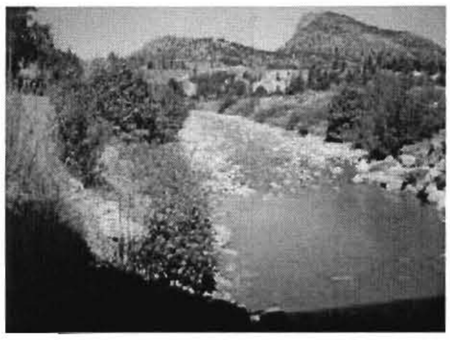
MINISTRY OF WATER, LAND AND AIR PROTECTION



NATURALIZED AND FISHERIES CONSERVATION FLOWS FOR TROUT CREEK NEAR SUMMERLAND, BC

April 2004

northwest hydraulic consultants nhc

Cover Photo:
Trout Creek Highway and Canyon Cross section Locations

NATURALIZED AND FISHERIES CONSERVATION FLOWS FOR TROUT CREEK NEAR SUMMERLAND, BC

Prepared For:

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Table of Contents

List of Tables

List of Figures

Notification

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Acknowledgements

This report was prepared by **northwest hydraulic consultants** with the assistance of three key individuals from the **Ministry of Water, Land and Air Protection**. This report is a living document, modified extensively as a result of the reoccurring drought conditions on Trout Creek, and the monitoring and information collected by many individuals. The report findings reinforce the premise that the foundation of understanding of watershed processes and water use management issues is supported fundamentally by the monitoring and collection of relevant and robust data.

Mr. Steve Matthews, R.P. Bio. was the project coordinator and provided overall document review and oversight. Mr. Phil Epp,, P.Ag. provided technical revisions and flow transect data that greatly enhanced the final product. Mr Ron Ptolemy, R.P. Bio. provided critical technical analyses – especially of the derived flow-habitat relationships for Trout Creek – that are the key products of the report. Their efforts and commitment to this endeavour are appreciated.

1 Introduction

The Trout Creek Stream Summary provides estimates of the naturalized streamflows and suggests instream flows for sustaining fish and fish habitat - notably rainbow trout and kokanee salmon. This stream summary reviews existing streamflow gauging records for Trout Creek and other Okanagan tributaries, and historical water use and water storage records to estimate naturalized annual and monthly stream flows. Where possible, this information describes the expected variation of daily, monthly and annual flows. Physical habitat information was analyzed to derive functional relationships between aquatic macrohabitats - riffle, pool, run or glides - and streamflows.

The process of determining instream flows included the review of historical flow information, current flow standards applied in BC, and physical information - including photo records of stream sections at various flows. Streamflow and fish habitat information was assessed and instream flows suggested to protect the life history requirements and aquatic habitat for rainbow trout and kokanee salmon in Trout Creek. These instream flows are based on available information and provide estimates for dry, normal and wet annual runoff conditions. Importantly, the stream summary for Trout Creek also provides a summary of recommended actions based on gaps in data and information discovered in this review.

2 Trout Creek Watershed

Trout Creek drains a 758.8 km^2 area on the west side of Okanagan Lake; it is the second largest tributary watershed entering Okanagan Lake as located in Figure 1. The watershed rises to an elevation of 1,864 m near Culmination Pt. at its western limit. With a median elevation of 1,356 m, a significant portion of tributary area generates flow from snowmelt runoff over the glaciated terrain of the Thompson Plateau. Tributaries tend to be incised with only minor bench and alluvial valley bottom area. The fourth order mainstem of Trout Creek flows generally southeast (approximately 80 km) before entering Okanagan Lake in a large terminal alluvial fan.

The mainstem is evenly graded between 1 and 2% in the upper watershed and increases only as the creek cuts through deep glaciofluvial deposits and bedrock in its lower reaches. The glaciofluvial deposits in the lower watershed provide sources of the groundwater to the system. The mouth of the creek is located in the District of Summerland, and much of the developed area of the district lies within the lower reaches of Trout Creek watershed. The watershed has a range of land-uses including forestry, range and recreation, and is the water supply watershed for the District of Summerland. Water storage has been developed in several of the high elevation lakes, as well as Thirsk Reservoir.

3 Trout Creek Streamflows

3.1 Ministry of Water, Land and Air Protection Data

Flow data were recorded by MWLAP through monitoring work undertaken under the Okanagan Lake Action Plan (OLAP) at sites and by methods described in Cassidy (2001). This data set was not field checked or verified with respect to data quality or methodology. MWLAP flow and gauge records for 1999, 2000 and 2001 are summarized in Table 1, and Table 2 shows the number of recordings per month in each year. Measurements were taken at four sites: at the Mouth, Canyon, upstream of Diversion and at the Flume. Okanagan Lake levels were found to influence water levels at the Mouth and the site was relocated 150 m upstream in 2001. Figure 1 in the overview report shows the site locations, and Cassidy (2001) provides descriptions of these sites.

Data was analyzed to determine rating curves for all sites. Measurements collected in 1999 and 2000 at the Mouth showed significant scatter and were not usable. With only six observations made at the 2001 Mouth (Figure 2), the best-fit equation given in Table 3 is approximate in spite of the high R^2 value. Gauge height measurements ranged from 0.42 m to 0.54 m and in this narrow range a linear rating curve fit the data best. The derived relationship is not applicable outside the range.

The data for the Canyon Site appears to be the strongest of all sites. Based on 23 measurements within a gauge height range of 0.38 m to 0.76 m, the logarithmic equation in Table 3 fit the data with an R^2 of 0.93. There is little annual variation from the curve (Figure 3), but overlap is limited. No measurements were taken at the site upstream of the Summerland District diversion in 2001. It was assumed that measurements would be influenced by instream work just downstream of the site (Cassidy 2000). Unfortunately, the 1999 and 2000 records were within a gauge range of approximately 0.1 m and showed little trend (Figure 4). The single high flow recording (4.2 m^3/s) was omitted as a data outlier and linear regression of the remaining 17 recordings gave an R^2 of 0.3.

Measurements were also taken inside the Summerland District diversion flume (Figure 5). Gauge height was recorded downward from the top of the flume, but the data appears to be good except for one reading and it was omitted. Based on the best-fit equations in Table 3, flows corresponding to available gauge readings were computed for the 2001

Mouth and Canyon in Table 1. Flows were not estimated for gauge readings outside the range of stream gauge data.

There are only a few days when overlapping data is available for the different sites. Based on these limited records some inaccuracies are apparent. By subtracting the 2000 flume flow from the flow above the diversion, the flow below the diversion was found to be negative in some instances. This is likely due to errors in the flow record for the site above the diversion.

Daily flows for the different sites are compared in Table 4 to determine local inflow or losses between the sites. In the reach from the diversion to the Canyon site, flow generally increased, likely due to local inflows. Between the Canyon and the two Mouth sites, losses to groundwater result in flow reductions. The Old Mouth data shows large and erratic losses due to the poor quality of the data at that site. The 2001 Mouth flow records show smaller and more consistent losses.

3.2 Water Survey Canada Data

Trout Creek has several Water Survey Canada (WSC) gauge sites within its watershed with both current and historic records. Historic data of interest includes WSC 08NM158 *Trout Creek at the Mouth* for the period of 1969 to 1982 with a gauged area of 764 km^2 (reported). This data set was reviewed and provided a basis for adjustments to naturalized flows, as the flow record includes the effects of water storage and both domestic and agriculture water use.

A summary of flow statistics on a monthly and daily time step for the station is included in Table 5 and Figure 6. Based on complete annual records, the mean annual discharge is estimated at 2.2 m^3/s, which is the residual streamflow after abstractions and regulation. Mean monthly flow ranged from a low of 0.07 m^3/s during December and January to a maximum of 29.4 m^3/s in June. The 10^{th} percentile daily flows (Q_{10d}) are 0.085 m^3/s, and 90^{th} percentile daily flows (Q_{90d}) are 5.5 m^3/s. Both daily and monthly flow duration curves for WSC 08NM158 are presented in Figure 7.

Current active WSC stations within the Okanagan Lake basin include several tributaries to Okanagan Lake, and one sub basin in the Trout Creek watershed. The available data set for Camp Creek WSC 08NM134 extends from 1965 to 2000. The Camp Creek watershed has a gauged area of 36.5 km^2 or 4.8% of the total Trout Creek watershed area, and a median elevation of 1,450 m. In the headwaters of Camp Creek, Chapman Lake provides 160,351 Mm^3 (130 ac-ft) of storage. With an estimated mean annual runoff to the lake approximately 3 times the available storage, Camp Creek hydrology generally behaves as a natural unregulated system. A summary of Camp Creek gauged flows is provided in Table 6, and in Figure 8 and Figure 9. Mean annual discharge for Camp Creek for the period of record is 0.157 m^3/s, with minimum mean monthly flows of 0.015 m^3/s in January and maximum mean monthly flows of 1.72 m^3/s occurring in May. On a daily basis, the Q_{10d} is 0.031 m^3/s, and the Q_{90d} is 0.404 m^3/s.

Unlike Trout Creek gauge (WSC 08NM158), which is affected by regulation, the flow duration curve for Camp Creek gauge (WSC 08NM134) monthly and daily flows are very similar. Another gauged tributary of Trout Creek is the inactive Bull Creek gauge (WSC 08NM133) with a period of record from 1965 to 1986 and a basin area of 48.2 km2 (Obedkoff 1998). The mean discharge over the period is 0.136 m3/s with minimum monthly flows of 0.010 m3/s occurring in September, January and February (Figure 10) and maximum monthly flows of 1.86 m3/s in both May and June (Table 7). With daily flows, the Q10d is 0.014 m3/s and the Q90d is 0.390 m3/s (Figure 11). Bull Creek has no man-made or natural lake storage, and the runoff pattern reveals a later broader freshet with lower shoulder and low flows – relative to mean annual discharge.

Other active and historic WSC gauging records are available for tributaries to Okanagan Lake, as well as in the same or similar hydrologic zone – 12B. Stations within the b sub zone include Bellevue Creek (WSC 08NM035), Daves Creek (WSC 08NM137), Greata Creek (WSC 08NM173), Shatford Creek (WSC 08NM036) and Vaseux Creek (WSC 08NM171). These records were reviewed, adjusted and used to provide a template for the distribution of mean annual runoff for systems naturalized for regulation or significant water use as calculated later in the report.

3.3 Water Use and Storage

Within the Trout Creek watershed – excluding the Garnett system – there is storage capacity for 14.355 Mm^3 or 11,638 ac-ft. The District of Summerland has a licence to store 15.363 Mm^3 (12,455 ac-ft) and licence to use 18.594 Mm^3 per year (15,075 ac-ft) as summarized in Table 8. District records for 1999 to 2001 show that during this period between 11-12 Mm^3 of water was used per year. Approximately 91% of the flow comes from Trout Creek and 9% from the Darke Creek basin. An additional 0.386 Mm^3 (313 ac-ft) of Trout Creek flows are licensed to other consumers (Table 9). The District of Summerland also holds a licence of 2.652 Mm^3 (2,150 ac-ft) for Okanagan Lake (McGregor 1999), which is not currently exercised.

3.3.1 **Storage Reservoir Records**

A schematic diagram of water reservoirs in the Trout Creek basin is shown in Letvak (1989) and included in Figure 12. At the upstream end of the watershed are Headwater Lakes #1, #2, #3 and #4, while Crescent Lake and Whitehead Lake are located east of the mainstem channel. A diversion ditch connects Crescent Lake to Headwater Lakes #2 and #4 and flow can be diverted from Crescent to either of these lakes. Below Whitehead is Thirsk Reservoir, located on the mainstem upstream of Camp Creek. Isintok (Canyon) Lake is on the west side of the basin and Garnett Reservoir is on the east side. Flow from Eneas Creek is diverted directly to the District of Summerland and does not enter the Trout Creek watershed. Additional minor reservoirs are Big Eneas, Tsuh (Deer) and Island Lakes. Flow from the main reservoirs can be regulated but the minor ones are unregulated. Associated Engineering (BC) Ltd (1997) provides a detailed summary of Trout Creek reservoirs in their Water System Master Plan.

A review of the above expected inflows and live capacity of the reservoirs indicate that with Mean Annual Runoff (MAR) runoff conditions, all will fill completely. In fact, with 36% of MAR, both Crescent and Thirsk fill completely with other reservoirs filling at least 30 - 70% of capacity. The Water System Master Plan (1987) prepared by Associated Engineering, provides a rough guideline for optimization of the water system. It states the priority should be to fill the reservoirs during freshet to the maximum extent possible and maximize the use of flows in the uncontrolled part of the watershed to meet water demands during the early part of the irrigation season. Next, withdraw the dry year inflow volume from Whitehead, Headwaters #1, Tsuh and Isintok Lakes. Finally, withdraw from reservoirs with the inflow / storage ratios ranked highest to lowest. Water Management Consultants Ltd. is currently reviewing and updating water use and management plan elements for the District of Summerland. A revised system operations and updated water use plan is expected in early 2004.

Reservoir Reports were obtained from District of Summerland for 1999 to 2001 along with storage elevation curves for seven of the reservoirs. Curves were derived for Whitehead and Isintok based on storage volumes and reservoir levels reported in 2001 as inflow / outflow records were not available. Gate settings were reported, but the rating curves for gates or spillways were not available and outflows could not be computed. Storage inflows and outflows were estimated based on storage volume changes at each reservoir between observation dates. Based on the individual reservoirs, the total net storage gain or loss per month was then estimated. The monthly inflows / outflows are approximate only as reservoir readings were taken intermittently and substantial storage changes may have occurred between readings that were not accounted for. With only a few recordings per month, the process of converting observed storage to mean monthly storage change should be considered approximate.

3.3.2 **Flow Consumption Records**

District of Summerland provided daily consumption records for 1999 – 2001, and mean monthly usage was computed for June to September in each year for the Trout Creek diversion and intake (Table 10) with reported monthly diversion flows ranged from 0.4 m^3/s to 1.0 m^3/s. Historical water use records indicate that the Darke Creek system provides 8.6% of the water supply relative to Trout Creek, which supplies 91.4%. The District adjusts the diversion flow daily depending on water supply and demand and balances daily usage through a balancing reservoir.

Licensed irrigation and waterworks flows (Table 9) constitute most of the licensed demand in the Trout Creek system. The licensed consumption by other users – mostly domestic flows - is small and not significant. It is expected that there is also some loss due to local groundwater use, but these flows are not licensed and are not expected to influence flows in this analysis. Water use data provided by the Corporation of the District of Summerland indcate that withdrawals outside of the period, typically influenced by storage in the system, is relatively small, ranging from 0.06 m^3/s to 0.11 m^3/s with total actual water use averaging 0.31 m^3/s.

3.4 Annual and Monthly Streamflows

3.4.1 **Mean Annual Flows**

Estimates of total annual flow or mean annual runoff (MAR) supported by stream flow gauging and monitoring are not currently available for the entire Trout Creek watershed. Current gauging is limited to seasonal measurements at water storage facilities and continuous measurements at the intake weir, all conducted by the District of Summerland, and measurements of the smaller sub basin – Camp Creek. Over 75% of the total flow in all Okanagan Lake tributary systems occurs from April to August in response to melt and runoff from the snow pack (**nhc** 1989; Obedkoff 1998). Elevation influences both total runoff and period of peak flows. Watersheds with higher mean elevations have greater mean runoff and peak runoff typically occurs a month later than lower elevation systems.

Measurements of total annual runoff or flows have been generated by Letvak (1984, 1989), Obedkoff (1998), and **nhc** (2001) for the Trout Creek watershed. Mean annual runoff values for unregulated Okanagan watersheds within the homogenous hydrological zone 12B-b with relatively low water use and similar mean elevations were reviewed and analyzed. The average MAR from these basins was 128 mm in comparison to earlier estimates of 110 mm (**nhc** 2001) and 82 mm (Letvak 1989). In consideration of the larger basin area and other hydrological factors, a MAR of 120 mm and mean annual discharge (MAD) of 2.89 m^3/s is estimated for the Trout Creek watershed.

The differences between estimated runoff and measured streamflows are numerous, and can easily explain the discrepancies between estimated and actual flows. Errors and differences can result during flow gauging and measurement, decadal variations in climate and runoff patterns resulting in wetter or drier periods during relatively short periods of streamflow gauging, inaccurate water use reporting, evaporation from storage lakes, seepage and losses from the water system, and losses to groundwater on the Trout Creek fan are a few of the many potential sources. Although small and speculative, they can obviously result in significant cumulative differences and could explain much of the discrepancy.

Snow course data has been collected in the watershed at three stations – two in upper Trout Creek and one in the Isintok Lake. Active snow pillow data from Brenda Mines (2F18P) indicates that snow pack begins decreasing April 1st and melt is completed by the middle of May in a normal year. Estimates of wet, dry and normal runoff years were reviewed for the period of record for Camp Creek (WSC 08NM134). Based on the data,1972 was the wettest year on record, 1988 was the driest year, and 1989 was the median year. It is not known if existing snow pillow data has been analyzed with respect to annual estimates of total runoff for periods of record or to estimates of peak runoff. Multivariate analysis with several stations, as well as total precipitation data, may provide key relationships between snow pack, rainfall and total annual runoff in Trout Creek.

3.4.2 Naturalized Mean Monthly Flows

Determining naturalized flow, the flow that would occur without any reservoirs, diversions, or water consumption, is a prerequisite for evaluating potential instream flows for the protection of fish and fish habitat. Reference is made to these adjusted flows as *naturalized flows* to differentiate them from natural flows in an unregulated system. Trout Creek naturalized flows were estimated in several ways in order to provide a robust estimate of mean monthly flows.

First, naturalized flows were estimated by adding mean monthly flows based on observations from the MWLAP data, flows that went into storage and flows diverted by

District of Summerland for the period of 1999 - 2001. Most of the discharge measurements were taken in the low flow season and these naturalized flows were developed for July, August and September only. Table 11 provides values of observed flows from data collected by MWLAP. Table 12 provides estimated monthly flume flows, computed average monthly diversion flows recorded by Summerland and estimates of naturalized mean monthly flows. These initial estimates of naturalized mean monthly flows for Trout Creek from the MWLAP data are compared to gauge records at WSC 08NM158. For some months the data agrees fairly well but others have discrepancies of almost +60% as estimating mean monthly consumption based on only a few daily readings can result in significant errors. Flows may also have been withdrawn from existing streamflows not supplied from storage. This estimate is the weakest, as the amount of data available for both flows and water use was extremely limited, and is not likely representative of long-term mean values. However, the naturalized values for 1999 - 2001 do fit within the range of expected flows developed later in the report (Table 23).

Second, estimates of mean monthly flow from the record of gauged flows at WSC 08NM158 were simply added to estimates of licensed water use diverted from Trout Creek to estimate potential mean monthly flows. This method would not account for the potential filling of storage early in the year that would depress spring freshet flows, likely in April and May. A check of the licensed demand (0.59 m^3/s) and recorded demand (0.31 m^3/s) and average gauged flows (2.15 m^3/s) provides an initial estimation of runoff for the system ranging from 2.37 - 2.65 m^3/s – but runoff is expressed in terms of $mm/km^2/yr$?. Letvak (1989) provided estimates of mean flows at the point-of-diversion that were adjusted for flows taken into storage and adding water demand (12.16 Mm^3, 0.58 m^3/s or 15,000 ac-ft). After translating those flows to the entire basin, a mean annual discharge of 2.57 m^3/s is calculated.

Finally, Trout Creek mean monthly flows were estimated by distributing estimates of mean annual runoff to normalize estimates of mean monthly flows for unregulated watersheds within the homogenous hydrological zones, with relatively low water use and similar mean elevations. These normalized factors were developed through a review of selected gauges within the same hydrological zone (12B); selected gauges with the same hydrological sub zone and comparable watershed attributes (12B-b); and results from sub-basins within the watershed – Camp Creek and Bull Creek. We selected the regional sub-watershed factors - hydrological zone 12B-b - for estimating Trout Creek mean monthly flow distributions (Table 13). Based on the selection of watersheds, regional data should adequately represent both the low flow conditions and freshet characteristics for a basin the size of Trout Creek. The smaller Camp Creek watershed appeared to have relatively higher flows during low flow months that may indicate contribution from groundwater or other conditions that may not be representative of the entire Trout Creek watershed (Figure 14). Bull Creek is also somewhat different than typical watersheds within the zone with its late season freshet and lower flows during low flow periods. We did consider that Camp Creek will likely have similar mean annual runoff to Trout Creek watershed due to similar elevation, climate and snow pack characteristics, and with continued flow gauging, would make a good candidate to use in future water use and hydrological studies.

Table 14 provides a summary and comparison of the estimated naturalized mean monthly streamflows for the Trout Creek watershed. The naturalized mean monthly flows were also plotted against flows from **nhc** (2001) and Letvak (1989) to illustrate the effects of normalizing to non-regulated basins (Figure 15). Normalization of flows resulted in increased flows, noticeably in April when flow would be routed to fill storage and in August and September when demand for irrigation is high (Figure 16). In an unregulated state, the daily and monthly flow duration curves are likely analogous to those unit curves illustrated in Figure 17.

Table 14 provides a summary and comparison of the estimated naturalized mean monthly streamflows for the Trout Creek watershed. The naturalized mean monthly flows were also plotted against flows from **nhc** (2001) and Letvak (1989) to illustrate the effects of normalizing to non-regulated basins (Figure 15). Normalization of flows resulted in increased flows, noticeably in April when flow would be routed to fill storage and in August and September when demand for irrigation is high (Figure 16). In an unregulated state, the daily and monthly flow duration curves are likely analogous to those unit curves illustrated in Figure 17.

An analysis of Camp Creek reveals that annual runoff varies between 44 – 226% of mean values over the period of record (Figure 18). If Camp Creek and Trout Creek are assumed to have similar responses with respect to mean annual runoff, then dry annual flows could be assumed to be less than Q_{25a} (70.4% MAR) and wet flows greater than Q_{75a} (119.8% MAR) with normal flows between those values. Expected mean monthly flow distributions for these events are provided in Table 14. Using these assumptions for Trout Creek, the estimated naturalized mean monthly flows in a wet year in May would range from 514.3 - 1094.7% MAR or 14.9 – 31.6 m^3/s whereas dry year naturalized mean monthly flows in December would range between 22.3 – 10.8% MAR or 0.64 – 0.31 m^3/s as described in Table 15.

Monthly flow distributions for wet, normal and dry years were used with corresponding estimates of runoff in order to provide representative naturalized mean monthly flow estimates for wet, normal and dry years, or selected frequency of occurrence. By applying the normalized frequency distribution of mean annual runoff from Camp Creek – assumed to be analogous to Trout Creek – and the variable distributions of monthly runoff normalized to mean annual flow, estimates of the mean monthly flows in wet, normal and dry years for Trout Creek can be prepared from an estimate of the mean annual discharge for the watershed. Obviously this approach relies on the assumption that the relative hydrological responses of the basins are approximately the same. They are likely subtle differences due to size, aspect, elevation and other factors, but given their close proximity and relative uncertainties, they are suitable for analysis. The estimates for Trout Creek are provided in Table 16.

4 Instream Flows for Fish and Fish Habitat

4.1 Historic Instream Flows

Historic instream flows for fish have been referenced in several documents (Sheppard and Ptolemy 1999; Wysocki 2000). Pinsett (1974) recommended minimal optimum flows of 0.58 m^3/s from April to September, 0.29 m^3/s from October to March, and an absolute minimum flow of 0.29 m^3/s. Wightman and Taylor (1978) suggested minimum spawning flows of 0.42 m^3/s, incubation and rearing flows of 0.28 m^3/s and absolute minimum flows of 0.14 m^3/s. Many references are enclosed in the Canada – British Columbia Okanagan Basin Agreement (OBA 1973), in Technical Supplements I and IX. In summary, the OBA suggests a total of 7,800 acre-feet (9.62 Mm^3 or 2,037 million US gallons) of instream flows for Trout Creek for the purposes of trout and kokanee production. The other reference to instream flows is contained in the District of Summerland Water System master plan (Associated Engineering 1997). These flows are listed as being referenced to MWLAP but no references are enclosed in the report and no records of these flows are available (Matthews 2002). These flows are attached, and compared to nhc (2001) flows in Table 21.

4.2 Instream Flow Rationale

Instream flows for Trout Creek were developed from three sources and applied using the hydrological data developed from estimates of monthly and daily flow durations, mean annual runoff and mean monthly flows. These metrics addressed include the magnitude, duration and timing of flows congruent with fish life history needs. The proposed instream flows for Trout Creek utilized fish use periodicity as described in Figure 20 and application of conservation flow standards, the meta-IFIM standards and monthly and daily flow duration data.

A key feature in the development of the rationale for instream flows in Trout Creek is that it considers hydrological variability. Flows are adjusted – increased or decreased – in response to higher or lower annual runoff conditions, and the distribution of those flows is also influenced. Analyzing streamflows, by month and with duration requirements, an instream flow release can achieve both inter and intra-annual variability. These variable instream flows can reflect the year-to-year and seasonal hydrological variability that both the periodicity of fish life history and ecosystem components have adjusted to through evolutionary processes. Second, the instream flows have a physical basis, and in the case of Trout Creek, are influenced by the macrohabitat and at-station analysis that reflects the morphological condition of the stream channel, and the type and distribution of aquatic habitats that develop in response to flows. Last, there is a biological rationale based on regional studies of limiting factors to fish production for the species of interest that can be directly related to flows and habitats in reaches in the creek. Based on earlier assessments of limits to fish production in Okanagan streams (Tredger 1989), we considered several key lifestages: rainbow trout spawning, rainbow trout parr rearing, and kokanee migration and spawning.

The combination of hydrological, geomorphological and biological attributes contributes to the strength and relevance of the analysis of instream flows for Trout Creek.

4.2.1 Macrohabitat and At-station Analyses

FHAP-level field data collected by MWALP between 1999 and 2001 was analysed to assess the types and amounts of habitat available for fish as a function of flow. We used the macrohabitat assessments of the reaches provided by Cassidy (2001). However, the macrohabitats did not fit the generally prescribed characteristics, likely due to the location of the reach and setting. For example, riffles in the canyon reach typically had width-to-depth ratios of 40 whereas they are typically greater than 70 - 80 in low-gradient pool-riffle stream and river systems. No pools were found in the canyon reach, but typical width-to-depth ratios of less than 10 would be expected.

Fish macrohabitat measures – riffle, run and rapid – were regressed at-station with flow to determine if significant relationships could be derived. Unfortunately, reach lengths were not consistent; varying with flow. In order to compare wetted width, stream depth, riffle area and rapid area with flow, it was necessary to trim the data to the shortest reach length surveyed at each site. As a result, some data were not useable for a direct comparison with flow. In order to reduce the amount of unused data, riffle area and rapid area were divided by reach length to give relative values of area, which could be compared to flows.

A summary of the data is presented in Table 17 and Table 18, and the results of the regression analysis are presented in Table 19 and Table 20. Figures of the significant relationships between flow and habitat are presented in Figure 19. The covariance statistic shows that there is a good relationship between flow and the various dependant variables, particularly at the Canyon. Results were considerably poorer at the mouth of Trout Creek, where flow data was less reliable. The high R^2 values for the Trout mouth data can be attributed to the fact that only three data points were available for this analysis, additional data would provide a truer value of R^2, which is likely to be reduced.

In addition, the covariance between the relative measures of riffle and rapid area were very low, suggesting little or no correlation, and only the trimmed reaches provide enough valid data to conduct analyses and much of the collected data cannot be used. Re-analysis of the data to include velocities and substrates might provide additional insight into potential fish habitat - flow interactions and suitability for both rainbow and kokanee.

At-station photo records were assembled and completed as plates (Photo Plates). All photos were provided with the MWLAP data except the last plate which is courtesy of R. Ptolemy. The plates were sequentially ordered from lowest flows to highest flows for the canyon site. There were insufficient photo records for the site at the mouth of Trout Creek, therefore only the canyon site was reviewed.

At flows of 0.05 m^3/s, visual analysis of the flows at the canyon site indicates very small wetted widths with few micro pool-rapids. Substrates are mostly exposed and there is no connectivity and poor fish passage potential. At flows between 0.27 and 0.37 m^3/s, wetted widths increase to nearly fill of the channel base, substrates are near 50% submerged, and at the higher flows, there is depth and connectivity for fish passage. At 0.50 to 0.63 m^3/s, the channel base is full, substrates are nearly submerged, and the unstructured rapid hydraulic is formed with micro jump-pool formations over larger bottom substrates. There is ample connectivity at these flows both longitudinally and laterally across the section of the stream. At flows of 2.2 m^3/s, most of the microhabitats are washed out, substrates are fully submerged and the channel is near bank full in this section with a relatively uniform rapid. There are no flow-limited fish passage issues at these flows. The final plates in the series show the station at the mouth at 2 flows (0.5 and 2.2 m^3/s), and the section upstream of the highway bridge where kokanee were migrating / holding in flows of 0.22 m^3/s.

Review of the habitat analyses and photo plates prepared for Trout Creek reveal that for the entire canyon reach, widths and depths are maintained at flows greater than approximately 0.4 m^3/s. These channel characteristics are relatively insensitive to increases in flow above this number and relatively sensitive to reductions in flow below this number. The behaviour and response of variables such as wetted width, riffle area, and depth of flow suggest that flows in the range near or greater than approximately 0.4 m^3/s optimize fish habitats that require wetted areas and suitable depth over substrates such as rearing habitat for juvenile rainbow trout.

4.2.2 **Hydrological Analysis**

Specific fisheries conservation flows for the Okanagan basin were developed in **nhc** (2001), and these provide a contemporary context of instream flow needs for Trout Creek. Conservation flows address the streamflows required for long-term sustainability and health of aquatic ecosystems, within the constraints of the naturalized flows available and on a stream specific basis. These standards utilize the Ptolemy method, as described in Hatfield et al. (2003), that uses flow criteria based on a percent of mean annual discharge and duration appropriate for specific criteria that encompass biological, physical and ecological needs of stream and river systems.

Direct application of conservation standard (**nhc** 2001) for kokanee spawning of 20% MAD results in a flow of 0.58 m^3/s in September and October. This data is supported by the results from physical habitat simulation (phabsim), weighted usable area (WUA) versus % MAD as presented by Tredger (1989) for Lambly, Powers, Shorts and Mission Creeks. WUA for kokanee spawning was at or near maximum available over a range of 2 – 30% MAD. While this clearly identifies requirements for spawning, the data does not provide an assessment of flows for migration. Low streamflows in Okanagan streams can limit the migration and distribution of kokanee spawners, and may limit access to spawning habitat due to low flow barriers, difficult hydraulic conditions, and lack of pool habitat and cover (**nhc** 2003). In a similar manner, the conservation standard for rainbow parr rearing (overwintering and juvenile rearing) from **nhc** (2001) provides a flow of 20% MAD or 0.58 m^3/s. WUA versus % MAD for Mission, Lambly, Powers, Shorts and Trepanier Creeks also shows maximum or near maximum available habitat for rainbow parr at 20% MAD over a range of approximately 5 – 30% MAD.

Second, specific instream flow requirements were based on meta-IFIM standards developed by Hatfield and Bruce (2000). Using the estimated mean annual discharge and location of the watershed, the estimated meta-IFIM flow for rainbow spawning is 3.7 m^3/s, the flow for parr rearing is 2.2 m^3/s and the fry rearing flow is 0.4 m^3/s. The parr rearing flow appears to be in excess of adequate or ideal streamflows based on review of the physical habitat in both the photo plates and site investigations. The spawning flows determined by the meta-IFIM could be considered a peak flow standard potentially to assess loss of freshet flows to storage. The meta-IFIM fry rearing flows would indicate potential minimum flow standards in non-freshet months during the growing season.

Third, instream flows were estimated by adjusting the mean monthly flows – according to flow frequency – to provide streamflows at reduced levels, but retains the shape and timing of flows critical to ecological and physical processes. Unit flow duration curves of percent mean monthly flow by mean annual discharge (%MMF/MAD) by month were calculated from naturalized data. A minimum monthly streamflow frequency of 5% - $Q_{5\ MMF}$ – was incorporated and, by month, the frequency of flows were reduced by up to 75% of the difference between the minimum frequency and the initial frequency of naturalized flows in that month. The reduced frequencies were then back calculated into mean monthly flows. This reduces the frequency of flows in all months to 5 – 21% with lower frequencies during non-freshet periods and higher frequency during the highest mean monthly flows.

4.2.3 Proposed Instream Flows

Both the Ptolemy and the conservation flow model (**nhc** 2001) provide similar results with both mean annual flows and monthly flows (Table 22), but the frequency model provides higher flows during the freshet period, as flows are only reduced by a fixed proportion (Figure 21). Although based on a monthly standard, the non-freshet flows in all cases satisfy both the meta-IFIM flows, as well as the rainbow parr rearing flows identified by Tredger (1989) and flows notionally outlined through examination of the physical habitat. The habitat - flow relationships provided in Figure 19 indicate that flows between 0.4 and 0.5 m^3/s maximize incremental benefits at both the mouth and canyon reaches of Trout Creek. The strength of the biological work undertaken earlier on other Okanagan tributaries tends to support the use of the flows identified with the conservation flow standards (**nhc** 2001). It is recommended that these standards be adopted for Trout Creek until more detailed fish habitat and fish use / distribution work is completed. Any instream flows should be adjusted to reflect notional flows at the point-of-diversion.

Using the conservation flows and estimates of mean annual runoff from the unit flow curve, the estimated mean monthly flows and conservation flows were estimated by month and summarized in Table 23 and in Figure 22. Annual flows were not normally distributed so all flow estimates are based on percentage or frequency. The results indicate that within the range of expected annual flow conditions, mean monthly instream flows provide both variation and seasonality.

Typically, flow standards are set for lower than expected flows due to water use and storage. However, the analysis also provided flow standards for greater-than-normal flows. Although these flows are calculated, they may not be practical from a management perspective or hydrologically applicable. As these high flows are typically not biologically or hydraulically limiting, there is typically an undefined area that provides for the use of those flows above those required for aquatic habitat, fish and the physical processes that support them.

4.2.4 Timing and Duration of Instream Flows

One issue with respect to flow standards is ensuring that those standards that have required durations less than a month – often a matter of days or weeks – are satisfied in a regulated state. Migration and spawning flows, out migration, geomorphic and off-channel connectivity flows are standards that require flows of relatively short periods (Table 24).

As shown in Figure 23, Trout Creek has a wide range of annual inflow conditions that may or may not provide the conditions required for these short duration flow standards in years of low inflow. This is especially true on shoulder months when the impacts of storage refill may be greater than in high annual inflow years. However, based on the historic flows, the naturalized daily inflows would appear to provide more than adequate flows for geomorphic, and other, processes that require relatively large freshet flows in relation to MAD, and the relatively small amount of storage relative to the total annual flow would indicate that typically this flow standard will be achieved in most years with higher than normal inflows.

Another critical time period is April (Julian day 90 – 120) where early freshet flows are required for rainbow trout migration and spawning. Again, the historical data indicates that flows approaching optimum are achieved, and only in years with low annual inflows are streamflows less than optimum for this lifestage requirement. However, even in low inflow years a freshet flow does occur, albeit at a greatly reduced ratio to the mean of high inflow years.

One method to achieve these timing requirements would be to ensure that the duration of flows is specified in operational plans. For example, in Table 24 the duration of flows is specifically referenced to life stage or biological requirements. Accordingly, a weekly or biweekly flow schedule may be required along with biological monitoring to better determine the flows, duration and timing required to provide the life stage requirements. For example, upstream adult trout migration may only occur over a period of days or weeks and require only short period of flows greater than 100% MAD.

Recommendations for

5 Monitoring and Future Studies

Data collection problems were previously identified by MWLAP at two sites. The Old Mouth was abandoned and the gauge relocated upstream to avoid backwater effects from Okanagan Lake. Records for the site upstream of the Summerland District diversion were found to be unusable. The Canyon and New Mouth appear to give reasonably good results, though photographs of the sites suggest they may not be ideally located. The streambed at the Canyon site consists of large boulders. At low discharges flow is split between boulders and likely difficult to measure. At high discharges there are standing waves and flow is quite turbulent. There is a large gravel bar by the New Mouth site that may shift over time.

Ideally, a stream gauge site should have as close to uniform flow as possible, a single fixed channel section with high banks and no backwater effects. A priority should be placed on the re-establishment of a long term gauging station for flows in lower Trout Creek. This station should be rebuilt concurrently with efforts by CDS to collect gauging data on their storage structures within the watershed – including the intake weir and Thirsk Dam. Streamflow and water temperature data should be collected at all stations

The review of limited habitat data for the lower portions of Trout Creek and from the scientific literature support the notion that naturalized instream flows during the non-freshet period were likely optimum with respect to fish utilization and the production of fish. A review of limited habitat data for the lower creek suggests that minimum flows less than 0.4 m^3/s may limit available fish habitat. Development of appropriate metrics and sample areas for future habitat surveys, along with a more significant sampling effort, might provide a more accurate description of the flow-habitat relationship for Trout Creek. Statistical power analysis might provide an indication of the minimum sampling effort required and design to provide meaningful results.

Tredger (1996) reports that rainbow trout parr habitat and kokanee spawning habitat are likely limiting in all studied streams in the Okanagan. Accordingly, a riffle analysis or physical habitat simulation (phabsim) type study-design, with collection of substrate, depth and velocity data should be implemented to assess critical life history requirements. This would include kokanee salmon migration and spawning habitat, and rainbow trout rearing habitat. Transect locations may include key macrohabitat features such as pool tail-outs, riffles and rapids with relatively high width-to-depth ratios, to increase the sensitivity to flow changes, and are representative of key important aquatic habitats for both fish life history requirements and fish food production.

In order to meet the long-term fish and fish habitat goals, the geomorphic and sediment characteristics of the watershed and channel should be assessed to ensure that physical and channel processes are incorporated into future instream flow assessments. As the range of flows likely investigated in Okanagan tributary streams will also be associated with lower, dry-year inflows and when water demand reduces streamflows to critical levels, the study should also identify potential mitigations to address limiting biological factors that might occur with reduced flows.

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