4.0 SUMMARY AND RECOMMENDATIONS

EFNs were recommended for 18 Okanagan streams using the Okanagan Tennant method and for 10 of those streams, were further refined using the Okanagan WUW method (Associated 2016). These EFNs were developed through an extensive collaborative effort including experts and stakeholders, are robust and realistic in the context of naturally available flows, and are based on the best available information at this time. In addition, critical flows were recommended for all streams based on a proportion of the LTMAD or fish habitat data, where available. The process of applying the EFN setting methods recommended in the Phase I report (Associated 2016) to the 18 streams created a deeper understanding of each stream's distinct biological, hydrological, and physical characteristics as well as history of human use and modifications, and EFNs were developed under careful consideration of each.

This section provides a review and summary of applying the prescribed methods, recommendations for adjustments, as well as considerations for EFN implementation. Further, a summary of EFNs and critical flows is provided as well as a discussion on data quality and data needs. This section concludes with recommendations for EFN setting initiatives specific to the Okanagan and in general, and a description of next steps.

4.1 Review of EFN Setting Methods and Data Sources

Okanagan Tennant EFNs were to be calculated for each stream as the lower of the highest flow standard or the median naturalized weekly flow for a given time step. They were to be further refined using the WUW information collected in 10 of the streams. Okanagan Tennant EFNs and final recommended EFNs are presented for all 18 streams in Appendices B1-B18. The EFN setting procedure generally followed the methods outlined in the Phase I report (Associated 2016). Refinement of the methods following their application was anticipated in the Phase I report and several adjustments to the methods, as well as sources of uncertainty, are discussed below. Further, stream-specific information on EFN setting methods, uncertainties, considerations for EFN implementation and recommendations are made in Table 4-1.

- **Naturalized and Residual Flow Data.** The EFN setting approach prescribed by the Phase I report relies heavily on naturalized or natural streamflow data (from proxy streams) to recommend EFN flows that are naturally feasible. Naturalized and residual flows for the study streams were estimated by Associated (2019) both on a weekly and on an annual basis (LTMAD), representing the most comprehensive and current estimates generated to date. Despite the significant effort and expertise devoted recently, considerable uncertainty remains resulting from a lack of historic and current hydrologic data that form the basis of naturalized flow estimation. In particular, there are no active and few historical hydrometric stations that represent natural and unmanaged flows in lower elevation stream reaches that were of particular interest for EFN setting because they contain the greatest variety of fish species, show the greatest cumulative flow diversions, and experience the greatest water use pressures. As a result, naturalized flows were derived from relatively few "natural" hydrometric stations typically at higher elevations, which required extrapolation and scaling between different watersheds and elevations, and in time. Local conditions (e.g., channel modifications, surface water - groundwater interactions, water use) can be highly variable particularly in the lower stream reaches where most human settlement occurs, and generalization from one watershed to another can be difficult for this reason.

  Accurate water use information was required for residual flow estimation. However, the lack of water use and diversion monitoring required that the assessment rely upon water use estimates generated from the Okanagan Water Demand Model (OWDM) (for a detailed description of the model see Associated 2019). Note that the OWDM is a GIS-based model that estimates water use from climate information and land-use (e.g., crop types) and soil characteristics for inventoried areas. The model provides an estimate of water use in the absence of actual records. However, review of estimated water use for some watersheds made apparent that the model was not capturing large offstream diversions since the model only estimates water use based on an inventoried land-base alone. Thus, further investigation regarding water diversions and their impact on flows would be prudent to better understand the impact of current water use on streamflows and the ability to meet EFN flows. Stream-specific recommendations are made in Table 4-1.

Also, considerable uncertainty exists in the naturalized flows with estimated data errors in approximately half of the 18 EFN streams between 10% and 25%, and the other half between 25% and 50% due to limited watershed-specific flow information. Some residual flow datasets have error estimates greater than 50% due to the lack of available water management information. Many naturalized flow estimates, particularly for summer and early fall low flows that were often most constraining on EFNs, appeared relatively low in comparison to both long-term and recent streamflow data recorded at hydrometric stations. Consequently, the EFN setting approach considered naturalized flows in the context of other available data and other stream-specific information, rather than a definitive upper limit to EFNs. This approach is described in the Phase I report as incorporation of "expert judgement" and amounts to a weight of evidence approach. In most cases, EFNs fall within the uncertainty range of the naturalized flows.

- **Flow Augmentation.** Many streams in the Okanagan are heavily regulated via headwater reservoirs or diversion of flows from other watersheds. The main purpose is typically for water supply during the irrigation season; but in some cases regulation is intended to benefit fish. Regulation typically involves storage of a portion of the freshet flows and subsequent release during the irrigation season. In some watersheds, regulation has resulted in flow augmentation over naturalized flows during the summer and early fall low flow period. Flow augmentation in those creeks has occurred over many years and fish populations have adapted to and likely benefited from the augmented flows. Since flows are naturally limiting during this time, a reduction over present flow conditions would likely reduce available fish habitat and may lead to future losses in fish production. Therefore, in streams with a history of flow augmentation EFNs were constrained by the higher residual flows rather than naturalized flows (i.e., Equesis Creek, Naramata Creek, Penticton Creek, and Mission Creek).

- **Critical Flows.** The Okanagan WUW method assesses habitat changes between the critical flow and the Okanagan Tennant EFN to determine the risk of flows lower than the Okanagan Tennant EFN. Therefore, critical flows are needed for each species/life stage to complete the analysis. The Phase I report recommended the commonly used value of 5% LTMAD as a starting point and identified the possibility of using WUW data from the study riffles to estimate critical flows based on minimum passage depths. Thus, a critical flow setting method was added to the EFN setting procedure. Critical riffle analysis was completed for the 10 streams with WUW data. In the remaining streams, critical flows were set using %LTMAD-based criteria commonly used by FLNRORD.

  Some of the streams maintained relatively high flows throughout the duration of the study so there were no WUW measurements at critical flow levels. This required extrapolation of low flow WUW measurements beyond the range of observed data to estimate critical flows. Where extrapolation was deemed too uncertain, the %LTMAD criteria were used instead. Where measurements existed reasonably close to critical conditions, extrapolations beyond the data range were made and results closely inspected for plausibility and consistency with other streams. Extrapolated critical flows deemed plausible over-ruled critical flows set using the %LTMAD criteria, due to the use of field-based information in the critical riffle analysis, which is superior to office-based information. Extrapolation was not required for Rainbow or Chinook spawning, which require relatively high flows for riffle passage.

- **WUW Analysis.** WUW information proved very useful in many streams to inform EFN setting, in particular those that either had unusual flow patterns or heavily modified channels. The relationship between LTMAD and channel conditions (and consequently, fish habitat characteristics) that forms the basis of the Tennant approach to EFN setting holds true in general. Nevertheless, local variations in channel and flow conditions greatly influence fish habitat conditions and are much better characterized by WUW data. WUW was calculated in a standard approach using depth and velocity measurements at the study transects with species and lifestage-specific HSI curves. The curves were not Okanagan-specific but discussion among the project team concluded that they were reasonably applicable to local streams. Two refinements were undertaken:
    - No HSI curve for Sockeye spawning was initially supplied and none were readily available from the literature. As a result, an Okanagan-specific HSI curve for Sockeye spawning was created from habitat data collected at Sockeye redds in the Okanagan River. The river is larger than all streams included in this study and it was not clear if resulting HSIs would be applicable in smaller streams with inherently shallower water depths. Resulting WUW curves, however, appeared reasonable at naturally available flows in the study streams and the project team supported using the Sockeye HSI curve for Okanagan EFN development.
    - The originally-provided Chinook spawning HSI curve for summer Chinook, who spawn in large river mainstems, was not considered representative of habitat preferences for the smaller-bodied spring Chinook that spawn in the study streams. Spawning HSI curves from the Nicola River were used instead to reflect the smaller body size of Okanagan spring Chinook and the small stream size of the study streams. However, the Nicola River is still larger than all of the study streams and it became evident during analysis that the curves may not be applicable to the smaller tributaries included in this study because estimated WUWs often appeared very low at naturalized flows. While there is uncertainty in the naturalized flow estimates, it is recommended to construct a spring Chinook spawning HSI curve for small streams to better characterize the habitat-flow relationship of local populations.

  Since average WUW curves were created from combined transect data for a given stream, there was considerable scatter in some of the WUW curves. Standardizing WUW data between transects by scaling the WUW relative to the peak of the curve was useful because it communicates the relative decline in habitat with flows. Further, it greatly reduced scatter in the transect data caused by different transect widths, and many of the resulting curves fit to standardized WUWs have relatively narrow error bands. Higher uncertainty existed in WUW curves for streams with a low number of field observations, highly variable habitat conditions between transects, or multi-year observations. Multi-year WUW data is rarely consistent between years due to channel changes during high freshet flows and we recommend focusing data collection over one season (spring freshet flows to fall low flows). However, while individual WUW transect geometry may change annually, the fundamental channel morphology in a given reach will rarely change. Selecting WUW transects with average channel conditions (e.g., width, depth) ensures that WUW-flow curves will remain representative of the channel in future seasons as long as there are no significant changes in dominant morphology characteristics.

Some streams maintained relatively high flows throughout the study period (e.g., Coldstream and Equesis creeks) and as a result, the lower end of the WUW curves in the flow range of interest for EFN setting was poorly defined. Those cases required extrapolation beyond the observed data range to characterize the decline in WUW at low flows. Due to the greater uncertainty, EFNs were set conservatively near the lowest observed data points where possible, under consideration of Okanagan Tennant EFNs and naturalized flows.

Upon review of WUW curves in relation to naturalized flows and critical flows, it was found that calculation of the WUW Index as described in the Phase I report was not particularly informative for EFN setting in some cases. Frequently, the critical flow (Index 0) and the Okanagan Tennant EFN (Index 1) were very close together, in particular for summer and fall periods with low flows. The difference in WUWs between the two points was sometimes very small (e.g., 5-10% WUW) and it was considered more informative to review the absolute change in WUW than to produce a scaled index over such a small WUW range. WUWs had already been scaled relative to their peak to standardize between transects, resulting in relative WUWs between 0% and 100%, which made it easy to assess relative changes between two points on the curve. Nonetheless, the WUW Index is useful for comparison of impacts between naturalized, residual and maximum licensed hydrographs. Residual and maximum licensed datasets are not yet available for all streams and the WUW Index percentile plots, as described in the Phase I report, should be prepared when all datasets are complete. An example of the WUW Index for McDougall Creek Rainbow spawning is provided in (Figure 4-1).

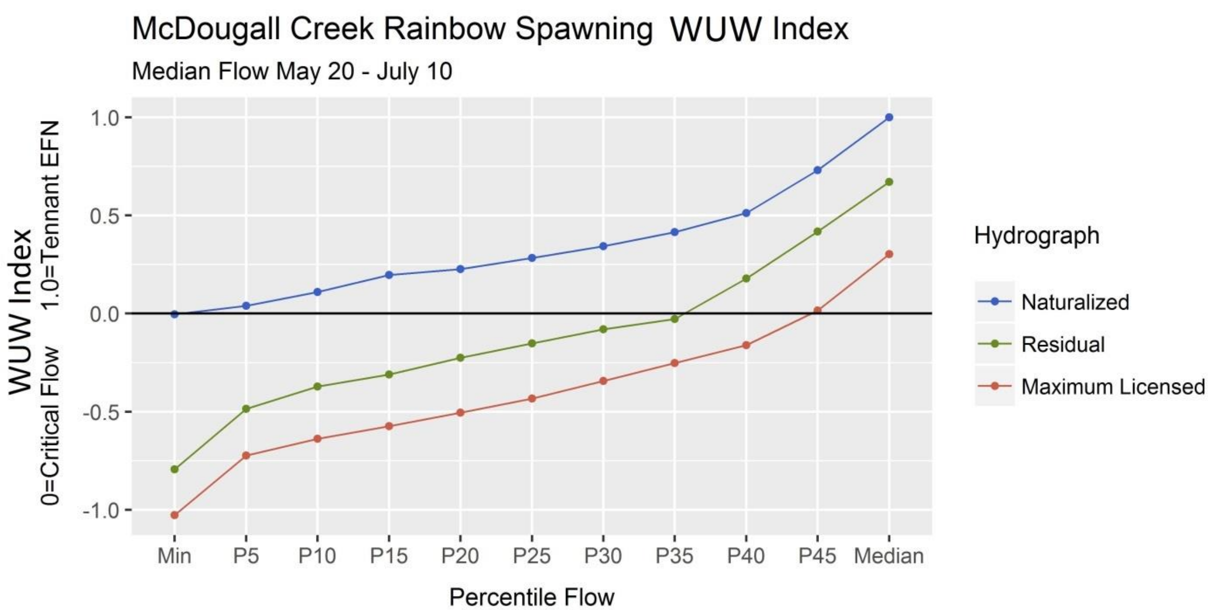

Figure 4-1: WUW Index Plot of Rainbow spawning in McDougall Creek

- **SEFA Analysis.** SEFA modeling was trialed in Coldstream Creek to determine if it could provide the necessary information on habitat-flow relationships to support EFN setting. Further, it was assessed whether SEFA could fill gaps in the data due to a lack of low flow measurements, which complicated critical riffle analysis and critical flow recommendations (Section 3.1.1). SEFA modelling was completed for Rainbow rearing and Kokanee spawning by FLNRORD (Appendix C). The modelled parameters differed slightly between SEFA and WUW analysis: for parr rearing EFNs, SEFA only utilized information on invertebrate production whereas WUW analysis also used parr rearing HSIs. Critical flow analysis used the same parameters between the two modelling approaches. SEFA produced similar, though not identical, information on the habitat-flow relationships as the WUW analysis. SEFA predicted a slightly more rapid decline in insect production with dropping flows. Similarly, Kokanee spawning WUW peaked at higher flows and declined slightly more rapidly than the curve produced by the WUW analysis; however, differences in the lower flow range that EFNs would actually be focused on were very small. Overall, EFN recommendations resulting from the two analytical approaches would have been similar in this case. SEFA modelling produced similar critical flows for Rainbow rearing but higher critical flows for Kokanee spawning. Application of the SEFA model is most useful where field surveys can be obtained over the full range of flows (low, moderate, and high) but where resource constraints prevent the number of field visits typically required for full WUW analysis (8-10). The utility of SEFA to fill data gaps beyond the range of measured observations could be re-assessed for a dataset with low flow data that allows for validation of predicted EFN and critical flows, though extrapolation beyond the range of measured data is generally fraught with high degrees of uncertainty.

- **Benthic Macroinvertebrate Monitoring.** Through the Environment and Climate Change Canada Okanagan Ecosystem Initiative, the ONA trialed a parallel project to assess biological indicators in relation to streamflow conditions and collect stream habitat attributes that could be integrated into fish habitat capacity modeling (Enns et al. 2020). Biological indicators included benthic macroinvertebrate community sampling, which was analyzed under the framework set out in the EFN methods, specifically using %LTMAD and the Okanagan Tennant Model. Results showed that the magnitude of low flows (expressed as %LTMAD) were a significant predictor of Ephemeroptera, Plecoptera, and Tricoptera richness (EPT Richness; taxa richness of mayflies, stoneflies, and caddisflies per sample), which are important prey for juvenile salmonids. For the stream reaches assessed, hydromodification and riparian function were also significant predictors of EPT Richness. These methods could be developed further to monitor the effectiveness of stream management decisions as benthic macroinvertebrate sampling is much less expensive than other methods and does not rely on intrusive sampling of juvenile salmonids.

Table 4-1: Summary of EFN setting approach, uncertainties and data needs by stream

Stream	EFN setting approach	Uncertainties	Considerations for EFN implementation	Recommendations
Coldstream	• Kokanee spawning and Rainbow rearing: used WUW data to adjust EFNs upwards from Okanagan Tennant EFNs because naturalized flows are much greater than flow standards and WUW declines rapidly; critical flows based on %LTMAD and reflecting naturally high baseflows • Rainbow spawning: set EFN just below Okanagan Tennant EFN; critical flows based on riffle analysis	• Lack of low flow WUW data. Greater uncertainty in low end of WUW curve for Kokanee spawning and Rainbow rearing. EFNs were set conservatively just below the lowest WUW measurement but well below naturalized flows and residual flows	• Significant groundwater contributions produce higher baseflows than most other streams; however, the water balance completed for this EFN did not consider withdrawals from hydraulically connected aquifers. The demands from this and other wells could be considered in future water balance work • EFNs and critical flows are relatively attainable due to comparatively high naturalized and residual flows • Large amount of high quality fish habitat remains due to low degree of channel modifications • Highly important Kokanee stream	• Collect low flow WUW data from riffle transects to confirm critical flow recommendations • Obtain residual and maximum licensed flow data estimates • Continue operating the hydrometric station near McClounie Road and upgrade to real-time to provide flow information in high quality fish habitats • Consider protecting available water resources and fish habitat
Equesis	• Kokanee spawning and Rainbow rearing: used WUW data to adjust EFNs upwards from Okanagan Tennant EFNs because of long-term flow augmentation from Pinaus Lake; critical flows set based on %LTMAD • Rainbow spawning: set EFN at Okanagan Tennant EFN; critical flows based on riffle analysis	• Naturalized LTMAD and summer low flow estimates were considered low • Lack of low flow WUW data. Greater uncertainty in low end of WUW curve for Kokanee spawning and Rainbow rearing. EFNs were set conservatively just below the lowest WUW measurement, greater than naturalized flows but no greater than residual flows	• EFNs and critical flows are relatively attainable due to flow augmentation from Pinaus Lake • Relatively large amount of high quality fish habitat remains • Highly important Kokanee stream • Stream would be dry from late July to mid-September if licensed withdrawal and storage volumes were maximized	• Collect low flow WUW data from riffle transects to confirm critical flow recommendations • Continue operating the hydrometric station near Westside Road • Confirm OKIB reservoir management to ensure it is consistent with previous management and/or assumptions included in Associated (2019) • Develop an operating plan for Pinaus Lake to meet EFN and water use needs • Monitor ditch diversions upstream and downstream of Westbank Road
Naswhito	• Kokanee spawning and Rainbow rearing: used WUW data to adjust EFNs upwards from Okanagan Tennant EFNs because: (1) naturalized flow estimates that confined the Okanagan Tennant EFN were low compared to measured flows (2) WUW at	• Lack of historical hydrometric records • Naturalized flow estimates for the summer and fall period were considered uncertain because they are lower than those recorded by the hydrometric station from 2016-2018.	• High quality fish habitat remains • August flows fall below the Rainbow rearing EFN sometimes • September flows fall below Kokanee spawning EFNs in some years • Actual water use is uncertain and individual points of diversion may have a large cumulative impact on streamflows	• Continue operating the hydrometric station near the mouth to reduce uncertainty regarding residual and naturalized flows at the mouth • Identify large points of diversion and determine their cumulative impact on flows

Stream	EFN setting approach	Uncertainties	Considerations for EFN implementation	Recommendations
	naturalized flows was extremely low; • Kokanee critical flows based on median naturalized flows and riffle analysis • Rainbow rearing critical flows based on riffle analysis • Rainbow spawning: set EFN at Okanagan Tennant EFN; critical flows based on riffle analysis	• Residual flow estimates may underestimate the magnitude of large diversions observed during field visits	• Stream would be dry from early August to mid-September if licensed withdrawals were maximized • Migratory access for Kokanee spawners is susceptible to riffle passage constraints. Maintenance of critical flows during the spawning period is crucial to spawning success. Fall rain events likely play an important role in providing spawner access.	• Explore streamflow restoration opportunities. This creek is a prime candidate because of: (1) rapidly increasing WUW for Kokanee spawning and Rainbow rearing with small increases in flow, (2) large diversions observed, (3) frequent failure to meet EFNs in August and September
Whiteman	• Kokanee spawning and Rainbow rearing set to Okanagan Tennant EFNs • Kokanee critical flows based on %LTMAD • Rainbow rearing critical flows based on riffle analysis • Rainbow spawning: set EFN slightly below Okanagan Tennant EFN; critical flows based on riffle analysis	• lack of recent hydrometric records from the mouth • Residual flow estimates indicate near zero water withdrawal but this needs confirming through field surveys	• High quality fish habitat remains • Low fall flows are a known problem during the Kokanee spawning season and EFNs may not be met during some years. • Migratory access for Kokanee spawners is susceptible to riffle passage constraints. Maintenance of critical flows during the spawning period is crucial to spawning success. Fall rain events likely play an important role in providing spawner access. • High quality Rainbow rearing habitat is susceptible to naturally low flows during summer and fall. • Flows would be below the EFN throughout the summer and below critical flows during the Kokanee spawning period if licensed withdrawals were maximized.	• Continue operating the hydrometric station near the mouth to obtain more recent flow data in key Kokanee spawning habitats • Identify points of diversion and determine their impact on flows • Explore streamflow restoration opportunities. This creek is a prime candidate because of: (1) rapidly increasing WUW for Rainbow rearing with small increases in flow, (2) diversions observed, (3) frequent failure to meet EFNs in August and September
Mission	• Kokanee spawning and Rainbow rearing: used WUW data to adjust EFNs upwards from Okanagan Tennant EFNs because of long-term flow augmentation stipulated by Water Use Plan. Residual flows used for EFN setting. Critical flows based on riffle analysis. Passage conditions highly variable due to the wide range of channel modifications	• Channel conditions highly variable due to channelization • Moderate scatter in some WUW curves because of varying transect characteristics (i.e., lower gradient near the mouth to higher gradient near the canyon) • Some transects unsuitable for critical riffle analysis due to lack of measurements over the required range of flows	• Highly important Kokanee and adfluvial Rainbow stream • Habitat availability in the lower reaches impacted by channel modifications • EFNs and critical flows are relatively attainable due to extensive headwater storage • Water Use Plan implementation is lacking during some years • High water temperatures likely impair Rainbow rearing in the lower reaches	• Work with water managers to implement flow releases to meet EFNs • Continue operating the real-time hydrometric station near the mouth to monitor flows in key Kokanee spawning habitats • Re-establish real-time hydrometric station on Pearson Creek • Estimate maximum licensed flows

Stream	EFN setting approach	Uncertainties	Considerations for EFN implementation	Recommendations
	• Rainbow spawning: set EFN at Okanagan Tennant EFN; critical flows based on riffle analysis			• Develop safe ramping rates to provide protection to fish during adjustments in reservoir releases
McDougall	• Kokanee spawning and Rainbow rearing EFNs set to Okanagan Tennant EFNs • Kokanee critical flows based on %LTMAD • Rainbow rearing critical flows based on riffle analysis • Rainbow spawning EFNs set to Okanagan Tennant EFN; critical flows based on riffle analysis	• Lack of historical hydrometric records and lack of water management information • Complicated surface water-groundwater interactions including dry sections and extensive wetland areas • Naturalized flow estimates for the summer and fall period were considered uncertain because they were extremely low for the stream size • Residual flow estimates indicate flow augmentation which is highly unlikely given observed flow records. They likely underestimate the true magnitude of diversions	• No Kokanee population observed in recent history • Stream dewatering and Rainbow stranding was observed during field visits • Habitat quality impacted by channel modifications • High water temperatures likely impair Rainbow rearing in the lower reaches • Severely impacted by flow diversions and critically low flows are common • Low fall flows are a known problem and EFNs are not met during August and September in most years • Stream would be dry from late July to mid-September if licensed withdrawal and storage volumes were maximized	• Continue operating the hydrometric station near the mouth to obtain more recent flow data • Obtain information on the operation of Hayman Lake in the headwaters to meet downstream water use needs • Identify points of diversion and determine their impact on flows • Explore streamflow restoration opportunities. This creek is a prime candidate because of: (1) rapidly increasing WUW for Kokanee spawning and Rainbow rearing with small increases in flow, (2) numerous diversions observed, (3) frequent failure to meet EFNs in August and September
Lower Shingle	• Juvenile fish rearing, Rainbow spawning and Steelhead spawning EFNs set to Okanagan Tennant EFNs; critical flows based on riffle analysis • Chinook spawning EFNs set to naturalized flows (well below the Okanagan Tennant flow standard); critical flows also set to naturalized flows due to riffle passage concerns • Kokanee and Sockeye spawning EFNs set to Okanagan Tennant EFN; critical flows for Kokanee and Sockeye spawning set based on %LTMAD	• Limited recent and historical hydrometric records from the mouth • Naturalized flow estimates for the summer and fall period were low for stream size • Moderate scatter in the WUW curves for Kokanee spawning and juvenile fish rearing • Impact of water use on instream flows is not well known due to limited recent hydrometric data	• Juvenile fish rearing EFNs and critical flows were mostly met in years with recent hydrometric data near the mouth; historical records show flows much below EFNs • EFNs for Chinook spawning and particularly migration were not always met in recent years • Kokanee and Sockeye spawning EFNs were generally met in recent years • Habitat quality impacted by channel modifications • Water temperatures approach tolerance limits of juvenile fish and Chinook spawners • One of few Okanagan streams with documented use of spring Chinook	• Obtain residual and maximum licensed flow estimates • Continue operating the hydrometric station near the mouth to obtain more recent flow data • Determine the impact of water use on flows • Explore streamflow restoration opportunities. This creek is a prime candidate because of: (1) high flow needs for spring Chinook, (2) numerous diversions observed, (3) frequent failure to meet EFNs in July and August

Stream	EFN setting approach	Uncertainties	Considerations for EFN implementation	Recommendations
			• Flows above the EFN from July-October would greatly benefit all fish species in the creek in particular Chinook spawners	
Upper Shingle	• Juvenile fish rearing EFNs: used WUW data to adjust Okanagan Tennant EFN upward to naturalized flows because of very low WUW; critical flows based on riffle analysis • Rainbow spawning and Steelhead spawning EFNs: used WUW data to adjust Okanagan Tennant EFN upward to near naturalized flows providing near maximum WUW; critical flows based on riffle analysis • Chinook spawning EFNs set to naturalized flows which were well below the Okanagan Tennant flow standard; critical flows based on %LTMAD which is near naturalized flows	• Limited recent and historical hydrometric records • Moderate scatter in WUW curves for Chinook fry rearing • Extent of Chinook distribution in the system is unknown	• High quality fish habitat remains • Spring Chinook spawning is constrained by naturally low fall flows • Extensive water diversion results in dry streambed during some years and EFNs for juvenile fish rearing, Chinook migration and spawning are frequently not met • Water temperatures approach tolerance limits of juvenile fish and Chinook spawners • Flows greater than the EFN from July-October would greatly benefit all fish species in the creek through rapidly increasing WUW	• Obtain residual and maximum licensed flow estimates • Continue operating the hydrometric station in the Gabriel field to obtain more recent flow data • Determine the impact of water use on flows • Conduct surveys to determine the extent of Chinook distribution in Upper and Lower Shingle Creek • Explore streamflow restoration opportunities. This creek is a prime candidate because of: (1) high quality fish habitat, (2) observed incidents of dewatering from water diversion, (3) high flow needs for spring Chinook (4) frequent failure to meet EFNs from July-September
Shuttleworth	• Juvenile fish rearing EFNs set to Okanagan Tennant EFN; critical flows based on %LTMAD • Rainbow and Steelhead spawning EFNs set to Okanagan Tennant EFN; critical flows based on riffle analysis • Chinook spawning EFNs set to Okanagan Tennant EFN which is well below the Tennant flow standard; critical flows based on %LTMAD which is near naturalized flows • Sockeye spawning EFNs set to Okanagan Tennant EFN which is well below the Tennant flow	• Limited recent and historical hydrometric records • Moderate scatter in WUW curves for Chinook fry rearing • Summer naturalized low flow estimates were very low • Due to very limited information, residual flow estimates likely do not reflect the amount of observed water use at large-scale diversions in the lower reaches	• Medium quality fish habitat remains • Spring Chinook and Sockeye spawning is constrained by naturally low fall flows • Extensive water diversion results in dry streambed during many years and EFNs for juvenile fish rearing and fall spawning species are frequently not met. Juvenile Rainbow stranding observed during field visits. • Water temperatures exceed tolerance limits of juvenile fish and Chinook spawners • Flows greater than the EFN from July-October would greatly benefit all fish species in the creek through rapidly increasing WUW	• Continue operating the hydrometric station at Maple Street and install a station upstream of water diversion to obtain more recent flow data • Confirm groundwater- surface water interactions across the alluvial fan • Determine the impact of water use on flows and monitor withdrawals at large diversion • Explore streamflow restoration opportunities. This creek is a prime candidate because of: (1) quality fish habitat, (2) observed incidents of dewatering from water diversion, (3) high flow needs for spring

Stream	EFN setting approach	Uncertainties	Considerations for EFN implementation	Recommendations
	standard; critical flows based on %LTMAD which is near naturalized flows			Chinook (4) frequent failure to meet EFNs from July-September
Vaseux	• Juvenile fish rearing EFNs: used WUW data to adjust Okanagan Tennant EFN slightly downward from median naturalized flows; critical flows based on %LTMAD • Rainbow spawning and Steelhead spawning EFNs set to Okanagan Tennant EFNs; critical flows based on riffle analysis • Chinook spawning EFNs: used WUW data to adjust Okanagan Tennant EFN upward from median naturalized flows; critical flows based on %LTMAD • Sockeye spawning EFNs: used WUW data to adjust Okanagan Tennant EFN upward from median naturalized flows; critical flows based on %LTMAD	• Limited recent and historical hydrometric records near the mouth • Naturalized flow estimates for the summer and fall period were considered uncertain because they were extremely low • Residual flow estimates likely underestimate the magnitude of diversions	• EFNs for juvenile fish rearing, and Chinook and Sockeye spawning are rarely met due to stream dewatering most summers • One of few Okanagan streams with documented use of spring Chinook • Water temperatures exceed tolerance limits of juvenile fish and Chinook spawners • Re-establishment of summer and fall flows in the lower reaches is critical to recovery of fish populations • Flows greater than the EFN from July-October would greatly benefit all fish species in the creek and particularly Chinook spawners	• Continue operating the hydrometric station near the mouth and at the outlet of the canyon • Confirm groundwater - surface water interactions across the alluvial fan • Determine the impact of water use on flows and monitor withdrawals at the large diversions on the fan • Explore streamflow restoration opportunities. This creek is a prime candidate because of: (1) high quality fish habitat (2) observed major water diversions, (3) high flow needs for spring Chinook (4) frequent dry streambed and failure to meet EFNs from July-September • Explore potential for development of a Water Sustainability Plan (as defined under the WSA) • Conduct spawning ground surveys to confirm Sockeye and Chinook spawning activity
Inkaneep	• Juvenile fish rearing EFNs: used WUW data to adjust Okanagan Tennant EFN upward to naturalized flows because of very low WUWs; critical flows based on riffle analysis • Rainbow spawning and Steelhead spawning EFNs set to Okanagan Tennant EFN; critical flows based on riffle analysis • Chinook spawning EFNs set to naturalized flows which were greater than the Tennant flow	• LTMAD estimated is low due to the low freshet values compared to other watersheds of similar size, leading to very low Okanagan Tennant EFNs • Limited number of WUW measurements required modelling of WUW at intermediate flows	• EFNs for juvenile fish rearing and Chinook spawning are frequently not met • TEK indicates a historical use by spring Chinook • Water temperatures exceed tolerance limits of juvenile fish and Chinook spawners • Flows greater than the EFN from July-October would greatly benefit all fish species in the creek and particularly Chinook spawners	• Determine the impact of water use on flows • Explore streamflow restoration opportunities. This creek is a prime candidate because of: (1) high quality fish habitat, (2) high flow needs for spring Chinook (3) frequent very low flows and failure to meet EFNs from July-September

Stream	EFN setting approach	Uncertainties	Considerations for EFN implementation	Recommendations
	standard; critical flows also set to naturalized flows		• Stream would be dry from mid-July to mid-September if licensed withdrawal and storage volumes were maximized	
Shorts	• Rainbow rearing and Kokanee spawning EFNs: used WUW data from nearby Whiteman Creek and the literature to adjust Okanagan Tennant EFN upward from naturalized flows; critical flows based on %LTMAD • Rainbow spawning EFN set to Okanagan Tennant EFN; critical flows based on %LTMAD	• Naturalized flow estimates for the summer and fall period were quite low and residual flows estimated very little water use, which needs verification • Changing sediment deposition conditions on the alluvial fan near the mouth lead to extremely low flows during some years	• EFNs for Rainbow rearing and Kokanee spawning are frequently not met • Significant potential for Kokanee spawning if sufficient flows are maintained • Stream would be nearly dry from mid-August to mid-September if licensed withdrawals were maximized	• Continue operating the hydrometric station above Westside Road • Complete a thorough investigation of water diversion locations and use to verify estimates used for flow naturalization • Confirm groundwater - surface water interactions across the alluvial fan • Ground-truth the recommended EFNs by collecting field measurements at or near the recommended EFN • Explore streamflow restoration opportunities. This creek is a prime candidate because of: (1) high quality fish habitat, (2) frequent very low flows and failure to meet EFNs from July-September, (3) unknown impact of water diversion on the alluvial fan
Mill	• Rainbow rearing and Kokanee spawning EFNs: adjusted Okanagan Tennant EFNs upward to reflect naturally high baseflows; critical flows based on %LTMAD • Rainbow spawning EFN set to Okanagan Tennant EFN; critical flows based on %LTMAD	• Lack of recent hydrometric data	• Significant groundwater contributions support higher baseflows than most other streams • EFNs and critical flows are relatively attainable due to comparatively high naturalized and residual flows • High degree of flow regulation • Rainbow spawning EFN is not met during some years due to flow regulation during freshet • Stipulated conservation flows	• Obtain residual and maximum licensed flow estimates • Continue operating and/or install hydrometric stations along the Mill Creek valley floor to provide information on residual flows and groundwater contributions during low flows
Powers	• Rainbow rearing and spawning EFNs set to Okanagan Tennant	• Lack of recent hydrometric data from the mouth	• Significant potential for Kokanee spawning if sufficient flows are maintained	• Obtain residual and maximum licensed flow estimates

Stream	EFN setting approach	Uncertainties	Considerations for EFN implementation	Recommendations
	EFNs; critical flows based on %LTMAD • Kokanee spawning EFN: adjusted Okanagan Tennant EFNs upward to naturalized flows based on historical WUW data; critical flows based on %LTMAD	• Recent channel modification from sediment dredging in key spawning areas at the mouth	• EFNs for juvenile fish rearing and Kokanee spawning were usually met historically but not recently • Stipulated conservation flows • High degree of flow regulation	• Install a hydrometric station near the mouth to monitor residual flows • Conduct field visits to confirm recommended EFNs are appropriate in recently modified channel near the mouth • Improve flow management to meet conservation flows
Trepanier	• Rainbow rearing and spawning, and Kokanee spawning EFNs set to Okanagan Tennant EFNs; critical flows based on %LTMAD	• Lack of recent hydrometric data from the mouth	• History of not meeting EFNs for Rainbow rearing and Kokanee spawning as a result of water withdrawal	• Obtain residual and maximum licensed flow estimates • Install a hydrometric station near the mouth to monitor residual flows • Conduct field visits to confirm recommended EFNs • Explore streamflow restoration opportunities
Naramata	• Rainbow rearing and Kokanee spawning EFNs: adjusted Okanagan Tennant EFNs upward to residual flows; critical flows based on %LTMAD (Rainbow) and 50% of spawning flows (Kokanee) • Rainbow spawning EFN set to Okanagan Tennant EFN; critical flows based on %LTMAD	• Complete lack of historical and recent hydrometric data • Uncertainty over continued flow augmentation by the highline diversion from Robinson and Chute creeks (to be determined by FLNRORD) • Uncertainty over availability of winter flows for Kokanee incubation	• History of flow augmentation from adjacent watersheds • Past widening of channel for flood control • Kokanee population maintained solely through flow augmentation • Fish kills documented during low flow events	• Install a hydrometric station near the mouth • Monitor the highline diversion rates and document the actual diversion operation between Chute, Robinson and Naramata creeks • Collect WUW and flow data to refine Kokanee EFNs and critical flows if continued flow augmentation is to be pursued
Trout	• Rainbow rearing and spawning EFN set to Okanagan Tennant EFN; critical flows based on %LTMAD • Kokanee spawning EFN adjusted upward to median naturalized flows based on historical WUW information; critical flows based on %LTMAD	• Lack of recent hydrometric data from the mouth	• History of extremely low flows and not meeting EFNs for Rainbow rearing and Kokanee spawning as a result of water diversion • History of unnatural daily flow regime with large deviations from natural flow regime • Past channelization for flood control greatly reduced available habitat • Water Use Plan stipulates conservation flows	• Obtain residual and maximum licensed flow estimates • Install a hydrometric station near the mouth • Explore streamflow restoration opportunities

Stream	EFN setting approach	Uncertainties	Considerations for EFN implementation	Recommendations
Penticton	• Rainbow rearing and Kokanee spawning EFNs: adjusted Okanagan Tennant EFNs upward to residual flows; critical flows based on %LTMAD • Rainbow spawning EFN set to Okanagan Tennant EFN; critical flows based on %LTMAD	• Naturalized summer low flow estimates were lower than expected • Critical flows highly uncertain due to lack of WUW measurements and heavy channelization	• Past channelization for flood control greatly reduced available habitat; restoration efforts underway • Higher EFNs required due to low-flow channel widening • High degree of flow regulation • Early and mid-summer EFNs not met in recent years • Minimum flow releases for water utility infrastructure maintenance	• Obtain maximum licensed flow estimates • Collect WUW and flow data to confirm EFNs and determine critical flows • Review EFNs periodically as habitat restoration projects are implemented
McLean	• Juvenile fish rearing, Steelhead, Rainbow and Kokanee spawning EFNs set to Okanagan Tennant EFNs; critical flows based on %LTMAD	• General lack of hydrometric data	• High quality fish habitat remains and high density of rearing *O. mykiss* observed • Cool water temperatures indicate groundwater influence	• Obtain residual and maximum licensed flow estimates • Install hydrometric station to monitor flows near the mouth • Conduct streamflow monitoring to investigate the influence of groundwater on baseflows

4.2 Summary of recommended EFNs and Critical Flows

This section provides a summary of the EFN and critical flow recommendations as well as comments on general patterns observed. Recommended EFNs for the study creeks are provided in Table 4-2 and critical flows and flow sensitivities are provided in Table 4-3. Climate change will affect both the timing and magnitude of hydrographs and stream temperatures and the EFNs and critical flows in this report apply only to current climate conditions. They should be reviewed periodically in the future and adjusted, if warranted, to reflect changing climate conditions and any other stream changes or new information.

Okanagan streams are characterized by snowmelt-driven hydrographs with a large freshet peak in the spring and early summer and comparatively low flows during the remainder of the year. As a result, flows are most limiting to fish populations in the summer, fall and winter periods. The following general observations were made:

- Naturally available streamflows during freshet are generally sufficient to produce optimum conditions for **Rainbow** and **Steelhead** that spawn during the spring freshet. Okanagan Tennant EFNs were mostly set at the presumptive flow standards and were rarely constrained by naturally lower flows, except for some smaller streams. Okanagan Tennant flow standards typically produced near optimum WUWs and as a result, final recommended EFNs were not further adjusted. Water use during this time is usually relatively low and residual streamflows typically meet EFNs and critical migration flows in most years. However, caution is advised in heavily regulated systems with large storage capacity to ensure that water storage does not reduce streamflows below spawning EFNs. Where residual flows were available they did not indicate substantial infringement by water storage activities on springtime EFNs except in one stream (Mill Creek); however, residual flows or flow estimates were unavailable for approximately 40% of the streams, some known to be heavily regulated. While some hydrometric records exist from these systems and are discussed in the body of this report, residual flow estimates will provide a better understanding of any negative impacts that water storage has on Rainbow and Steelhead spawning EFN flows in these systems. Water regulation activities during freshet should ensure that a relatively natural flow pattern is maintained with appropriate timing of high flows as specified by the recommended EFNs, and that abrupt changes in flow are strictly avoided.

  Critical riffle analysis indicates that safe riffle passage ($\geq$25% of transect with depths $\geq$0.18 m) for Rainbow and Steelhead spawners would be achieved between 18% and 129% LTMAD and the %LTMAD required declines with increasing stream size (Figure 4-2). The relationship is similar to that of the large-bodied salmonid flow standard calculation used for Okanagan Tennant flow standards (Ptolemy & Lewis 2002; Section 2.2.2. and Table 2-5), which incorporated documented fish movement data (Ptolemy pers. comm.). Critical flows for Rainbow and Steelhead spawners are usually met in the study streams due to naturally high freshet flows during their spawning period.

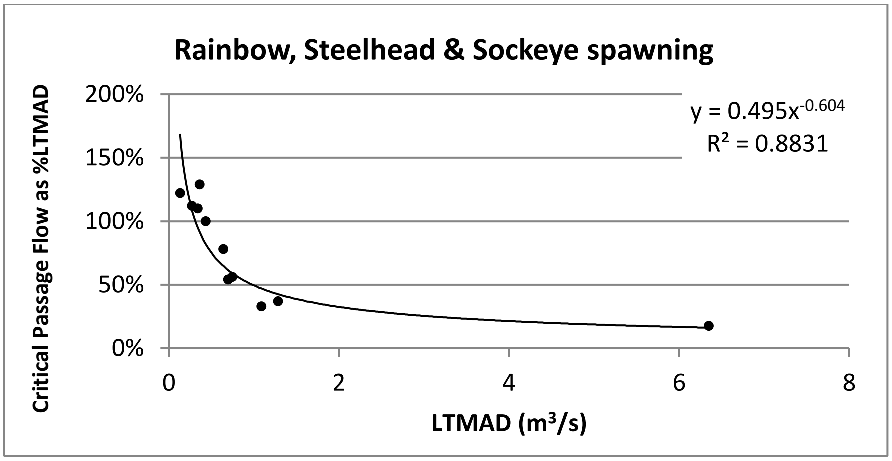

Figure 4-2: Rainbow, Steelhead and Sockeye spawner critical riffle passage flows vs. LTMAD for 11 Okanagan streams

- Streamflows are typically very low during later summer and early fall with a small increase in later fall following rain events. Thus, Okanagan Tennant EFNs for summer and early fall were generally most constrained by low naturalized flows and were mostly lower than presumptive flow standards. As a result, final EFNs were rarely further reduced based on WUW. In systems with a history of flow augmentation from storage, WUW information was used to increase EFNs from Okanagan Tennant EFNs to match residual flows to preserve the status quo. Specific observations for summer and fall EFNs include:
  - EFNs for **spring Chinook** migration and spawning in July-September were most constrained by naturally low flows during later summer as well as small stream size. The recommended EFNs were associated with relatively low WUWs (6%-28% of maximum) and riffle analysis indicated migration difficulties. Thus EFNs and, in some cases, critical flows, were set to naturalized flows in systems that are known or suspected to support spring Chinook to provide maximum available flows. Migration and spawning conditions for spring Chinook greatly improve at flows higher than the recommended EFNs.

    Critical riffle analysis indicates that commonly used %LTMAD-based migration (20%) and spawning (10%) critical flows do not produce safe riffle passage conditions ($\geq$25% of transect with depths $\geq$0.24 m) for Chinook in smaller streams due to shallow water depths and large body sizes. Safe riffle passage would be achieved between 91%-394% LTMAD and the %LTMAD required declines with increasing stream size (Figure 4-3). Rain events and associated flow increases are likely critically important in providing spawning migration access and should be protected. Due to their typical early-summer spawning migration, spring Chinook have an extraordinarily long holding period and maintaining suitable flows throughout the summer is of critical importance to their ability to successfully spawn. Stream temperatures were not explicitly considered in this analysis but it is likely that they further constrain habitat suitability for spring Chinook spawners in some of the streams as described in Table 4-1.

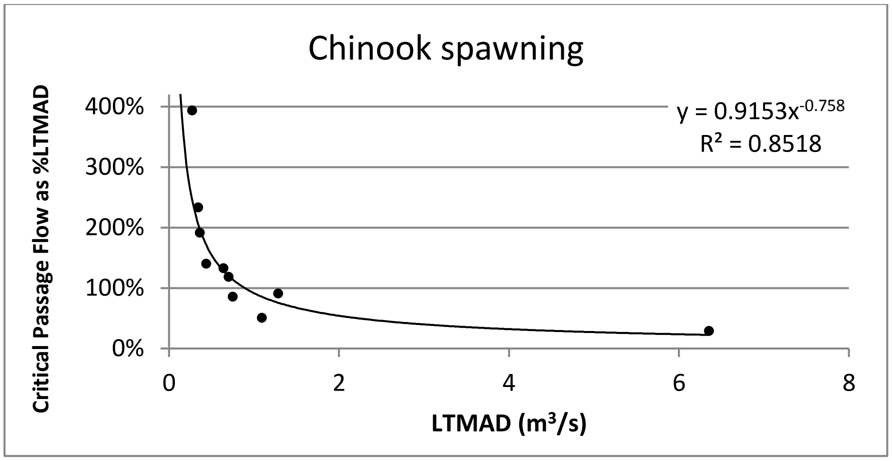

Figure 4-3: Spring Chinook spawner critical riffle passage flows vs. LTMAD for 11 Okanagan streams

- **Juvenile Rainbow and Chinook rearing** in most streams is naturally constrained by low flows through the summer and fall (July-September). As a result, many EFNs fall below the Tennant flow standard (20% LTMAD) during some portion of that period. There were a number of streams, however, with a history of flow augmentation or naturally higher baseflows, where recommended EFNs are at or greater than presumptive flow standards. WUWs at the recommended EFNs range from 25%-85% of maximum for O. mykiss parr, and from 35%-60% of maximum for Chinook fry. Optimum flows, indicated by the peak of the WUW curve, occur in all study streams at flows greater than naturally available in summer and fall. Rearing conditions improve rapidly at flows greater than the recommended EFNs. Stream temperatures were not explicitly considered in this analysis but it is likely that they further constrain suitable rearing habitats for cold water species in some of the streams as described in Table 4-1.

  Riffle width analysis (Table 2-7) produced critical flow recommendations for juvenile rearing that were slightly greater than those commonly applied by FLNRORD (5%) with a mean of 8% and a range of 3%-12% (Figure 4-4), excluding streams without WUW information and those lacking low flow measurements (Coldstream and Equesis). Recommended critical flows were always greater than or equal to 5% (Table 4-3). Unlike critical passage flows for spawners, there was no clear relationship with LTMAD.

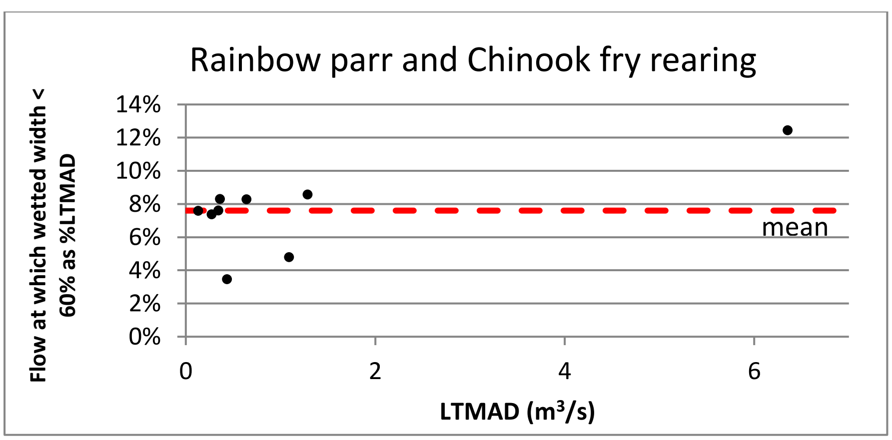

Figure 4-4: Rainbow parr and Chinook fry rearing critical riffle width flows vs. LTMAD for 11 Okanagan streams

- **Kokanee** spawners, particularly the early fall spawning populations, are naturally constrained by low flows in September. Later spawning populations as well as **Sockeye** are less affected because flows often increase in October following rainfall events. WUWs at the recommended EFNs range from 30%-98% of maximum for Kokanee spawning, and from 30%-43% of maximum for Sockeye spawning with the exception of Shuttleworth Creek, where Sockeye access and spawning is likely limited to wet years due to small stream size and naturally low flows. Migration and spawning conditions greatly improve at flows higher than the EFNs.

  Critical riffle analysis indicates that commonly used %LTMAD-based critical flows (10%) do not produce safe riffle passage conditions (≥25% of transect with depths ≥0.12 m) for Kokanee in most of the study streams due to shallow water depths. Safe riffle passage for Kokanee would be achieved between 10%-82% LTMAD and the %LTMAD required declines with increasing stream size. Safe riffle passage for Sockeye would be achieved between 18% and 129% LTMAD (Figure 4-2) and flows are typically lower during the Sockeye spawning season. Rain events and associated flow increases are likely important in providing spawning migration access.

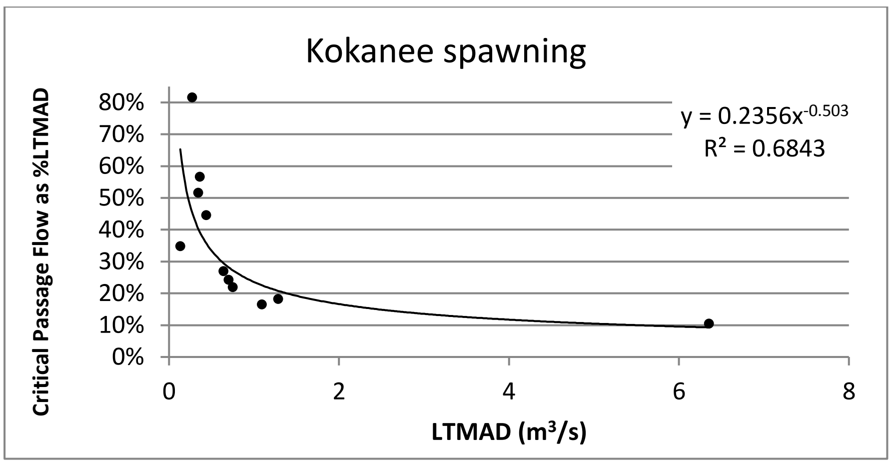

Figure 4-5: Kokanee spawner critical riffle passage flows vs. LTMAD for 11 Okanagan streams

- Most of the 18 study streams are naturally 'flow sensitive' during summer (Table 4-3) and without careful consideration of mitigation options (e.g., off-channel storage), any further water withdrawals may be detrimental to ecosystem health.

- Most of the 18 study streams are naturally 'flow sensitive' during winter (Table 4-3). Winter low flows have the potential to negatively affect egg incubation and overwintering habitats. Water demand is generally lower during the winter and streams for which maximum licensed flow estimates were produced did not indicate significant impacts on streamflows in the winter. However, care should be taken in highly regulated streams to ensure that sufficient winter flows are maintained. Measurement of flow under ice is fraught with error and introduces uncertainty in streamflow records as well as naturalized flow estimates during this period.

- In some streams, most or all migratory fish accessible low-gradient reaches are situated on valley-side alluvial fans (e.g., Shorts Creek). These transitional fan areas between steep valley side and valley bottom are naturally sensitive to low flows as they are often zones of groundwater recharge that lose some streamflow to the aquifers below. As a result, those creeks tend to experience extremely low base flows. Streams with long low-gradient valley-bottom reaches (e.g., Coldstream and Mill creeks) experience substantial groundwater inflows in those lower reaches and tend to have much higher baseflows than average.

- Streams for which maximum licensed flows were provided by Associated (2019) frequently showed extreme impacts of water use on summer and fall streamflows and five of nine creeks would dry up entirely from mid-July to mid-September under maximum licensed flow conditions. Coincidentally, the two streams showing little impact from licensed water use (Vaseux and Shuttleworth creeks) are known to dry up most summers and have large points of diversion above the dry reaches. Monitoring of actual water use is vital to understanding whether this is a natural phenomenon or whether licensed amounts are exceeded.

Table 4-2: Recommended EFNs for the 18 study streams

Stream	Drainage Area (km^2)	LTMAD (m^3/s)	Median 30-Day summer naturalized low flow in m^3/s (%LTMAD)	Naturalized flow Data Quality Rating (Error Range)	Median recommended EFNs in m^3/s (%LTMAD)						
					Juvenile overwinter	Juvenile rearing	Steelhead spawning	Rainbow spawning	Chinook spawning	Kokanee spawning	Sockeye spawning
Coldstream	206	0.748	0.360 (48%)	B (>10% and ≤25%)	0.250 (33%)	0.250 (33%)	x	0.995 (133%)	x	0.250 (33%)	x
Equesis	204	0.700	0.059 (8%)	B (>10% and ≤25%)	0.137 (20%)	0.174 (25%)	x	1.10 (157%)	x	0.180 (26%)	x
Naswhito	87	0.363	0.045 (12%)	C (>25% and ≤50%)	0.054 (15%)	0.090 (25%)	x	0.774 (213%)	x	0.090 (25%)	*x*
Whiteman	203	1.09	0.108 (10%)	B (>10% and ≤25%)	0.138 (13%)	0.158 (14%)	x	1.10 (101%)	x	0.141 (13%)	x
Mission	845	6.35	1.10 (17%)	B (>10% and ≤25%)	0.925 (15%)	1.40 (22%)	x	4.83 (76%)	x	1.40 (22%)	x
McDougall	54	0.132	0.024 (18%)	C (>25% and ≤50%)	0.026 (20%)	0.026 (20%)	x	0.363 (274%)	x	0.028 (21%)	x
Lower Shingle	299	0.641	0.109 (17%)	B (>10% and ≤25%)	0.073 (11%)	0.128 (20%)	1.12 (174%)		0.125 (19%)	0.127 (20%)	0.126 (20%)
Upper Shingle	118	0.272	0.036 (13%)	B (>10% and ≤25%)	0.023 (9%)	0.064 (24%)	0.900 (331%)		0.041 (15%)	x	x
Shuttleworth	90	0.436	0.049 (11%)	C (>25% and ≤50%)	0.043 (10%)	0.080 (18%)	0.871 (200%)		0.060 (14%)	x	0.053 (12%)
Vaseux	294	1.29	0.042 (3%)	C (>25% and ≤50%)	0.070 (5%)	0.15 (12%)	1.50 (117%)		0.200 (16%)	x	0.150 (12%)
Inkaneep	179	0.362	0.081 (22%)	C (>25% and ≤50%)	0.082 (23%)	0.136 (38%)	0.771 (213%)		0.100 (28%)	*x*	x
Shorts	186	1.01	0.029 (3%)	B (>10% and ≤25%)	0.057 (6%)	0.100 (10%)	x	1.49 (148%)	x	0.140 (14%)	x
Mill	224	0.744	0.266 (36%)	C (>25% and ≤50%)	0.250 (34%)	0.250 (34%)	x	1.23 (165%)	x	0.250 (34%)	x
Powers	145	0.643	0.137 (21%)	C (>25% and ≤50%)	0.143 (22%)	0.141 (22%)	x	1.12 (174%)	x	0.141 (22%)	x
Trepanier	260	1.28	0.263 (20%)	B (>10% and ≤25%)	0.257 (20%)	0.257 (20%)	x	1.73 (135%)	x	0.257 (20%)	x
Naramata	42	0.157	0.012 (8%)	C (>25% and ≤50%)	0.028 (16%)	0.090 (52%)	x	0.492 (285%)	x	0.056 (32%)	x
Trout	747	2.17	0.512 (24%)	B (>10% and ≤25%)	0.441 (20%)	0.520 (24%)	x	2.44 (112%)	x	0.520 (24%)	x
Penticton	180	1.16	0.104 (9%)	B (>10% and ≤25%)	0.373 (32%)	0.497 (43%)	x	1.63 (142%)	x	0.417 (36%)	x
McLean	63	0.167	0.023 (14%)	C (>25% and ≤50%)	0.021 (13%)	0.032 (19%)	0.428 (256%)	0.471 (282%)	x	0.026 (15%)	x

x denotes fish species and life stages not present in the study stream

Table 4-3: Critical flows and flow sensitivities for the 18 study creeks

Stream	LTMAD (m^3/s)	1 in 2 yr 30-Day naturalized summer low flow %LTMAD (Sensitive if <20%)	1 in 2 yr 30-Day naturalized winter low flow %LTMAD (Sensitive if <20%)	Critical flows in m^3/s (%LTMAD)						
				Juvenile over-winter	Juvenile rearing	Steelhead spawning	Rainbow spawning	Chinook spawning	Kokanee spawning	Sockeye spawning
Coldstream	0.748	48%	33%	0.075 (10%)		x	0.419 (56%)	x	0.164 (22%)	x
Equesis	0.700	8%	7%	0.035 (5%)		x	0.380 (54%)	x	0.070 (10%)	x
Naswhito	0.363	12%	11%	0.031 (9%)		x	0.502 (138%)	x	0.06 (17%)	x
Whiteman	1.09	10%	9%	0.052 (5%)		x	0.361 (33%)	x	0.109 (10%)	x
Mission	6.35	17%	11%	0.662 (10%)		x	1.12 (18%)	x	0.662 (10%)	x
McDougall	0.132	18%	17%	0.010 (8%)		x	0.161 (122%)	x	0.013 (10%)	x
Lower Shingle	0.641	17%	10%	0.053 (8%)		0.493 (77%)		0.125 (19%)	0.064 (10%)	0.064 (10%)
Upper Shingle	0.272	13%	7%	0.020 (7%)		0.306 (113%)		0.027 (10%)	x	x
Shuttleworth	0.436	11%	6%	0.022 (5%)		0.445 (102%)		0.044 (10%)	x	0.044 (10%)
Vaseux	1.29	3%	0%	0.064 (5%)		0.477 (37%)		0.129 (10%)	x	0.129 (10%)
Inkaneep	0.362	22%	20%	0.030 (8%)		0.468 (129%)		0.100 (28%)	x	x
Shorts	1.01	3%	3%	0.050 (5%)		x	0.503 (50%)	x	0.101 (10%)	x
Mill	0.744	36%	35%	0.037 (5%)		x	0.372 (50%)	x	0.074 (10%)	x
Powers	0.643	21%	18%	0.032 (5%)		x	0.321 (50%)	x	0.064 (10%)	x
Trepanier	1.28	20%	17%	0.064 (5%)		x	0.642 (50%)	x	0.128 (10%)	x
Naramata	0.157	8%	6%	0.009 (5%)		x	0.086 (50%)	x	0.017 (10%)	x
Trout	2.17	24%	18%	0.109 (5%)		x	1.09 (50%)	x	0.217 (10%)	x
Penticton	1.16	9%	7%	0.058 (5%)		x	0.576 (50%)	x	0.115 (10%)	x
McLean	0.167	14%	10%	0.008 (5%)		0.084 (50%)		x	0.017 (10%)	x

x denotes fish species and life stages not present in the study stream

4.3 Recommendations

This section contains recommendations specific to this study and the Okanagan as well as for future EFN projects in general. Further, knowledge gaps and potential research topics are discussed.

Specific recommendations for the Okanagan EFN project are:

- **Collect hydrometric data**. Continue operation of existing hydrometric stations and install additional stations as outlined in Table 4-1. This information is useful for continued validation of naturalized flow estimates and EFNs, as well as monitoring the status of EFN implementation and alerting to potential flow problems.
- **Refine water use estimates and obtain information on reservoir management.** Water diversions and releases from reservoirs and their impact on flows should be documented through field observations (audit), particularly where there appears to be a mismatch between estimated and observed water use (Table 4-1). This has been trialed in Trout Creek where actual use was greater than projected use. Locations of water diversions should be confirmed prior to conducting field monitoring, followed by collection of the necessary streamflow and diversion information to help inform the streamflow naturalization process. Consider the requirement of diversion monitoring within the water licensing process.
- **Support development of operational plans for reservoirs.** Creating new or updating existing operational plans will permit inclusion of EFN needs and support meeting EFNs in the future.
- **Obtain residual and maximum licensed flow estimates**. Residual and maximum licensed flow datasets are not yet available for all 18 study streams. These datasets should be completed and the WUW Index percentile plots, as described in the Phase I report, should be prepared when all datasets are available. The impact of water use on fish habitat under residual and maximum licensed conditions can then be compared between streams which will help to identify problem areas and opportunities for streamflow restoration efforts.
- **Address over-allocation**. Over-allocation is evident in the maximum licensed flow estimates provided by Associated (2019), which indicate dry streambeds in five of nine creeks. Streamflow restoration efforts are needed to reduce the licensed amounts to realistic levels that balance the needs of water users and the ecosystem, or support the licensed amounts from off-channel storage. The increasing tendency for lower summer baseflows in recent decades revealed in the flow naturalization analysis should be considered during this exercise.
- **HSI curve for Okanagan spring Chinook.** An HSI curve should be developed for spring Chinook who spawn in small tributary streams. WUWs produced by the HSI curve from the Nicola River yielded WUWs so low that spring Chinook spawning EFNs were set to naturalized flows throughout the migration and spawning period. While it is likely that small stream sizes and naturally low flows do require Chinook spawning EFNs at or near naturalized flows, it is recommended to develop an HSI curve for spring Chinook that spawn in smaller streams. Okanagan spring Chinook spawners may currently be too low in abundance to derive HSI curves as few spawners are observed annually and monitoring is sporadic. Smaller streams with spring Chinook populations in nearby watersheds, such as Bessette Creek, Salmon River, and Coldwater River would serve as useful proxies. Similarly, confirmation of the Sockeye HSI curve in small tributaries would be useful.
- **Okanagan Lake tributaries.** EFNs and critical flows for Okanagan Lake tributaries should be determined for Sockeye and Chinook spawning. Fish passage at the outlet of Okanagan Lake was

implemented in the fall of 2019 and these species now have access to Okanagan Lake tributaries. Efforts should be focused on larger tributaries with potential to support these large-bodied species.

- **Temperature analysis**. Stream temperature data were collected at hydrometric stations operated by the ONA, however they were not explicitly analyzed due to resource and technique/method limitations, but were considered during EFN and critical flow setting. Streams with problematic thermal conditions were noted in the results section and in Table 4-1. For these streams, it is recommended that the already-collected data be further analyzed, using methods such as quantile regression, to determine whether EFNs and critical flows warrant adjustment to mitigate the impact of high stream temperatures. However, possible EFN increases are likely very limited without exceeding naturally available flows.

- **Confirm critical flows and EFNs**. Critical flows and, in some cases, EFNs (specific recommendations in Table 4-1) should be confirmed with actual field-based fish observation data to assess the effectiveness of this approach. In particular, critical flows for juvenile fish rearing should be further investigated to confirm that the recommended critical flows are sufficient. Passage flows should be verified with fish movement information from the study streams to confirm they are appropriate.

- **Collect climate data**. Climate data in conjunction with hydrometric data will improve climate change modeling and provide information on the ability to meet EFNs in the future.

- **Restore and enhance fish habitats.** Many Okanagan streams have experienced physical impacts which have reduced the quantity and quality of available fish habitat. In addition, ongoing climate change may progressively restrict the ability of the managers of Okanagan Lake dam to provide flows to the Okanagan River that fully supply anadromous fish spawning needs, which in turn could negatively impact fish populations in streams throughout the Okanagan. Accordingly, instream work to restore physical and biological functioning in areas of degraded fish habitat should be a priority throughout the Okanagan - particularly where the degradation is most severe and in areas of potentially high fisheries value. In addition to stream restoration, enhancing fish habitat to provide greater benefits than currently exist should also be considered.

Additionally, the following recommendations are made for consideration in future EFN studies:

- Highly modified streams with high fisheries value or potential value should be prioritized for field-based EFN setting as habitat-flow relationships highly depend on channel configuration within each stream. Thus, highly altered streams should be prioritized for WUW analysis in future studies.
- Information on naturalized flows is useful for constraining EFNs to realistically achievable flows. However, uncertainty in naturalized flow estimation can be high and often habitat conditions change rapidly particularly at low flows. Thus, the reliance on naturalized flows as a constraint on EFNs should be examined on a stream-by-stream basis. In the absence of recent field data, historical information on channel conditions, fish populations, and flow regimes can provide useful context for verifying naturalized flows and EFNs.
- Early identification of potential flow augmentation and resultant effects on habitat suitability assists with focusing data collection and estimation efforts (e.g., development of naturalized vs. residual streamflow datasets).
- Traditional Ecological Knowledge (TEK) should be incorporated into naturalized hydrograph development where available. TEK on historical ecosystem flow characteristics (predominantly wetland or side channel inundations levels) and the magnitude of the flow standards needed, as well

as summer and fall low flows, could provide useful contributions and context to naturalized flow development and EFNs.

- Collaborative projects such as this, with representatives from the provincial government, regional water stewardship agencies, First Nations organizations, and local experts, are likely to lead to increased support for recommended EFNs and success in future EFN implementation.
- Where resources are limited, focusing WUW assessments on moderate and low flows is a reasonable adjustment because in the B.C. Interior, summer low flows are typically most limiting to EFNs and occur when water demand is highest. Springtime migration, spawning and rearing EFNs were not typically limited by low flows; thus, setting those EFNs with the Okanagan Tennant approach carries relatively low risk except in highly regulated watersheds. Potential transects should be selected pre-freshet, and WUW measurements should be focused on moderate (~75% LTMAD) to very low flows from post-freshet to early fall. Capturing the lowest flows is key to properly define the bottom of the WUW curve and to determine critical flows.
- It is recommended to collect all WUW measurements in one season; minor channel geometry changes during freshets can bias the habitat-flow relationship leading to uncertainty. However, average conditions in a given stream or reach should persist between years if representative transects are chosen.
- Conduct analysis of stream temperatures and flows to guide EFN and critical flow setting.
- The impacts of very short term (i.e., days or hours) flow fluctuations within the weekly EFN time steps cannot be addressed within the EFN setting exercise, but could / should be considered in licensee-specific operating plans to make better use of water supplies (Associated 2016). This is a serious issue in some regulated streams or those experiencing very high water use.
- Habitat types selected for analysis should be carefully defined to ensure consistency when it comes to transect positioning within a habitat unit (e.g., glide). For instance, habitat conditions at a pool tailout may be different than mid-glide though both may be used for spawning by certain species. During this study, care was taken to position transects in the center of each habitat unit (e.g., mid-riffle, mid-glide) to ensure consistency between transects and represent average conditions.
- The number of study transects on each stream was chosen from stream length, variability between reaches, logistics and time constraints. While some authors recommend a higher number of study transects (e.g. 18-20, Payne et al. 2004), there is a direct tradeoff between the number of streams that can be sampled and the number of transects on each stream when resources are limited. Conducting detailed habitat mapping to determine average conditions by habitat unit and reach, and then installing transects representative of average conditions, was expected to produce representative results even with a lower number of transects. Ideally, this assumption should be verified in future studies.

During the course of this project, several knowledge gaps were identified. More research is recommended in the following areas to better refine:

- **Flow ramping rates**. The EFNs presented herein do not contain specific ramping rates. Ramping guidelines for fish below hydroelectric facilities are provided by Knight Piesold (2005). Current ramping standards in B.C. are noted as ignoring several key stream functions and also need to be site specific. More research is recommended on ramping rates resulting from “point of diversion” withdrawals and water storage release rates at all times of the year. In addition, ramp down rates should be studied in relation to impacts on riparian vegetation rejuvenation (Richter & Richter 2000;

Mahoney & Rood 1998), in particular in Cottonwood ecosystems which are an endangered Okanagan ecosystems with very poor modern regeneration rates (BC MELP 1997; Lea 2008).

- **Fish life history information.** Further information on Kokanee juvenile migration timing in Okanagan streams should be compiled or collected to create a more robust and locally derived timing window. Further, research on locally-applicable flow standards is required for the following;
  - overwintering juvenile Steelhead, Chinook and Coho
  - all life stages of Sockeye, and
  - small bodied Rainbow Trout adult migration.
- **Confirm fish population health and abundance in contrast to summer baseflows and habitat models.** Fish population response to a variety of flows above and below the recommended EFNs and critical flows should be confirmed with actual fish abundance and/or health data. While the literature suggests increased fish abundance with greater minimum flows in some cases, the response is not unequivocal and local verification is recommended (Bradford & Heinonen 2008).
- **Groundwater-surface water interactions.** Groundwater-surface water interactions on alluvial fans, in particular losses to groundwater, should be quantified where possible to assist with naturalized flow estimation. Further, effects of channelization, groundwater pumping and urbanization of the lower reaches on these interactions should be considered.
- **Channel maintenance flows**. The flood stage where the stream reaches bankfull discharge is the dominant channel form flow (Newbury 2010, Leopold et al. 1964). These bankfull discharges maintain average rates of sediment transport, bankfull widths and depths, pool-riffle ratios, and the average rates of bank migration (Leopold et al. 1964), thus stable bed and bank erosion that creates fish habitat. The bankfull discharge is derived from a flood exceedance assessment and is always a greater number than the median spring flows calculated in the Okanagan Tennant method. More research is needed on;
  - testing the validity of estimates derived on channel stability and fish habitat, and
  - how to create flow estimates within the Okanagan Tennant method that protect channel forms.

4.4 Next steps

The goal of the Okanagan EFN Project was to produce defensible, transparent and robust EFN values for Okanagan streams. Following completion of this technical exercise, the initial next step is for the larger community to review the EFN and critical flow recommendations for each stream. This will include a review by ONA bands for creeks within their areas of responsibility. The Phase I Report (Associated 2016) should be updated with the changes to the methods described above and any changes identified during the review phase.

Upon agreement on this technical report, there will be a collaborative effort to set final EFNs that balance water demands with ecological needs within a socio-economic context. The focus of this next step will be to identify societal values, and allow for the ability to understand, identify, and make informed decisions as they relate to tradeoffs that exist between EFNs and societal demands (Associated 2016). The undertaking would conclude with the development of an implementation plan. On behalf of ONA, the ONA Natural Resource Council and Chiefs Executive Committee will be engaged in implementation planning with the long term goal of using EFNs for Okanagan water law development.

> kʷu‿yʕayʕát iʔ‿kʷu‿sqilxʷ kscpútaʔstm áłiʔ y̓lmixʷmtət iʔ‿siwłkʷ.
>
> Water must be treated with reverence and respect.
>
> áłiʔ íʔ ṅxʷl̓xʷl̓taṅtət lut kstaṅmúsmṅtm, áłiʔ ksctxṫstim yʕayʕat iʔ‿stim.
>
> Our relationship with water is not taken lightly, we are responsible to ensure that our relation can continue to maintain the health and resiliency of our land and animals.
>
> *-Excerpt, Okanagan Water Declaration, July 31, 2014*