G.G.Oliver and Associates Environmental Science

●Watershed Restoration ●Aquatic Science ●Fisheries Research
●

Joseph Creek Restoration: Opportunities in water supply management to accommodate downstream ecosystem needs

Prepared for

Columbia Basin Trust
Box 22
Nakusp, B.C. V0G 1R0
and
Columbia-Kootenay Fisheries Renewal Partnership
#7468 Mission Road
Cranbrook, B.C. V1C 7E5

Prepared by

G. G. Oliver, M.Sc., R.P.Bio.
GG Oliver and Associates Environmental Science
2291 1st Ave S.
Cranbrook, B.C. V1C 6Y3

and

Engineering Aspects Reviewed by

R.F. Rodman, P. Eng., M. Eng.
Klohn Crippen Consultants Ltd.
202 – 542 Baker Street
Nelson, B.C. V1L 4H9

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EXECUTIVE SUMMARY

Water quantity and water quality issues identified in previous studies are critical to the long-term restoration of ecosystem processes in Joseph Creek downstream of Phillips Reservoir. Attainment of an effective restoration ~~program~~strategy for native cutthroat trout, as an indicator of ecosystem health, ~~in Joseph Creek~~ is contingent upon the long-term procurement of suitable flows to meet specific life history needs. ~~The lack of suitable flows to support upstream adult migration and habitat requirements associated with summer and winter juvenile rearing has resulted in a shift in the present species complex, favouring non-native fish species.~~ Resolution of water quantity and quality issues in lower Joseph Creek has been ~~previously identified~~suggested as an integral component of cutthroat trout recovery, predicated on ~~its~~the importance of tributaries ~~in~~that support~~ing~~ trout recruitment to the St. Mary River. In the present context, a routing model was developed to balance water supply inputs and outputs from Phillips Reservoir, in an effort to identify periods where shortfalls in supply affect downstream releases for both fisheries and consumption requirements. Simulation runs for selected years, representing below average, average and above average runoff, were conducted to identify changes in reservoir storage volume relative to annual consumptive use and identify opportunities to augment downstream release within the existing water supply system. Under each runoff scenario, shortfalls in water supply for downstream fisheries requirements were confirmed under present reservoir operations. Augmentation during critical flow periods resulted in substantial drawdowns in final reservoir storage at the end of each simulation. Recognizing the limitations of the existing water supply facilities to meet consumptive and non-consumptive demands, alternative simulations with external sources of water were conducted to identify make-up volume requirements to satisfy downstream fisheries needs and provide suitable storage within Phillips Reservoir to satisfy domestic needs. Given the magnitude of make-up volume requirements, ~~it was confirmed that~~ external sources of water ~~would~~will likely ~~be required to~~ satisfy annual, long-term consumptive and non-consumptive uses within the Joseph Creek watershed, yet, at considerable cost. This report reviews model simulations, identifies ~~opportunities for diversion of storage from an adjacent watershed~~available options to meet ~~water use~~consumptive

and non-consumptive demand, and provides recommendations on future opportunities for water supply improvements and water conservation.

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1.0 Introduction

Phase 1 and 2 of the Joseph Creek Restoration Project was funded ~~on behalf of~~by Fisheries Renewal BC and the Columbia Basin Trust, with administrative support from the Columbia-Kootenay Fisheries Renewal Partnership, to collect background water quantity and water quality information in support of a long-term aquatic ecosystem restoration plan for the lower watershed. The project has focused on improving Westslope cutthroat trout habitat owing to the historical importance of this tributary as a critical recruitment stream to the lower St. Mary River. The restoration plan has considered a number of aquatic ecosystem issues that are directly linked to flow regime, fish habitat requirements, historical water use and future water management planning. The scope of environmental issues encompass every aspect of cutthroat trout life history that manifest as impacts on migration, spawning, incubation and rearing. Resolution of present water use conflicts center on issues of water supply to, and water quality in, the lower one-third of the basin. The purpose of this report is to investigate run-off events under low, average and high snow pack years and identify where opportunities exist, once consumptive water use needs have been satisfied, to provide suitable downstream flows for ecosystem maintenance. Where limitations to operational changes in current use patterns are identified, further recommendations on alternative storage opportunities will be addressed.

1.1 Background

Phase 1 of the Joseph Creek project provided background information on the major issues (i.e., annual flow regime, timing of release, water quality, and fish passage) affecting fish and fish habitat as a consequence of present water use and private or urban land development (Oliver 2000). The initial report provided an overview of reach-specific habitat conditions downstream of Idlewilde Reservoir and summarized flow and temperature characteristics from April through June 2000. A conceptual plan prioritized issues, identified specific sites with the highest likelihood for success and suggested a restorative approach to resolve present habitat limitations (both instream and riparian concerns). Based on the collective information provided, an appropriate strategy was advanced to improve cutthroat trout recruitment to the lower St. Mary River. Conceptual plan review by stakeholder groups was recommended to provide an opportunity for feed-back on a number of political, societal and environmental issues and garner community-wide acceptance and support prior to proceeding with actual prescriptive work. Development of a community working group is presently on-going.

Specific objectives of the Phase 2 study included the collection of summer flow and temperature data in combination with a fish habitat suitability and population assessment to ultimately develop a minimum flow requirement for fish (Oliver 2001). An analysis of suspended sediment and sediment deposits to the channel bed from storm sewer inputs during winter melt-water or rain-on-snow events was also investigated. Stream summer temperatures displayed an increasing downstream trend below Phillips Reservoir with daily maxima often exceeding optimal growth temperatures for cutthroat trout. Up to three-fold differences in diel variation were noted in downstream reaches when compared to background conditions above Phillips Reservoir. Summer flow releases clearly indicated a reduction in habitat suitability and fish utilization, particularly for older age classes, across riffle and glide habitats; the declining flow regime approximated 3 and 10% of the mean annual discharge in 2001. Although habitat suitability in pool environments mirrored a similar reduction with declining flow, fish abundance displayed an increasing trend as individuals were forced to aggregate in the only remaining habitat having adequate depth. Suspended sediment concentrations were highly elevated during winter run-off when associated with melt-water or rain-on-snow events. An increasing, downstream trend in fine sediment stored in the streambed suggested that inputs exceeded outputs and that peaking flows associated with the spring freshet were incapable of balancing sediment input. Collectively, high summer temperature, low summer flow and poor habitat quality have likely contributed to the decline in cutthroat trout since 1994 when initial studies on the status of this species were first investigated. The absence of bull trout, limited presence of cutthroat trout (8%) and dominance of eastern brook trout (92%) downstream of Idlewilde Park suggest that the shift in species composition from native to exotic species is a clear indication of severe habitat degradation.

Opportunities for flow manipulation to support downstream ecosystem needs will ~~therefore,~~ likely require changes within the present operating regime of the community water supply area. In recognition of this problem, the Ministry of

Environment, Lands and Parks commissioned a study in 2001 to investigate the relationship between water supply and consumptive use and investigate the availability of water to satisfy environmental, domestic and irrigation requirements on the creek. A routing model for the Joseph Creek catchment and attendant drainage supplies (i.e., Gold Creek diversion) was developed by Klohn Crippen Consultants Ltd. to portray patterns of water use relative to water supply, based on differences in annual simulated run-off (Rodman 2002). A monthly simulation model was developed to account for City water demands, local water licenses and available inflows from Joseph and Gold creeks. The intent of the present study is to apply the routing model under conditions of below average, average and above average run-off, derive design flows for each run-off scenario that considers both consumptive and non-consumptive uses, identify present shortfalls in flow for fisheries, and recommend possible flow modifications to the current operating regime that provide opportunities to satisfy consumptive and non-consumptive needs. Where deficiencies in present storage exist, the report will consider alternative water supply strategies.

2.0 Methods

2.1 Routing model parameters and calculations

A detailed description of the routing model and its limitation is contained in a previous study (Rodman 2002). The routing model was developed to account for inflows to Phillips Reservoir, City of Cranbrook water consumption, Phillips Reservoir operations, other licensed withdrawals, and local inflows to Phillips Reservoir and Joseph Creek between the diversion channel and Kinsmen Park. Monthly synthetic flows for Joseph and Gold creeks, at Environment Canada Stations 08NG068 and 08NG017 (respectively), were developed using multiple regression analyses based on flow, rainfall, and snow course data. These monthly flows were then prorated by catchment area to obtain other local inflows for modelling purposes. Several years of the City's water consumption records were processed to estimate annual water usage. Licensed withdrawals were estimated from information contained in the water licenses. Instream flow needs for fish were based on fisheries investigations completed to date (Oliver 2000; 2001).

A spreadsheet was developed to estimate flow values along Joseph Creek, from the confluence of the new diversion with Joseph Creek to the mouth at the St. Mary River (Rodman 2002). With respect to Gold Creek diversion water availability, initial analyses allowed for a 25 percent withdrawal during low flow months to maintain fisheries values in upper Gold Creek. When 25 percent of the Gold Creek flow exceeded 0.12 m^3/s, the total withdrawal diverted to Baker/Joseph Creek was limited to 0.12 m^3/s due to leakage issues associated with higher discharge in the diversion pipeline. Inflows into the reservoir include Gold Creek diversion inflow, Upper Joseph Creek above the diversion, and local inflows. Gold Creek diversion inflow is calculated as the difference between the Gold Creek diversion withdrawal and the amount released to new diversion channel. When the model shows that the Gold Creek diversion inflow is negative, the City is releasing more water into the new diversion around Phillips Reservoir and into Joseph Creek below the reservoir, than it is withdrawing in the Gold Creek diversion. This negative inflow is compensated for by inflow from Upper Joseph Creek. Inflow from Upper Joseph Creek can also be diverted into the new diversion channel, augmenting the water from the Gold Creek diversion, so that the City can maintain a constant release of water into Joseph Creek below Phillips Dam. This situation can occur due to the maximum withdrawal limit of 25 percent of the Gold Creek low flows or 0.12 m^3/s, whichever is smaller. The Gold Creek and Upper Joseph Creek flows are synthetic data described above. Local flow to Phillips Reservoir is the runoff from the 3.3 km^2 area east of the reservoir. It has been assumed that the unit flow from this area is the same as that estimated for Baker Creek. The next portion of the model simulates the operation of Phillips Reservoir. A storage curve and a spillway rating curve, provided by the City of Cranbrook, were digitized and used in the model.

Outflows from Phillips Reservoir include domestic usage and spill. No allowance was made for seepage losses or evaporation losses since less than 2 percent of the outflow was attributed to evaporation losses in an earlier study (Reid Crowther 1998). In the original model, three years of water usage data (1992, 1996, and 1997) were compared to determine the range of the most recent consumptive use during years of low to moderate run-off. The highest estimates for consumptive use from 1996 were incorporated into that analysis to provide an upper limit to monthly domestic water consumption given the reality of increased demand relative to future community growth. In the present study water consumption rates in 1996 were compared to 2002 values to demonstrate if the same upper limit was applicable or whether changes in consumptive use were warranted. The other outflow, i.e. spill, was iteratively calculated until the reservoir routing equations of inflow, outflow and change in storage balanced. Spill occurred when the reservoir level was above the free overflow spillway crest at elevation 3570 feet.

In addition to the inflow and outflow information, the model requires a reservoir level beginning in January. A review of the available operating data indicated that in 6 years out of 11 the reservoir was full in January. In the other years the reservoir was 1 to 12 feet below the spillway crest in January. For ease of comparison between simulations, ~~It was decided to start all of the present simulations~~each run was initiated with a full reservoir level ~~of~~ (3570 feet) to contrast differences in drawdown at the end of the calendar year relative to consumptive and non-consumptive needs.

The flow in Joseph Creek has been estimated at the following key locations along the creek: the confluence of the New Phillips Diversion Channel; Kinsmen Park; Lower Joseph Creek (08NG074), adjacent to the City's sewage treatment plant; and at the confluence of Joseph Creek and the St. Mary River. For the purpose of this investigation, the assessment of adequate fisheries flows is based on instream flows at Kinsmen Park, in recognition of this portion of stream channel with a higher potential for habitat restoration. Therefore a specific line was included in the routing model to identify make-up requirements at Kinsmen Park where summer flows are <0.12 m^3/s (or <30% of the mean annual discharge (MAD)). Negative values therefore indicate the need for additional water release at the new Phillips diversion structure or from Phillips Dam itself to attain adequate fisheries flows at Kinsmen Park.

2.2 Design flow derivation

Two flow periods are considered critical to the long-term survival of cutthroat trout in Joseph Creek: the ascending limb of the hydrograph, to accommodate spawning migration, and summer base flow, to accommodate juvenile rearing. A stepped flow requirement during the month of May is required to attract spawners and provide sufficient flow volume to assist in upstream passage; 50% of the ~~mean weekly~~monthly background flow in Joseph Creek is anticipated, incremented weekly in response to the natural hydrograph. The derivation of a design flow to accommodate summer rearing should consider the habitat requirements of individuals most susceptible to flow limitation. Since juvenile cutthroat trout generally rear in tributaries from 1-3 years prior to river entry (Likness and Graham 1988), suitable habitat should be made available to support individuals up to 3 years of age to promote optimum survival and maximize juvenile recruitment. Based on habitat suitability evaluations completed in Kinsmen Park in 2001, fry habitat limitations are unlikely due to ample habitat availability along stream margins at variable flow stages. The importance of depth to older juveniles however is critical to their long-term survival. This aspect of cutthroat ecology is supported by habitat suitability criteria developed for this species (Oliver 1994), the results of the 2001 habitat suitability analysis and, to a lesser extent, the observed aggregation of older trout in pools at flows <10% MAD (Oliver 2001). Equally important, pool habitat with suitable depth and cover represent critical aspects regarding over-winter survival, particularly where prevailing temperatures prevent anchor ice formation (Brown and Mackay 1995; Jakober et al. 1998).

Recognizing the importance of depth in regulating the distribution of the larger juvenile cutthroat trout size classes, the 2001 suitability analysis suggests that flows representing 20% MAD (or 0.081 m^3/s) at Kinsmen Park are insufficient to meet the summer habitat needs of the oldest age classes encountered. Low summer flow established at 30% MAD has been recommended in other studies to provide suitable widths, depths and velocities for fish survival (Tennant 1976). Under these conditions, the majority of the streambed will carry water and prevailing pools and glides will have sufficient depth to provide suitable cover for a variety of age classes. A design flow 0.12 m^3/s has been previously recommended as a suitable target to promote juvenile cutthroat trout rearing (Oliver 2001). Tennant also recognizes that rising water temperature under declining summer flow can create a serious limitation which is not expected to occur under the 30% MAD criterion. Non-consecutive short-term (7-day) reductions in flow to 20% MAD may provide some flexibility without substantial mortality during periods when consumptive use places exceptional demand on water supply during below average run-off years. The minimum summer flow target for the purpose of this study has therefore been established at 0.12 m^3/s while the minimum winter flow has been set at 0.081 m^3/s to accommodate over-winter survival.

2.3 Variable flow stage and design flow simulations

To estimate shortfalls in water supply for downstream fisheries needs, three variable run-off events were simulated to characterize flow conditions over the range of climatic conditions provided in nature. To this end, simulations were devised to include typical run-off events during periods of below average, average and above average snow pack. The synthesized monthly flow data from 1968 to 1996 was plotted graphically and visually inspected to distinguish specific years representative of the three variable flow stages when peak flow was observed in either May or June. The mean annual discharge of each selected year was further compared to the mean, maximum and minimum annual discharge over the period of record to judge the representativeness of the three selected years. Simulations of each representative flow year were then run under the current operating regime to detect in which months shortfalls in design flow (i.e., summer and winter minima) were encountered and to determine the extent of peak flow at Kinsmen Park relative to background inflow in the Upper Joseph Creek watershed. Further simulations to provide fisheries make-up requirements were run to describe the severity of expected shortfalls in the community water supply. Make-up volumes were then calculated to identify the amount of additional storage required to meet non-consumptive uses in Joseph Creek.

2.4 Water supply relationship

A linear regression was developed between annual snow pack and spring runoff volume to estimate the magnitude of future annual runoff events, allow water managers to distinguish between wet and dry years and provide insight relative to make-up requirements for downstream needs given predictions of annual water supply availability. Runoff volume (m^3) for Joseph Creek, expressed as the dependent variable, was calculated as the sum of the mean monthly synthetic volume for May, June, July and August for individual years from 1968 to 1996. Snow pack water equivalent data (mm), expressed as the independent variable, were obtained from snow course information collected at the Sullivan Mine in Kimberley, B.C. over the same period and Moyie Mountain for individual years from 1969 to 1996. The regression is intended for future runoff volume forecasting to facilitate operational changes associated with each annual snow pack.

For the purpose of confirming water supply trends beyond the period of synthetic data (i.e., 1997 to 2002), mean annual discharge for these latter years was reconstructed by comparing the water equivalent of the snow pack for individual years between 1997 and 2002 with water equivalent information for individual years between 1968 and 1996. Mean annual discharge for the latter years was estimated by adopting the corresponding MAD value for the 1968 to 1996 snow course data set with near equal snow course measurements for the 1997 to 2002 data set.

3.0 Results

3.1 Water supply trends, runoff frequency and water consumption rates

A plot of the synthesized data for Joseph Creek from 1968 to 1996 and estimated mean annual discharge based on related snow course information from 1997 to 2002 ~~indicates a decreasing trend~~is reflective of the variation in annual run-off during wet and dry climatic ~~in MAD in response to prevailing climatic condition~~periods (Fig. 1); ~~a period of drought was most evident during the 1980's (Fig. 1) and the overall trend~~below average run-off events ha~~s~~ve contributed to sub-optimal summer base flows for fish (Oliver 2001) due to competing demands between consumptive and non-consumptive uses for water. An extreme maximum runoff event occurred in 1974 while the lowest runoff event was observed in 1992; average MAD over 29 years of record was calculated at ~0.28 m^3/s (range = 0.16 to 0.46 m^3/s). Closer inspection of the runoff frequency distribution indicates that a near-equal number of events have occurred above and below MAD (i.e., median = 0.27 m^3/s; Fig. 2), but more importantly, average runoff conditions are bounded by events within the range of 0.225 to 0.325 m^3/s. Categories above or below this range reflect conditions of above average or below average runoff, respectively. To this end, three scenarios have been simulated: 1978 has been incorporated as a year ~~representative of average runoff conditions whereas 1977 is representative of a low runoff event and 1972 a high runoff event. Use of the 1974 maximum event was considered an outlier and non-representative of normal high runoff.~~

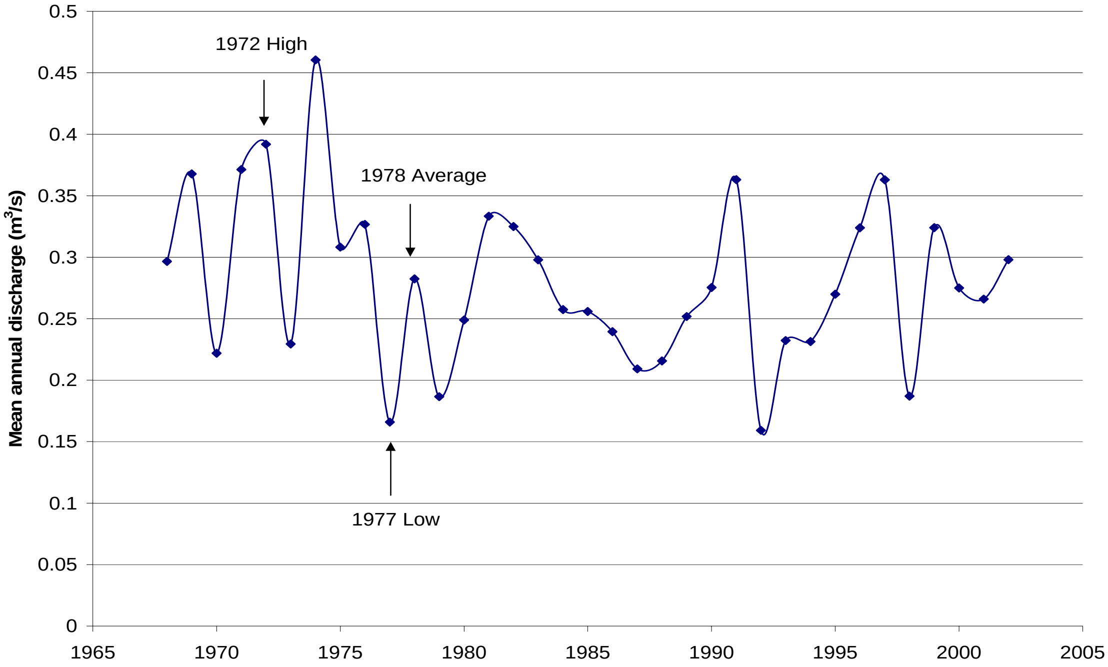


Figure 1. Mean annual discharge in Joseph Creek based on synthesized data reconstructed from 1968 to 1996. 1997 to 2002 estimated from Sullivan Mine snow course data. ~~Overall trend line~~Simulation years ~~indicated~~are highlighted.

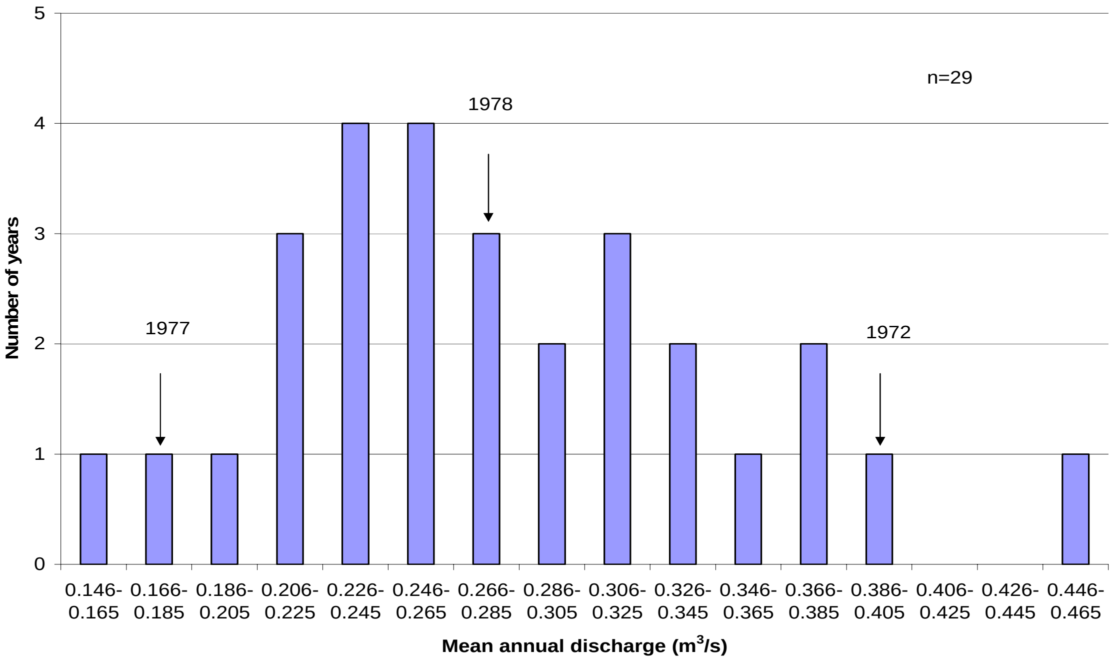


Figure 2. Frequency of occurrence of mean annual discharge categories above Phillips Reservoir from 1968 to 1996. 1977 represents a low runoff event, 1978 an average runoff event and 1972 a high runoff event for simulation

comparisons.

representative of average runoff conditions whereas 1977 is representative of a low runoff event and 1972 a high runoff event. Use of the 1974 maximum event was considered an outlier and non-representative of normal high runoff.

Water consumption rates applied in the model were based on the maximum annual consumption values identified for a high runoff event within the period of record; accordingly, in 1996 water consumption was measured at 1.19 B Imperial gallons (Fig. 3). A comparison of more recent water consumption rates clearly shows that usage has increased to 1.23 B Imperial gallons in 2002, however, 14% (185 M Imperial gallons) of that volume was obtained from the three groundwater wells newly constructed within the city boundary (refer to Fig. 3). As a result, annual water withdrawal from Phillips Reservoir in 2002 was actually reduced by 149 M Imperial gallons compared to that observed for 1996. The pattern of use between years is relatively unchanged and therefore, the 1996 consumption rates have been applied to all model simulations to provide an upper limit of water withdrawal for domestic purposes and further illustrate under what conditions limitations for downstream ~~relatively unchanged and therefore, the 1996 consumption rates have been applied to all model simulations to provide an upper limit of water withdrawal for domestic purposes and further illustrate under what conditions limitations for downstream release exist within the present water supply.~~

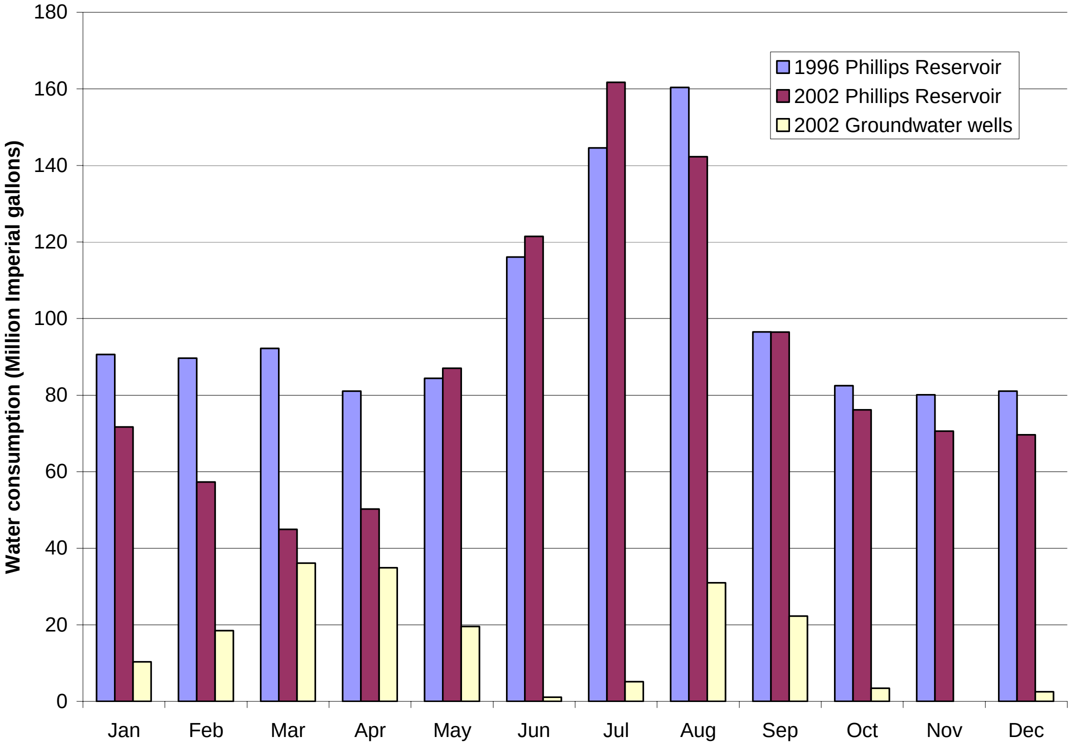


Figure 3. Monthly water consumption rates for the City of Cranbrook in 2002 in comparison to consumption rates identified in 1996.

release exist within the present water supply.

3.2 Model simulations

3.2.1 Runoff scenarios under current water management operations

Under conditions of high annual runoff (1972 event), reservoir drawdown begins from its volume high of 2.3 M m^3 in January and gradually declines to 1.94 M m^3 at the beginning of April (Fig. 4; Appendix 1; 1972a). Gradual filling proceeds through April but complete filling is not accomplished until May at which time surplus storage is conveyed through the spillway. Under prevailing climatic conditions, peak freshet is not achieved until June at which time mean monthly discharge reaches 1.93 m^3/s. Channel maintenance flows are more than adequate under flooding conditions. The reservoir remains at storage capacity through July and an outflow is maintained through the spillway. Higher domestic demand during August in conjunction with declining inflows result in gradual drawdown of the reservoir and downstream ~~declining inflows result in gradual drawdown of the reservoir and downstream~~

~~releases of 0.032 m^3/s (or 8% of MAD) at Kinsmen Park are well below the design flow (0.121 m^3/s) for late summer. Under a much reduced demand over the fall of~~

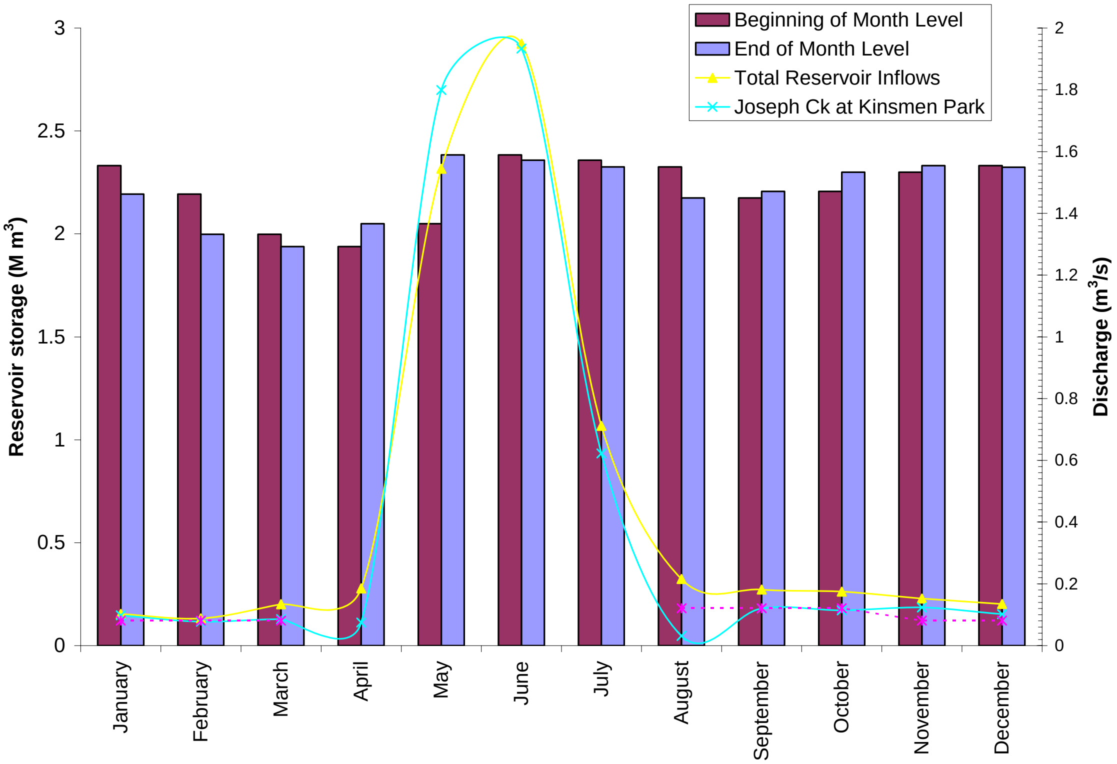


Figure 4. Simulation run during a high runoff event (1972) to contrast reservoir and stream channel dynamics under standard reservoir operating conditions. Dashed line indicates required maintenance flows for fisheries.

releases of 0.032 m^3/s (or 8% of MAD) at Kinsmen Park are well below the design flow (0.121 m^3/s) for late summer. Under a much reduced demand over the fall of 1972, the reservoir continues to fill reaching maximum storage capacity by the end of December and fisheries flows are largely satisfied (slight deficits noted in September and October; refer to Appendix 1; 1972a) over the same period. The provision for make-up flows to accommodate fisheries requirements in August by allowing more water through the new diversion (bypass) channel would result in a final storage volume of ~2.1 M m^3 by the end of December (i.e., supplementation of 0.089 m^3/s), and satisfy winter consumptive needs until the following freshet. High run-off ~~E~~events of this magnitude or better, however, have only occurred 2 out of 29 years over the period of record.

Under conditions of average runoff (1978 event), the pattern of winter use is similar to that observed during the high runoff event however, with higher mean monthly flows occurring in early spring, the reservoir fills by the end of April and remains at capacity until the end of July (Fig. 5; Appendix 1; 1978a). Accordingly, a small ~~capacity until the end of July (Fig. 5; Appendix 1; 1978a). Accordingly, a small amount of flow is spilled in April and increases to near equal discharges during May and June; the mean monthly flow at Kinsmen Park in May reaches 1.29 m^3/s and provides an adequate stage to accommodate channel maintenance and~~

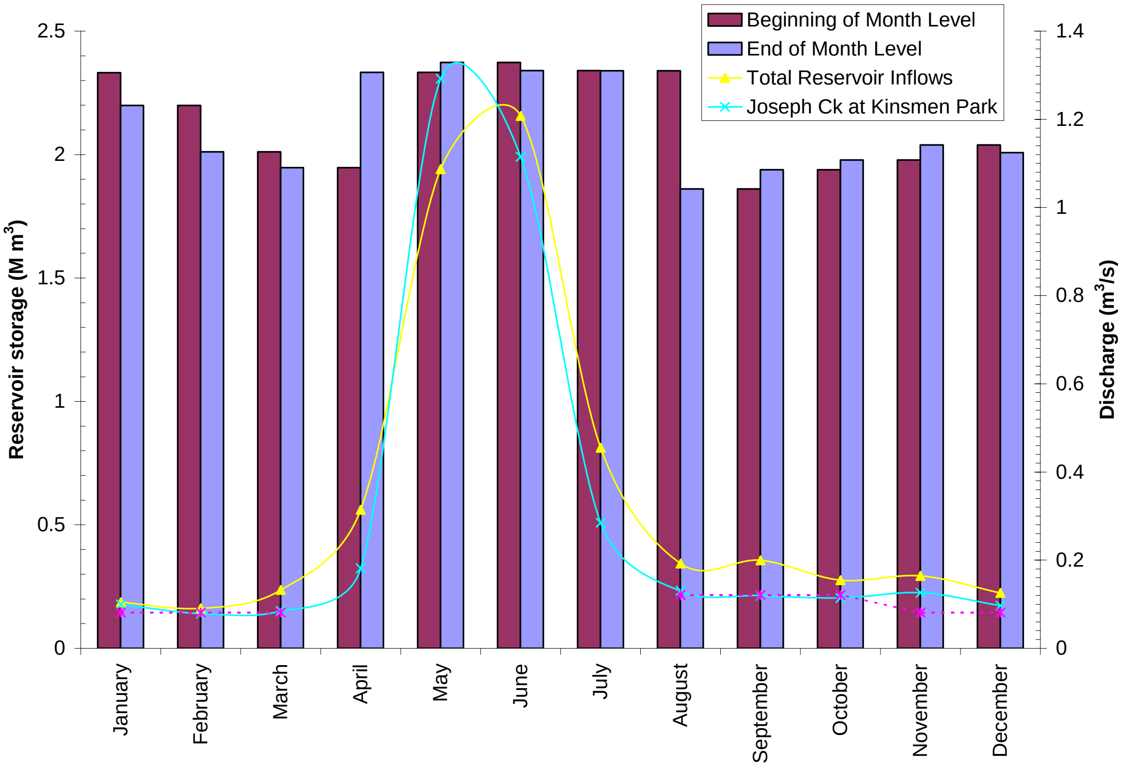


Figure 5. Simulation run during an average runoff event (1978) to contrast reservoir and stream channel dynamics under standard reservoir operating conditions. Dashed line indicates required maintenance flows for fisheries.

amount of flow is spilled in April and increases to near equal discharges during May and June; the mean monthly flow at Kinsmen Park in May reaches 1.29 m^3/s and provides an adequate stage to accommodate channel maintenance and fish passage needs. Due to the nature of a peaking freshet condition in June, ~~I~~inflows remain high during July and August and despite the higher demand for domestic and irrigation use, maintenance flows for fisheries are sustained at adequate levels ~~due to~~as a consequence of continu~~ity~~ued ~~of~~ outflow through the spillway for a portion of ~~the month~~August. Notwithstanding, by the end of ~~the~~ August, the seasonally high withdrawal rate leaves the reservoir volume at 1.86 M m^3 and under reduced utilization over the remainder of the fall, filling gradually proceeds reaching a final volume of 2 M m^3 at the end of December. Events of this magnitude or better have been observed 15 out of 29 years. In contrast, when the peak freshet condition during an average run-off event is observed a month earlier in May, ~~S~~slight shortfalls in fisheries flow requirements ~~are~~can be observed in February, September and October ~~(refer to Appendix 1; 1978a) however~~but ~~further~~larger shortfalls are experienced in July and August ~~flow can be expected in average runoff years where peak freshet occurs in May with corresponding lower maximum flows in~~due to spillway outflows that terminate by the end of June (Appendix 1; 1985a simulation) rather than mid-August (refer to Appendix 1; 1978a). Differences in timing of the freshet between May and June, therefore, have a dramatic effect on downstream water release during critical summer months (i.e. July and August) as well as end of year reservoir storage volume (1.72 M m^3; 1985a vs 2 M m^3; 1978a).

Under conditions of below average runoff (1977 event), domestic water consumption reduces the storage volume of the reservoir to 1.75 M m^3 by the beginning of April and remains at a level less than capacity by the end of the month (Fig.6; Appendix 1; 1977a). Filling is completed by the end of May but in the absence of sustained spring runoff in June, storage remains less than capacity by the end of the month. Since the spillway is only active from ~mid-May to mid-June and as a consequence of the below average inflow condition, downstream releases during the freshet are about 50% of that observed during an average year (i.e., <0.7 m^3/s compared to 1.14 m^3/s in 1978). Increasing demand during July and August reduces storage to ~1.5 M m^3 by the end of August and instream flow needs for fish at Kinsmen Park are severely limited in both July and August (i.e., 19 and 26% of the summer design flow requirement, respectively). Despite reductions in water use over the remainder of the fall, the reservoir only reaches a capacity of 1.55 M m^3 by the end of the year. ~~Over the 12 month period, slight shortfalls in fisheries flow requirements are also observed in February, March, September and October (refer to Appendix 1; 1977a). Under the present scenario, the provision of make-up for fisheries requirements would result in a final storage volume of 1.05 M m~~^{3} ~~at the end of the year (refer to Appendix 1; 1977b). Events of this magnitude, or worse, have only been observed twice over the period of record, however, below average runoff has occurred ~10 out of 29 years. Although the focus of this review has centered on design flows for Kinsmen Park, it is also apparent that freshet flows at the confluence of Joseph~~

~~Creek are inadequate for~~

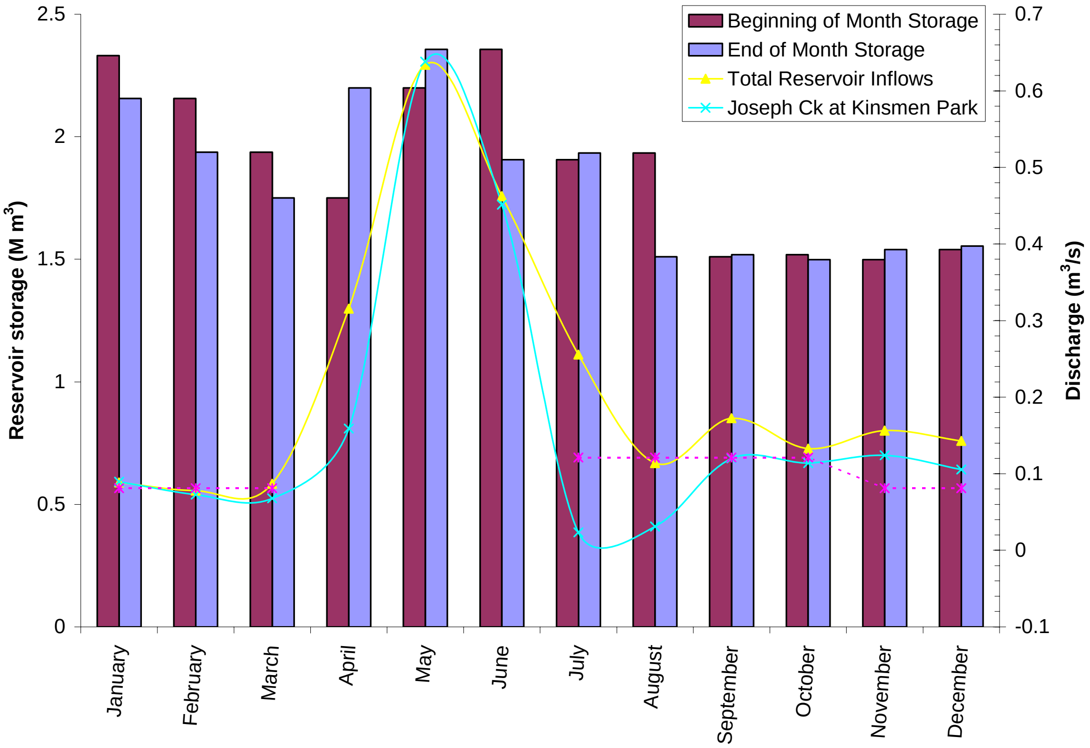


Figure 6. Simulation run during a low runoff event (1977) to contrast reservoir and stream channel dynamics under standard reservoir operating conditions. Dashed line indicates required maintenance flows for fisheries.

Over the 12 month period, slight shortfalls in fisheries flow requirements are also observed in February, March, September and October (refer to Appendix 1; 1977a). Under the present scenario, the provision of make-up for fisheries requirements would result in a final storage volume of 1.05 M m^3 at the end of the year (refer to Appendix 1; 1977b). Events of this magnitude, or worse, have only been observed twice over the period of record, however, below average runoff has occurred ~10 out of 29 years. Although the focus of this review has centered on design flows for Kinsmen Park, it is also apparent that freshet flows at the confluence of Joseph Creek are inadequate for channel maintenance functions and may be insufficient to allow fish passage at locations previously considered to be problematic under reduced flow condition (Oliver 2000). Flows during the freshet of a low runoff event at the stream confluence would likely not exceed 1 m^3/s (refer to Appendix 1; 1977b) and are expected to inhibit spring spawning migration.

3.2.2 Expected shortfall in the water supply to accommodate design flows for fisheries

The preceding simulations provide an example of the expected shortfall in fisheries flow requirements under low flow conditions (summer and winter) and under standard reservoir operating procedures currently in use. The simulations suggest that the greatest shortfall under any given runoff scenario is largely restricted to the month of August as demand rises and surface supplies diminish. However, the simulations do not consider design flows to facilitate the spring spawning migration (identified earlier as 50% of the ~~mean~~ monthly flow during May (Oliver 2001)) and the model is not sensitive enough to distinguish at what time in any given month spill is first encountered. Flow monitoring activities in the spring of 2000 have provided further insight suggesting that outflow from the reservoir is dependent upon timing of snowmelt and that under prevailing climatic conditions leading to slow release, spill may be delayed until the third week of May once maximum storage capacity in Phillips Reservoir is achieved (Oliver 2000). Make-up requirements to achieve design flows in August for each runoff scenario, therefore, are relatively small in comparison to the much larger requirements identified during the spring (Fig. 7). The provision of 50% of the ~~mean~~ monthly flow for May during below average and average runoff conditions as well as a 35% reduction in ~~mean~~ monthly flow under high runoff conditions would require a substantial volume of water that would otherwise impair reservoir operations. In all cases, make-up requirements attributed to both spring and summer periods would significantly reduce the final storage volume at the end of each year. Under a low runoff event (1977), the final storage volume would approach 0.41 M m^3, under an average runoff event (1978) the final storage volume would reach 1.15 M m^3 and under a high runoff event (1972) the final storage volume is near capacity at 2.30 M m^3 (Appendix 2; 1977c; 1978b; 1972b, respectively). The below average and average runoff examples illustrate the importance of high summer demand in the regulation of final storage volume in Phillips Reservoir that is largely governed by available surface supplies from July to December. To this end, simulations that allow flow manipulation beyond the current operating regime suggest that the provision of make-up requirements for fisheries flows, within the existing water supply framework, will ultimately lead to shortfalls in storage for consumptive use. These simulations indicate that some flexibility exists ~~to accommodate August make-up requirements but severe limitations exist where~~

~~spring make-up requirements are considered. It is also important to acknowledge that the foregoing examples are for a single year. Simulation results over several years are necessary to fully understand the overall stability of a given scenario under diverse climatic conditions or changes in operating regime. Notwithstanding this concern, the present model suggests that the balance between water supply and demand remains fragile, based on the available storage capacity in Phillips Reservoir. Further allocations of~~

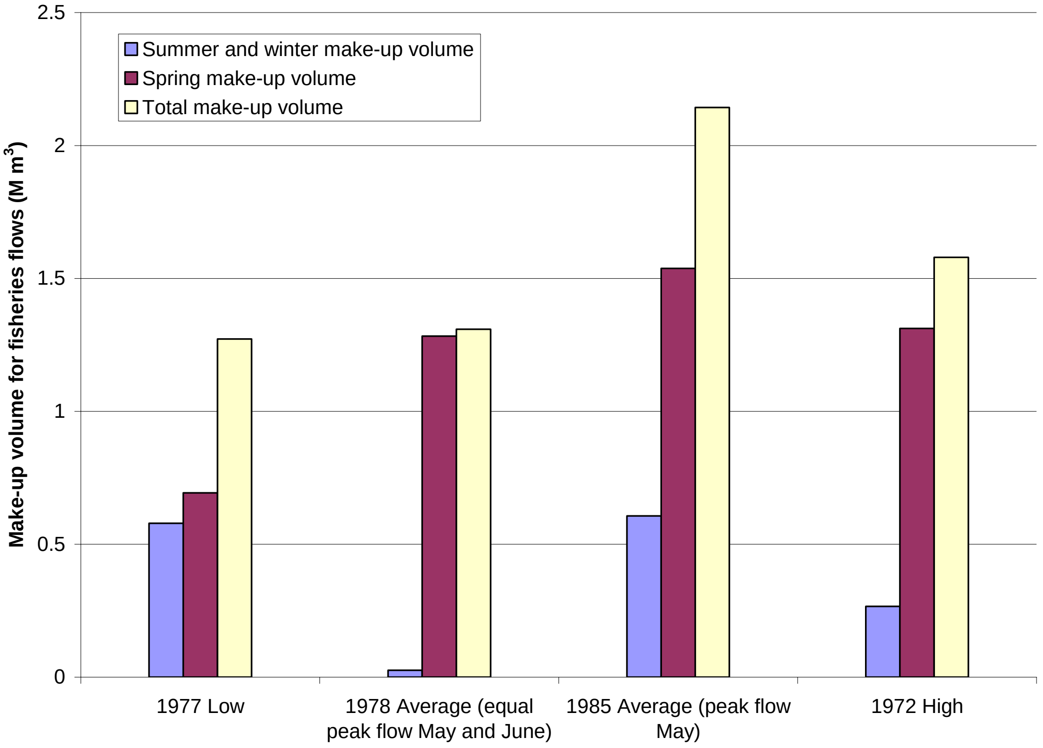


Figure 7. Make-up volume requirements to accommodate fisheries flows during spring, summer and winter. Calculations are based on 50% of the ~~mean~~ monthly flow in May and actual make-up volumes for all other months of the year.

to accommodate August make-up requirements but severe limitations exist where spring make-up requirements are considered. It is also important to acknowledge that the foregoing examples are for a single year. Simulation results over several years are necessary to fully understand the overall stability of a given scenario under diverse climatic conditions or changes in operating regime. Notwithstanding this concern, the present model suggests that the balance between water supply and demand remains fragile, based on the available storage capacity in Phillips Reservoir. Further allocations of water to accommodate fisheries make-up

requirements ~~the water supply to accommodate make-up requirements~~ will have to ~~come from external~~ consider alternative sources or alternative use strategies. Supplementation of the present water supply system with groundwater ~~make-up~~ sources has provided the City of Cranbrook with a short-term surplus to address increasing consumptive demand. Current rates of supplementation from the new wells have not disrupted the volume of the groundwater aquifer or its rate of recharge. ~~and f~~Future domestic ~~operation~~supplementation ~~of the wells~~ is ~~intend~~expected to proceed at the current rate of withdrawal ~~without compromising~~to avoid any disruption ~~groundwater supplies~~to the aquifer (Gary Mott, City Engineer, Cranbrook, B.C.; pers. comm.). Due to the required volumes associated with ~~make-up~~instream flows for fisheries, the future use of groundwater wells to offset downstream surface supply deficiencies below Phillips Reservoir ~~does not appear feasible~~should only consider the smaller make-up flows from July through March. As such, pumping requirements to accommodate the smaller make-up volumes would increase the 2002 groundwater consumption level by a factor of 1.69, 1.72 and 1.32 in consideration of those amounts required for representative low (1977), average (1985) and high (1972) run-off scenarios, respectively. ~~The only reasonable opportunity to accommodate future consumptive and non~~Satisfying annual non-consumptive needs, particularly spring flow requirements to meet upstream migration concerns, is beyond the current capacity of the Joseph Creek watershed, without impairing domestic supply, and future resolve may ~~lies~~ have to consider ~~with external surface supplies in~~inter-basin transfers from an adjacent watershed~~s~~. Replacement of spring make-up volumes from existing groundwater reserves leaves considerable uncertainty relative to the amount of aquifer drawdown, the rate of groundwater recharge, pumping costs, differences in water quality between surface and groundwater supplies (i.e., iron content) and groundwater supply to Joseph Creek in the lower portion of the basin due to potential drawdown effects at each well site.

Recent improvements to the diversion pipeline from Gold Creek, allowing a much higher discharge to accommodate inter-basin transfer, provide a reasonable alternative toward additional volume storage to meet the longer-term consumptive and non-consumptive needs within the Joseph Creek watershed. Alternative strategies to meet the above-mentioned needs ~~sh~~could therefore consider improvements in storage within the Gold Creek drainage. Recommended strategies ~~will~~could complement dam design information completed for the City of Cranbrook in an earlier study that was commissioned to address long-term water supply requirements in response to expected population growth (EPEC Consulting Ltd. 1980).

3.2.3 Make-up requirements for fisheries design flows and alternative water supply strategies

Examination of the current operational regime at Phillips Reservoir, through simulations described above, have revealed two important flow regulation aspects relative to filling patterns and potential impacts on fish: 1) annual filling of the reservoir is initially dependent on the volume of water provided by the spring freshet and 2) maintenance of a high reservoir volume at years end is largely dependent upon the magnitude of volume depletion in August relative to natural inflows provided from August to December. Impacts on spawning migration are inextricably tied to delays in downstream release and magnitude associated with the period of reservoir filling (i.e., in relation to item 1). Juvenile rearing habitat suitability in late summer is similarly defined by the magnitude of downstream release during the period of peak consumptive demand (i.e., in relation to item 2). Given an external supply of water to supplement the two major periods where deficiencies currently exist, modifications to the present operating regime would necessarily augment spring and summer flows to resolve conflicts between consumptive and non-consumptive uses. To this end, a strategy has been developed to provide a full pool volume in Phillips Reservoir by the end of April and accommodate downstream design flows in all other months of the year. This strategy allows for a natural pattern of ascending flow in May, to ~~attract spring spawners, and~~ facilitate ~~their upstream~~spawning migration in spring, as well as provide suitable juvenile habitat for summer and winter rearing. Simulations based on these modifications in water supply are examined below to describe differences in reservoir storage and determine additional water supply volumes to meet consumptive and non-consumptive uses. The simulations employ larger water diversion transfers (i.e., supplementation to facilitate Phillips Reservoir filling) during April and, in some cases August as well as smaller transfers (i.e., make-up requirements for fisheries via the bypass) from August through March. Simulations operate on a single storage volume that would be provided by the proposed reservoir on Gold Creek (i.e., not exceeding 24 M m^3), without impairing annual flow requirements for native fish species in Gold Creek downstream of the structure. Simulations are again provided for the three run-off scenarios previously discussed without allowing changes in established consumption patterns.

To achieve full storage capacity during a below average runoff event (1977), a total discharge of 0.50 m^3/s (or an increment of 0.38 m^3/s above standard operations) through the Gold Creek diversion would be required during the month of April to fill Phillips Reservoir; a small amount of spill would occur by months end (Fig. 8). A further 0.~~10~~31 m^3/s would be provided during the month of August to augment storage ~~during peak consumptive demand. Additional make-up flows of 0.009 m^3/s in July, 0.090 m^3/s in August, 0.001 m^3/s in September, 0.007 m^3/s in October, 0.008 m^3/s in February, and 0.013 m^3/s in March would be required from the Gold Creek diversion to accommodate fisheries requirements during low flow periods (Appendix 3; 1977d). Individual make-up flows are carried around Phillips Reservoir via the bypass channel. Mean monthly spring flows would vary from 0.638 to 0.699 m^3/s at Kinsmen Park and reach 1 m^3/s at the Joseph Creek confluence. At the end of December, a final storage volume of 2 M m^3 would be attained in Phillips Reservoir. The storage required the Gold Creek Diversion for simulation would be 1. M m^3.~~

~~To simulate conditions during an average runoff event, 1985 synthetic data has been~~

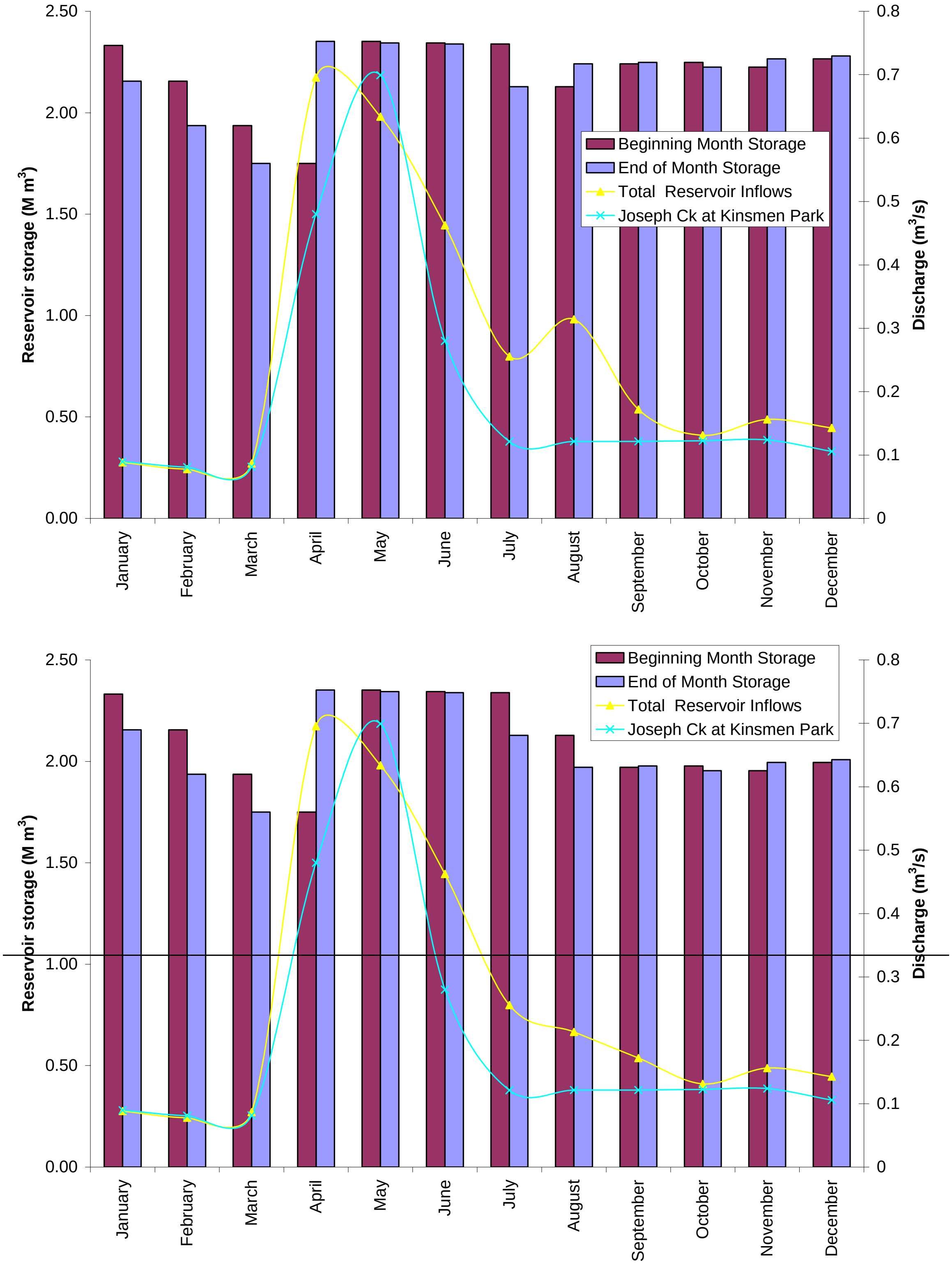


Figure 8. Simulation run during a low runoff event (1977) to contrast reservoir and stream channel dynamics under full supplementation from Gold Creek. Maintenance flows for fisheries are satisfied on annual basis.

during peak consumptive demand. Additional make-up flows of 0.009 m^3/s in July, 0.090 m^3/s in August, 0.001 m^3/s in September, 0.007 m^3/s in October, 0.008 m^3/s in February, and 0.013 m^3/s in March would be required from the Gold Creek diversion to accommodate fisheries requirements during low flow periods (Appendix 3; 1977d). Individual make-up flows to meet annual minimum flow requirements are carried around Phillips Reservoir via the bypass channel. Mean monthly spring flows would vary from 0.638 to 0.699 m^3/s at Kinsmen Park and reach 1 m^3/s at the Joseph Creek confluence. At the end of December, a final storage volume of 2.28 M m^3 would be attained in Phillips Reservoir. The total storage required from the Gold Creek Diversion dam for the 1977 simulation would be 2.7 M m^3.

To simulate conditions during an average runoff event, 1985 synthetic data has been used as a consequence of the higher freshet flow during May. In this example, Gold Creek diversion flows, to facilitate Phillips ~~r~~Reservoir filling, are augmented by an additional 0.15 m^3/s during April with a further 0.30 m^3/s required during August (Fig. 9). Deficit downstream fisheries flows for February (0.017 m^3/s), March (0.016 m^3/s), July (0.099 m^3/s), August (0.090 m^3/s), September (0.001 m^3/s) and October (0.005 m^3/s) are balanced accordingly (Appendix 3; 1985b). Spring flows at Kinsmen Park reach a peak of 1.56 m^3/s in May and the reservoir produces spill at the end of April and during May and June. Reservoir storage at the end of December reaches 2.28 M m^3. The total storage required from the Gold Creek Diversion dam for the 1985 simulation would be 1.81 M m^3.

Simulations of a high runoff event (1972) do not require reservoir supplementation flows in April or August but do require make-up flows in February (0.004 m^3/s), August (0.089 m^3/s), September (0.001 m^3/s), and October (0.007 m^3/s) for downstream releases (Fig. 10; Appendix 3; 1972c). May and June flows at Kinsmen

~~and during May and June. Reservoir storage at the end of December reaches 2.2 M m^3.~~

~~Simulations of a high runoff event (1972) do not require reservoir supplementation flows in April or August but do require make-up flows (February, 0.004 m^3/s; August, 0.089 m^3/s; September, 0.001 m^3/s; October, 0.007 m^3/s) for downstream releases (Fig. 10; Appendix 3; 1972c). May and June flows at Kinsmen Park reach 1.80 and 1.93 m^3/s, respectively while reservoir storage approaches full capacity at the end of~~

~~December (2.32 M m^3). Channel modifying flows are anticipated under this latter~~

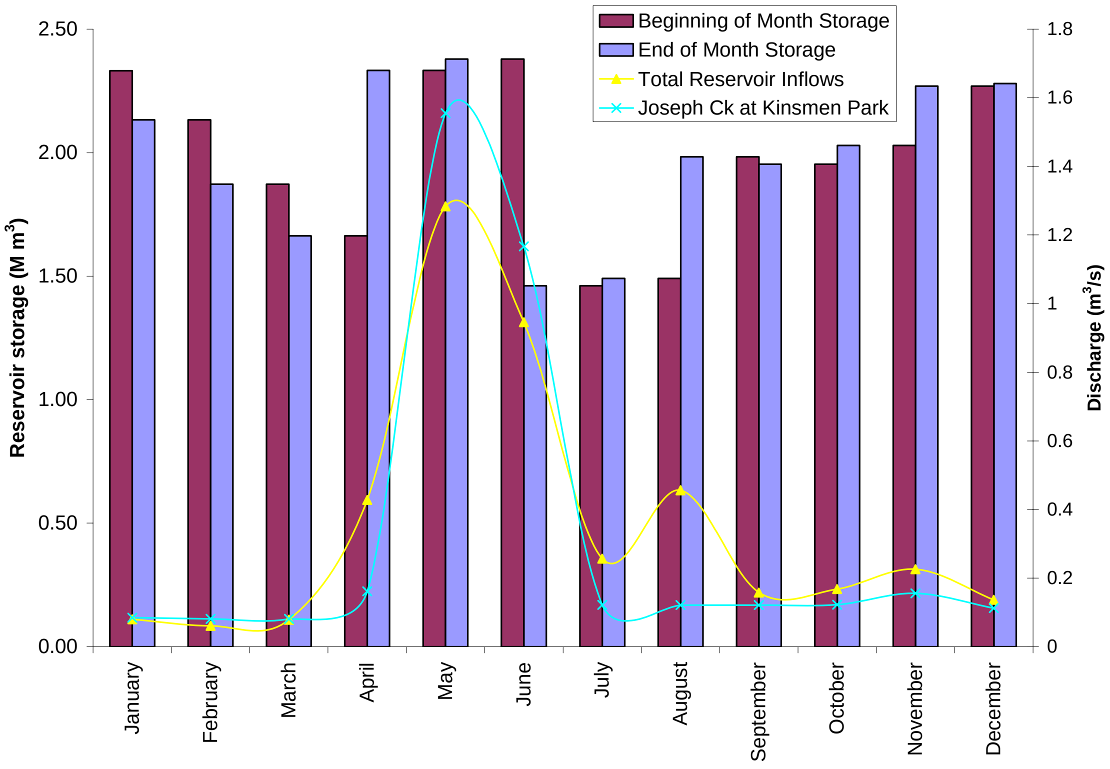


Figure 9. Simulation run during an average runoff event (1985) to contrast reservoir and stream channel dynamics under full supplementation from Gold Creek. Maintenance flows for fisheries are satisfied on annual basis.

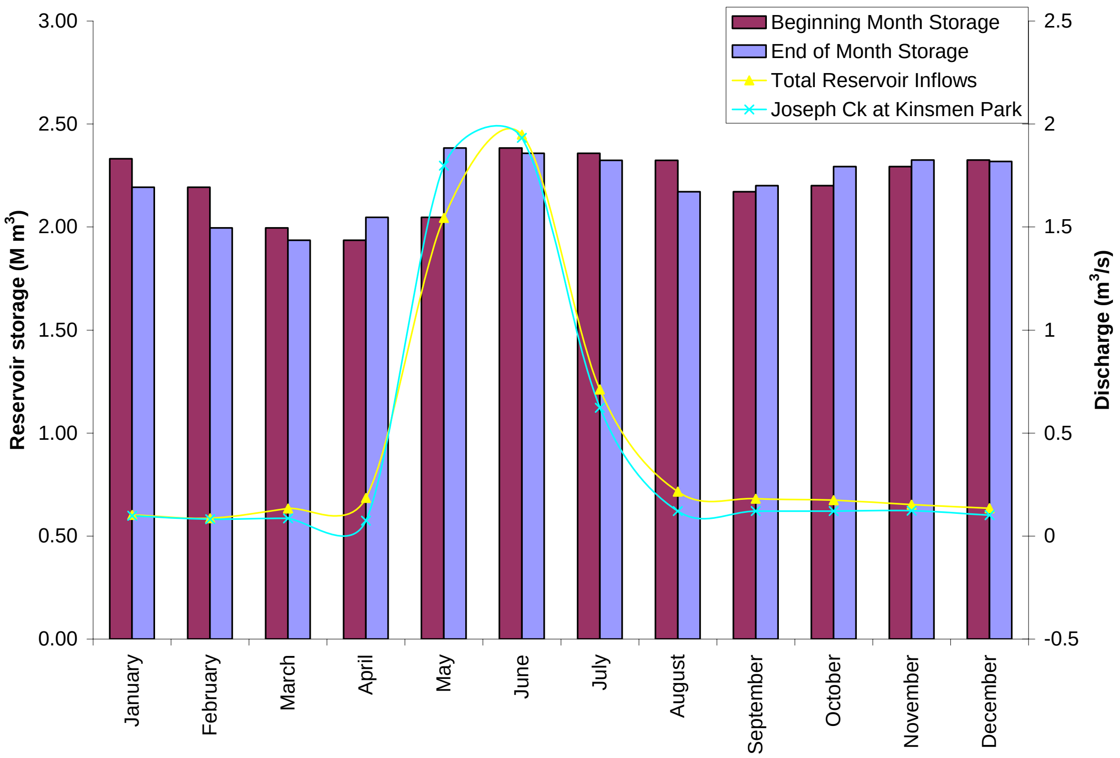


Figure 10. Simulation run during a high runoff event (1972) to contrast reservoir and stream channel dynamics under partial augmentation from Gold Creek. Maintenance flows for fisheries are satisfied on annual basis.

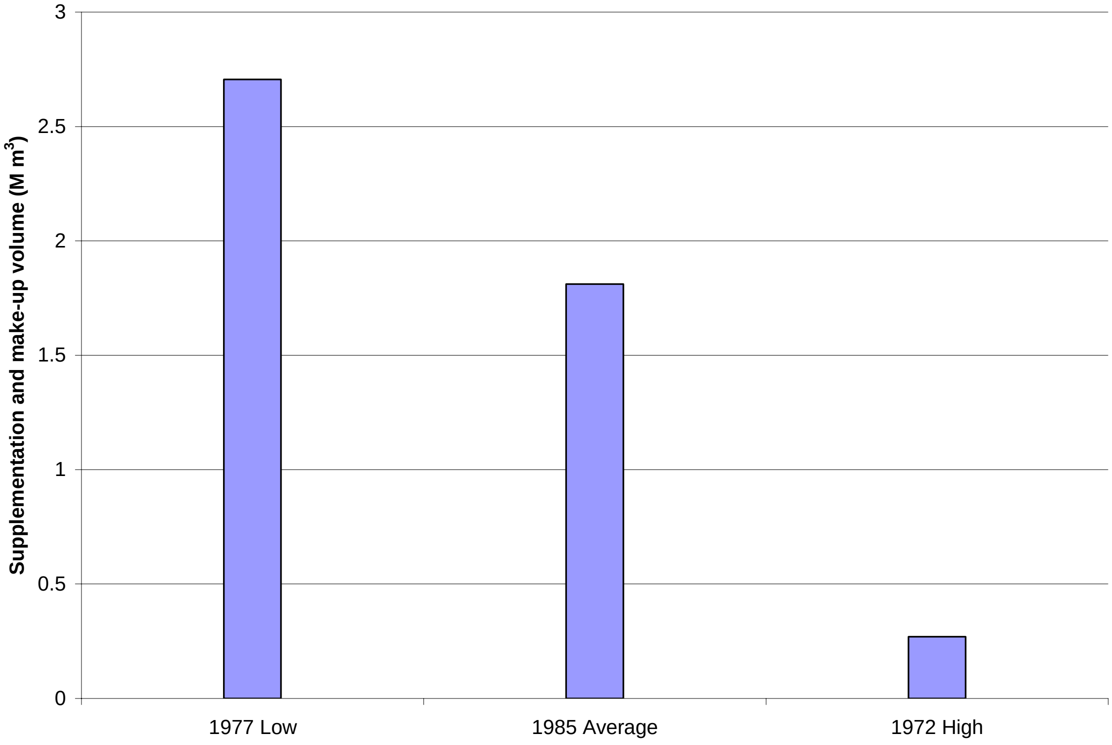
Park reach 1.80 and 1.93 m^3/s, respectively while reservoir storage approaches full capacity at the end of December (2.32 M m^3). Channel modifying flows are anticipated under this latter scenario where instream flows at the Joseph Creek confluence reach 2.72 and 2.30 m^3/s in May and June, respectively. The total storage required from the Gold Creek Diversion dam for the 1972 simulation would be 0.27 M m^3.

~~scenario; downstream flows at the stream confluence reach 2.72 and 2.30 m^3/s in May and June, respectively.~~

Consumptive and non-consumptive needs are met under each of the three aforementioned scenarios but require substantial volumes of water beyond the water supply capability of the Joseph Creek watershed. Estimated supply rates of up to 0.50 m^3/s in the Gold Creek diversion are possible following recent upgrades to the pipeline, however, required storage volumes exceed present capabilities in the upper Gold Creek drainage. A previous proposal by EPEC Consulting Ltd. (1980) identified a location upstream of the existing diversion dam on Gold Creek to construct a new facility in support of expected consumptive demands associated with population growth. The new dam would provide storage for ~2.4 M m^3 at full capacity to meet population growth estimated to reach 28,200 by 1990 and 56,000 by 2010. Population growth has, in fact, lagged behind these initial projections; current statistics place the population of the City of Cranbrook at 18,476 (Statistics Canada 2001 census). Notwithstanding this shortfall in expected growth, the proposed diversion dam provides sufficient capacity to support present consumptive and non-consumptive needs of Joseph Creek with expected capacity to accommodate further population growth in the City of Cranbrook.

A summary of the make-up volume to offset present shortfalls in the Joseph Creek watershed indicates that up to ~~1.9~~2.7 M m^3 of water would be required to support consumptive and non-consumptive use during low runoff years with as little as 270,000 m^3 required under high runoff conditions (Fig. 11). The maximum requirement for supplementation purposes ~~is less~~only exceeds~~ than~~ the total storage capacity of the proposed ~~new ~~Gold Creek facility by 0.3 M m^3 during a below average run-off event. These same volumes would ensure that Phillips Reservoir remains near full storage capacity at the end of each calendar year.~~, ??~~ The simulations provided in the above, identif~~ies~~y the maximum storage volume quantit~~y~~ies for a given runoff scenario per annum ~~and~~but do~~es~~ not take into account the filling dynamics of the Gold Creek facility; additional storage volume for diversion release is anticipated in consideration of the timelines to satisfy water use demands in the Joseph Creek watershed relative to the timing of storage filling and flow volumes within the Gold Creek drainage. Further modeling of storage opportunities on Gold Creek are required to confirm this assumption and estimate the external water supply to meet population growth water demands. For the foreseeable future, the combination of the upgraded pipeline and a new diversion dam on Gold Creek represents a workable solution to present water use issues in the Joseph Creek watershed.

An alternative to the provision of more water is a reduction in domestic consumption through water conservation efforts. A review of the monthly consumption rates (based on 1996 statistics) for the City of Cranbrook from September through May indicates a mean value of 86.5 million Imperial gallons whereas an average of 140 million Imperial gallons is used from June through August. Substitution of a maximum consumption rate of 90 million Imperial gallons per month for the three month summer period during an average (1985) runoff event, under standard



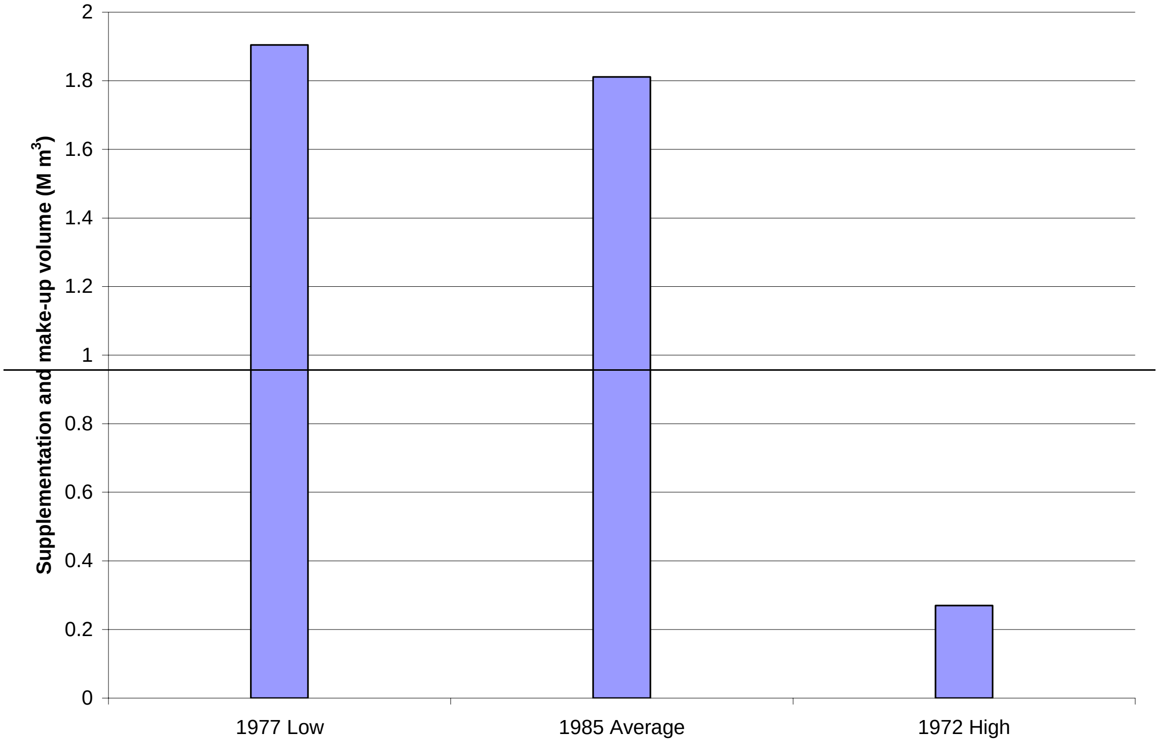


Figure 11. Estimated annual water surplus to supplement filling of Phillips Reservoir and provide make-up requirements for downstream fisheries flows in Joseph Creek.

~~confirm this assumption and estimate the external water supply to meet population growth water demands,. For the foreseeable future, the combination of the upgraded pipeline and a new diversion dam on Gold Creek represents a workable solution to present water use issues in the Joseph Creek watershed.~~

operating procedures and without further downstream supplementation, indicates an increase of 570,000 Imperial gallons in the final reservoir storage volume at the end

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of December (Fig. 12). Approximately 606,000 Imperial gallons are required for make-up fisheries flows during February, March, July, August, September and October. Ninety four percent of that volume may be achieved for downstream release through water conservation efforts.

3.3 Water supply forecasting

The inclusion of snow course information in future management of Phillips Reservoir operations would assist in attaining optimum water management of this system. Regressions are included for both the Sullivan Mine and Moyie Mountain stations (Figs. 13 and 14) to evaluate correlations between snow pack and runoff for forecasting purposes. Each relationship shows some scatter with moderate correlation (r^2's of 0.74 and 0.70). Application of the Moyie regression is

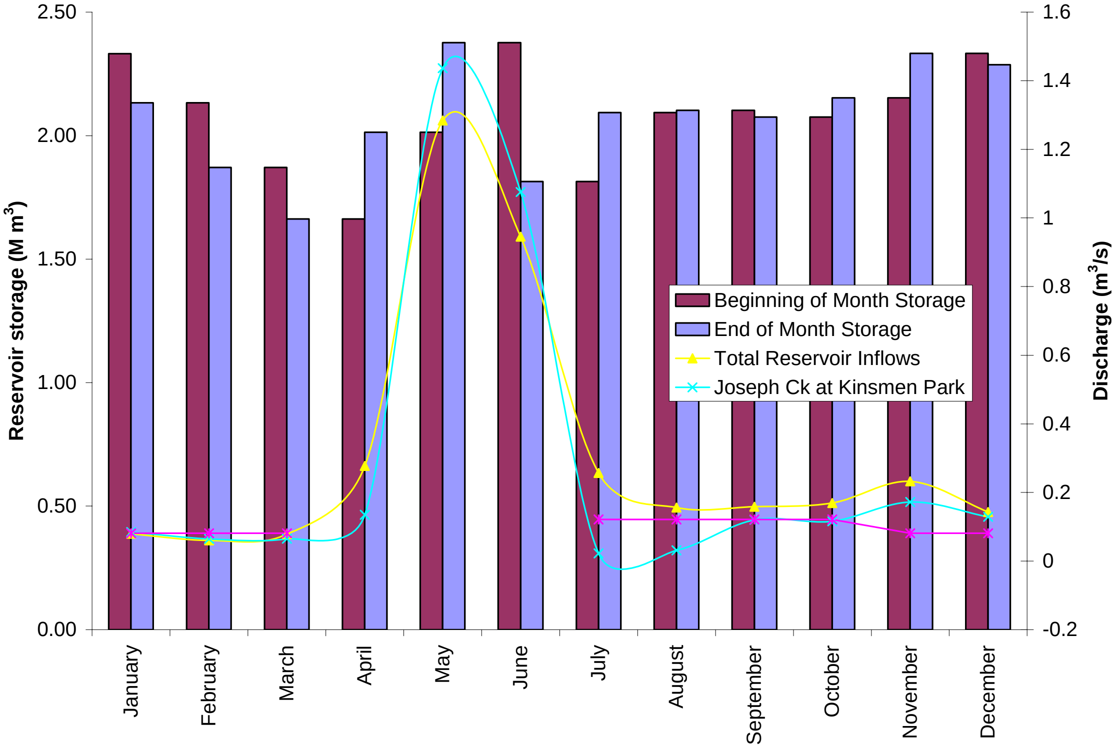

Figure 12. Simulation run during an average runoff event (1985) to contrast reservoir and stream channel dynamics under standard reservoir operating conditions and reduced domestic consumption from June to August. Dashed line indicates required maintenance flows for fisheries.

recommended for future forecasting since collection of snow course information at this station is expected to continue into the future whereas uncertainty remains over continuity of data collection at the Sullivan Mine. Incorporation of the highest water equivalent value ~~for make-up fisheries flows during February, March, July, August, September and October. Ninety four percent of that volume may be achieved for downstream release through water conservation efforts.~~

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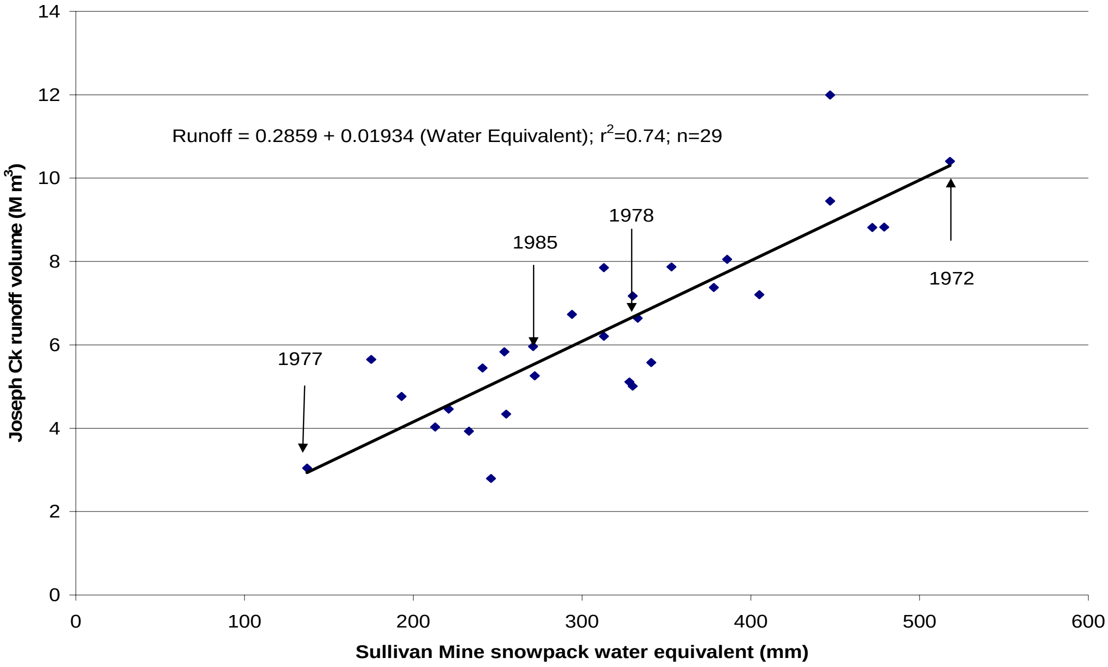

Figure 13. Runoff/snowpack relationship to predict spring-summer flow conditions in Joseph Creek based on Sullivan Mine snow course data. Below-average, average and above-average runoff scenario years are included for comparative purposes.

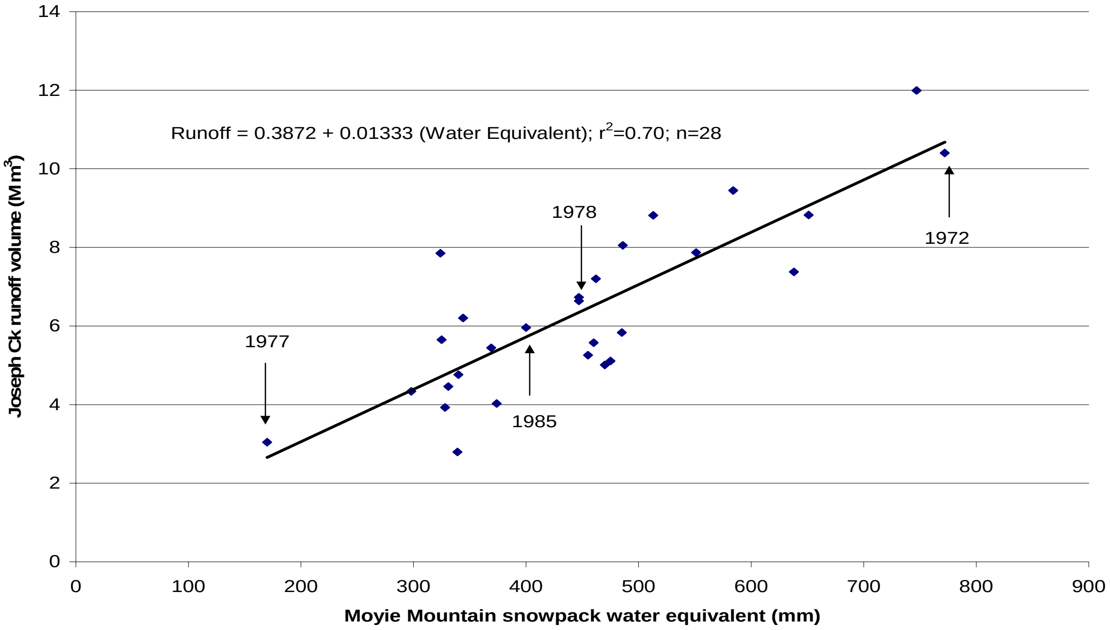

Figure 14. Runoff/snowpack relationship to predict spring-summer flow conditions in Joseph Creek based on Moyie Mountain snow course data. Below-average, average and above-average runoff scenario years are included for comparative purposes.

~~future whereas uncertainty remains over continuity of data collection at the Sullivan Mine. Incorporation of the highest water equivalent value for snow course events during the months of March, April or May into the regression equation will yield an estimate of the expected magnitude of runoff during spring through late summer. Estimated runoff volume values <4 M m^3 should be interpreted as low runoff events while values within the range of 4 to 8 M m^3 should be interpreted as average runoff events and values in excess of 8 M m^3 would represent high runoff events.~~

4.0 Discussion

As demonstrated in previous reports (Oliver 2000; 2001), the ability to improve habitat condition for cutthroat trout in lower Joseph Creek hinges on attainment of increased downstream flows during critical life history stages and higher standards of instream water quality. The former issue is of paramount importance in consideration of the effects of flow regulation on cutthroat trout life history needs and the shift in species composition favouring non-native species. Changes in ecosystem health have been previously identified by reductions in habitat suitability (i.e., space limitations), extreme modifications in summer temperature regime and fine sediment deposition in bed materials of the stream channel (Oliver 2001). Yet, obstacles to improving downstream releases for fisheries are currently ~~thwarted~~compromised by variations in inter-~~an apparent decreasing trend in water supply~~annual flow that place natural limitations on water yield ~~and~~as well as an increasing trend in domestic water ~~consumption~~use. Collectively taken, there are few options available within the existing water supply system to ~~meet~~satisfy the volume requirements of ecosystem maintenance and fish passage needs on an annual basis.~~ the competing demands of consumptive and non-consumptive uses.~~ Based on model simulations within the present study and the present water supply facilities, attempts to improve conditions for non-consumptive use can only occur at the expense~~l~~ of consumptive use; simply stated, alternative strategies are required to satisfy all user needs.

Alternative strategies to address the present water supply issue can essentially be approached in three ways: 1) by supplementation, 2) by conservation or 3) a combination of both supplementation and conservation. Increasing the water supply

~~through increasing~~beyond existing inter-basin transfer volumes is likely the most expedient means of meeting both consumptive and non-consumptive demands, under present water use regimes. In consideration of recent upgrades to the Gold Creek diversion pipeline, supplementation options directed at increased storage in the upper Gold Creek watershed would seem~~s~~ a ~~logical choice~~long-term solution. The City of Cranbrook recognizes the need for additional storage and the recent augmentation of groundwater well volumes to the existing distribution system presently serves as a transition strategy until such time as a more permanent solution is determined (Gary Mott, pers. comm.). Reservoir storage volumes on Gold Creek, associated with a new diversion dam proposal provided in an earlier study (EPEC Consulting Ltd. 1980), are expected to meet water supply demands within the Joseph Creek watershed over the foreseeable future. Although further modeling of storage dynamics in upper Gold Creek are required, simulations conducted within the present study suggest that supplementation volumes to address consumptive and non-consumptive needs in the Joseph Creek watershed can be met ~~within the~~by storage capacit~~y~~ies ~~of~~provided by the proposed Gold Creek diversion dam. Moreover, augmentation of Gold Creek storage can be timed accordingly to address shortfalls in supply to Phillips Reservoir as well as provide make-up flows to satisfy annual fisheries requirements in Joseph Creek. Construction of a new diversion dam on Gold Creek is regarded as a possible solution to the medium-term requirements for consumptive and non-consumptive water demands.

Notwithstanding, there are a number of concerns with respect to infrastructure costs and environmental issues that deserve further consideration to determine which option or combination of options achieve a reasonable and affordable resolve for all user interests. Inter-basin transfer is likely the most expensive option. Upgrades to the existing diversion dam on Gold Creek require significant investment; replacement costs in 1980 were estimated at $2.7 M (EPEC Consulting Ltd. 1980). Increased use of groundwater is an alternative strategy to inter-basin transfer that would incur increased pumping costs to augment domestic use, making a larger portion of existing storage within Phillips Reservoir available for ecosystem needs. The cost of increased pumping relative to the amount of storage available for ecosystem needs however, requires further evaluation. A user-pay strategy represents a third alternative to obtain revenue towards future water supply improvements but significant investment of up to $3 M has been suggested to retrofit Cranbrook residences with water metering equipment (Alderman Allan Gordon, pers. comm.). The latter option, however, indirectly provides a means to instill a water conservation ethic among the residential community. The tradeoffs between options seem rather straightforward: inter-basin transfer may satisfy all user needs but at considerable cost or the more inexpensive approach may not satisfy all user needs on an annual basis. From an environmental perspective, further storage on Gold Creek will undoubtedly alter ecosystem processes associated with similar water quality issues (nutrients, temperature) consistent with reservoir operations and may have certain implications on native fish species relative to migration patterns or behavioural changes associated with impoundment operations. The magnitude of environmental issues associated with storage in upper Gold Creek however, may be more localized in light of the large basin area of the entire Gold Creek drainage and the contribution of flow from large attendant tributaries. The effects of water diversion in upper Gold Creek on fisheries resources are similarly expected to be more limited since make-up requirements for fish flows on Joseph Creek approximate the maximum storage volume of the proposed reservoir on Gold Creek and filling requirements can be timed over the duration of the spring freshet to facilitate full storage and accommodate downstream flows for fish in Gold Creek. Further studies are required however, to assess fish community dynamics above and below the existing diversion structure in advance of any new construction to determine possible impacts on individual populations. Furthermore, while increased use of groundwater wells to satisfy domestic use is appealing, continued drawdown of the aquifer has untold implications on changes in water table levels that may impact on rates of groundwater recharge or contributions of groundwater supply to Joseph Creek at locations downstream in the watershed. Further studies will likely be required to fully understand groundwater dynamics associated with increased withdrawal.

~~Until suitable funding is obtained, alternate strategies aimed at water conservation deserve further attention over the short-term.~~

Routing model parameters have necessarily included domestic use as a key component of the water supply and demand relationship with the highest monthly demands occurring from June through August. Of particular interest is the fact that average water consumption during the months of July and August is almost double the consumption of that observed from September through May. The increased demand during these two months is largely associated with ~~residential~~ outdoor watering. As model simulations have clearly shown, peak demand during August also coincides with a dramatic drop in surface inflows and a dramatic reduction in reservoir storage volume. Improvements in reservoir storage and downstream release could therefore be realized by reducing the amount of outdoor water use on residential properties by placing an emphasis on alternative outdoor yard development strategies that ~~require a much reduced~~reduce outdoor watering demand (e.g., yard beautification projects that reduce lawn surface area; summer lawn watering protocols in local municipal parks). A pivotal shift in attitude is therefore required on behalf of City residents to affect this change; it seems apparent that current annual household demand can be met within the limitations of the present water supply, yet, ecosystem and domestic needs are placed at considerable risk at the expense of outdoor watering. Future stewardship programs will therefore serve a useful purpose to affect attitudinal change towards water conservation and allow greater flexibility within the available water supply to address downstream ecosystem needs in Joseph Creek. Stewardship efforts would best be coordinated with ongoing environmental awareness programs within the present education system.

~~Opportunities to affect attitudinal change based on environmental concerns may be limited without some form of motivation to forge that change. To this end, the implementation of residential water metering is highly recommended to encourage water conservation efforts as well as provide a source of funding for future water supply upgrades in the Gold Creek drainage.~~

In consideration of the water supply options available, the combination of both supplementation and conservation is most realistic. Even with a reduction in summer consumption rates, shortfalls in downstream fisheries flows will continue to plague the long-term recovery of native fish species and any future habitat restoration effort.~~. In this regard, surface augmentation is recognized as the most practical solution to improve the water supply for all water uses. Upgrades to the existing diversion dam on Gold Creek require significant investment; replacement costs in 1980 were estimated at $2.7 M (EPEC Consulting Ltd. 1980).~~ Discussions with the City of Cranbrook are therefore encouraged to begin exploring cost/benefit relationships associated with inter-basin transfer, increased groundwater utilization and water conservation (water meter retrofitting). Moreover, development of a community watershed working group is encouraged to assist with this discussion as well as explore~~-sharing~~ future cost-sharing opportunities for infrastructure upgrades between the City and ~~the Columbia-Kootenay Fisheries Renewal Partnership~~external funding sources. A collaborative process is considered essential to review the available options, reach consensus on the most realistic approach to issue resolution and select the most appropriate course of action to achieving a solution (i.e., short-term vs long-term; single or multiple approaches; cost-effective measures). Without further resolution of present water quantity issues described in the above, future investment in habitat restoration opportunities below Idlewilde Reservoir is not advised. Cost-sharing opportunities towards improvements in the water supply remain the best option to serve both consumptive and non-consumptive interests ~~into the future~~given the expectation of high infrastructure cost and the requirement for external funding to support water supply improvements into the future.

Further work required to confirm the feasibility of the water supply options presented in this report include: a ~~fisheries~~ study of the effects of additional water diversion ~~from~~on Gold Creek fisheries; calibration of the routing model over several years so that multiple year simulations can be carried out to confirm the additional water requirements for non-consumptive and consumptive requirements; changes in groundwater dynamics associated with additional pumping; and updating of the design and costs for a new diversion dam on Gold Creek.

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APPENDIX 1

Model simulations under variable flow scenarios and standard reservoir operations

APPENDIX 2

Model simulations of spring and summer make-up requirements from Phillips Reservoir

APPENDIX 3

Model simulations of annual make-up requirements from Gold Creek storage