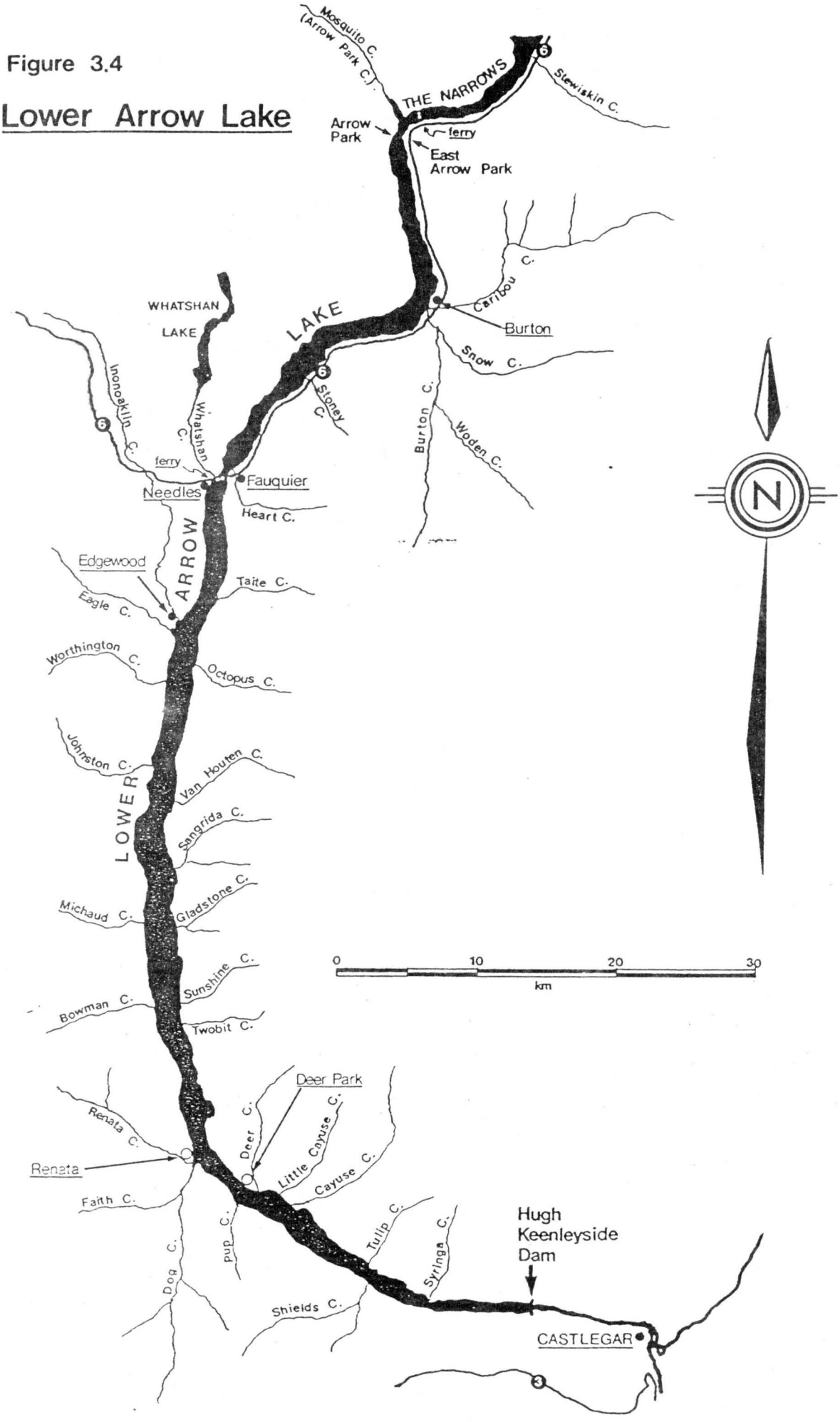


Figure 3.4

Lower Arrow Lake



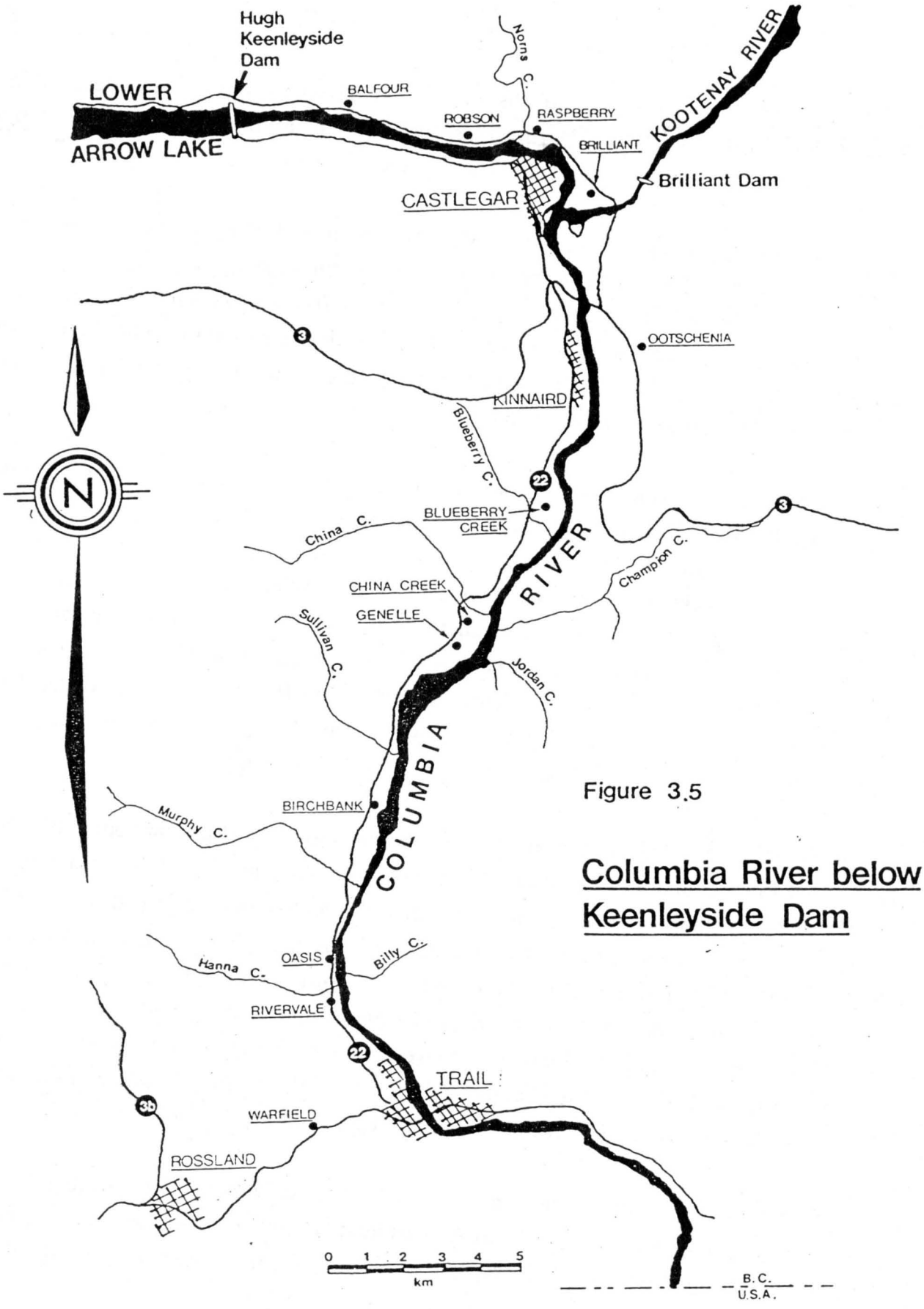


Figure 3.5

Columbia River below Keenleyside Dam

reaches its lowest point in April and fills during May through August. The rate of filling varies with the rate of inflow. During those years when inflow is sufficient to fill the reservoir, the full pool level is usually attained in July or August.

There is limited knowledge of the use of Mica Reservoir and its tributaries by fish. The reservoir is a deep, cold, nutrient-poor lake, with low biological productivity. Rainbow trout, kokanee, Dolly Varden char and mountain whitefish are the most important and abundant sport fish. Lack of shallow areas coupled with the extensive annual drawdown limits fish habitat in the lake itself. Many streams tributary to Mica Reservoir are steep, ephemeral and have little or no spawning habitat.

Most of the tributaries which contain good spawning habitat accessible to migrating fish are large, cold, glacial streams more suited to the propagation of cold water fish species such as mountain whitefish and Dolly Varden. Kokanee have successfully colonized the lake in recent years via stocks which had been introduced into Windermere Lake to the south. Kokanee spawning appears to be confined to small, non-glacial streams in the southern portion of the reservoir (Figure 3.6) and throughout the Columbia River as far south as Windermere Lake. Three streams, Beaver River, Wood River, and Foster Creek have been identified as having fish migration barriers which could be exposed and cause problems for migrating fish under certain reservoir operating conditions.

Due to the steepness of the slopes above the reservoir and in the drawdown zone itself, and the annual fluctuations in water level, Mica Reservoir does not provide good habitat for most species of wildlife. The reservoir is usually ice-covered from January to April. While information on wildlife occurrence and abundance is limited, small numbers of waterfowl, shore birds and birds of prey such as bald eagles and ospreys utilize the reservoir at certain seasons. River otters are likely the only fur-bearing mammals associated directly with the reservoir. Beaver and muskrat inhabit some wetland areas adjacent to the reservoir. Most waterfowl use occurs in the few areas of flat or gently-sloping shoreline around the reservoir such as Valemount Flats and Columbia Reach Island (Figure 3.7).

The vast majority of land bordering the reservoir is Crown Land although there are a few small isolated privately-held lots. BCHPA owns land around the Mica Dam and has some property at the north end of the reservoir near Valemount. Forestry is the dominant

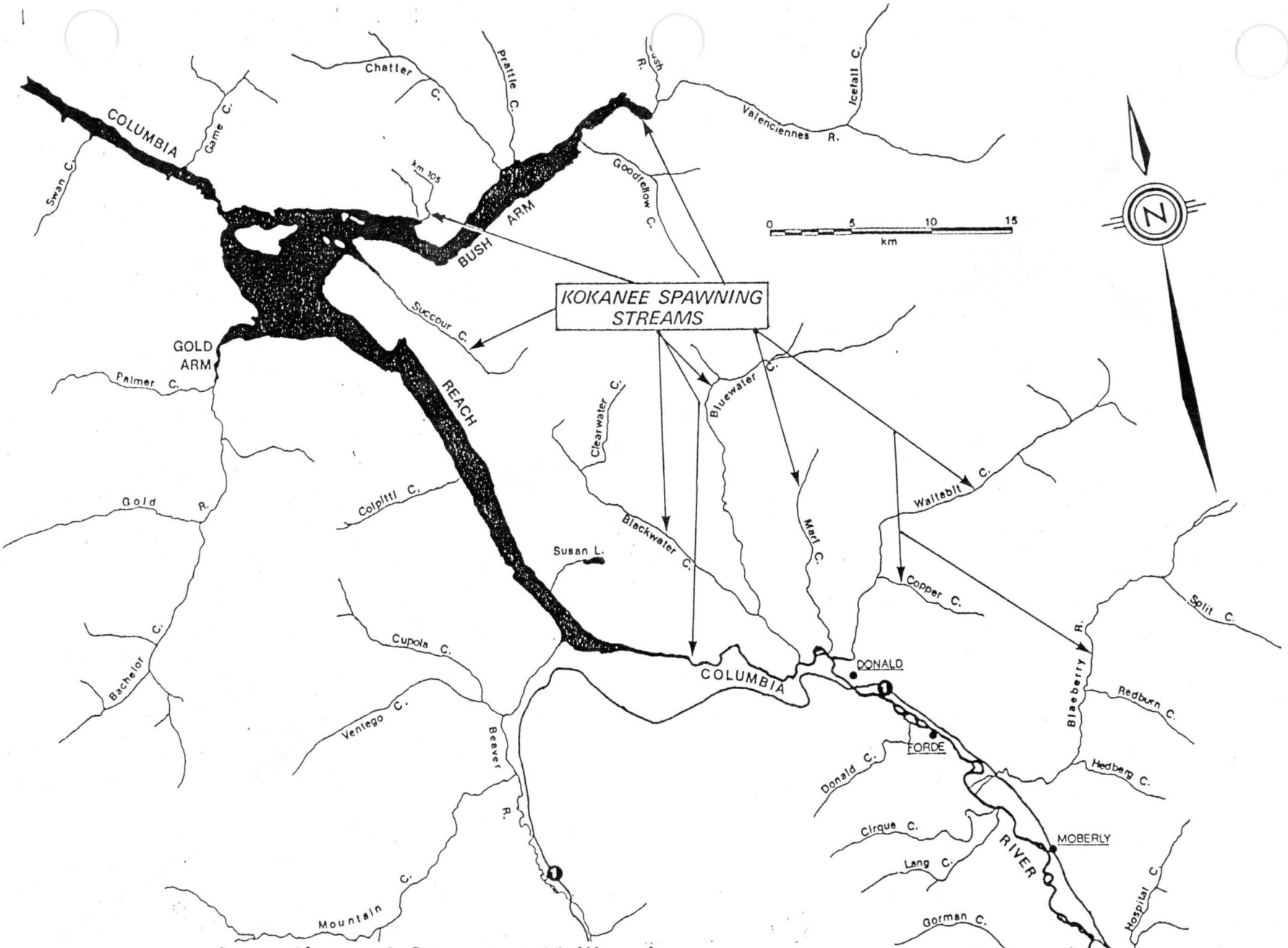
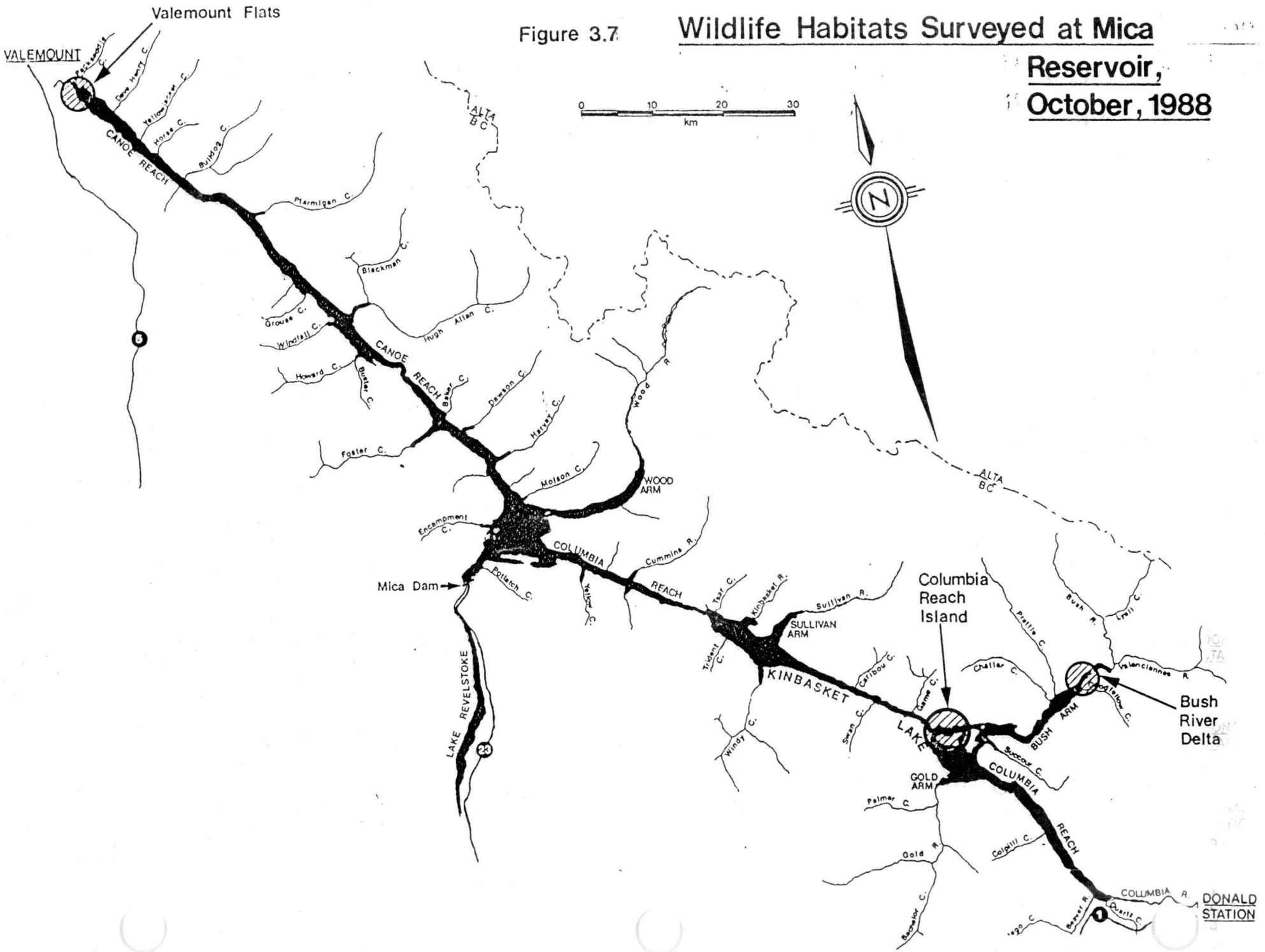


Figure 3.6 **Location of Streams Utilized by Mica Reservoir Kokanee for Spawning (all are non-glacial)**

Figure 3.7 **Wildlife Habitats Surveyed at Mica Reservoir, October, 1988**



resource industry in the region and large areas of Crown Land near the reservoir are held under various forest tenures.

Rugged physiography, severe climate and lack of access limit settlement to the Valemount area at the north end of the reservoir and from Bush Lakes south to Golden at the southern end of the reservoir. Valemount (population 1161)[1] and Golden (population 3584) are the major employment, transportation, retailing and service centers for the region.

Heritage surveys were not conducted prior to creation of the Mica Reservoir. Only one prehistoric and one historic site have been identified to date.

Forestry sustains most of the labour force in the area. The major operator in the northern portion of the reservoir (Canoe Reach) is Slocan Forest Products, which operates a large sawmill at Valemount. Canadian International Timber Corporation operates a small sawmill bordering the reservoir approximately 13 km (8 mi) south of Valemount. Westar Timber Corporation is a major operator in the central reservoir area. Their logging operations supply a sawmill located in Malakwa, west of Revelstoke. Evans Forest Products is the major operator in the southern portion of the reservoir (Columbia Reach), supplying a large sawmill at Donald Station and a plywood plant at Golden. These companies all use the reservoir for transporting logs. Figure 3.8 indicates the locations of forest company facilities.

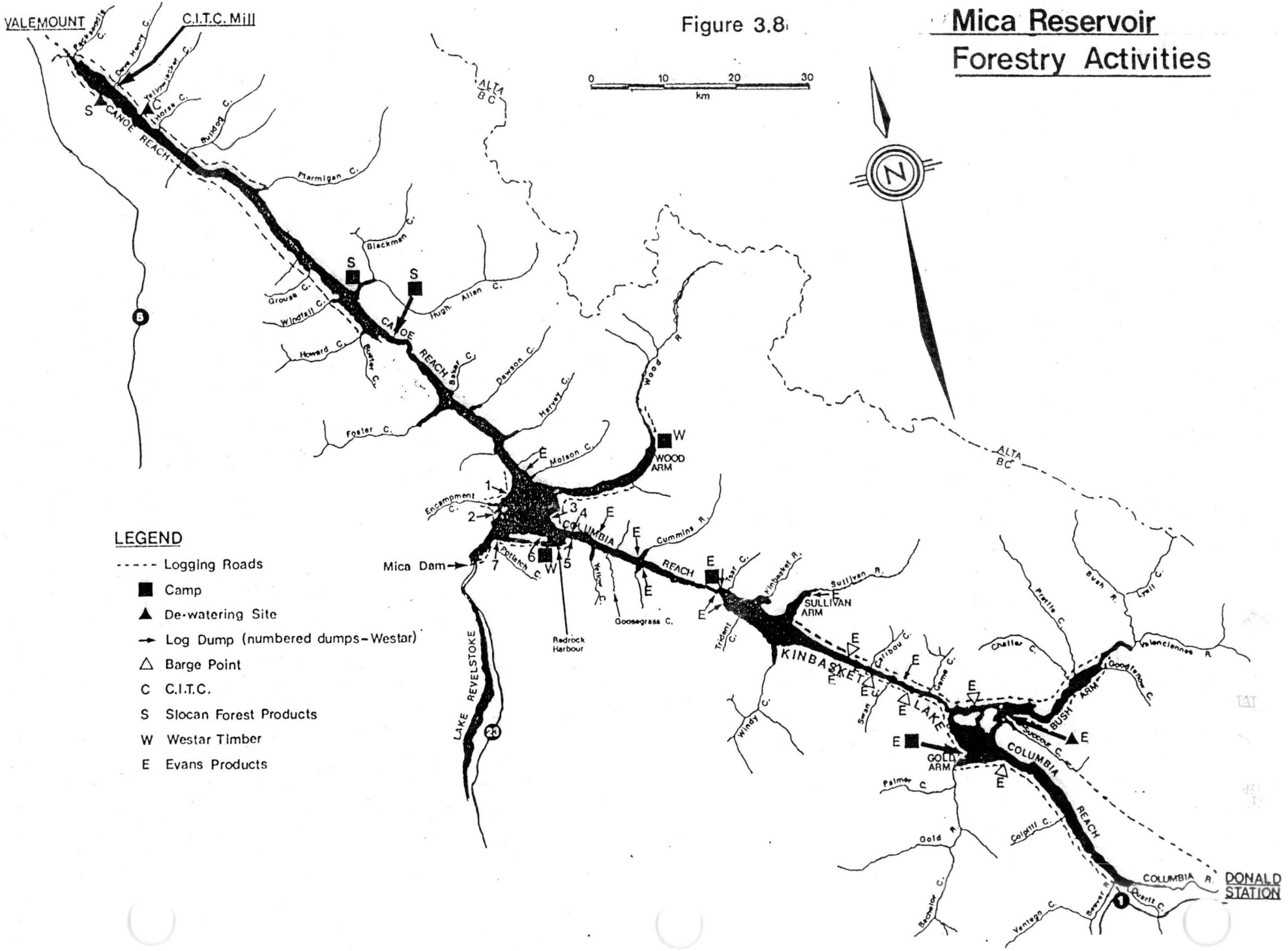
Poor soils, a short growing season and distance to markets severely limit agricultural activity in the Mica Reservoir area.

Recreation activity on and around the reservoir is light and confined mainly to the local population due mainly to lack of road access and facilities. Accumulations of wood debris create hazards for boating. To address this problem, BCHPA has recently implemented a debris removal program. Floating debris is collected and burned. Most collection has taken place in the northern end of the reservoir where there is greater accumulation of floating debris. If future reservoir levels are high enough, the program will be expanded to

1 All population figures are from the Statistics Canada 1986 Census.

Figure 3.8

Mica Reservoir Forestry Activities



include debris removal from beaches which will alleviate the problem to a large extent. However, protruding stumps in certain areas during low water years will remain a navigational hazard. Recreational use of the reservoir has been slowly increasing over the years. Figure 3.9 indicates the location of recreation facilities.

3.2 Arrow Lakes Reservoir

The Arrow Lakes Reservoir is comprised of two former lakes: Upper and Lower Arrow Lakes, and a small section of river south of Nakusp known as the Narrows. The reservoir is impounded by the Hugh Keenleyside Dam, completed in 1968. A navigation lock was installed within the dam to allow log transport to the Westar Timber sawmill at Castlegar and access through the dam for recreational boat traffic. There are no power generation facilities at present, although the potential for low-head generation is currently being explored. The reservoir presently has a minimum elevation of 420 m (1378 ft) and a normal maximum elevation of 440.1 m (1444 ft), an operating range of 20 m (66 ft). The reservoir reaches its lowest point in late March or early April and usually starts to fill in mid-May, reaching its highest level during the latter half of July. Drawdown often begins in early August.

The Arrow Lakes Reservoir is deep and has fairly low biological productivity, although it is slightly more productive than Mica Reservoir. Rainbow trout, Dolly Varden char and kokanee are the principal sport fish. Rainbow trout stocks declined from pre-impoundment levels due to the creation of this reservoir and those further upstream which have blocked access to spawning habitat. To offset this decline, two enhancement projects have been constructed with funding from BCHPA; a kokanee and rainbow trout spawning facility at Hill Creek managed by the provincial Fish and Wildlife Branch and a kokanee spawning facility at Bridge Creek maintained by Revelstoke residents (Figure 3.10). The Hill Creek Hatchery was a result of compensation for creation of the Revelstoke Reservoir. In addition, BCHPA and the Revelstoke Rod and Gun Club enhanced the lower portion of Moses Creek in 1989. These enhancement measures have done much to offset the decline in sport fish populations experienced after the creation of this and upstream reservoirs. Many of the streams tributary to the Arrow Lakes have natural barriers to upstream migration within a few hundred meters of the reservoir. Most of these streams have too little natural habitat to justify the expense of bypassing the barrier.

Figure 3.9

Mica Reservoir Recreation Sites

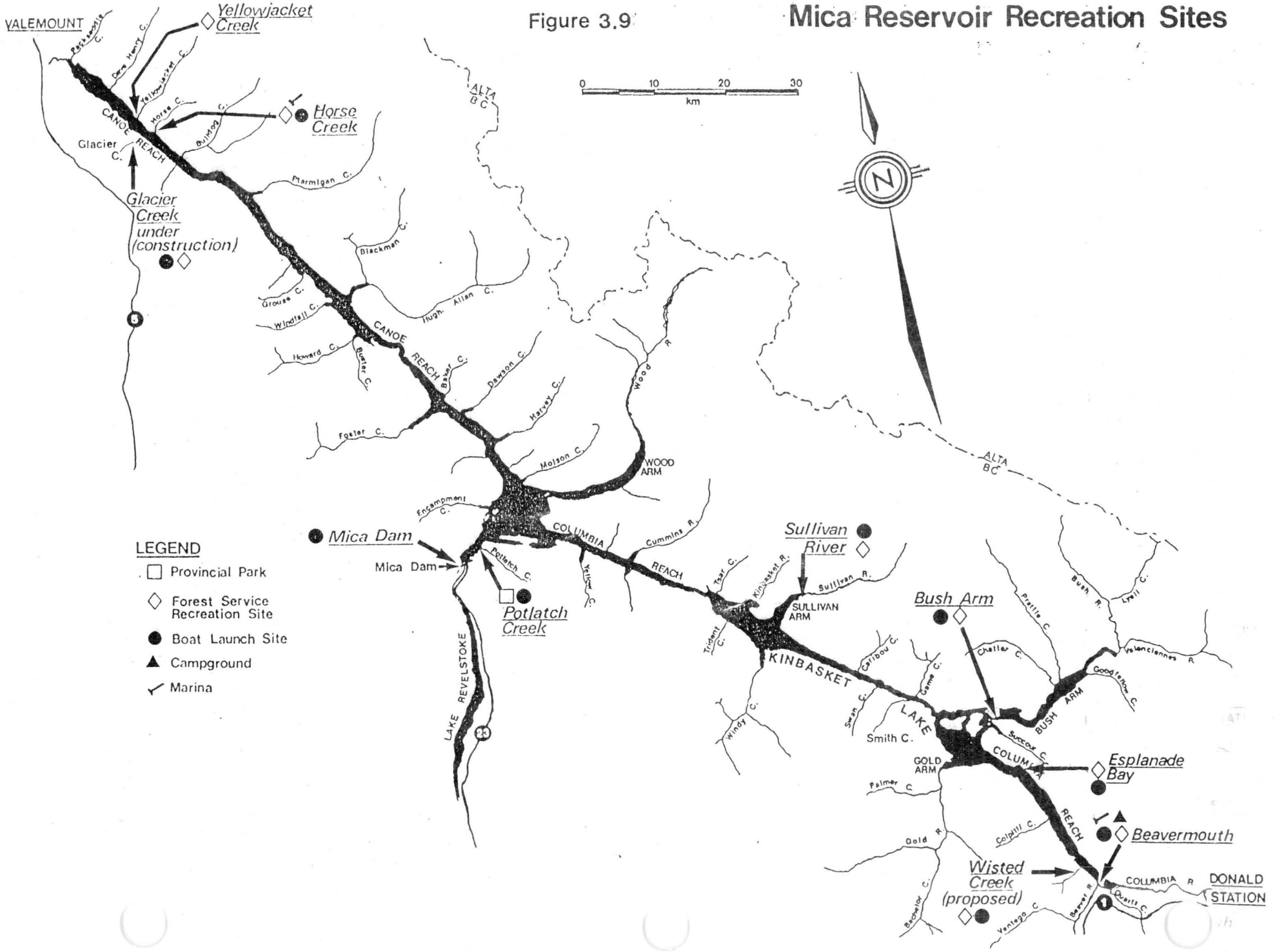
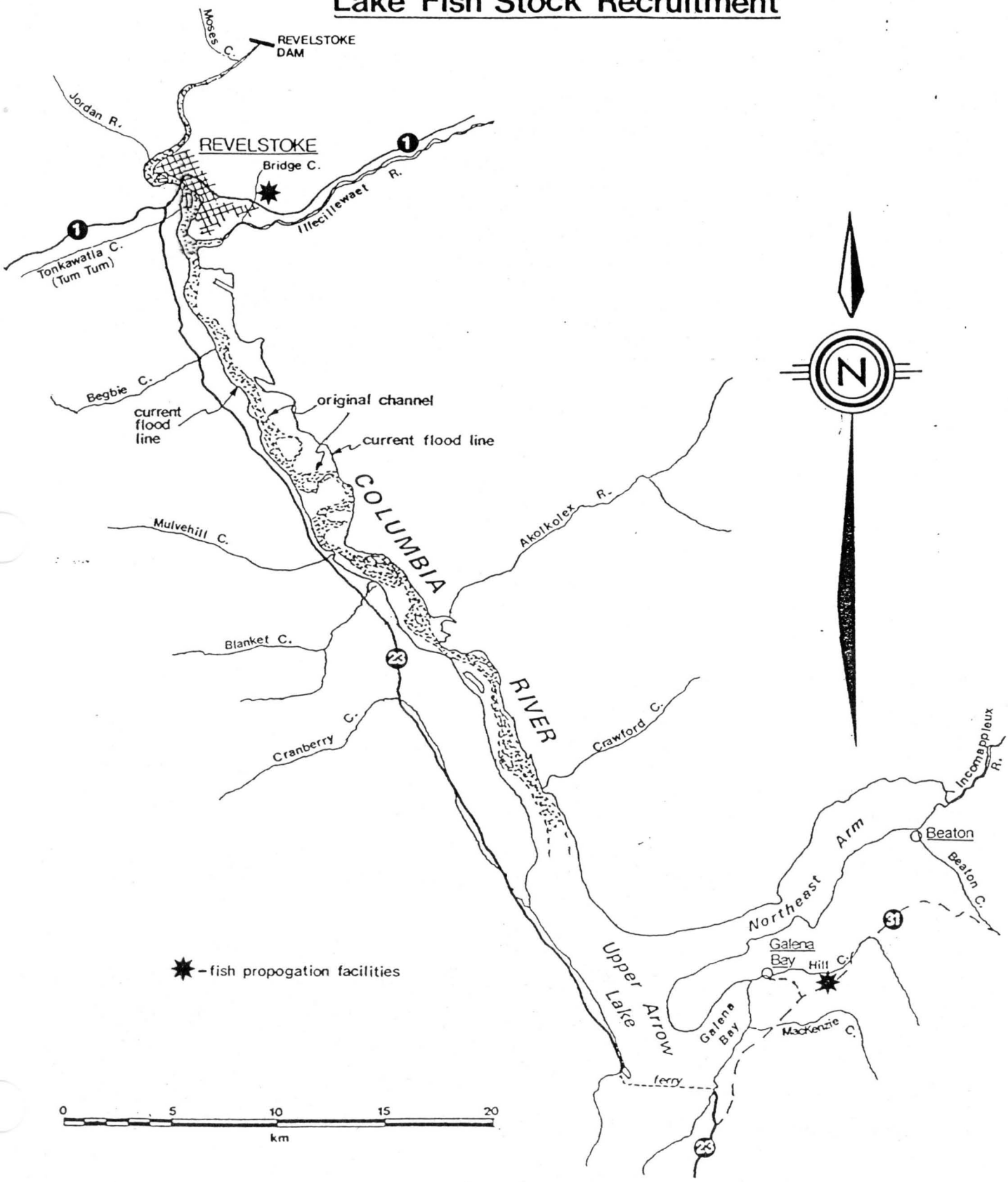


Figure 3.10 **Location of the Two Operational Fish Propagation Facilities for Upper Arrow Lake Fish Stock Recruitment**



The Arrow Lakes occupy a deep north-south oriented valley which forms a natural migration route for many birds during spring and fall. The species of importance are primarily waterfowl and other aquatic/wetland species. Smaller numbers of birds nest in the area and are present through the summer. Key wildlife species are the Canada goose, dabbling ducks, such as mallard and teal, ospreys, coots, and muskrats. Vegetated waterfowl habitats are largely above the 435 m (1427 ft) level, where shorelines are flat to gently sloping. Such conditions occur mainly at the north end of the reservoir (the former floodplain of the Columbia River), at the Narrows between the two lakes and at stream deltas elsewhere around the reservoir. Up to 6000 waterfowl may use these locations during migration. Nest flooding due to rising water levels in spring is a limiting factor for waterfowl production in most areas of the reservoir.

Approximately 67% of the land flooded by the reservoir was privately owned prior to development of the facilities. BCHPA undertook a major program of land acquisition and rebuilt several communities in new locations. Much of the land bordering the reservoir has now been returned to private ownership or transferred to the Crown, although B.C. Hydro still retains a number of land parcels.

Suitable land for settlements in the vicinity of the Arrow Lakes is limited to the narrow remnants of the Columbia Valley bottom along the reservoir, creek fans, alluvial benches and the flatter sections of tributary valleys.

The population of the Arrow Lakes region has fluctuated considerably from the time of early settlement. At present, the largest communities are Revelstoke (population 8279) at the north end of Upper Arrow Lake, the City of Castlegar (population 6385) at the south end of Lower Arrow Lake, and Nakusp (population 1410) near the Narrows area. Revelstoke and Castlegar act as sub-regional employment, transportation, retail and service centers. There are three ferries traversing the reservoir: the Galena Bay/Shelter Bay ferry on Upper Arrow Lake, the Needles/Fauquier ferry on Lower Arrow Lake, and the Arrow Park/East Arrow Park ferry crossing the Narrows area (Figures 3.3 and 3.4). None of the communities except Castlegar use the reservoir as a source of water supply. There are only two domestic household water supply licences issued for the reservoir itself.

A total of 110 heritage sites have been identified around the Arrow Lakes Reservoir. Many of the sites have suffered erosion impacts since inundation; several sites were excavated prior to flooding.

The majority of land surrounding the reservoir is within Tree Farm Licence (TFL) #23 owned by Westar Timber Corporation. Logs from TFL #23 are transported, predominantly by water to a large sawmill just north of Castlegar. Figures 3.11 and 3.12 indicate the location of Westar's log dumps and storage areas. Westar also supplies small sawmills at Nakusp and at Poplar Creek. Westar experiences problems with log dumping, storage, removal and transport when reservoir levels are at about 427 m (1401 ft) or lower. The Celgar Pulp and Paper Company operates a water intake just upstream of Hugh Keenleyside Dam which supplies process and drinking water to its pulp mill near Castlegar, the Westar sawmill, and drinking water to Castlegar itself.

At present, there is limited agriculture in the Arrow Lakes area, mostly in the vicinity of Edgewood, Nakusp and Burton. This light agricultural activity involves mainly stock raising and production of forage crops. In the northern region, productivity and range of crops are limited by climate and topography. Distance to markets limits agriculture in the overall region. No irrigation or stock watering licences have been issued with the reservoir as the source of supply.

The Arrow Lakes Reservoir is large, scenic and more accessible than Mica Reservoir, and provides numerous recreation opportunities. Figures 3.13 and 3.14 indicate recreation sites. As noted, stocks of hatchery-raised sport fish are an important component of recreation use by both residents and visitors. The dominant use season is May through September, with most use occurring during June, July and August. Recreational use by both residents and tourists is increasing. However, at present, in years when the reservoir does not fill, access to the water is often difficult and the unattractive exposed drawdown area discourages water and foreshore use. Boating is also affected, particularly in the northern part of Upper Arrow Lake and the Narrows area. As well, dust problems are experienced in some communities near large expanses of drawdown area. B.C. Hydro has initiated seeding programs near the affected communities to mitigate this problem.

Figure 3.11

Upper Arrow Lake Forestry Activities

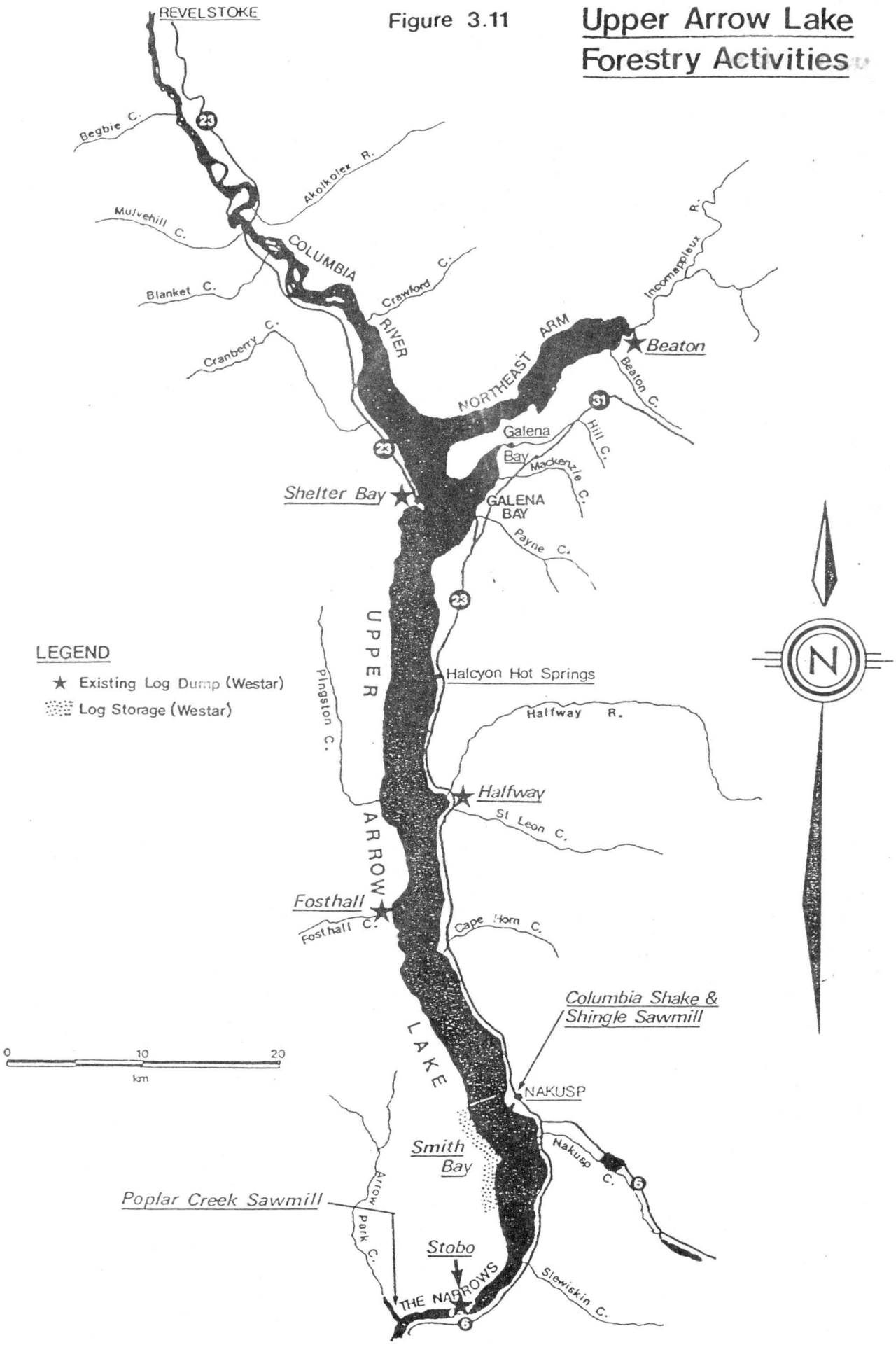


Figure 3.12 **Lower Arrow Lake Forestry Activities**

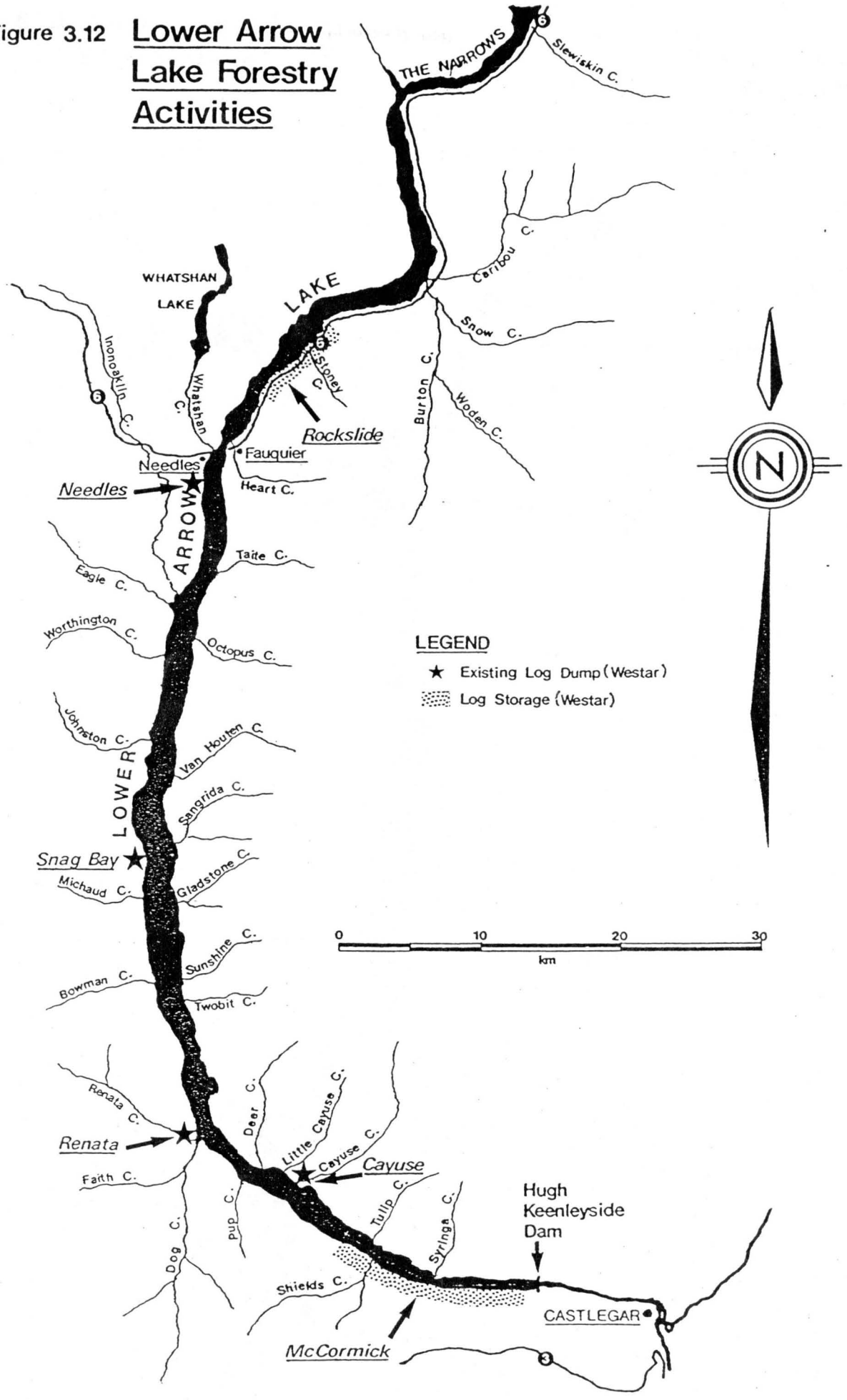


Figure 3.13 **Upper Arrow Lake Recreation Sites**

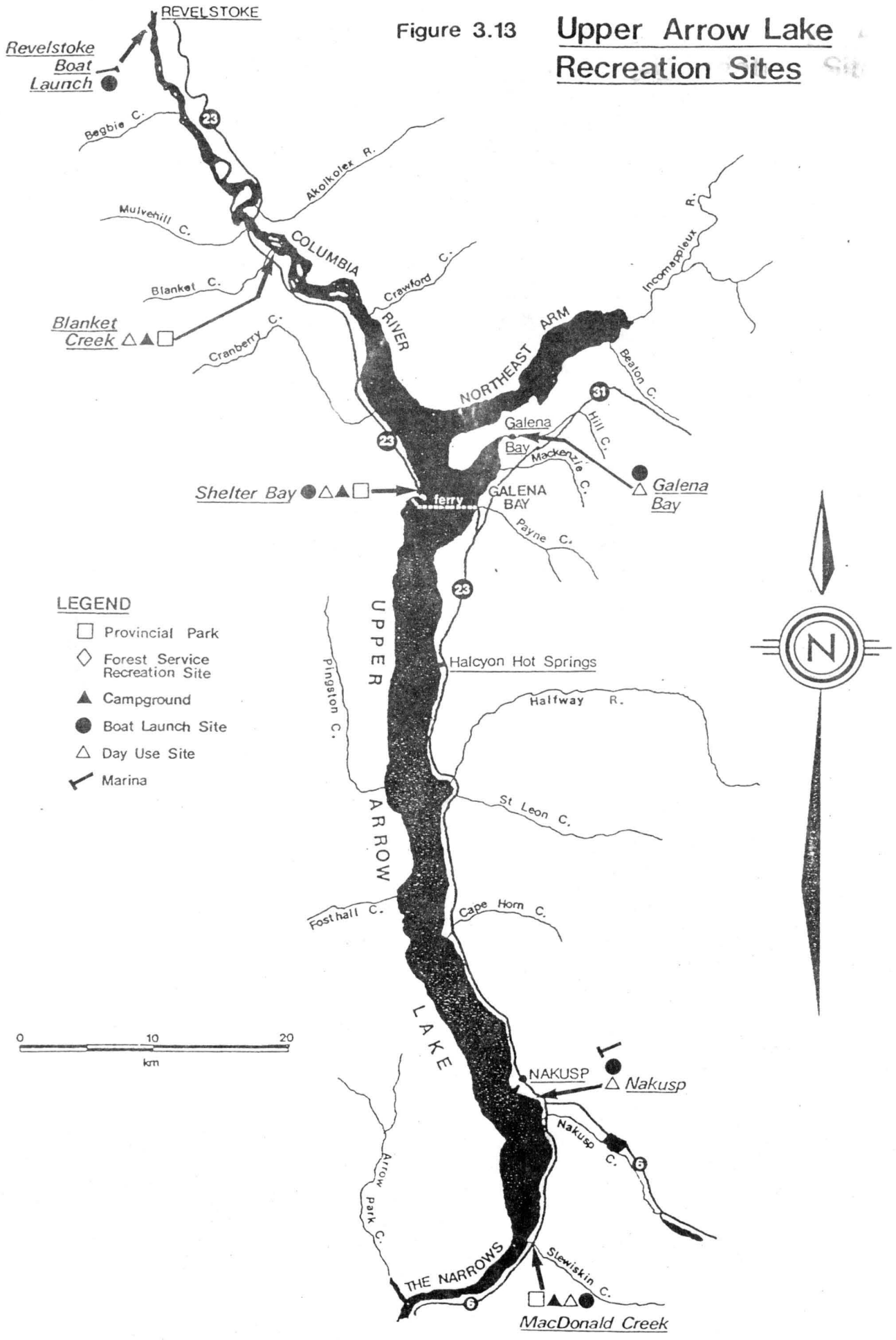
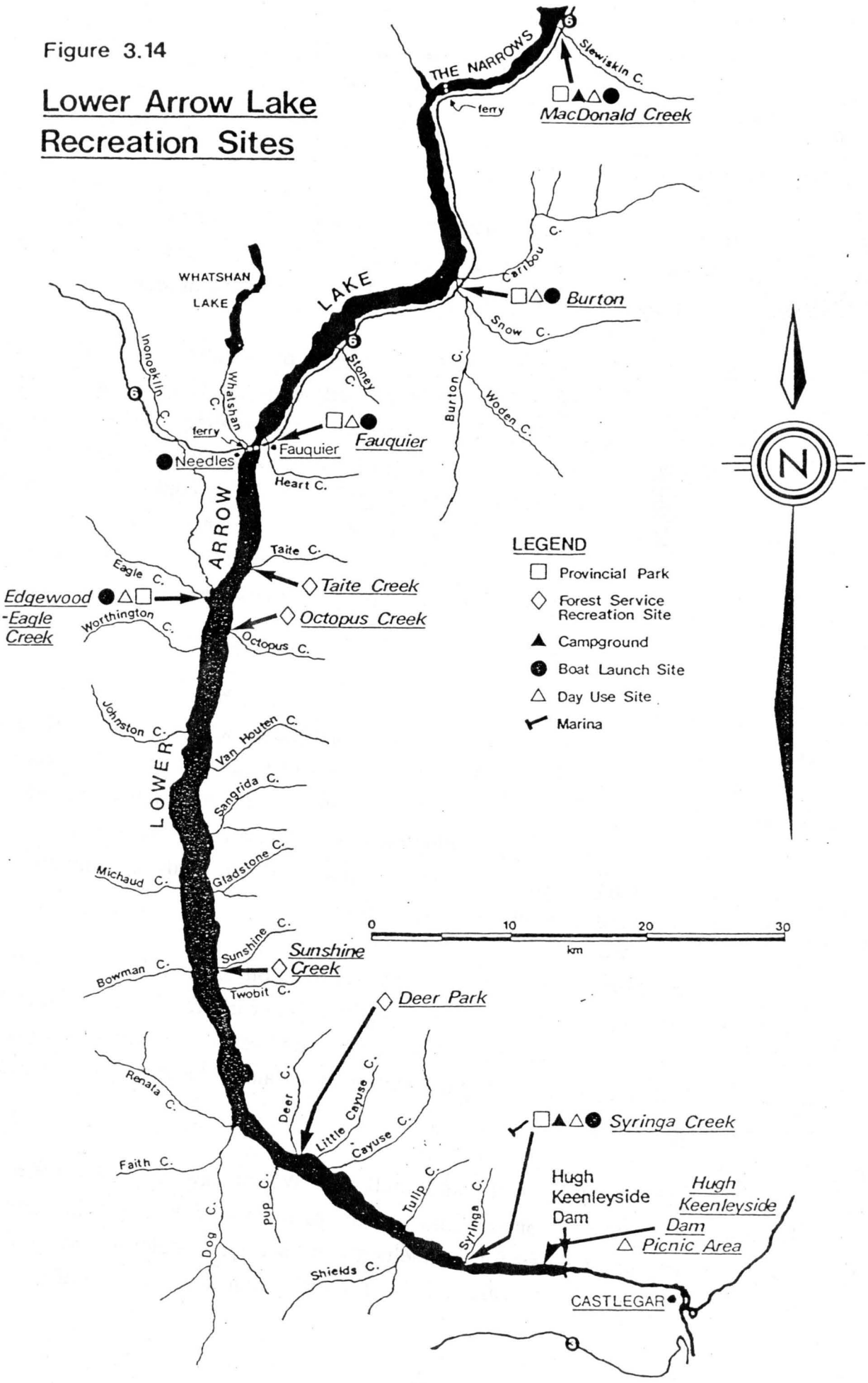


Figure 3.14

Lower Arrow Lake Recreation Sites



3.3 Downstream Area

Flows released from Hugh Keenleyside Dam control Columbia River water levels in the reach upstream of the confluence with the Kootenay River. Flows are greatest during winter in response to downstream water demands and decline to a low in March-April.

The river provides resident fish with year-round, mostly open-water habitat with high rearing potential. With the exception of point source effluents (e.g. Celgar mill), nutrient levels (phosphorous and nitrogen) are low. There is a continuous supply (during drawdown periods) of food for fish from the reservoir as a result of invertebrate entrainment through or over Hugh Keenleyside Dam. However, this benefit is probably confined to the area immediately downstream of the dam. Fish populations are large and varied; eight sport fish and 10 non-sport fish species have been noted. A mixed sport fishery exists below the dam and catch success is reported to be high. Rainbow trout, kokanee, Dolly Varden char, whitefish and burbot are the principal sport fish species.

Because the flows are controlled and the spring freshet has been reduced, the river provides relatively stable habitat conditions for aquatic/riparian wildlife although riparian habitats are of limited extent. Relatively small numbers of birds, primarily migrants and wintering birds, utilize the river. Some birds nest along the river but production levels are low, mostly due to a lack of productive feeding habitat. Predatory fish-eating birds such as osprey nest along the river and bald eagles are common in winter. Only small numbers of beavers, otters, mink and raccoon inhabit the river area.

The largest community downstream of Castlegar (population 6385) is the City of Trail (population 7948) (Figure 3.5). Trail is a major urban center in the region, with a stable economic base created by the large smelter, refinery and fertilizer complex owned by Cominco Ltd. There are many other small communities along the river between Hugh Keenleyside Dam and the border.

As previously mentioned, the Celgar pulp mill, the Westar sawmill and the City of Castlegar obtain their water from an intake just upstream of the dam. In addition, Cominco uses water from the river for its smelting and fertilizer complex at Trail and the Village of Warfield (population 1840) and the Tadanac subdivision of Trail also obtain

their water from this intake. Effluent from these industrial complexes and from Castlegar's sewage treatment facility is discharged to the Columbia River.

Currently, two water quality concerns have been noted. First, total dissolved gas levels just below Hugh Keenleyside Dam are consistently above levels reported to cause acute total gas pressure trauma in fish although no major fish mortalities have been noted to date. Second, effluent discharged from the Celgar pulp mill creates water quality problems downstream, especially during periods of minimum flow releases. Due to the toxicity of the discharged effluent, sublethal effects on fish could occur at flows less than 350 m^3/s (12,400 ft^3/s).

In earlier studies for the Murphy Creek project, a total of 16 heritage sites were identified along the Columbia River below Hugh Keenleyside Dam at or below the 424 m (1391 ft) elevation. Of these, only four were determined to warrant conservation or mitigation.

The major industrial user of the river, other than as a source of water, is the Westar Timber Corporation. Westar stores log rafts on the west side of the river until they are required by the mill. Differing river flows can pose problems for log storage and movement to the mill. At high discharges (about 1840 m^3/s (65,000 ft^3/s) and greater) the strong current makes storing and moving log bundles into the mill difficult. At low discharges (about 255 m^3/s (9000 ft^3/s) or lower), the water-based mill feed system is difficult to operate, requiring increased maintenance. Also, stored log bundles can become grounded. The Columbia River is used to load water bombers utilized to fight forest fires in the region. An intake pipe and pump is located just upstream of the highway bridge linking Castlegar and the eastern side of the river. Low flows presently necessitate repositioning of the pipe.

There is very little active agriculture in the vicinity of the Columbia River. At present, only about 20 ha (49 acres) are cultivated. Most formerly cultivated lands have been abandoned or converted to hobby farms, rural residential use, or other urban-related uses.

The river is considered to have moderate recreation capability. At present, there are few developed recreation facilities (Figure 3.15). The river is mainly used for recreation by regional residents. Swimming, sight-seeing, picnicking, fishing and boating are the major recreational activities.

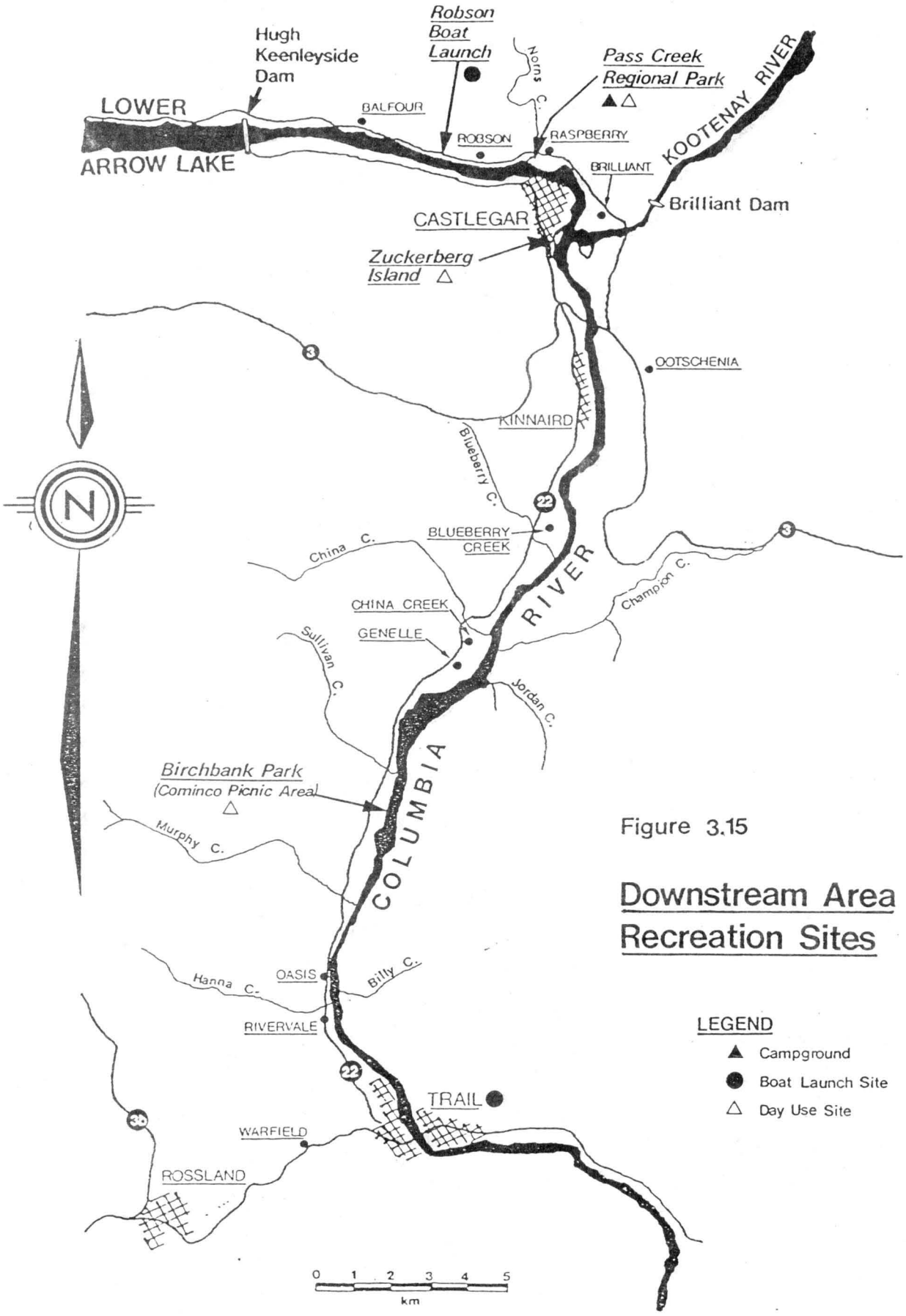


Figure 3.15

Downstream Area Recreation Sites

4.0 IMPACT ASSESSMENT

The discussion of potential impacts is based on median elevations and outflows except where minimum/maximum data are explicitly considered.

The median and average data are listed in Tables 4.1 to 4.4, for each respective regime. Also indicated are the high and low values for reservoir elevations and outflows over the 20 year period. These data are reported in feet (reservoir elevations) and cubic feet per second (reservoir outflows) in the tables as this is the form of the data when it was supplied to Triton. Metric equivalents have, however, been used in the text.

4.1 Physical Effects

4.1.1 Regime 1 (Medium Load) Compared to Base Case (Medium Load)

Mica Elevations

The proposed new Non-Treaty Storage Agreement would increase the use of non-treaty storage behind Mica Dam from 2.47 x 10^9 m^3 to 6.18 x 10^9 m^3 (2.0 MAF to 5.0 MAF). Consistent with this increase, with Regime 1 (medium load), the average elevation of the Mica Reservoir decreases during all times of the year, and the annual operating range increases by up to 6.4 m (21 ft) compared to the Base Case (medium load). The greatest changes occur during the months of October through April. With Regime 1, annual reservoir elevations fluctuate between 724.3 and 749.2 m (2376.3 and 2458.1 ft) with an operating range of 21.7 to 28.4 m (71 to 93 ft). Differences between Regime 1 and Base Case annual elevations range from no change to a 12.5 m (41 ft) decrease. The average difference in reservoir elevation is presented in Figure 4.1 (4.1.1). Maximum elevations at Mica would remain near full pool but would be achieved less frequently. Minimum elevations would drop from 723.9 m (2375 ft) to 707.1 m (2320 ft).

TABLE 4.1 COMPARISON BETWEEN REGIME 1 AND BASE CASE, MEDIUM LOAD

MICA ELEVATIONS, REGIME 1

	HIGH	LOW	AVG
SEP	2468.1	2435.8	2451.9
OCT	2460.0	2429.8	2446.1
NOV	2448.7	2424.3	2438.6
DEC	2431.3	2410.8	2424.0
JAN	2417.6	2392.7	2407.9
FEB	2413.0	2378.8	2396.0
MAR	2403.9	2363.0	2383.5
AP1	2400.0	2354.5	2376.3
AP2	2399.9	2353.8	2376.7
MAY	2413.2	2378.2	2396.1
JUN	2443.3	2414.6	2429.6
JUL	2470.8	2439.5	2455.1
AG1	2471.8	2443.6	2457.8
AG2	2472.0	2443.6	2458.1
AVG	2436.7	2404.5	2421.3
HIGH	2472.0	2443.6	2458.1
LOW	2399.9	2353.8	2376.3

MICA ELEVATIONS, BASE CASE

	HIGH	LOW	AVG
SEP	2475.0	2455.6	2472.3
OCT	2473.1	2453.6	2469.5
NOV	2469.7	2447.5	2465.0
DEC	2459.1	2428.6	2451.7
JAN	2444.4	2417.6	2437.8
FEB	2431.1	2412.2	2426.1
MAR	2417.0	2398.8	2412.6
AP1	2410.0	2392.6	2406.0
AP2	2410.2	2394.1	2405.9
MAY	2424.4	2410.5	2419.5
JUN	2451.4	2441.0	2447.7
JUL	2471.8	2466.9	2470.1
AG1	2473.9	2470.7	2473.3
AG2	2475.0	2471.9	2474.4
AVG	2449.0	2433.0	2445.1
HIGH	2475.0	2471.9	2474.4
LOW	2410.0	2392.6	2405.9

ARROW ELEVATIONS, REGIME 1

	HIGH	LOW	AVG
SEP	1444.0	1444.0	1444.0
OCT	1442.1	1441.9	1441.9
NOV	1442.1	1438.1	1440.8
DEC	1436.2	1431.8	1435.4
JAN	1414.4	1406.6	1411.2
FEB	1407.6	1396.8	1402.6
MAR	1399.9	1392.7	1399.2
AP1	1400.7	1398.7	1399.9
AP2	1403.9	1399.9	1402.1
MAY	1417.9	1414.6	1415.2
JUN	1437.5	1435.3	1436.4
JUL	1444.0	1444.0	1444.0
AG1	1444.0	1444.0	1444.0
AG2	1444.0	1444.0	1444.0
AVG	1427.0	1423.7	1425.8
HIGH	1444.0	1444.0	1444.0
LOW	1399.9	1392.7	1399.2

ARROW ELEVATIONS, BASE CASE

	HIGH	LOW	AVG
SEP	1444.0	1443.5	1443.8
OCT	1441.9	1440.5	1441.6
NOV	1442.1	1438.1	1440.4
DEC	1436.2	1431.7	1435.3
JAN	1413.8	1406.6	1410.8
FEB	1406.7	1396.8	1401.9
MAR	1399.9	1396.2	1399.3
AP1	1399.9	1399.5	1399.9
AP2	1403.9	1399.9	1401.4
MAY	1415.3	1413.0	1414.9
JUN	1437.5	1435.3	1436.1
JUL	1444.0	1444.0	1444.0
AG1	1444.0	1444.0	1444.0
AG2	1444.0	1444.0	1444.0
AVG	1426.7	1423.8	1425.5
HIGH	1444.0	1444.0	1444.0
LOW	1399.9	1396.2	1399.3

MICA FLOWS, REGIME 1

	HIGH	LOW	AVG
SEP	33291	20518	30849
OCT	24320	14350	20470
NOV	23327	14270	17449
DEC	34000	22000	25645
JAN	27000	21036	26051
FEB	25000	10165	21666
MAR	22481	17000	19572
AP1	27000	15000	23547
AP2	18000	10000	10400
MAY	10000	10000	10000
JUN	10000	7239	9599
JUL	26304	20962	23681
AG1	40639	34000	35960
AG2	37089	32659	33830
AVG	25604	17800	22052
HIGH	40639	34000	35960
LOW	[illegible]0	7239	9599

MICA FLOWS, BASE CASE

	HIGH	LOW	AVG
SEP	30228	20518	22434
OCT	19996	14350	15770
NOV	19192	13061	15125
DEC	34000	22000	25673
JAN	27000	21036	26359
FEB	25000	10165	23647
MAR	23000	17000	21991
AP1	27000	15000	24750
AP2	18000	10000	10400
MAY	10000	10000	10000
JUN	10000	10000	10000
JUL	30960	21633	27541
AG1	40639	32576	33895
AG2	37706	31573	32719
AVG	25194	17779	21450
HIGH	40639	32576	33895
LOW	10000	10000	10000

ARROW FLOWS, REGIME 1

	HIGH	LOW	AVG
SEP	47692	34978	45595
OCT	40162	33279	36931
NOV	37171	25330	28862
DEC	51676	39515	43067
JAN	80428	68443	72801
FEB	50137	38068	46242
MAR	34436	28057	31783
AP1	29103	21155	25340
AP2	15980	10826	13014
MAY	29593	27325	28580
JUN	24663	16415	21010
JUL	52297	48638	50303
AG1	65172	57921	59886
AG2	55913	51749	53323
AVG	43887	35836	39767
HIGH	80428	68443	72801
LOW	15980	10826	13014

ARROW FLOWS, BASE CASE

	HIGH	LOW	AVG
SEP	45257	34726	37273
OCT	37105	31156	32862
NOV	32430	23021	26872
DEC	48282	40894	42866
JAN	79692	68900	74365
FEB	52529	38068	48588
MAR	37191	28057	33218
AP1	32870	22486	28822
AP2	19487	12796	17139
MAY	32838	27982	30557
JUN	24663	18166	21594
JUL	56134	48638	52427
AG1	65172	54459	57691
AG2	55492	51282	52299
AVG	44224	35759	39755
HIGH	79692	68900	74365
LOW	19487	127[illegible]	17139

TABLE 4.2 COMPARISON BETWE IME 1 AND BASE CASE, ARO

MICA ELEVATIONS, REGIME 1

	HIGH	LOW	AVG
SEP	2468.5	2436.1	2451.7
OCT	2461.1	2432.6	2447.0
NOV	2448.7	2426.2	2439.5
DEC	2432.5	2411.5	2424.6
JAN	2417.6	2392.6	2408.1
FEB	2412.2	2376.8	2395.6
MAR	2399.1	2362.7	2382.1
AP1	2396.4	2352.6	2375.1
AP2	2398.7	2353.0	2375.6
MAY	2410.1	2377.6	2395.3
JUN	2443.1	2412.6	2429.1
JUL	2470.8	2438.8	2454.5
AG1	2471.8	2442.1	2457.3
AG2	2472.0	2443.5	2457.6
AVG	2435.9	2404.2	2420.9
HIGH	2472.0	2443.5	2457.6
LOW	2396.4	2352.6	2375.1

MICA ELEVATIONS, BASE CASE

	HIGH	LOW	AVG
SEP	2475.0	2455.6	2472.3
OCT	2473.1	2453.6	2469.8
NOV	2469.7	2447.5	2465.2
DEC	2459.1	2428.6	2451.6
JAN	2444.4	2417.6	2437.5
FEB	2431.1	2411.3	2425.9
MAR	2417.0	2398.8	2412.2
AP1	2410.0	2391.6	2405.7
AP2	2410.2	2393.3	2405.6
MAY	2424.4	2409.5	2419.3
JUN	2451.4	2441.0	2447.6
JUL	2471.8	2465.5	2470.0
AG1	2473.8	2470.0	2473.3
AG2	2475.0	2471.4	2474.4
AVG	2449.0	2432.5	2445.0
HIGH	2475.0	2471.4	2474.4
LOW	2410.0	2391.6	2405.6

ARROW ELEVATIONS, REGIME 1

	HIGH	LOW	AVG
SEP	1444.0	1443.8	1443.9
OCT	1441.9	1440.7	1441.7
NOV	1442.1	1438.1	1440.4
DEC	1436.2	1432.0	1435.4
JAN	1414.1	1405.9	1411.0
FEB	1407.1	1395.2	1402.2
MAR	1399.9	1394.6	1399.2
AP1	1400.7	1399.5	1399.9
AP2	1403.9	1399.9	1401.8
MAY	1416.3	1414.1	1415.1
JUN	1437.5	1435.3	1436.2
JUL	1444.0	1444.0	1444.0
AG1	1444.0	1444.0	1444.0
AG2	1444.0	1444.0	1444.0
AVG	1426.8	1423.7	1425.6
HIGH	1444.0	1444.0	1444.0
LOW	1399.9	1394.6	1399.2

ARROW ELEVATIONS, BASE CASE

	HIGH	LOW	AVG
SEP	1444.0	1443.5	1443.8
OCT	1441.9	1440.4	1441.4
NOV	1442.1	1438.1	1440.3
DEC	1436.2	1431.9	1435.3
JAN	1413.8	1405.9	1410.7
FEB	1406.7	1396.5	1401.8
MAR	1399.9	1396.2	1399.3
AP1	1399.9	1399.5	1399.9
AP2	1403.9	1399.9	1401.5
MAY	1415.3	1413.0	1414.9
JUN	1437.4	1435.3	1436.2
JUL	1444.0	1444.0	1444.0
AG1	1444.0	1444.0	1444.0
AG2	1444.0	1444.0	1444.0
AVG	1426.7	1423.7	1425.5
HIGH	1444.0	1444.0	1444.0
LOW	1399.9	1396.2	1399.3

MICA FLOWS, REGIME 1

	HIGH	LOW	AVG
SEP	32815.0	20518.0	30292.6
OCT	23367.0	14350.0	19007.1
NOV	25805.0	14898.0	18535.2
DEC	34000.0	22000.0	26467.7
JAN	27000.0	21036.0	26118.6
FEB	25000.0	10165.0	22160.3
MAR	23000.0	17000.0	20057.3
AP1	27000.0	15000.0	22637.3
AP2	18000.0	10000.0	10400.0
MAY	10000.0	10000.0	10000.0
JUN	10000.0	5577.0	9503.0
JUL	26531.0	20317.0	23321.8
AG1	40000.0	33779.0	35734.5
AG2	37409.0	32957.0	33866.8
AVG	25709	17686	22007
HIGH	40000	33779	35735
LOW	10000	5577	9503

MICA FLOWS, BASE CASE

	HIGH	LOW	AVG
SEP	30389.0	20518.0	22406.5
OCT	19150.0	14350.0	15518.5
NOV	19466.0	13243.0	15348.2
DEC	34000.0	22000.0	25726.8
JAN	27000.0	21036.0	26353.5
FEB	25000.0	10165.0	23653.5
MAR	23000.0	17000.0	22000.0
AP1	27000.0	15000.0	24723.3
AP2	18000.0	10000.0	10400.0
MAY	10000.0	10000.0	10000.0
JUN	10000.0	10000.0	10000.0
JUL	30877.0	21633.0	27474.3
AG1	40639.0	32576.0	33790.8
AG2	37779.0	32037.0	32754.1
AVG	25164	17826	21439
HIGH	40639	32576	33791
LOW	10000	10000	10000

ARROW FLOWS, REGIME 1

	HIGH	LOW	AVG
SEP	47735.0	34978.0	45282.3
OCT	41497.0	33209.0	36250.6
NOV	37610.0	25589.0	29007.8
DEC	51533.0	40010.0	43449.9
JAN	81090.0	69417.0	73929.6
FEB	50548.0	38842.0	45987.1
MAR	34718.0	28559.0	31607.4
AP1	29249.0	21155.0	25381.0
AP2	16040.0	10439.0	12801.8
MAY	29571.0	27325.0	28379.0
JUN	24691.0	16733.0	21113.6
JUL	51596.0	47521.0	49990.3
AG1	65172.0	56677.0	59212.2
AG2	56019.0	51846.0	53755.4
AVG	44076	35879	39725
HIGH	81090	69417	73930
LOW	16040	10439	12802

ARROW FLOWS, BASE CASE

	HIGH	LOW	AVG
SEP	45675.0	34724.0	37337.8
OCT	36949.0	31142.0	32894.4
NOV	32537.0	23303.0	26896.4
DEC	48815.0	40836.0	42874.2
JAN	79658.0	68759.0	74334.6
FEB	52529.0	38842.0	48836.6
MAR	37088.0	28559.0	33228.9
AP1	32870.0	21470.0	28741.9
AP2	19487.0	12775.0	17156.4
MAY	32838.0	27982.0	30552.7
JUN	24766.0	18166.0	21540.1
JUL	55971.0	47521.0	52373.4
AG1	65172.0	54459.0	57611.0
AG2	55879.0	51282.0	52453.5
AVG	44302	35701	39774
HIGH	79658	68759	74335
LOW	19487	12775	17156

TABLE 4.3 COMPARISON BETWEEN REGIME 1 AND BASE CASE, AOS

	MICA ELEVATIONS, REGIME 1		
	HIGH	LOW	AVG
SEP	2464.6	2424.9	2439.6
OCT	2457.7	2421.7	2433.5
NOV	2447.5	2417.7	2426.1
DEC	2428.5	2404.2	2411.9
JAN	2412.7	2385.1	2394.9
FEB	2407.9	2366.5	2381.4
MAR	2395.6	2351.4	2365.7
AP1	2391.5	2342.2	2357.3
AP2	2391.2	2341.8	2358.0
MAY	2407.3	2365.6	2380.4
JUN	2440.7	2402.6	2416.4
JUL	2467.4	2430.8	2442.9
AG1	2468.1	2432.8	2445.4
AG2	2467.8	2431.4	2445.0
AVG	2432.0	2394.2	2407.0
HIGH	2468.1	2432.8	2445.4
LOW	2391.2	2341.8	2357.3

	MICA ELEVATIONS, BASE CASE		
	HIGH	LOW	AVG
SEP	2475.0	2455.6	2471.4
OCT	2473.1	2453.6	2468.5
NOV	2469.7	2447.5	2463.8
DEC	2459.1	2428.5	2450.7
JAN	2444.4	2412.7	2436.5
FEB	2431.1	2407.9	2425.0
MAR	2417.0	2395.1	2411.4
AP1	2410.0	2388.7	2404.8
AP2	2410.2	2388.8	2404.5
MAY	2424.4	2407.1	2418.6
JUN	2451.4	2438.1	2446.9
JUL	2470.8	2462.7	2469.4
AG1	2473.6	2466.5	2472.5
AG2	2475.0	2467.8	2473.6
AVG	2448.9	2430.0	2444.1
HIGH	2475.0	2467.8	2473.6
LOW	2410.0	2388.7	2404.5

	ARROW ELEVATIONS, REGIME 1		
	HIGH	LOW	AVG
SEP	1444.0	1444.0	1444.0
OCT	1442.0	1441.9	1441.9
NOV	1442.1	1438.1	1440.8
DEC	1436.2	1432.0	1435.4
JAN	1414.6	1406.0	1411.2
FEB	1406.7	1396.4	1402.4
MAR	1399.9	1393.6	1399.3
AP1	1400.6	1398.7	1399.9
AP2	1403.9	1399.9	1402.0
MAY	1416.8	1413.4	1415.0
JUN	1437.5	1435.3	1436.3
JUL	1444.0	1444.0	1444.0
AG1	1444.0	1444.0	1444.0
AG2	1444.0	1444.0	1444.0
AVG	1426.9	1423.7	1425.7
HIGH	1444.0	1444.0	1444.0
LOW	1399.9	1393.6	1399.3

	ARROW ELEVATIONS, BASE CASE		
	HIGH	LOW	AVG
SEP	1444.0	1443.5	1443.8
OCT	1441.9	1440.4	1441.5
NOV	1442.1	1438.1	1440.4
DEC	1436.2	1431.6	1435.3
JAN	1413.8	1406.2	1410.7
FEB	1406.7	1396.4	1401.9
MAR	1399.9	1395.9	1399.2
AP1	1399.9	1399.5	1399.9
AP2	1403.9	1399.9	1401.4
MAY	1415.3	1413.0	1414.9
JUN	1437.5	1435.3	1436.1
JUL	1444.0	1444.0	1444.0
AG1	1444.0	1444.0	1444.0
AG2	1444.0	1444.0	1444.0
AVG	1426.7	1423.7	1425.5
HIGH	1444.0	1444.0	1444.0
LOW	1399.9	1395.9	1399.2

	MICA FLOWS, REGIME 1		
	HIGH	LOW	AVG
SEP	32816	20838	30033
OCT	26319	14470	20722
NOV	25453	15016	18544
DEC	34000	22001	26631
JAN	28000	23000	26800
FEB	25000	9528	22145
MAR	23000	14917	19354
AP1	27000	15000	21951
AP2	18000	10000	10400
MAY	10000	10000	10000
JUN	10000	5481	9077
JUL	25760	19437	22443
AG1	40639	34000	36174
AG2	37779	32560	34413
AVG	25983	17589	22049
HIGH	40639	34000	36174
LOW	10000	5481	9077

	MICA FLOWS, BASE CASE		
	HIGH	LOW	AVG
SEP	32227	20518	22909
OCT	21410	14470	15997
NOV	18332	13061	15090
DEC	34000	22000	25600
JAN	28000	23000	26800
FEB	25000	9528	23377
MAR	23000	17000	21953
AP1	27000	15000	24710
AP2	18000	10000	10400
MAY	10000	10000	10000
JUN	10000	10000	10000
JUL	30960	21455	27380
AG1	41171	32434	34011
AG2	38249	31573	32839
AVG	25525	17860	21505
HIGH	41171	32434	34011
LOW	10000	9528	10000

	ARROW FLOWS, REGIME 1		
	HIGH	LOW	AVG
SEP	47735	34978	45298
OCT	43110	33627	37649
NOV	37852	25708	29463
DEC	51275	41734	43783
JAN	79546	69335	74655
FEB	48262	36846	44770
MAR	34824	28006	32017
AP1	28522	20381	25623
AP2	18639	9797	13377
MAY	29567	26397	27832
JUN	22546	15149	20710
JUL	52355	48349	50243
AG1	65162	58087	59978
AG2	56810	51905	53528
AVG	44015	35736	39923
HIGH	79546	69335	74655
LOW	18639	9797	13377

	ARROW FLOWS, BASE CASE		
	HIGH	LOW	AVG
SEP	47682	34726	37706
OCT	37899	31156	33066
NOV	32758	23021	26827
DEC	48765	40894	42733
JAN	79658	68900	74872
FEB	52529	36846	48310
MAR	37191	28006	32970
AP1	32870	22834	28706
AP2	19487	13235	17210
MAY	32838	27982	30449
JUN	24663	18166	21581
JUL	56134	48586	52419
AG1	65172	54459	57736
AG2	55982	51282	52414
AVG	44545	35721	39786
HIGH	79658	68900	74872
LOW	19487	13235	17210

TABLE 4.4 COMPARISION BETWEEN R 2 AND BASE CASE, MEDIUM LOAD

	MICA ELEVATIONS, REGIME 2		
	HIGH	LOW	AVG
SEP	2470.7	2450.6	2458.6
OCT	2465.9	2448.6	2454.9
NOV	2458.2	2444.8	2449.7
DEC	2441.6	2432.7	2436.1
JAN	2427.9	2416.7	2421.5
FEB	2417.4	2403.6	2409.3
MAR	2405.3	2388.1	2395.2
AP1	2401.3	2380.4	2388.1
AP2	2401.1	2380.2	2387.9
MAY	2417.3	2400.1	2405.0
JUN	2444.8	2429.0	2435.3
JUL	2470.8	2451.6	2459.0
AG1	2472.5	2454.0	2461.5
AG2	2473.6	2454.2	2461.9
AVG	2440.6	2423.9	2430.3
HIGH	2473.6	2454.2	2461.9
LOW	2401.1	2380.2	2387.9

	MICA ELEVATIONS, BASE CASE		
	HIGH	LOW	AVG
SEP	2475.0	2455.6	2472.3
OCT	2473.1	2453.6	2469.5
NOV	2469.7	2447.5	2465.0
DEC	2459.1	2428.6	2451.7
JAN	2444.4	2417.6	2437.8
FEB	2431.1	2412.2	2426.1
MAR	2417.0	2398.8	2412.6
AP1	2410.0	2392.6	2406.0
AP2	2410.2	2394.1	2405.9
MAY	2424.4	2410.5	2419.5
JUN	2451.4	2441.0	2447.7
JUL	2471.8	2466.9	2470.1
AG1	2473.9	2470.7	2473.3
AG2	2475.0	2471.9	2474.4
AVG	2449.0	2433.0	2445.1
HIGH	2475.0	2471.9	2474.4
LOW	2410.0	2392.6	2405.9

	ARROW ELEVATIONS, REGIME 2		
	HIGH	LOW	AVG
SEP	1444.0	1443.1	1443.8
OCT	1441.9	1438.8	1441.4
NOV	1441.9	1437.5	1439.7
DEC	1436.2	1431.5	1434.9
JAN	1413.3	1405.5	1410.2
FEB	1406.4	1396.1	1401.2
MAR	1399.9	1395.9	1399.4
AP1	1399.9	1399.5	1399.9
AP2	1403.9	1399.9	1401.9
MAY	1415.3	1413.1	1414.9
JUN	1437.5	1435.3	1436.4
JUL	1444.0	1444.0	1444.0
AG1	1444.0	1444.0	1444.0
AG2	1444.0	1444.0	1444.0
AVG	1426.6	1423.4	1425.4
HIGH	1444.0	1444.0	1444.0
LOW	1399.9	1395.9	1399.4

	ARROW ELEVATIONS, BASE CASE		
	HIGH	LOW	AVG
SEP	1444.0	1443.5	1443.8
OCT	1441.9	1440.5	1441.6
NOV	1442.1	1438.1	1440.4
DEC	1436.2	1431.7	1435.3
JAN	1413.8	1406.6	1410.8
FEB	1406.7	1396.8	1401.9
MAR	1399.9	1396.2	1399.3
AP1	1399.9	1399.5	1399.9
AP2	1403.9	1399.9	1401.4
MAY	1415.3	1413.0	1414.9
JUN	1437.5	1435.3	1436.1
JUL	1444.0	1444.0	1444.0
AG1	1444.0	1444.0	1444.0
AG2	1444.0	1444.0	1444.0
AVG	1426.7	1423.8	1425.5
HIGH	1444.0	1444.0	1444.0
LOW	1399.9	1396.2	1399.3

	MICA FLOWS, REGIME 2		
	HIGH	LOW	AVG
SEP	27432.0	13561.0	25786.8
OCT	19204.0	11650.0	17398.3
NOV	19052.0	13215.0	15408.3
DEC	33583.0	22000.0	26525.0
JAN	27000.0	22311.0	25855.2
FEB	25000.0	17657.0	23694.2
MAR	23000.0	17000.0	21588.9
AP1	27000.0	15000.0	24668.1
AP2	18000.0	10000.0	10400.0
MAY	10000.0	10000.0	10000.0
JUN	10000.0	10000.0	10000.0
JUL	28500.0	21184.0	25137.6
AG1	40000.0	33500.0	34903.6
AG2	37687.0	32037.0	33725.4
AVG	24676	17794	21792
HIGH	40000	33500	34904
LOW	10000	10000	10000

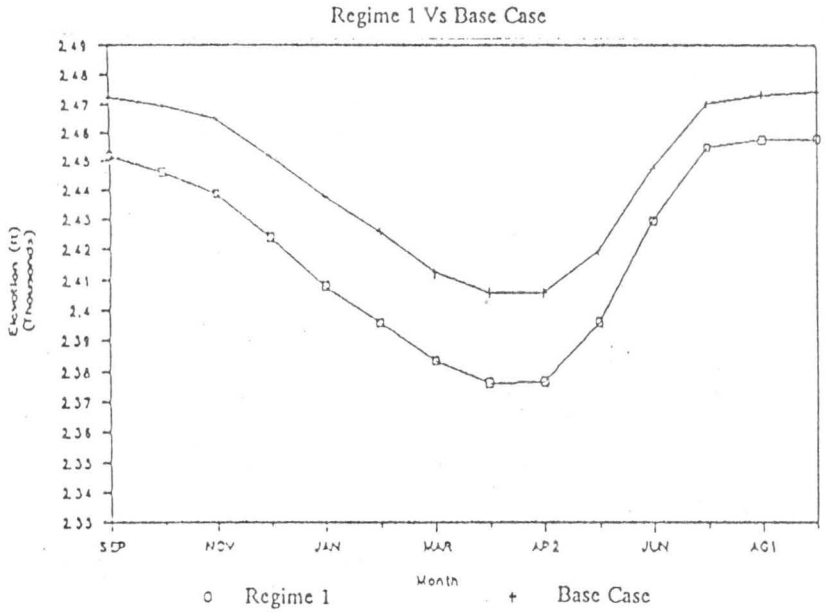
	MICA FLOWS, BASE CASE		
	HIGH	LOW	AVG
SEP	30228.0	20518.0	22433.7
OCT	19996.0	14350.0	15770.0
NOV	19192.0	13061.0	15124.9
DEC	34000.0	22000.0	25672.8
JAN	27000.0	21036.0	26359.3
FEB	25000.0	10165.0	23647.3
MAR	23000.0	17000.0	21990.6
AP1	27000.0	15000.0	24750.0
AP2	18000.0	10000.0	10400.0
MAY	10000.0	10000.0	10000.0
JUN	10000.0	10000.0	10000.0
JUL	30960.0	21633.0	27540.7
AG1	40639.0	32576.0	33895.4
AG2	37706.0	31573.0	32719.1
AVG	25194	17779	21450
HIGH	40639	32576	33895
LOW	10000	10000	10000

	ARROW FLOWS, REGIME 2		
	HIGH	LOW	AVG
SEP	42616.0	30467.0	40837.9
OCT	35987.0	32744.0	34900.7
NOV	35096.0	24040.0	27645.8
DEC	50856.0	40305.0	43506.8
JAN	80174.0	68862.0	74545.1
FEB	50171.0	41785.0	45748.3
MAR	35371.0	26835.0	31947.7
AP1	32870.0	22337.0	28975.5
AP2	19192.0	15117.0	17111.8
MAY	29571.0	27446.0	28745.0
JUN	26926.0	19097.0	23510.0
JUL	53890.0	48717.0	50795.9
AG1	65172.0	55457.0	58355.5
AG2	55492.0	52323.0	53793.3
AVG	43813	36109	40030
HIGH	80174	68862	74545
LOW	19192	15117	17112

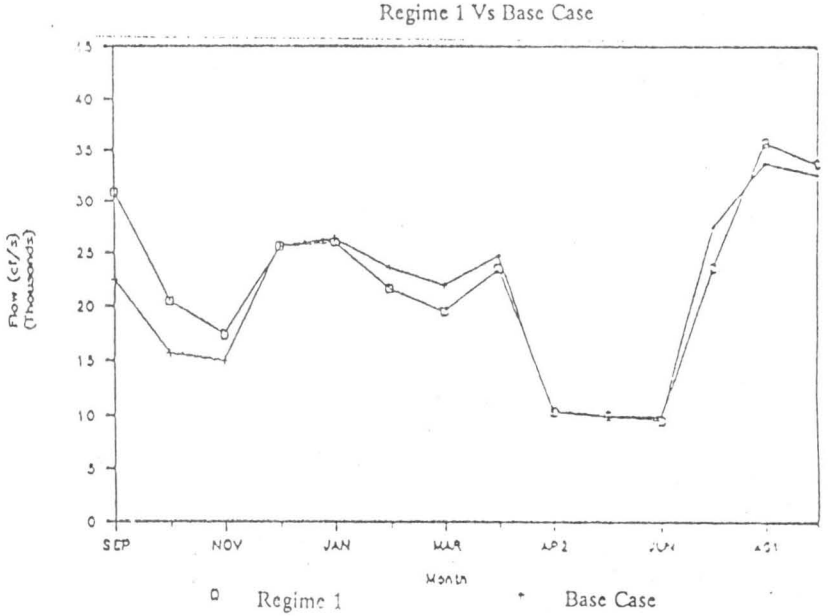
	ARROW FLOWS, BASE CASE		
	HIGH	LOW	AVG
SEP	45257.0	34726.0	37272.5
OCT	37105.0	31156.0	32861.7
NOV	32430.0	23021.0	26871.5
DEC	48282.0	40894.0	42866.0
JAN	79692.0	68900.0	74365.0
FEB	52529.0	38068.0	48587.6
MAR	37191.0	28057.0	33218.2
AP1	32870.0	22486.0	28822.0
AP2	19487.0	12796.0	17138.6
MAY	32838.0	27982.0	30557.4
JUN	24663.0	18166.0	21594.3
JUL	56134.0	48638.0	52427.3
AG1	65172.0	54459.0	57691.3
AG2	55492.0	51282.0	52299.4
AVG	44224	35759	39755
HIGH	79692	68900	74365
LOW	19487	12796	17139

Figure 4.1 Average Reservoir Elevations and Outflows - Regime 1 (Medium Loads) Versus Base Case (Medium Loads)

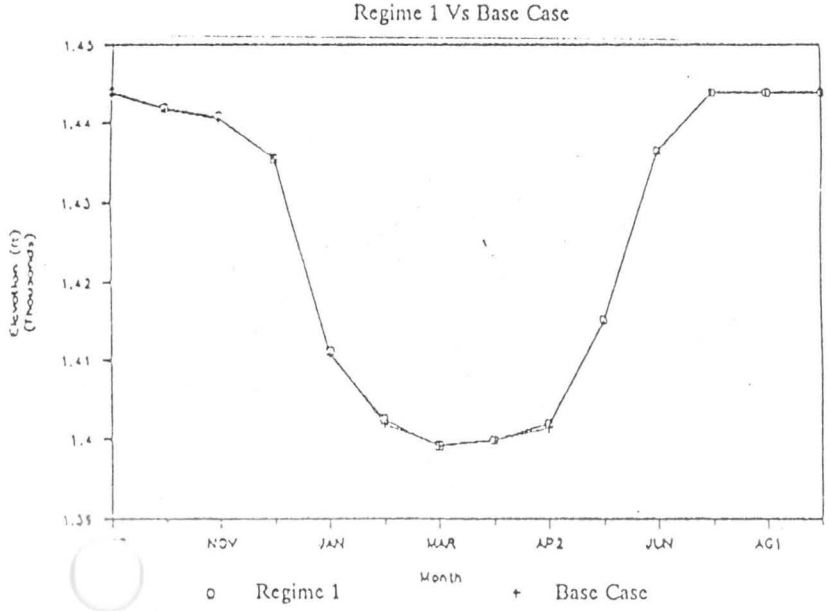
4.1.1 Elevations at Mica, MED



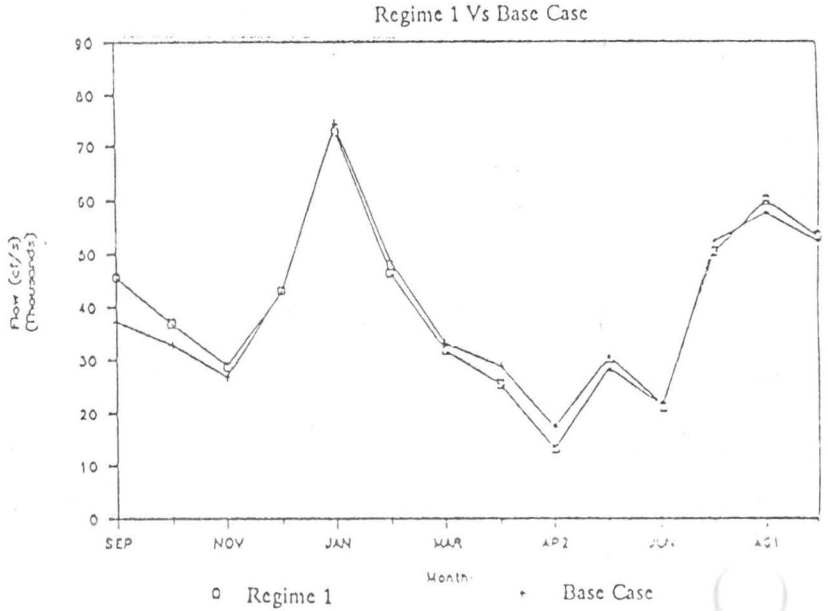
4.1.2 Flows at Mica, MED



4.1.3 Elevations at Arrow, MED



4.1.4 Flows at Arrow, MED



Mica Outflows

Under Regime 1 (medium load) operating conditions, average outflows generally increase in August through November, and decrease in December through July, compared to the Base Case (medium load) (Figure 4.1 (4.1.2)). With Regime 1, the highest average flow increase (238.3 m^3/s (8415 ft^3/s)) occurs during September, and the highest average flow reduction (109 m^3/s (3859 ft^3/s)) occurs in July, compared to the Base Case. Over the 20-year study period, Regime 1 annual average flows are approximately 595 m^3/s (21,000 ft^3/s). The lowest average flow (283 m^3/s (10,000 ft^3/s)) occurs in May, while the highest average flow (1018 m^3/s (35,960 ft^3/s)) occurs in August (similar to the Base Case). The highest and lowest flows for Regime 1 over the period of study are 1150.8 m^3/s (40,639 ft^3/s) and 205.0 m^3/s (7239 ft^3/s), respectively. Changes in maximum and minimum outflows would be small.

Arrow Elevations

The annual average elevation difference between Regime 1 and the Base Case (medium loads) is 0.07 m (0.3 ft). Average elevations range from a decrease of 0.03 m (0.1 ft) in March, to an increase of 0.2 m (0.7 ft) in early April (Figure 4.1 (4.1.3)). The highest and lowest average elevations with Regime 1 are 440.1 m (1444 ft) (full pool) and 426.5 m (1399.2 ft), occurring in the months of July through September and March, respectively. Changes in maximum and minimum elevations would be small.

Arrow Outflows

Under Regime 1 (medium load), average outflows increase in August through December and decrease January through July compared to Base Case (medium load) outflows (Figure 4.1 (4.1.4)). With Regime 1, the highest average flow increase (235.7 m^3/s (8322.1 ft^3/s)) occurs in September, while the highest average flow reduction (116.8 m^3/s (4124.5 ft^3/s)) occurs in April, compared to Base Case flows. Minimum outflows would not change but maximum flows increase from 2775 m^3/s (98,000 ft^3/s) to 3115 m^3/s (110,000 ft^3/s).

4.1.2 Regime 1 (ARO) Compared to Base Case (ARO)

Mica Elevations

Under Regime 1 (ARO), the average elevation of the Mica Reservoir decreases, and its annual operating range increases by up to 6.7 m (22 ft) compared to the Base Case (ARO) (Figure 4.2 (4.2.1)). The changes are very similar to those which occur under the medium energy load comparison. With Regime 1 (ARO), annual reservoir elevations fluctuate between 733.3 m (2405.9 ft) and 742.1 m (2434.6 ft) with an operating range of 22.8 to 28.2 m (74.8 to 92.5 ft). Differences in annual elevations range from no change to a 12.6 m (41.3 ft) decrease. The greatest changes in average elevation occur during the months of September through April. As with Regime 1 (medium load), maximum elevations would remain near full pond while minimum elevations would drop from 723.9 m (2375 ft) to 707.1 m (2320 ft).

Mica Outflows

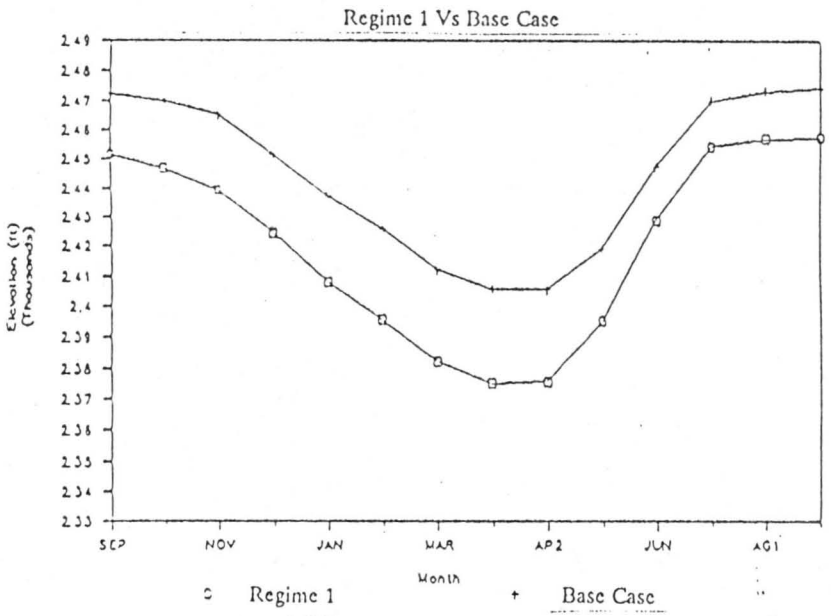
Average outflows generally increase in August through December, and decrease in January through July with Regime 1 (ARO) compared to the Base Case (ARO) (Figure 4.2 (4.2.2)). With Regime 1 (ARO), the highest average flow increase (223.3 m^3/s (7886 ft^3/s)) occurs during September, while the highest average flow reduction (117.6 m^3/s (4152.4 ft^3/s)) occurs in July, compared to the Base Case (ARO). Differences in maximum and minimum flows would be small.

Arrow Elevations

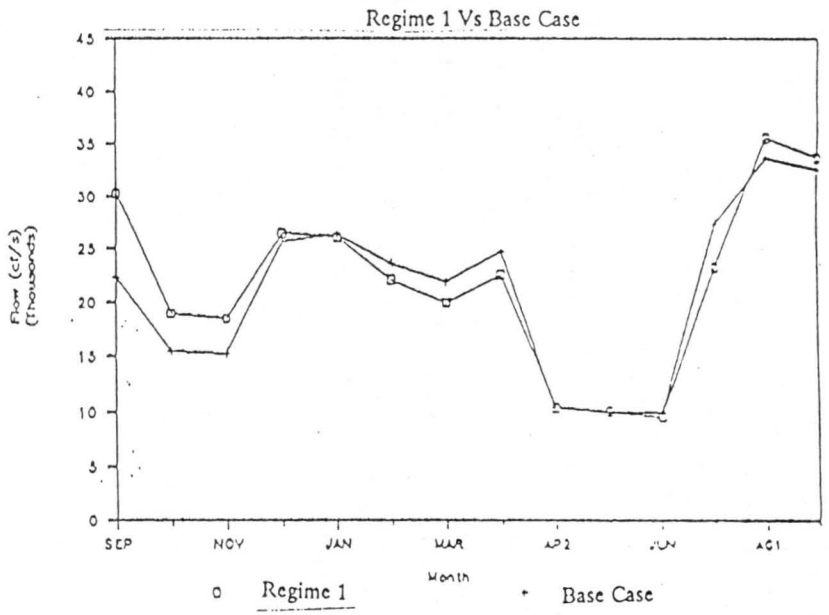
The annual average elevation difference between Regime 1 (ARO) and the Base Case (ARO) is 0.03 m (0.1 ft). Average changes in elevation range from no change in March, and June through August, to a 0.12 m (0.4 ft) increase in late April (Figure 4.2 (4.2.3)). No changes in maximum and minimum elevations will occur.

Figure 4.2 Average Reservoir Elevations and Outflows - Regime 1 (ARO) Versus Base Case (ARO)

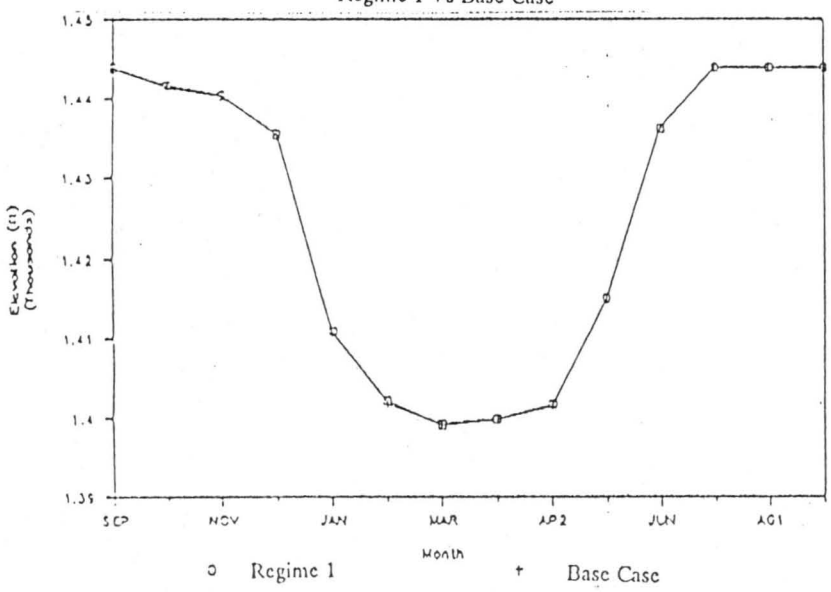
4.2.1 Elevations at Mica, ARO



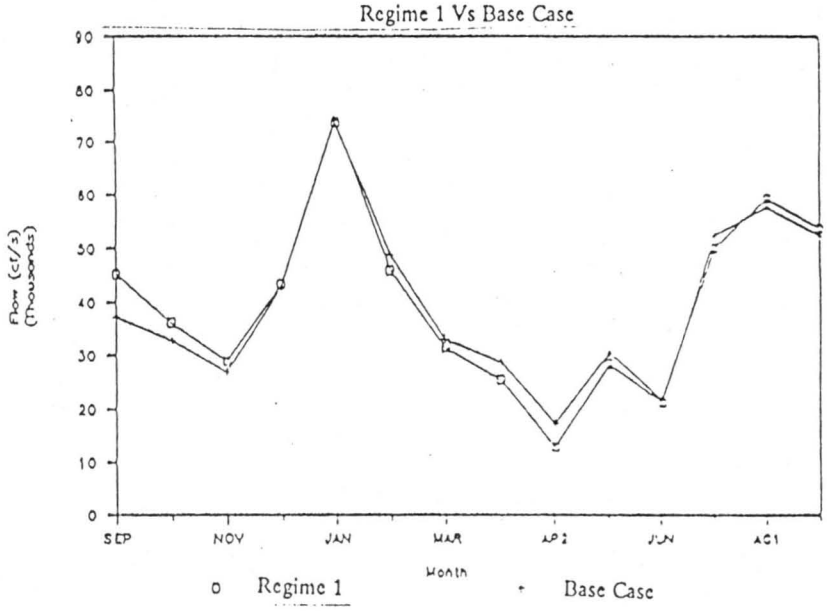
4.2.2 Flows at Mica, ARO



4.2.3 Elevations at Arrow, ARO



4.2.4 Flows at Arrow, ARO



Arrow Outflows

With Regime 1 (ARO), average outflows generally increase in August through December and decrease in January through July, compared to the Base Case (ARO) (Figure 4.2 (4.2.4)). With Regime 1 (ARO), the highest flow increase (225 m^3/s (7944.5 ft^3/s)) occurs in September, while the highest flow reduction (123.3 m^3/s (4354.7 ft^3/s)) occurs in late April, compared to Base Case (ARO) flows. Maximum and minimum flows would not change between Regime 1 (ARO) and the Base Case (ARO). With both, maximum flows will be up to 3442 m^3/s (118,000 ft^3/s).

4.1.3 Regime 1 (AOS) Compared to Base Case (AOS)

Mica Elevations

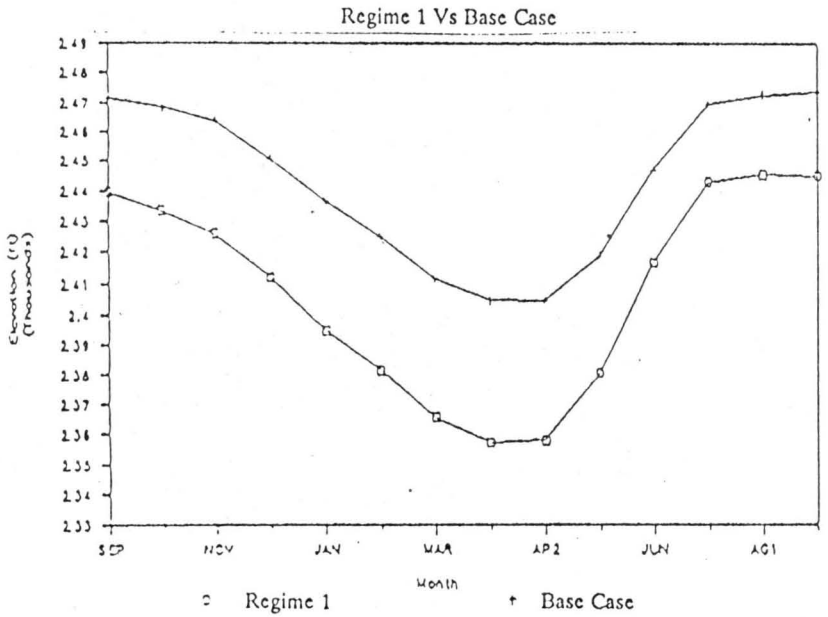
Under Regime 1 (AOS), the average elevation of Mica Reservoir decreases and its annual operating range increases by up to 7.8 m (25.6 ft) compared to the Base Case (AOS). With Regime 1 (AOS), annual reservoir elevations fluctuate between 730.4 m (2396.2 ft) and 741 m (2431.1 ft) with an operating range of 22.9 to 28.7 m (75.2 to 94.3 ft) (Figure 4.3 (4.3.1)). The greatest changes in average elevation occur during the months of September through May. Differences in annual operating levels range from no change to a 15.6 m (51.1 ft) decrease which is the largest of any of the regimes studied. As with Regime 1 (medium load), maximum elevation would remain at 754.4 m (2475 ft) but the minimum elevation would decrease from 723.9 m (2375 ft) to 707.1 m (2320 ft).

Mica Outflows

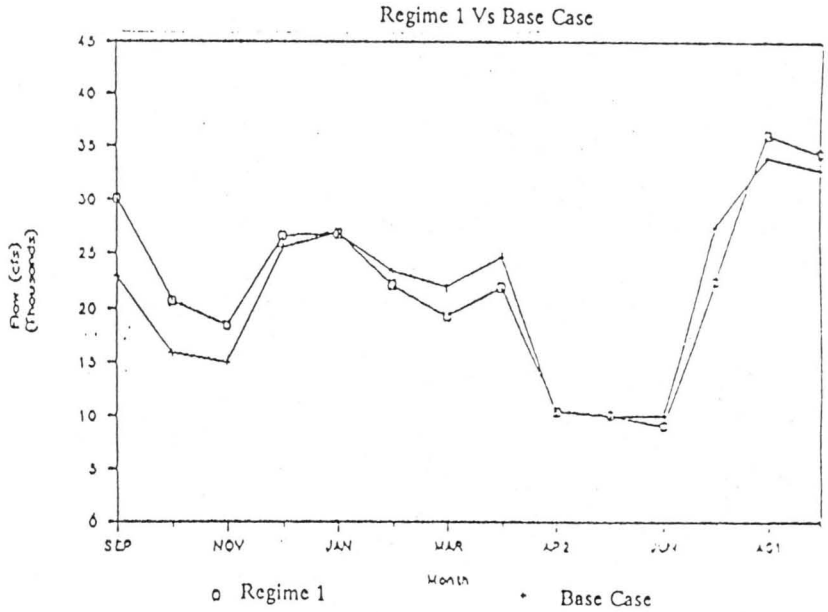
With Regime 1 (AOS), average outflows generally increase in August through December, and decrease in January through July, compared to Base Case (AOS) outflows (Figure 4.3 (4.3.2)). With Regime 1 (AOS), the highest average flow increase (201.7 m^3/s (7124.1 ft^3/s)) occurs during September, while the highest average flow reduction (139.8 m^3/s (4937.5 ft^3/s)) occurs in July, compared to the Base Case (AOS). There would be little change in maximum or minimum outflows.

Figure 4.3 Average Reservoir Elevatio[illegible]d Outflows - Regime 1 (AOS) Versus Base Case (AOS)

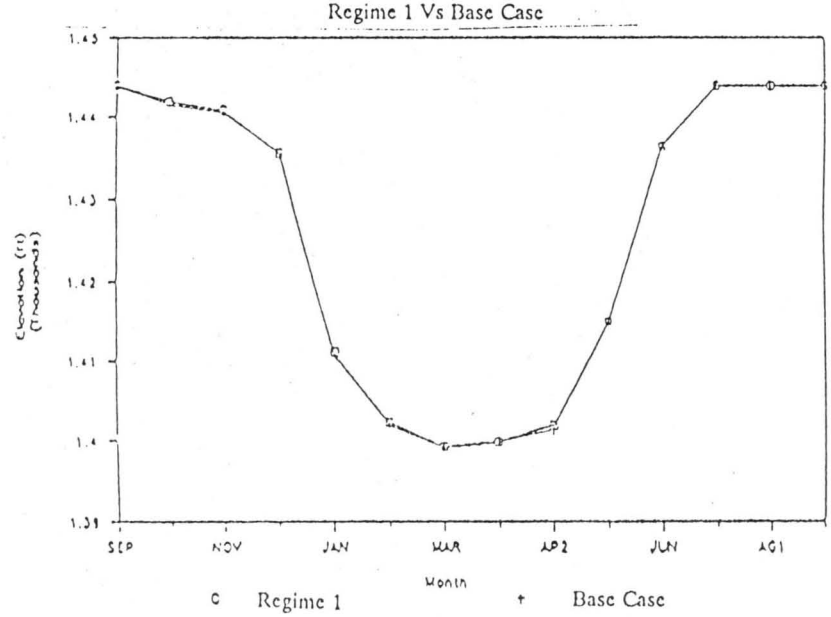
4.3.1 Elevations at Mica, AOS



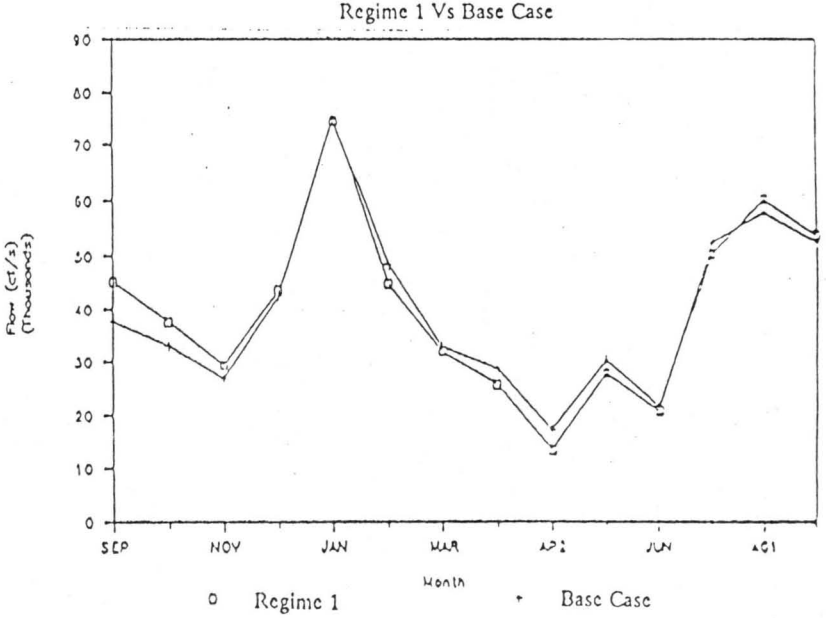
4.3.2 Flows at Mica, AOS



4.3.3 Elevations at Arrow, AOS



4.3.4 Flows at Arrow, AOS



Arrow Elevations

The annual average elevation difference between Regime 1 (AOS) and the Base Case (AOS) is 0.07 m (0.22 ft). Average changes in elevation range from no change in early April, July and August to a 0.18 m (0.6 ft) increase in late April (Figure 4.3 (4.3.3)). There would be no change in maximum or minimum elevations.

Arrow Outflows

Under Regime 1 (AOS) operating conditions, average outflows generally increase in August through December, and decrease in January through July, compared to the Base Case (AOS) (Figure 4.3 (4.3.4)). With Regime 1 (AOS), the highest average flow increase (215 m^3/s (7591.7 ft^3/s)) occurs in September, while the highest average flow reduction (108.5 m^3/s (3833.1 ft^3/s)) occurs in late April, compared to the Base Case (AOS). Minimum outflows would not change while maximum outflows would decrease approximately 283 m^3/s (10,000 ft^3/s) to 2832 m^3/s (100,000 ft^3/s).

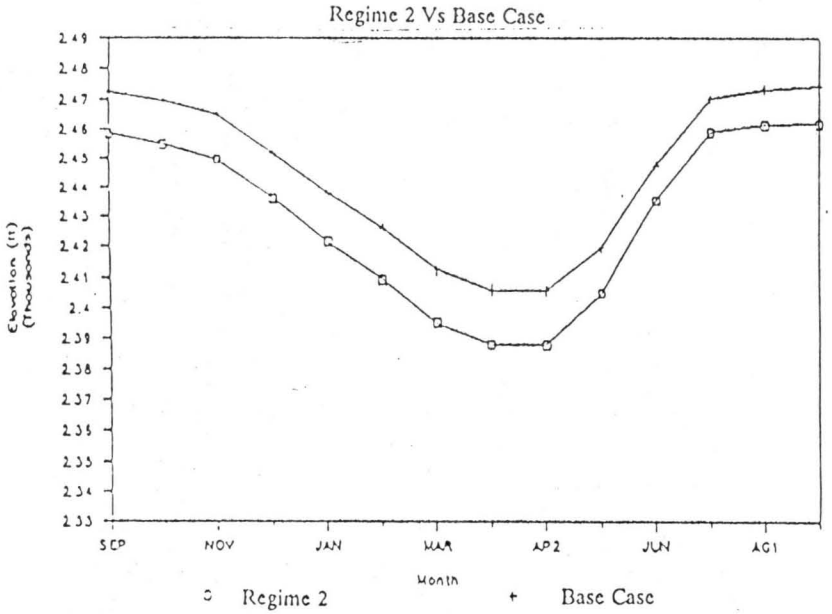
4.1.4 Regime 2 (Medium Load) Compared to Base Case (Medium Load)

Mica Elevations

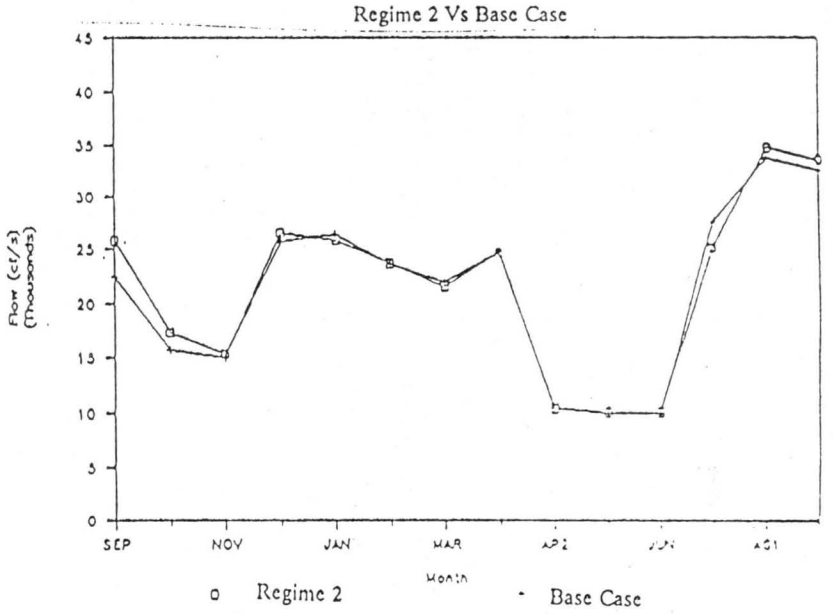
Under Regime 2 (medium load), the average elevation of the Mica Reservoir decreases at all times of the year, and the annual operating range increases by up to 3.4 m (11.1 ft) compared to the Base Case (medium load) (Figure 4.4 (4.4.1)). These changes are smaller than under Regime 1 (medium load). With Regime 2, annual reservoir elevations fluctuate between 739.5 and 744.0 m (2426.1 and 2440.9 ft) with an operating range of 21.2 to 23.6 m (69.7 to 77.5 ft). Over the period of study, average differences between Regime 2 and Base Case annual elevations range from a 1.0 m (3.2 ft) increase to a 7.0 m (22.9 ft) decrease. The greatest changes in average elevation would occur during the months of September through April. Maximum elevations would not change. However, minimum elevations would decrease from 723.9 m (2375 ft) to 707.1 m (2320 ft).

Figure 4.4 Average Reservoir Elevatio[illegible]d Outflows - Regime 2 (Medium Loads) Versus Base Case (Medium Loads)

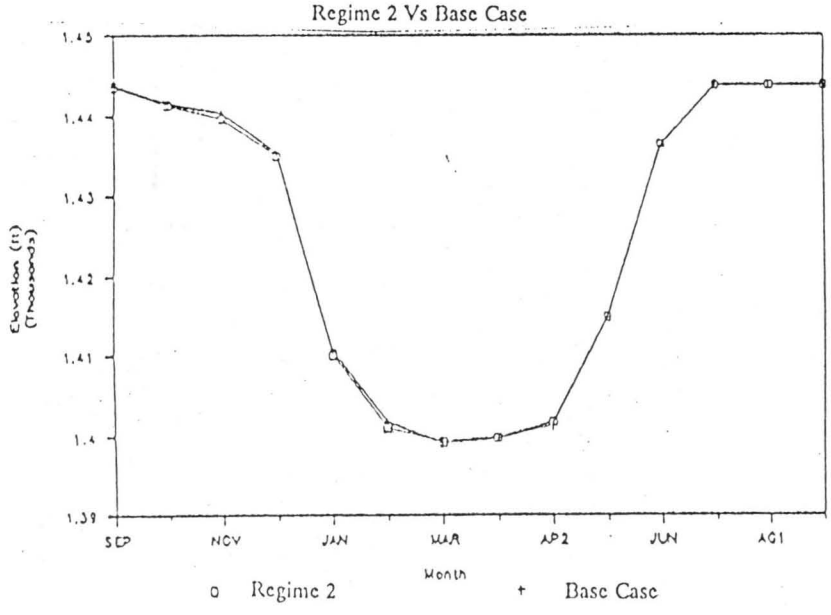
4.4.1 Elevations at Mica, MED



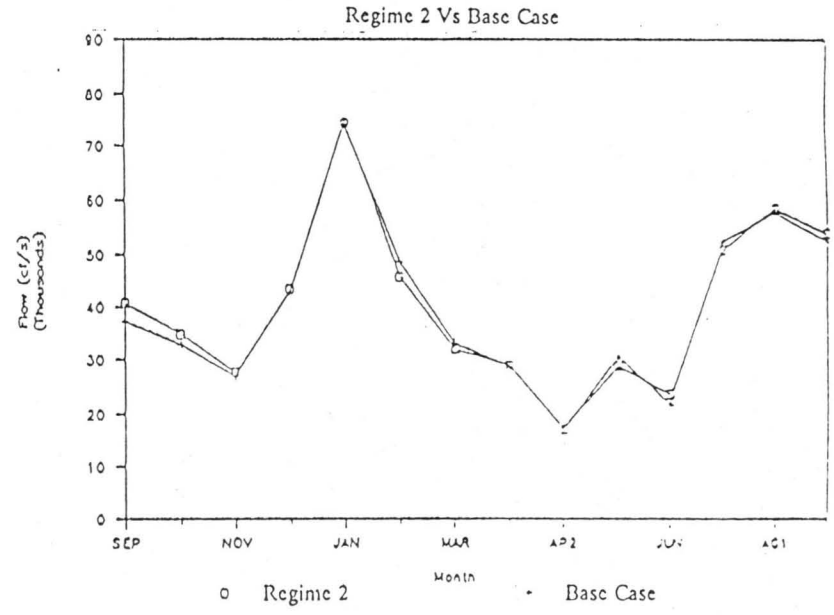
4.4.2 Flows at Mica, MED



4.4.3 Elevations at Arrow, MED



4.4.4 Flows at Arrow, MED



Mica Outflows

Under Regime 2 (medium load) operating conditions, average outflows generally increase in August through December, and decrease in January through July, compared to Base Case (medium load) outflows (Figure 4.4 (4.4.2)). Under Regime 2, the highest average flow increase (95.0 m^3/s (3353 ft^3/s)) occurs during September, while the highest average flow reduction (68.1 m^3/s (2403 ft^3/s)) occurs in July, compared to Base Case flows. Changes in maximum and minimum flows would be small.

Arrow Elevations

The annual average elevation of the reservoir with Regime 2 (medium load) decreases by 0.03 m (0.1 ft) compared to the Base Case (medium load). Average changes in elevation range from a 0.2 m (0.7 ft) decrease in February, to a 0.15 m (0.5 ft) increase in late April (Figure 4.4 (4.4.3)). Maximum and minimum reservoir elevations would not change.

Arrow Outflows

With Regime 2 (medium load), average outflows generally increase in August through January, early April and June, and decrease in February, March, late April and May, compared to Base Case (medium load) outflows (Figure 4.4 (4.4.4)). Under Regime 2, the highest flow increase (101.0 m^3/s (3565.4 ft^3/s)) occurs in September, while the highest flow reduction (80.4 m^3/s (2839.4 ft^3/s)) occurs in February, compared to Base Case flows. Changes in maximum and minimum outflows would be small.

4.2 Biological Effects

4.2.1 Water Quality

The only area where water quality is a concern at present is the reach of the Columbia River downstream of Hugh Keenleyside Dam, due mainly to the effects of the Celgar pulp mill effluent.

Recent legislation has been introduced which requires pulp mills in B.C. to comply with the guidelines for effluent toxicity and effects on water quality outlined in the B.C. Waste Management Act. By 1991, all mills will be required to have secondary effluent treatment capability and reduced emissions of absorbable organic halogens, which are implicated in the production of dioxin-related compounds in the aquatic environment. Accordingly, future water quality in the vicinity of the Celgar pulp mill near Castlegar will be improved compared to what it is today. In general, water quality will be improved under all flow regimes by the required work on the pulp mill effluent treatment system.

4.2.2 Fish and Fish Habitat

Mica Reservoir

All operating regimes will result in an overall reduction of the annual elevation of Mica Reservoir, compared to the base cases, such that the frequency with which the upper 5 m (16 ft) of the drawdown zone will be flooded will decrease. Regime 2 will result in the smallest overall reduction, Regime 1 (medium load) and Regime 1 (ARO) are virtually identical, both resulting in moderate reductions in elevation. Regime 1 (AOS) will result in the largest overall reduction. The Regime 1 (AOS) SAM data indicate that the upper 10 m (32.5 ft) of the wetted drawdown zone that is currently being flooded is likely to be flooded less frequently. In addition, outflows from the reservoir will increase during the months of August through November and decrease during December through July.

Relatively minor changes in plankton production can be expected due to alterations in nutrient concentrations, light, temperatures and grazing pressures that will result from water level changes. One direct effect of increased drawdown will likely be increased removal of plankton from the epilimnion (upper layers) of the reservoir. Data from Mica and other oligotrophic reservoirs such as Revelstoke and Williston indicate that peak plankton production occurs in the period July to October. Increased outflows during this period could result in plankton production being concentrated in the vicinity of the dam. This, in turn, could result in fish stocks being concentrated in the same area thereby exacerbating a known fish entrainment problem. However, losses to Mica fisheries resources due to increased entrainment of plankton and fish would likely be offset by positive, incremental effects on fish stocks in the area immediately below the dam.

Lower reservoir levels will not adversely affect access to tributaries by migratory spawning fish with the exception of the Beaver and Wood Rivers and Foster Creek. These three streams have natural barriers to fish migration which are currently inundated and, therefore, made passable to fish for reservoir levels above 735 m (2410 ft). With Regime 1 (medium load) and Regime 1 (ARO), these barriers would be exposed January through May. With Regime 1 (AOS), average elevations indicate that these barriers would be exposed occasionally in December and June and always in January through May. The net effect of barrier exposure on the fisheries resources of Mica Reservoir under these operating regimes would be to impede migration and spawning of rainbow trout stocks, which usually spawn in April through June in the Columbia System, and cause a reduction in the amount of available tributary rearing habitat. However, since rainbow trout spawning coincides with spring runoff, hence reservoir filling, it is probable that rainbow trout spawning would only be delayed rather than arrested. Furthermore, it is likely that these three streams contribute little to the overall production of the reservoir's rainbow trout population given the low water temperatures and turbid conditions prevalent in all three.

During excessively dry years, the migration barriers would be exposed for periods of time encompassing all or part of the spawning season for rainbow trout, Dolly Varden char, kokanee and mountain whitefish. Kokanee production would probably not be affected as this species is not known to spawn in these cold, glacial streams. Dolly Varden char and mountain whitefish production could be compromised. However, it is estimated that these three streams would only contribute between 5 and 10% of the overall reservoir production of these two species. Furthermore, losses would be confined to extremely dry years.

The current drawdown zone does not provide productive fish habitat. Therefore, it is unlikely that reduced overall reservoir levels will have any effect on the amount of available rearing habitat in the reservoir or its tributaries over the short term. The data indicate an increased exposure of the upper 5 m of the reservoir with Regime 1 (medium load and ARO) and the upper 10 m with Regime 1 (AOS), creating the potential for long term recovery of riparian vegetation and fish habitat in the lower sections of tributary streams. With Regime 2 (medium load), the upper drawdown zone will remain wetted over the long term, precluding recovery of "old" tributary spawning and rearing habitat.

Due to the steep-sided slope of the reservoir and the effects of drawdown, shoreline spawning is already extremely limited and would remain so under both base case and alternate regime conditions.

Arrow Lakes Reservoir

For all regimes, the projected Arrow Lakes Reservoir elevations are very similar to the associated base case elevations. Average monthly differences in elevations are less than 0.03 m (0.1 ft) with maximum differences of $\pm$0.4 m ($\pm$1.3 ft).

Increased entrainment of plankton, benthic invertebrates and fish from the Arrow Lakes during periods of rapid discharge may have a minor effect on the biological productivity of fish resources of the Arrow Lakes Reservoir. Overall, there are no anticipated impacts on fish utilizing the Arrow Lakes Reservoir.

Downstream Area

The different regimes will result in elevated outflows during August to December from the Arrow Lakes Reservoir compared to the base cases. There will likely be minor beneficial effects downstream of the Hugh Keenleyside Dam as increased outflows result in increased numbers of juvenile fish and invertebrates from Lower Arrow Lake being entrained over the dam to the downstream area.

Since the present high total dissolved gas (TDG) levels currently found in the waters downstream of the Hugh Keenleyside Dam do not appear to have any adverse effect on downstream fish stocks, it is not expected that any increase in TDG associated with the anticipated increases in maximum flows will have an incremental effect.

Decreased outflows from Hugh Keenleyside Dam during the period January through July would result in small decreases in overall discharge in the Columbia River downstream of the dam which, in turn, could adversely affect important sport fish rearing and/or spawning habitat in the Columbia River below Hugh Keenleyside Dam. Eggs deposited during the

high water period may become exposed when late winter - early spring downward fluctuations in water depth occur.

One indirect beneficial effect of the proposed increased flows (August-November) will be the dilution effect of greater volumes of water flowing past the Celgar pulp mill at Castlegar. This could alleviate potential sublethal toxic effects in fish during periods of high effluent discharge. Alternatively, decreased flows could accentuate potential toxic effects. However, since minimum flows will not be decreased and since new regulations regarding the effluent discharge guidelines for pulp mills have been introduced and the pulp mill effluent treatment system is being redesigned, it is not possible to quantitatively assess the effect changes in water levels will have on effluent toxicity. Improvements in the pulp mill effluent treatment system should generally improve downstream water quality.

4.2.3 Wildlife Resources

Mica Reservoir

At present, variations in reservoir level, combined with other factors such as steepness of terrain, severely limit production of aquatic/wetland wildlife at Mica Reservoir. Therefore, increased annual ranges in reservoir level due to any of the reservoir operating regimes would have little incremental effect compared to the associated base cases. Generally lower reservoir levels at times when waterfowl, shorebirds and other species are migrating along the Rocky Mountain Trench should have no adverse impact because those birds primarily rest on sandbars and mudflats and such habitats will still be available.

A possible reduction in aquatic productivity due to loss of plankton during periods of extensive discharge of water from the reservoir could adversely affect wildlife species which depend on aquatic food chains. This includes diving ducks, loons, ospreys, bald eagles, and river otters. However, populations of those species at Mica Reservoir are small and few individuals would be affected. Reduced access into Beaver River, Wood River, or Foster Creek for spawning fish is not expected to have impacts on species such as bears and bald eagles which feed on spawners, as few fish will be affected.

The data indicate that with the alternate regimes, the upper part of the drawdown zone would be flooded less frequently than under base case conditions. In about 10 years out of 20 there might be no flooding in the upper 5 m (16 ft) zone, including runs of up to six consecutive years, with Regime 1 (medium load) and Regime 1 (ARO). This would allow early successional vegetation, probably mostly annual grasses, sedges, and weedy forbs, to become temporarily established where gradients and soil conditions are suitable. Approximately 500 to 1000 ha (1,235 to 2,470 acres) of the drawdown zone could be involved, based on estimated shoreline slopes of 30 to 50%. This could provide some benefit for terrestrial wildlife. With Regime 2 (medium load), the upper drawdown zone could remain wetted over the long term, and vegetation would not become established to the same degree, lessening potential benefits to terrestrial wildlife.

With Regime 1 (AOS), infrequent flooding of the upper 10 m (32.5 ft) portion of the current drawdown zone, especially after 1991, could result in more terrestrial habitat being available around the reservoir perimeter. With this regime, reservoir levels would rise to within 5 m (16 ft) of full pool in only about 2 years out of 20, and to within 10 m (32.5 ft) of full pool in 11 years out of 20. There could potentially be no flooding in the upper 10 m (32.5 ft) zone for periods of up to 5 years and no flooding at all in the upper 5 m (16 ft) zone after 1991. Thus, some vegetation could potentially become permanently established in the upper part of the Mica Reservoir drawdown zone. Although the kind and production of vegetation would vary with aspect, slope steepness, and soil conditions, some plant growth could be expected to colonize most newly exposed substrates. After 1991, up to 1000 ha (2470 acres) could be colonized by terrestrial vegetation. Over the long term this could undergo succession from grass-forb communities to coniferous forest and would eventually be used by most species of terrestrial wildlife which presently occur at low elevations in this area. In the zone 5 to 10 m (16 to 32.5 ft) below full pool, early successional stages of vegetation such as grasses, sedges, forbs and willows could become at least temporarily established in favourable sites, and would provide forage for moose, elk, black bears and Canada geese.

Lower water levels should have no adverse impact on any cross-reservoir big game movements. Seasonal timing of open water and ice cover should not change. Lower reservoir levels will mean that the crossing distance, on average, is slightly less than under base case conditions.

Of all the regimes studied, Regime 1 (AOS) results in greater deviations from its Base Case than in any of the other comparisons. Therefore, potential impacts on wildlife will be greatest for this regime.

Arrow Lakes Reservoir

With all regimes, differences between Arrow Lake elevations and the associated base case conditions are small. Slight, if any, incremental impacts on wildlife habitat or on waterfowl occurrence will result.

Subtle variations in the frequency and duration of flooding of plant communities in the upper part of the Arrow Lakes drawdown zone could initiate minor changes in those communities which are either harmful or beneficial for wildlife. Since these differences are very small, only slight, if any, impacts on wildlife would occur.

Changes in reservoir levels and discharge rates should not cause measurable changes in productivity or fish abundance, therefore, no impacts on wildlife species which feed on plankton, aquatic invertebrates, or fish should occur.

Downstream Area

With the alternate reservoir operating regimes, differences in average monthly outflows from Arrow Lake Reservoir compared to their associated base case flows are slight. Resulting changes in water depth and channel width in the Columbia River will be minor and are expected to have no measurable impact, positive or negative, on wildlife habitats or populations along the river.

4.3 Human Habitation and Resource Uses

4.3.1 Heritage Resources

Inundation of heritage sites does not necessarily adversely affect heritage resources. Rather, adverse effects result from wave action, reservoir level fluctuation, currents and

seiches, wind and water erosion, stream and ice action, and redeposition of sand and silt. Site exposure during reservoir operation can also result in discovery and unauthorized removal of artifacts.

Mica Reservoir

With all reservoir operation regimes examined, the two documented heritage sites at Mica Reservoir will remain inundated even with the increase in reservoir drawdown, thus will not be affected. Any undocumented heritage sites which are underwater at all times or exposed for only part of the year could be uncovered for longer periods of time as the operating ranges of the different regimes are greater than the base case ranges. Disturbance by wave action, particularly at mid-range elevations, could result. The possibility of discovery and removal of artifacts without authorization is greater with the regimes, although access to any sites is limited primarily to the summer months when boating and other recreation activity takes place, and the reservoir is normally at its highest elevations during this period. With all regimes, average reservoir elevations during the summer months range from 3.4 m (11.1 ft) to 9.7 m (31.8 ft) lower than corresponding Base Case elevations.

Arrow Lakes Reservoir

For all reservoir operating regimes examined, the differences in reservoir elevations between the regimes and the associated base cases are very small. Most known heritage sites have already received impacts from present reservoir operation. Therefore, no further impacts on heritage sites are expected from implementation of the different operating regimes rather than the associated base cases.

Downstream Area

Changes in average outflows from the Arrow Lakes Reservoir with all reservoir operation regimes studied compared to the associated base cases will not have incremental impacts on known downstream heritage sites. The two sites considered in past studies to warrant conservation or mitigation, which are at or below El. 422 m (1386 ft), the elevation associated with the current maximum outflows from Hugh Keenleyside Dam, have already

been disturbed by those flows and no new impacts are expected. The two heritage sites at El. 424 m (1391 ft) which have been judged in past studies to warrant conservation or mitigation will not be affected by the maximum flows projected under any regime. Although the elevation associated with the projected maximum flows is approximately 424 m (1391 ft) just below the dam, river stage downstream drops considerably.

4.3.2 Settlements

Mica Reservoir

There are no settlements located adjacent to Mica Reservoir and none depend on the reservoir for water supply. Therefore, there are no adverse impacts on settlements as a result of any of the four operating regimes or their associated base cases.

Arrow Lakes Reservoir

For all reservoir operation alternate regimes examined, no potential impacts on settlements around the reservoir are expected due to the very small differences in reservoir elevation between the regimes and the associated base cases.

Downstream Area

The majority of communities along the Columbia River downstream of Hugh Keenleyside Dam are not expected to be affected by the small changes in average monthly river flows contemplated with any of the reservoir operation regimes, compared to the associated base cases, as their drinking water is not supplied by the river, and they have already adjusted to fluctuating flows. Prior to the creation of reservoirs upstream, maximum flows during flood years were three or four times greater than projected maximum flows under any of the regimes or base cases. The City of Trail apparently experiences some minor flooding problems during current maximum flows and this situation can be expected to continue or to be exacerbated with the slight rise (>0.6 m (2 ft)) in river stage anticipated as a result of the higher maximum flows projected with Regime 1 (medium load and AOS), Regime 2 and their base cases. With Regime 1 (ARO) and Base Case (ARO) maximum flows, a rise in river stage of approximately 1.2 m (4 ft) is projected.

The intake in the river which supplies the Cominco smelter at Trail with process and in-plant drinking water, and also supplies the Village of Warfield and the Trail subdivision of Tadanac with drinking water, will not be affected under average conditions. While average flows in late April with Regime 1 (medium load, ARO and AOS) are lower than the 425 m^3/s (15,000 ft^3/s) needed to operate this intake efficiently, average inflows from the Kootenay River, which is upstream of this intake, are 699 m^3/s (24,679 ft^3/s) in late April, thus no operating problems are anticipated with this water intake under any of the regimes with median flows. However, prolonged periods of minimum flows could create problems for this intake and for loading the Ministry of Forests' water bomber with all regimes and base cases.

4.3.3 Forestry

Mica Reservoir

The problems forest companies experience with fluctuating reservoir levels, particularly with low levels, during June through October when water-based forestry activities occur on Mica Reservoir, will be exacerbated if any of the regimes are implemented. All logging companies using the reservoir for log transport at present have to rebuild most, if not all, of the log dump and dewatering sites each year and this may be required more frequently.

Lower reservoir elevations will cause increased navigation problems in shallow areas near log dewatering sites such as Evans Forest Products' site at Bush Harbour. While the site can be used down to levels of 741 m (2430 ft), navigation to the site is impeded at reservoir levels of 739 m (2425 ft). During 6 of 20 years of the study period, median June elevations are at or below this level with Regime 1 (medium load) and Regime 1 (ARO) while levels are well above this with the associated base cases. Minimum elevations with Regime 1 (medium load and ARO) during July to October are too low for navigation in 19 of the 20 years studied. By comparison, minimum elevations with the Base Case (medium load and ARO) are a problem only in June of some years (7 of 20).

Impacts on navigation and log dewatering would be less severe with Regime 2 than with the other regimes. No problems would be experienced with navigation and log dumping in all

operating months with median elevations under both Regime 2 (medium load) and the Base Case (medium load). However, minimum Regime 2 elevations are lower than 739 m (2425 ft) needed to navigate in shallow areas during June through October in 19 of the 20 years studied. As noted above, minimum Base Case elevations are a problem only in June of some years (7 out of 20).

As average elevations are substantially lower with Regime 1 (AOS) than with any other proposed operating regime, this regime will generally have the greatest impacts on forest industry activities in the area. Median elevations for June through October with the Base Case (AOS) are all above the 739 m (2425 ft) level, so that no problems would occur with navigation and most barge points. Slocan Forest Products' log removal and dumping site would be slightly affected as, in 2 of the 20 years studied, average Base Case (AOS) elevations are below the 744 m (2440 ft) needed to operate the site at the northern end of the reservoir. With Regime 1 (AOS), average elevations are at or below 739 m in June of 16 of the 20 years studied, therefore, problems would occur with forestry activities then. Average elevations in July and August are above this level but are below it in September and October, in 1 of the 20 years and 5 of the 20 years studied, respectively. As well, with Regime 1 (AOS), average elevations are below 744 m in June in 19 of 20 years, in July in 10 of 20 years, in August in 8 of 20 years, in September in 12 of 20 years, and in October in 15 of the 20 years, therefore, Slocan's dewatering site could not operate then. Minimum elevations during all months of logging operations are too low for navigation in 19 of the 20 years studied with Regime 1 (AOS). With the Base Case (AOS), minimum elevations are a problem for navigation and other water-based logging activities in June in 11 years, in October in 4 years and in all operating months in 1 year of the 20 year study period.

With lower elevations, some barge points, log dumps and dewatering sites will require modification by lengthening ramps and skids, which would add to operating and maintenance costs. Some companies may have to delay start-up until July and may have difficulties even then, particularly with Regime 1 (AOS).

Arrow Lakes Reservoir

The very small differences in average reservoir elevations between all the regimes and their associated base cases, coupled with the fact that the range of elevations will not change,

will result in slight, if any, impacts on water-based forestry activities, over and above those presently experienced. Westar, the only company using the reservoir for water-based storage and transport, currently experiences operating problems due to reservoir fluctuations and cannot use some log dumps when reservoir levels are at their lowest. At present, problems begin to be experienced with the reservoir at about El. 427 m (1401 ft). Average reservoir elevations during February through April are very close to or lower than 427 m with all regimes and associated base cases. Minimum elevations are below 427 m in December or January and through May or June of all years with all regimes and associated base cases.

The Celgar water intake is approximately 19 m (64 ft) below the minimum average reservoir elevation in March, the lowest water month, with the regimes and slightly lower with the base cases and is well below absolute minimum elevations (approximately 15 m [49 ft.])

Downstream Area

Monthly increases in outflows during August to December and decreases from January to July are small with all reservoir operating regimes compared to the associated base case. Present problems encountered by Westar in navigation, log storage and mill feeding operations may be exacerbated. Incremental impacts may occur due to more frequent daily flow changes from the implementation of alternate regimes. Westar presently encounters problems at flows above 1840 m^3/s (65,000 ft^3/s) and below 255 m^3/s (9000 ft^3/s). For all regimes and their base cases, outflows in January are above 1840 m^3/s (65,000 ft^3/s).

Problems with low flows will be encountered in dry years with all regimes and base cases. Minimum monthly flows below 255 m^3/s (9000 ft^3/s) are projected during March through June with all regimes and base cases. The frequency of occurrence of minimum flows appears to be the same for the regimes and their base cases. During years of high inflows, maximum monthly flows are projected above 1840 m^3/s (65,000 ft^3/s) during December through February and May through August with all regimes and base cases, occasionally reaching as high as 3442 m^3/s (118,000 ft^3/s) with Regime 1 (ARO) and Base Case (ARO).

Again, the frequency of these maximum flows appears to be the same for the regimes and their base cases.

4.3.4 Agriculture

Mica Reservoir

There are no agricultural activities bordering the Mica Reservoir, therefore, no impacts will result on this resource use from changes in reservoir operation under any of the regimes considered.

Arrow Lakes Reservoir

The minor changes in water levels with any of the regimes considered will not restrict any of the limited agricultural activities presently occurring around the reservoir, or cause incremental impacts. No irrigation or stock watering is dependent on the reservoir.

Downstream Area

No impacts on the limited amount of agricultural activity along the shores of the Columbia River below Hugh Keenleyside Dam are expected due to changes in outflows as a result of any of the regimes studied.

4.3.5 Recreation

Mica Reservoir

Recreational use occurs mainly from June through September when the reservoir is filling. The substantial decreases in reservoir levels during June through September under the different regimes compared to their associated base cases will cause access problems and an unattractive exposed drawdown area which will detract from the recreational appeal of the area.

Wood debris has posed hazards to boaters from the time of reservoir creation. As previously noted, BCHPA has recently initiated a floating debris removal program and is proposing to expand the program if reservoir levels are high enough to permit removal of beached material. If the program is expanded, it should greatly alleviate the dangers to navigation from floating debris.

Protruding stumps apparently occur in the shallow northern and southern ends of the reservoir. At Bush Harbour, the problem occurs at water levels below 739 m (2425 ft). While average June elevations under all base cases are above this level, elevations of 739 m or lower occur in June in 6 of the 20 years studied with Regime 1 (medium load and ARO) and in 16 of the 20 years studied with Regime 1 (AOS). The problem would not occur with Regime 2 (medium load). Minimum elevations during June through September are too low for safe navigation in 19 of the 20 years studied will all regimes. By comparison, minimum base case elevations are a problem only in June in 7 of the 20 years.

With average base case elevations, all boat launch ramps will be usable from June through September, however, most ramps will not be usable in May. Under average conditions, with Regime 1 (medium load) and Regime 1 (ARO), ramps extending to El. 742 m (2435 ft) will not be usable in June in 15 of the 20 years, and those extending to El. 739 m (2425 ft) will not be usable in 6 of the 20 years. No problem will occur with ramps extending to El. 735 m (2410 ft) in June or with any of the ramps in July, August or September. With Regime 1 (AOS), ramps to El. 742 m will not be usable in June in 18 of the 20 years, those to El. 739 m will not be usable in 16 of the 20 years, and those to El. 735 m will not be usable in 6 of the 20 years. In July, August and September, problems will be experienced with ramps extending to El. 742 m in 4 of the 20 years, 3 of the 20 years and 8 of the 20 years, respectively. No problems will be experienced during these months with the ramps which extend to lower elevations. With Regime 2 (medium load), a problem is encountered only for the ramps extending to El. 742 m during June in 12 of the 20 years studied. No problems would occur for any of the ramps in any other recreation month. A new ramp planned for the Horse Creek Forest Service Recreation Site, which will extend to El. 728 m (2388 ft), will not be affected by changes in average elevation of the reservoir under any of the alternate regimes.

With all alternate regimes and base cases, minimum elevations are generally always too low for use of the boat launch ramps. With minimum elevations in June through September (which would occur infrequently in years of low inflow), private resorts in the southern half of the reservoir (at Esplanade Bay and Beavermouth Creek) and recreation sites at the northern end will be severely impacted by lack of access for recreational boating and fishing. While it may be feasible to lengthen some ramps to accommodate lower reservoir elevations, site-specific data would be required to estimate the feasibility at each location.

Implementation of the alternate regimes will thus create impacts on recreational access to the reservoir, navigation, and general attractiveness. Proposed changes in reservoir operation will need to be taken into account during development of new recreation sites, such as the new Forest Service Recreation Sites on Glacier Creek and Wisted Creek, and the potential Provincial Park in the vicinity of Potlatch Creek where boat launches usable to low water are planned.

Sport fish populations may be affected by the alternate regimes (Section 4.2.2), which may compound access and navigation impacts on recreational fishing. However, impacts on sport fish are expected to be small. Recreational hunting should not be affected.

Arrow Lakes Reservoir

The very slight differences in Arrow Lakes elevations between all four alternate regimes and their associated base cases are not expected to affect recreation, over and above those impacts presently experienced. A reservoir elevation of 433 m (1420 ft) is considered the lower limit of recreation site usability without excessively separating the shoreline from facilities above the high water line. With all the alternates and the base cases, average water levels are below 433 m in May of all years but this is the only month during which this situation occurs. The reservoir is generally near full pool during July and August. However, in low water years, minimum reservoir elevations are normally below 433 m for the Base Case (medium load) in June through September but only rarely for Regime 1 (medium load), Regime 1 (ARO) and Regime 2 (medium load). Minimum elevations are sometimes below 433 m with both Regime 1 (AOS) and the Base Case (AOS) during the other recreation months (June through September).

Only minor, if any, impacts are predicted on sport fish and wildlife, therefore recreational fishing and hunting should not be affected by the change in operating regime.

Downstream Area

With all alternates, the slight changes in median monthly outflows projected compared to the associated base case should not significantly affect recreation facilities, which have been constructed to accommodate changes in flows. However, recreational boaters could experience navigation and access difficulties during prolonged periods of minimum or maximum flows under both alternates and base case. The frequency of occurrence of minimum and maximum flows appears to be the same for all regimes, therefore, no incremental impacts are expected. As previously noted, maximum flows projected are higher than those presently experienced.

5.0 CONCLUSION

The proposed increase in the use of non-treaty storage behind Mica Dam for energy production will mainly have effects on fish, fish habitat, forestry and recreation in the Mica Reservoir. Regime 1 (medium load), Regime 2 (medium load) and Regime 1 (ARO) would have generally similar effects and may all be implemented at certain times in extending and expanding the Non-Treaty Storage Agreement. Potential impacts resulting from implementation of Regime 1 (AOS) would have the greatest magnitude as the projected physical changes resulting from this regime are the greatest.

Impacts on fish and fish habitat are expected to be small with all regimes and offset somewhat by benefits such as recovery of fish habitat in the lower sections of tributary streams. Both negative effects and potential benefits are expected to be greatest with Regime 1 (AOS).

As average elevations are substantially lower with Regime 1 (AOS) than with any other proposed operating regime, further impacts on forest industry activity will result. In June in the majority of years of the 20 year period, average water levels would be too low for navigation, log dumping, barging and log removal in the shallower northern and southern

areas of the reservoir. Average elevations would be sufficient for most such activities in the other operating months (July through October). However, in several years over the 20 year study period, certain log dewatering sites could not be operated under average conditions in all months of forestry operations. These problems would be experienced to a more limited extent with the implementation of the other regimes.

Implementation of the alternate regimes will create impacts on recreational access to the reservoir, navigation and general attractiveness. Regime 1 (AOS) will have the greatest impacts. Navigation in June will be affected in several years under average Regime 1 (medium load and ARO) and in the majority of years with Regime 1 (AOS). The problem would not occur with Regime 2 (medium load). Boat launch ramps will not generally be usable in May with any of the regimes, and several will not be usable during other recreation months, particularly June. Minimum elevations are generally always too low for use of the boat launch ramps. Use of the reservoir by patrons of private resorts would be impacted under minimum elevation conditions with all regimes due to the very restricted access and navigation difficulties near these sites. Sport fish populations may be affected which may compound access and navigational impacts on recreational fishing.

The potential effects of all four alternate regimes on the environmental resources of the Arrow Lakes Reservoir are minimal. The projected Arrow Lakes Reservoir elevations are very similar to the associated base case elevations, the average monthly difference being very small. Fish and fish habitat would not be affected by such small differences. Water-based forestry activities and recreation would also not be affected.

Elevated outflows from Hugh Keenleyside Dam during August to December and decreased outflows from January through July would result from the implementation of all the regimes. Such changes could have minor effects, both negative and positive, on fish and fish habitat in the Columbia River below the dam. Present problems with water-based forestry activities may be exacerbated. Potential effects would be similar with all regimes. Recreation is not expected to be affected by the small changes in outflows projected with the different regimes.

As virtually all potential impacts would be realized on the Mica Reservoir, it is recommended that BCHPA implement a Mica Reservoir Compensation Program to offset the potential impacts. Such a program would be similar to the present Williston Compensation Program, which utilizes the interest from a trust fund for compensation activities.

APPENDIX 1

GLOSSARY

GLOSSARY

As with any statistical study, the terminology utilized can be confusing to the lay reader. In order to simplify and add clarity to the text, the following standard terminology has been adopted in this volume:

study year - means a year beginning on 1 September and ending on 31 August

monthly - means the average over a monthly period

monthly period - means the complete months of January, February, March, May, June, July, September, October, November, December, and the four semi-monthly periods comprising the first 15 days of April, the last 15 days of April, the first 15 days of August, and the last 16 days of August

median - means the median or 50th percentile of a 200 game statistical distribution for a specific monthly period of a specific study year

average - means the average over all study years of the medians for a specific monthly period

annual - means the average over all monthly periods of the average medians

high - means the highest median value for a specific month over the 20 year study period

low - means the lowest median value for a specific month over the 20 year study period

minimum - means the 0th percentile of a 200 game statistical distribution for a specific monthly period of a specific study year

average minimum - means the average over all study years of the minimum for a specific monthly period

annual minimum - means the average over all monthly periods of the minimums for a specific study year

annual average minimum - means the average over all monthly periods of the average minimums

maximum - means the 100th percentile of a 200 game statistical distribution for a specific monthly period of a specific study year

average maximum - means the average over all study years of the maximums for a specific monthly period

annual maximum - means the average over all monthly periods of the maximums for a specific study year

annual average maximum - means the average over all monthly periods of the average maximums