

## WORKING DOCUMENT VERSION 1

### Okanagan Basin Water Board Okanagan Nation Alliance B.C. Ministry of Forests, Lands and Natural Resource Operations

Collaborative Development of Methods to  
Set Environmental Flow Needs in Okanagan Streams



May 2016

ISO 9001 and 14001 Certified | An Associated Engineering Company

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## Changes from Previous Version

This document is Working Document Version 1. There are no previous versions.

It is intended that this document will be a living document, subject to periodic revision as new information is obtained, and experience is gained with the Environmental Flow Needs (EFN)-setting methods recommended herein.

It is intended that in subsequent versions of this report, notable changes from the previous version will be highlighted in this section.

As of the time of writing of Version 1, it is anticipated that a future revision will be made following the receipt of additional technical and non-technical Okanagan Nation Alliance information, and another revision will be made following the completion of a test application and evaluation of the EFN-setting methods recommended herein.

## Executive Summary

This report presents the results of a study to develop robust methods for determining the Environmental Flow Needs (EFN) of Okanagan streams, and provide information needed to customize the methods for 19 specific tributaries within the Okanagan Basin. The work represents Phase 1 of an Okanagan EFN-setting project. EFNs for specific streams will be established in future phases. The Phase 1 study is titled: “Collaborative Development of Operational Environmental Flow Designations for Okanagan Streams”. The study proponents were the Okanagan Basin Water Board (OBWB), the Okanagan Nation Alliance (ONA), and the B.C. Ministry of Forests, Lands, and Natural Resource Operations (FLNRO). The work was completed by a consulting team led by Associated Environmental Consultants Inc.

This report acknowledges that EFN-setting can be a complex decision-making process involving information from multiple sources. The work described herein is purely technical. The outcomes of an EFN-setting exercise conducted using the methods described in this report would provide credible science-based information to a decision-making body.

Section 1 of this document introduces the project and provides the background and approach used to complete the study. Collaboration was a core element of the approach. The consulting team was purposefully large, to bring a significant diversity of ideas to bear on the issue. In addition, consultation occurred with a wide range of individuals and agencies, in an effort to promote a broad consensus on the suitability of the approaches ultimately recommended herein. Section 2 summarizes the individuals and agencies consulted during the project. Notably, the Okanagan Nation Alliance (ONA) has agreed to provide additional technical information in the future, and the advice and review of one or more Knowledge Keepers, to add value to a future revision of this report.

Approaches to EFN-setting used elsewhere in North America are listed in Section 3. In Section 4, the report describes previous EFN investigations completed in the Okanagan, including the B.C.-Modified Tennant method, the B.C. Instream Flow Methodology, and the Weighted Useable Width method.

Section 5 describes a context for EFN-setting that includes both technical recommendations and subsequent consideration of other factors before an EFN regime is adopted by a decision-making body. It also lists several Okanagan-specific considerations relevant to EFN-setting, including the concept of meta-populations, which implies that fish populations in some streams may be connected rather than isolated from each other, and the concept that habitat degradation may have rendered aquatic populations less resilient than they were under historic natural conditions.

Section 5 describes a recommended approach to EFN-setting that combine a desktop method and a field-based method. The desktop method is recommended for establishing EFNs in low-risk situations; and the desktop method should be followed by the field-based method for EFN-setting in higher risk situations. The recommended approach is characterized as a “moderately prescriptive guideline” to highlight the concepts

that while the methods can be described as a sequence of steps in a flowchart, there is flexibility on the level of effort to apply at each step, and that experience and good judgment are required to execute the approach.

The desktop method is termed the “Okanagan Tennant method”, and is a variation of the B.C.-Modified Tennant method successfully used in the Okanagan in the past. The field-based method is a variation of a Weighted Useable Width (WUW) method previously used successfully in the Okanagan, termed the “Okanagan Weighted Useable Width method”. The Okanagan WUW method does not prescribe a particular level of field effort, but instead allows flexibility as a function of the risk tolerance of a decision-maker, key aquatic resources dependent upon the stream, the available data, and other factors.

The Okanagan Tennant method is focussed on setting an EFN flow regime that meets the *Water Sustainability Act* definition of a properly functioning ecosystem. It recommends adopting a monthly time step for August through March, and a weekly time step for April through July. EFNs should be set at the lower of the median flow for the time period of interest and the “instream presumptive flow standard”. The method includes an approach to understanding the implications of flows lower than the recommended EFNs. It also acknowledges that flows in dry years will drop below EFN values, and recommends, for real-time operational management purposes (not for water licensing purposes), allowing the EFN to drop to match the natural low flow. The Okanagan Tennant method will be useful for developing an initial understanding of the risks to aquatic habitat and ecological processes from existing and proposed water allocations relative to natural or naturalized flows, and will act as a useful starting step for setting EFNs in the Okanagan.

The Okanagan WUW method extends the Okanagan Tennant method to consider site-specific fish and fish habitat conditions in the streams and reaches of interest and refine the EFNs recommended using the Okanagan Tennant method. WUW analysis is a standard technique that has been used throughout B.C., including several watersheds in and near the Okanagan. WUW is calculated using depth and velocity measurements at intervals along transects located in the appropriate habitat units for the species and life stage of interest, in conjunction with Habitat Suitability Index (HSI) curves. Section 5 discusses the relevance of existing HSI curves, and provides advice on choosing the level of field intensity needed for a given application. The Okanagan WUW method addresses the tendency to recommend optimal flows by scaling streamflows between zero and one, where “zero” is defined as the critical environmental flow threshold (a flow below which severe consequences to aquatic populations are expected), and “one” is defined as the median (or suitable alternative based on stream-specific considerations) flow for the particular time period. Section 5 also provides guidance on using the information collected to judge the risks associated with flows less than EFNs; and for collecting additional data needed to inform “expert judgment”, which is intended to be considered before an EFN recommendation is made. Finally, the Okanagan WUW method includes provision for specifying ecological function flows, and riffle passage flows.

Section 6 outlines the steps required to implement the method(s) in a specific application. It includes advice on how to choose the approach (i.e. the Okanagan Tennant method alone or the Okanagan Tennant method followed by the Okanagan WUW method); and, using a flowchart and accompanying text, it

describes the steps needed to implement each of the methods in a specific case. Section 6 also outlines the steps needed to “naturalize” a streamflow record that has been affected by water storage and diversions (i.e. to convert that record into an estimated “natural” record by removing the effects of human flow management).

Section 7 recommends several studies to improve the EFN-setting methods proposed in the report. The first recommendation is to complete a test of the recommended methods by applying them to two or three selected tributaries. On the basis of this test, the methods would be refined and a new version of this report would be issued. Other recommendations of Section 7 will improve the EFN-setting methods, but none are needed before implementation can begin. Conclusions and Recommendations are presented in Section 8.

Appendix A contains an agenda and summary of a technical workshop held March 23, 2016 amongst the project team consultants, key members of the proponent team (OBWB, ONA, and FLNRO), and representatives of many other agencies. Appendix B contains a tabular listing of EFN-setting methods used elsewhere. Appendices C and D contain supplemental information on the Okanagan Tennant method and the Okanagan WUW method, respectively, that is not provided in the main body of the report. Appendix E contains fish periodicity information and HSI curves relevant to the Okanagan. Appendices F through X contain information and data specific to each of 19 selected Okanagan tributaries identified for this first Phase of the Okanagan EFN project.

This report is referred to as a Working Document, Version One. It is primarily a technical document. The title conveys the intent that the document is a living document, and is likely to be revised as new information becomes available, and experience is gained using the methods recommended herein. In the relatively short term, it is anticipated that additional technical information will be contributed by the Okanagan Nation Alliance Fisheries Department, and that the report will be reviewed and refined by Okanagan Nation Knowledge Keepers.

## Acknowledgements

The study was led by the Okanagan Basin Water Board (OBWB), the Okanagan Nation Alliance (ONA), and the B.C. Ministry of Forests, Lands, and Natural Resource Operations (FLNRO). A core leadership team consisting of Nelson Jatel of the OBWB, Richard Bussanich of the ONA, and Richard McCleary of FLNRO managed the study.

The consulting team hired to conduct the study was led by Associated Environmental Consultants Inc. Ecoscape Environmental Consultants Inc., and Mr. Phil Epp. Other members of the consulting team included Lars Uunila of POLAR Geoscience Ltd., Bob Hrasko of Agua Consulting Ltd., Don Dobson of Urban Systems Ltd., Brian Symonds, and Steve Matthews.

Key contributions to the work of the core consulting team were made by Brent Phillips, Drew Lejbak, Kellie Garcia, Nicole Penner, Brian de Jong, and Lawrence Bird of Associated Environmental Consultants Inc.; Jason Schleppe and Kyle Hawes of Ecoscape Environmental Consultants Ltd.; and Phil Epp. The study was managed by Brian Guy of Associated Environmental Consultants Inc.

Other members of the three proponent organizations made significant contributions, including Elinor McGrath and Joe Enns of ONA, and Jason Marzinzik, Mike Epp, and Ryan Whitehouse of FLNRO.

A large additional group of individuals and agencies participated in reviewing an interim technical document and attending a workshop, and these individuals and agencies are identified in Section 2 of this report.

Finally, it is understood that ONA has agreed to provide additional information, data, habitat mapping, and other technical information that could add value to a future version of this report. ONA has also agreed to provide the advice and knowledge of one or more Knowledge Keepers to add additional value to a future version of this report.

The consulting team thanks each of the above-noted individuals and agencies for their contributions to this study.

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## Glossary

**Critical Environmental Flow Threshold.** Defined in Section 1 of the *Water Sustainability Act* as “the volume of water flow below which significant or irreversible harm to the aquatic ecosystem of the stream is likely to occur”.

**Conservation Flow.** Essentially equivalent to EFNs. Used by nhc (2001) and other historic EFN work in the Okanagan and elsewhere in BC.

**Environmental Flow Needs (EFNs).** In relation to a stream, means the volume and timing of water flow required for the proper functioning of the aquatic ecosystem of the stream (*Water Sustainability Act*, Section 1).

**Habitat Suitability Indices (HSI).** HSIs are models that weight locations relative to one another considering key criteria. Fisheries HSIs typically relate velocity and depth to spawning or rearing habitats of fish using preferences for different conditions.

**Inflection Point.** Inflection point is used to characterize the point on a trend line where the slope of the curve appears to change from an almost linear increase in useable width with increasing flow, to a much more gradual increase in useable width with flow.

**Instream Flow Needs (IFNs).** Equivalent to EFNs. Used in the BCIFN method and other historic EFN work prior to current adoption of EFN terminology.

**Long Term Mean Annual Discharge (LT mad).** The arithmetic mean of individual **naturalized** mean annual discharge values at a specific point on a stream over a multi-year period. Calculated by adjusting the measured or estimated mean annual flow to compensate for flow regulation and water withdrawals. The long term mean annual discharge is equivalent to the mean annual flow rate that would occur naturally in the absence of storage reservoirs and water extractions.

**Lower Quartile (P25).** The value represented by the 25th percentile in a range of data. 25% of the values will be lower, and 75% will be higher.

**Maximum (Max).** The highest value in a range of data.

**Maximum Weighted Useable Width Flow.** The flow, expressed as %LT mad, that corresponds to the highest point (i.e., the maximum amount of weighted useable habitat width for that transect) on the weighted useable habitat width curve.

**Mean.** The arithmetic mean of all values in a range of data.

**Median (P50).** The value represented by the 50th percentile in a range of data. Establishes the average flow condition when used with flow data, as 50% of the values are lower, and 50% are higher.

**Mean Annual Discharge (MAD).** Not used in this report. Historical EFN methods such as Tennant refer to %MAD, and it is understood that the usage is synonymous with “LT mad” as used in this report, but LT mad is preferred as it is defined as both naturalized and long term.

**Mean Annual Flow (MAF).** The arithmetic mean of all of the individual daily mean flows for a given water year at a specific site on a stream.

**Mean Monthly Flow (MMF).** The arithmetic mean of all of the individual daily mean flows for a given water month at a specific site on a stream.

**Minimum (Min).** The lowest value in a range of data.

**Naturalized Flow.** This is the flow that would occur naturally in the absence of all forms of flow regulation such as storage reservoirs and water withdrawals.

**Percentile (Pn).** A measure used in statistics indicating the value below which a given percentage of observations in a group of observations fall. For example, the 20th percentile (P20) is the value below which 20 percent of the observations may be found.

**Percentile Flow.** The flow value represented by the nth percentile of a range of flows at a specific site in the stream. For example, the P20 mean monthly August flow in Mission Creek is 1.07 m<sup>3</sup>/s, indicating that that August mean monthly flows have been lower than 1.07 m<sup>3</sup>/s in 20% of the years and higher in the other 80% of the years on record.

**Productivity.** Productivity is the maximum potential production under optimal growth conditions, and is measured in terms of both area and a specific unit of time (Wetzel 2001).

**Productive Capacity.** The natural maximum capability of habitats to produce healthy fish, safe for human consumption, or to support aquatic organisms upon which fish depend (DFO 1986)

**Residual Flows.** The actual volume of water flowing at a specific point on a stream or river at a point in time that can be recorded by stream flow measurements. The term residual flow is used to describe the flow that remains in the stream after flow reductions due to water extractions. Residual flows are also known as net flows.

**Spatial.** Considering things in terms of where they exist in the real world. This is typically accomplished using GIS applications, where data can be expressed as either existing at a specific point, line, or polygon in real world coordinates such as UTM or latitude / longitude for instance.

**Upper Quartile (P75).** The value represented by the 75th percentile in a range of data. 75% of the values are lower, and 25% are higher.

**Weighted Useable Width (WUW).** Weighted Useable Width is the estimated “suitable width” of a stream, calculated by determining the suitability of the flow for fish at each increment of width across the stream. The suitability is derived from HSI curves where velocity and depth are the two parameters used to estimate suitability. HSI curves and the resultant WUW vary by species and life stage.

## 1 Introduction

In the Okanagan, an understanding of environmental flow needs (EFNs) is required by a number of governments and external stakeholders for various purposes. For example, according to Section 15 of the *Water Sustainability Act* (alternately referred to herein as “the Act”) a decision maker must consider the EFN when deciding on a water licence application. This requirement extends to a decision-maker considering an application to extract groundwater from a well located in close proximity to a stream. First Nations and others require an understanding of EFNs when developing fish population and fish habitat restoration plans. Regional Districts consider residential, agricultural, industrial, and environmental flow needs in their long range development plans. BC Agriculture is working to ensure the security of existing licences during times of scarcity when the requirements to protect critical environmental flows could warrant the imposition of restrictions on water use. Thus, in the Okanagan, a robust system for developing and interpreting EFNs is required.

Work on establishing EFNs in the Okanagan has been ongoing since the early 1970's, and this report builds on this previous work. Notwithstanding the significant volume of work previously undertaken to understand aquatic ecosystems and the streamflows required to sustain them, in general for most Okanagan tributaries there is insufficient information available to describe an appropriate EFN flow regime.

Accordingly, the Okanagan Basin Water Board (OBWB), the Okanagan Nation Alliance (ONA), and the B.C. Ministry of Forests, Lands, and Natural Resource Operations (FLNRO) issued a Request for Proposals (RFP) to develop defensible, transparent and robust methods for determining the environmental flow needs of Okanagan tributaries. The study is titled “Collaborative Development of Operational Environmental Flow Designations for Okanagan Streams”, and is intended as Phase 1 of an EFN-setting project in the Okanagan. Appropriate EFN flow regimes would be established in subsequent phases. The objectives of Phase 1 (this study) were listed in the RFP as follows:

1. Consult with key water users and managers, and seek input on the desired characteristics of stream-specific EFN methods;
2. Identify and describe the characteristics of EFN methods or models that can efficiently and reliably support water allocation decisions;
3. Identify gaps between the current models and fully functional EFN methods;
4. Develop a high level work plan to extend the development of the current water management models, and complete the development of stream-specific EFN tools; and
5. Provide approximate work scopes, budgets, and schedules for applying identified EFN methods.

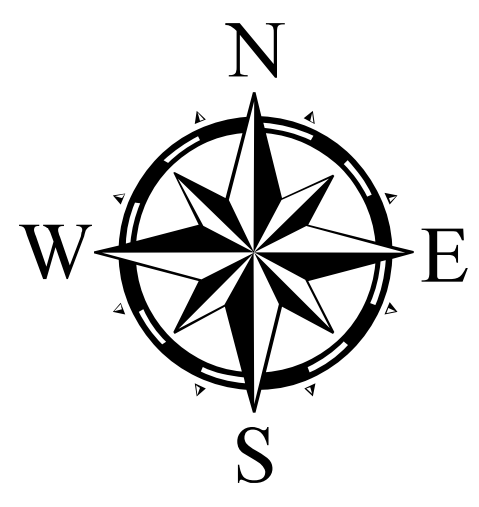
A consulting team led by Associated Environmental Consultants Inc. was chosen by the proponent group (OBWB, ONA, and FLNRO). The present report describes the steps taken and the results of the work completed to achieve each of these five objectives. The intent of the fifth objective was to provide customized EFN-setting plans for each of 19 identified tributaries. During the project, this objective was scaled back to avoid the development of work scopes, budgets, and schedules for each tributary, because these details will depend on the risk tolerance of regulatory agencies and other interested parties, as well as other factors. Those decisions cannot be made in a technical document such as this. Nonetheless the

report does provide customized information and advice for each of the 19 tributaries. The 19 selected tributaries are listed in Table 1-1, and shown on Figure 1-1.

**Table 1-1**  
**List of the 19 tributaries identified for consideration in this study**

<b>List of tributaries</b>
Coldstream Creek
Equesis Creek
Inkaneep Creek
McDougall Creek
McLean Creek
Mill Creek
Mission Creek
Naramata Creek
Naswhito Creek
Penticton Creek
Powers Creek
Shingle Creek
Shorts Creek
Shuttleworth Creek
Trepanier Creek
Trout Creek
Vaseux Creek
Vernon Creek
Whiteman Creek

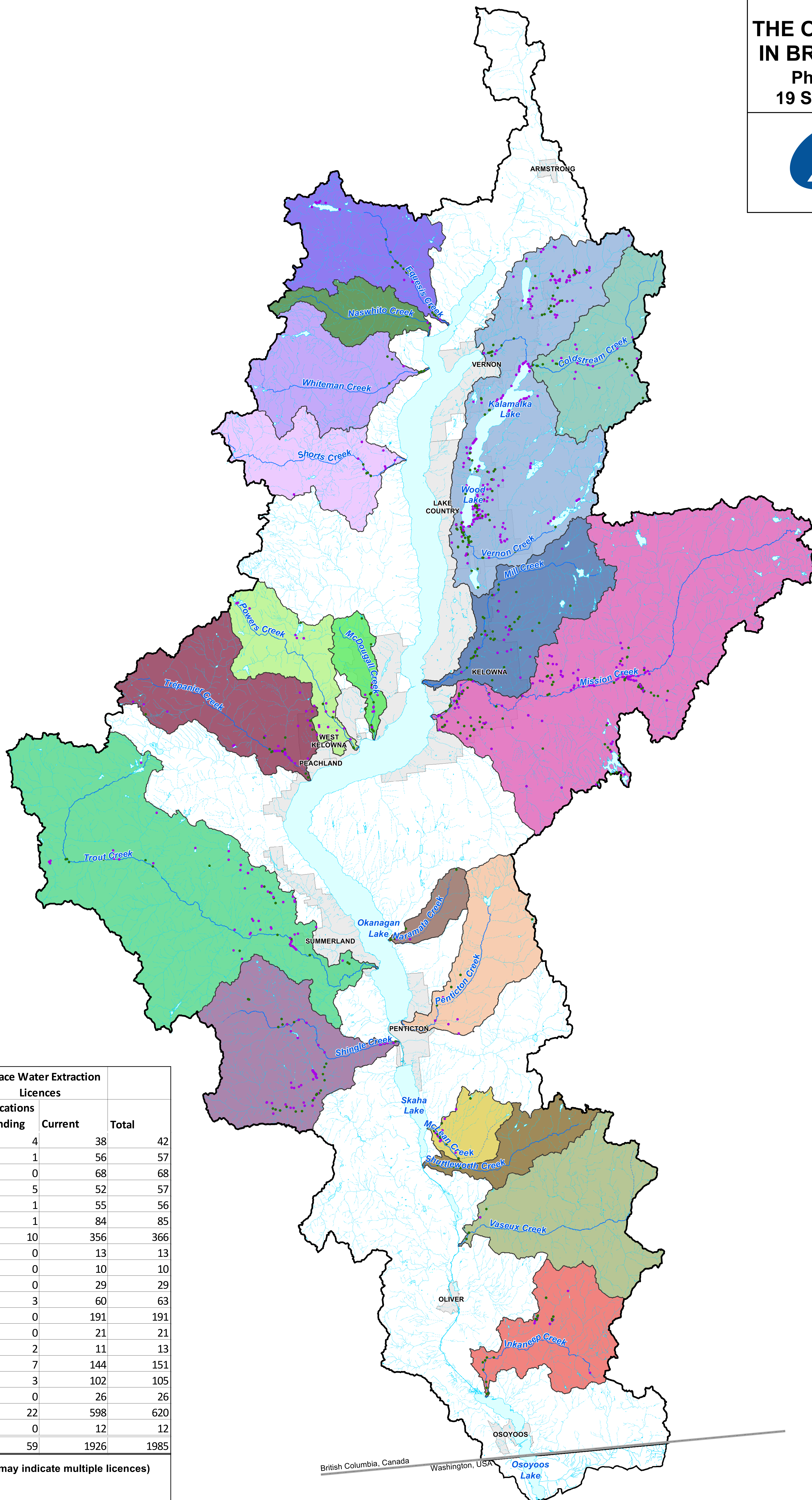




**FIGURE 1-1**  
**THE OKANAGAN BASIN**  
**IN BRITISH COLUMBIA**  
 Phase 1 EFN Study:  
 19 Selected Tributaries



Map produced by: BJJ  
 May 2016

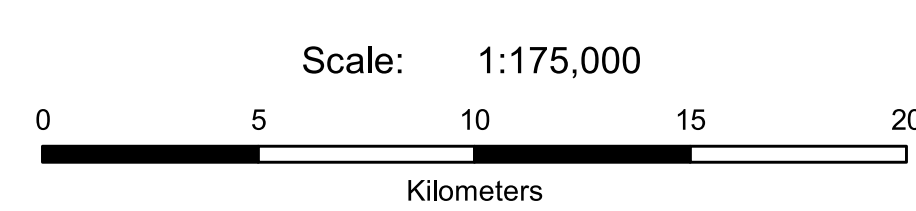


Subbasin	Surface Water Extraction Licences		
	Applications & Pending	Current	Total
Coldstream Creek	4	38	42
Equesis Creek	1	56	57
Inkaneep Creek	0	68	68
McDougall Creek	5	52	57
McLean Creek	1	55	56
Mill Creek	1	84	85
Mission Creek	10	356	366
Naramata Creek	0	13	13
Naswhito Creek	0	10	10
Penticton Creek	0	29	29
Powers Creek	3	60	63
Shingle Creek	0	191	191
Shorts Creek	0	21	21
Shuttleworth Creek	2	11	13
Trepanier Creek	7	144	151
Trout Creek	3	102	105
Vaseux Creek	0	26	26
Vernon Creek	22	598	620
Whiteman Creek	0	12	12
<b>Grand Total</b>	<b>59</b>	<b>1926</b>	<b>1985</b>

**Water licence points of diversion (may indicate multiple licences)**

- Irrigation Use
- Other Use

British Columbia, Canada Washington, USA



The study began in late 2015. An Interim Report containing an outline of two recommended EFN-setting methods, as well as detailed descriptions of the two proposed methods, was developed by the consulting team and presented to the proponent group in February 2016. It was reviewed by the core leadership team of the proponent group, then distributed to a large and diverse group of provincial and federal agency staff and other experts. A workshop was held on March 23, 2016, at which the Interim Report was discussed at length. Comments and feedback received at and subsequent to the workshop was considered in development of the present report.

Five specific deliverables were produced during the study:

- Example Literature Tables (a list of relevant literature) for a subset of the 19 selected tributaries;
- Interim Report containing a description of the recommended EFN-setting methods;
- Method details (which were presented in the Interim Report);
- A summary of the March 23, 2016 technical workshop; and
- This report, that summarizes the results of the study.

All five deliverables are contained within the text or Appendices of the present report.

This document is the final deliverable of the Phase 1 study. It recommends a general approach to EFN-setting that combines a desktop method and a field-based method, and provides guidance on how to apply the methods in an EFN-setting exercise, along with specific information relevant to EFN-setting for each of the 19 selected tributaries. The recommended approach is characterized as a “moderately prescriptive guideline” to highlight the concepts that while the methods can be described as a sequence of steps in a flowchart, there is flexibility on the level of effort to apply within each of the methods, and that experience and good judgment are required to execute the approach.

The document is primarily a technical document, and it makes reference to the distinction between a technical EFN-setting exercise and a higher level decision-making exercise that considers other factors in establishing an EFN flow regime. As a technical document, it requires some scientific background to fully grasp the method details that are presented. Accordingly, the report is summarized in a plain language Executive Summary.

This report is referred to as a Working Document, Version One. This title conveys the intent that the document is a living document, and is likely to be revised as new information becomes available and experience is gained using the methods recommended herein. In the relatively short term, it is anticipated that additional technical information will be contributed by the Okanagan Nation Alliance Fisheries Department, and that the report will be reviewed and refined by Okanagan Nation Knowledge Keepers.

## 2 Consultation Completed for the Study

The consulting team communicated with, and was guided by, the proponents' leadership team throughout the study. In addition, during development of the recommended EFN-setting methods, additional communication took place with technical experts within the proponent team (OBWB, ONA, and FLNRO). Advice from other external experts also helped shaped the methods.

Following completion of an Interim Report describing the two recommended Okanagan EFN-setting methods, the consulting team led a full –day workshop in Kelowna (on March 23, 2016). A large number of participants was requested to attend the workshop based on their roles working with EFN flow regimes in the Okanagan. The Interim Report outlining the two recommended EFN-setting methods was distributed to the attendees prior to the workshop. The workshop included a presentation of the draft EFN-setting methods by the consulting team, followed by structured discussions and feedback from attendees. Participants were also offered an opportunity to provide written feedback following the workshop. Workshop attendees are listed in Table 2-1.

**Table 2-1  
March 23, 2016 Workshop Participants**

<b>Name</b>	<b>Organization</b>
Andrew Petersen	Ministry of Agriculture
Anna Warwick Sears	OBWB
Bernie Bauer	UBC Okanagan
Brian Guy	Associated Environmental
Christian St. Pierre	FLNRO – Ecosystems
Craig Nichol	UBC Okanagan
Don Dobson	Urban Systems
Doug Edwards	Fisheries and Oceans Canada
Elinor McGrath	ONA Fisheries
Hillary Ward	FLNRO – Fish & Wildlife
James Littley	OBWB
Jason Marzinzik	FLNRO – Allocation
Jason Schleppe	Ecoscape Environmental Consultants
Jen Turner	Ministry of Environment – Watershed
Joe Enns	ONA Fisheries
Kim Hyatt (by phone)	Fisheries and Oceans Canada
Kellie Garcia	Associated Environmental
Michael Epp	FLNRO – Allocation
Natasha Neumann	UBCO
Nelson Jatel	OBWB
Phil Epp	Consultant
Rich McCleary	FLNRO – Stewardship
Richard Bussanich	ONA Fisheries
Ron Ptolemy (by phone)	Ministry of Environment
Ryan Whitehouse	FLNRO – Ecosystems
Skye Thomson	FLNRO – Water Management

The workshop agenda and report are provided in Appendix A. There was general consensus at the workshop that the methods recommended in the Interim Report were sound, but constructive suggestions for refinement of the methods and the report text were also provided.

The proponents' team intends to put additional effort into obtaining both technical information, and Elder's knowledge following delivery of the present report. To this end, the OBWB has begun discussions with the ONA to obtain data, information, habitat mapping, and other technical knowledge that may be held within the ONA system. In addition, these two parties have agreed to seek the advice and input of ONA elders on the historic presence and abundance of fish in the Okanagan, including information on species that may no longer be present. This information will be included in a future revision of the present report.

## 3 Overview of Available EFN-Setting Methods

This section provides an overview of the most commonly used methods for determining environmental flows and the strengths and weaknesses of each method. Many methods and techniques have been developed over the last four decades, going at least as far back as the original Tennant method, described in Tennant (1976). Linnansaari et al. (2013) provides an excellent 75-page review of the many EFN-setting methods used in Canada and discusses the strengths and weaknesses of each. The methods are grouped into 4 categories:

- Hydrological;
- Hydraulic Rating;
- Habitat Simulation Modelling; and,
- 'Holistic' Frameworks.

Linnansaari et al. (2013) does not recommend a specific method for use in Canada, but does favour the holistic approaches, which combine elements of the other methods in conjunction with professional judgment and expert opinion.

Table B-1 in Appendix B provides an overview of EFN-setting methods used in Canada and elsewhere.

## 4 Previous EFN Investigations for the Okanagan

EFN-setting methods previously used in the Okanagan include the:

- B.C.-Modified Tennant;
- B.C. Instream Flows (BCIFN); and
- Weighted Useable Width (WUW).

The B.C.-Modified Tennant and BCIFN are both Hydrological methods, and the WUW method is a Habitat Simulation method.

### 4.1 B.C.-MODIFIED TENNANT

Conservation flows (i.e. EFNs) were recommended for 21 Okanagan Lake tributaries in a 2001 report prepared for the B.C. Fisheries Management Branch by Northwest Hydraulic Consultants Ltd. (nhc 2001). These flows were based on the B.C.-Modified Tennant approach with recommended flows ranging from 20% of the naturalized long term mean annual discharge (LT mad<sup>1</sup>) for winter flows to 200%LT mad in May.

The Acknowledgements section in nhc (2001) indicates that the Fish Periodicity and Conservation Flows sections were prepared by Ron Ptolemy (B.C. Fisheries Management Branch). Ptolemy and Lewis (2002) provide a detailed discussion of Tennant style criteria as modified for use in B.C. The Tennant method considers fish periodicity for each species and life stage, including adult migration or passage, spawning, incubation, emergence, rearing, overwintering, and juvenile migration. Ecological needs such as channel maintenance flows for channel geometry, flushing flows for sediment removal, wetland and off-channel wetted linkage, and persistent wetting of riffle habitats for benthic invertebrate survival are considered. Recommended flows are referenced as %LT mad. As discussed by Ptolemy and Lewis (2002), there is a reasonable scientific basis to support the recommendations, and the Tennant method has been adopted for use in many locations in North America. In the absence of more detailed information, the B.C.-Modified Tennant flow targets are currently used as the default EFNs by Okanagan provincial fisheries staff. Nonetheless, experience in the Okanagan has revealed some of the method's shortcomings, which are addressed subsequently in this report.

Table 4-1, adapted from nhc (2001), demonstrates the recommended monthly conservation flows (i.e. EFNs) as %LT mad using the B.C.-Modified Tennant method for Okanagan Lake tributary streams. A fish periodicity table for Mission Creek is provided by nhc (2001) and was used as the basis for the species and life stages considered in Table 4-1. The fish periodicity table for Mission Creek has also recently been updated (Ptolemy 2016a). Both the original fish periodicity tables presented by nhc (2001) and the new

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<sup>1</sup> Mean Annual Discharge (MAD) is the arithmetic mean of all the recorded individual mean annual discharge values for a stream. Historic reports like nhc (2001) used MAD to refer to naturalized flows (i.e. measured flows adjusted for diversion), but the term MAD is not exclusively used for naturalized flows. Long Term mean annual discharge (LT mad) is defined as the arithmetic mean of all of the individual **naturalized** mean annual discharge values at a specific point on a stream or river over a multi-year period of record. Within this report, LT mad is considered exclusive to **naturalized** mean annual discharge.

tables by Ptolemy (2016a) are included in Appendix E. Focal species in Okanagan Lake tributaries at the time of publication of nhc (2001) were Kokanee Salmon and Rainbow Trout. When applying the percentages in Table 4-1, the highest flow requirement for any given month is the recommended flow (e.g. the recommended flow for April is 100% LT mad based on the stream ecosystem requirements, rather than the lower flow requirements for Kokanee Salmon and Rainbow Trout functions in that month). EFNs for 21 Okanagan Lake tributaries were recommended by nhc (2001) using this method, with the same %LT mad values as per Table 4-1 applied to each tributary.

**Table 4-1  
EFN (Conservation Flow) as % of LT mad (adapted from nhc 2001)**

Month	Kokanee	Rainbow	Stream Ecosystem	Life Stage / Function
<b>Jan</b>	20%	20%	20%	Egg Incubation (KO) / Juvenile Over-Wintering (RB)
<b>Feb</b>	20%	20%	20%	Egg Incubation (KO) / Juvenile Over-Wintering (RB)
<b>Mar</b>	20%	20%	20%	Egg Incubation (KO) / Juvenile Over-Wintering (RB)
<b>Apr</b>	20%	46%	100%	Incubation & Emergence (KO) / Adult & Parr Migration (RB)
<b>May</b>	>50%	100%	200%	Incubation & Emergence (KO) / Adult & Parr Migration (RB) / Flushing (note 1)
<b>Jun</b>	----	100%	100%	Spawning, Adult Emigration & Egg Incubation (RB)
<b>Jul</b>	---	40%	40%	Spawning, Adult Emigration & Egg Incubation (RB)
<b>Aug</b>	---	30%	30%	Juvenile Rearing / Temperature Moderation (RB)
<b>Sep</b>	20%	25%	25%	Adult Migration & Spawning (KO), Juvenile Rearing (RB)
<b>Oct</b>	20%	20%	20%	Adult Migration & Spawning (KO), Juvenile Rearing (RB)
<b>Nov</b>	20%	20%	20%	Egg Incubation (KO) / Juvenile Over-wintering (RB)
<b>Dec</b>	20%	20%	20%	Egg Incubation (KO) / Juvenile Over-wintering (RB)

Note 1: For channel maintenance over the longer term, a maximum instantaneous flow of 500%LT mad is recommended.

Fish periodicity information for Sockeye, Coho and Chinook Salmon for the Okanagan Region is provided by ESSA and Solander (2009); and the Okanagan Nation Alliance Fisheries Department (2003) provides similar information for other noted species at risk (e.g. Umatilla Dace and Chiselmouth). This information is

summarized in Appendix B. In addition to the information included in these reports, based on recent research the ONA may have updated fish periodicity information available for all species within the Okanagan (e.g. Salmon, Steelhead Trout).

### 4.2 B.C. INSTREAM FLOW METHODOLOGY

Instream Flow Needs (now referred to as EFNs) were estimated by ESSA and Solander (2009) for 36 Okanagan Basin tributaries in the Phase 2 Okanagan Water Supply and Demand Project. These flows were estimated using the B.C. Instream Flow Methodology (BCIFN)<sup>2</sup>. They are higher than the B.C.-Modified Tennant target flows.

The BCIFN method:

- uses percentile flows as the basis for the assessment without any direct consideration of fish periodicity or habitat functions, on the basis that fish that are present are adapted to the flow regime. Therefore, preserving key features of the natural hydrograph is a major element of the method;
- provides “minimum risk” EFNs (i.e. EFN values are relatively high);
- provides EFNs that are routinely higher than median flows outside the freshet period; and
- has no mechanism for the EFN to vary when natural flow is smaller than the BCIFN-recommended EFN.

The BCIFN method essentially defaults all Okanagan streams to the detailed assessment tier, so it has been viewed as not particularly useful. However, the concept of using percentile flows as a factor in EFN-setting based on aquatic adaptation to flow regimes does have considerable merit for consideration in the Okanagan EFN-setting recommendations in this project.

Considerable effort was expended by both nhc (2001) and ESSA and Solander (2009) to derive EFNs for Okanagan streams, but the resulting EFN recommendations have been considered as "non-operational" for water allocation purposes in the Okanagan. This is likely because the recommended EFNs are often higher than natural low flows, particularly in drier than average years. Neither the B.C.-Modified Tennant nor the BCIFN method deals with the implications of not meeting EFNs, so they provide little guidance for water licensing or real time operational flow management when the natural flows drop to lower than the specified EFN values.

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<sup>2</sup> The BCIFN method is described in the report *BC Instream Flow Thresholds as Guidelines for Reviewing Proposed Water Uses* by Hatfield et al. (2003). The method was developed by the B.C. Ministry of Water, Land and Air Protection, the B.C. Ministry of Sustainable Resource Management, Land and Water BC Inc., and Fisheries and Oceans Canada to aid in the process of setting instream flows in B.C. streams. The guidelines support a two-tiered review process for proposed water uses on B.C. streams. The first tier is a scoping level process that provides thresholds for alterations to natural stream flows that are expected to result in low risk to fish, fish habitat, and productive capacity. These thresholds are meant to act as a "coarse filter" during the review of proposed water uses on B.C. streams when there is little or no biological or physical data available. Projects that propose to exceed these flow thresholds must collect additional data, to be reviewed and used during a more detailed project review (the second tier).



### 4.3 WEIGHTED USEABLE WIDTH METHOD

A habitat simulation approach (for more detailed consideration of rearing and spawning flows) using the WUW method was successfully used to inform EFN considerations for water use planning purposes in Trout Creek (nhc 2005; Water Management Consultants 2005) and Mission Creek (Epp 2008, 2009, 2010a; Water Management Consultants 2010). The advantage of habitat simulation is that it demonstrates how useable habitat changes with flow, thereby demonstrating the habitat reduction impacts associated with lower flows, whether the lower flows result from natural variation or from flow reduction due to water use. Experience indicates that for a WUW approach to be successful, the habitat suitability indices must be reasonably representative of the target stream (Ayllon et al. 2012; Conklin et al. 1996).

WUW data was also used for the less formal Trepanier Water Use Plan (Epp 2010b, 2010c), as well as to set EFNs for the Bessette Creek Watershed with Duteau Creek Operational Guidelines (Epp 2014, 2015), and is currently being used to set environmental flow targets for Middle Vernon Creek in the Middle Vernon Creek Action Plan (Epp and Neumann 2015, 2016). Stream-specific EFN assessments using the WUW approach have also been conducted in Peachland (Deep), Powers, and Ellis creeks between 2004 and 2009. The WUW method used in conjunction with the B.C.-Modified Tennant method is accepted as a valid approach for EFN-setting by FLNRO's Environmental Stewardship Division in the Thompson Okanagan Region.

## 5 Recommended Methods for Setting Environmental Flows in the Okanagan

### 5.1 OVERALL DECISION-MAKING PROCESS FOR ESTABLISHING EFNS

In the new B.C. *Water Sustainability Act*, "environmental flow needs" (in relation to a stream) are defined as "the volume and timing of water flow required for the proper functioning of the aquatic ecosystem of the stream". The methods recommended herein focus on how to set values that meet this definition, considering both habitat, and factors that may affect fish populations such as forage availability. Furthermore, Section 15 (1) of the Act requires a decision-maker to consider the environmental flow needs of a stream in deciding a water licence application. One of the primary and near-term uses of the present work will be to assist decision makers in rendering appropriate decisions.

Herein we provide an outline of a recommended desktop method and a recommended field-based method for EFN-setting, and evaluating impacts due to flows that are lower than the EFNs for Okanagan streams. The desktop method can be used alone (e.g. in low-risk situations), or it can be followed by the field-based method (e.g. in higher-risk situations). The choice of whether to use the Desktop method alone, or the two methods in sequence will depend on the significance of the decision to be made, and other factors such as the relative value of a stream in maintenance of key fish populations. In either case, it is likely that the technical EFN-setting work would be done within the context of a broader decision-making process that brings not only technical expertise but also practical considerations and social values into play before a final decision is made and implemented. The use of such committees and boards is consistent with the Act. For example, Section 66 of the Act provides provisions to establish a "technical advisory committee" to support development of a Water Sustainability Plan. Section 115 (1) of the Act allows the minister to establish an advisory board to provide advice in relation to methods for determining EFNs. It is beyond the scope of the present assignment to provide recommendations towards this higher level decision-making process. Nevertheless, we use language in the present report that assumes that a future decision-making process will include both an "Expert Panel" to consider and validate technical EFN-setting recommendations and an "Advisory Panel" that would bring non-aquatic interests to the table before a regulatory decision is rendered.

### 5.2 CONSIDERATIONS FOR EFN-SETTING IN THE OKANAGAN

This section introduces several factors relevant to establishing EFNs in Okanagan tributaries. These factors have influenced the recommendations presented herein, and should be reviewed during application of the methods.

In their study of hydrology and habitat in 21 Okanagan Lake tributaries, nhc (2001) identified several important considerations for EFNs that this report attempts to build upon. First, where flow related impacts are existing or expected, there are two types of response: (1) modify operations; and (2) manage the supply. Therefore, EFNs should be developed in consideration of the range of management response

options that will be considered (Table 5-1). Different indicators may be required to assess operations versus supply management.

Second, while it is common practice to consider all of the life stages and functions for a specific value, it is essential that EFNs consider the known bottlenecks or limiting factors that are affecting the environmental value of concern (Table 5-2). Thus EFNs should include flow targets and associated monitoring criteria specific to the known limiting factors.

Third, land management activities that modify hydrologic processes and thereby impact aquatic habitat quality can change the EFNs that are required to maintain productive capacity of an ecosystem.

**Table 5-1  
Typical management responses to existing or anticipated flow impacts**

Management response category	Example management response
1. Modify operations	<ul style="list-style-type: none"> <li>• Increase water use efficiency.</li> <li>• Implement flow ramping restrictions during sensitive periods.</li> <li>• Retain natural hydrograph characteristics during reservoir filling.</li> <li>• Develop drought response plans.</li> </ul>
2. Manage the supply	<ul style="list-style-type: none"> <li>• Deny a water licence application for additional use</li> <li>• Suggest a modified application that uses less water during times of scarcity (indexed use).</li> <li>• Create additional storage to meet human and/or EFNs</li> <li>• Develop Water Sustainability Plan that consider the need for restrictions, reductions of water rights, and compensation as required.</li> </ul>

**Table 5-2  
Example environmental values and expected limiting factors**

Environmental value	Expected limiting factors
Riparian vegetation – willows and cottonwoods	<ul style="list-style-type: none"> <li>• Creation of new sites for seedling establishment (primary succession).</li> <li>• Post-freshet down-ramping rates that support root growth.</li> </ul>
Rainbow Trout	<ul style="list-style-type: none"> <li>• Sufficient flow magnitude for migration to spawning areas.</li> <li>• Post-freshet down-ramping rates that minimize stranding potential.</li> <li>• Adequate summer rearing flows.</li> </ul>
Kokanee	<ul style="list-style-type: none"> <li>• Sufficient flow magnitude for migration to spawning areas.</li> <li>• Spawning flow.</li> <li>• Incubation flow.</li> </ul>

## 5 - Recommended Methods for Setting Environmental Flows in the Okanagan

Several other considerations underlying our recommended approach to EFN-setting in the Okanagan are outlined below.

1. A useful and practical EFN-setting approach for the Okanagan must go beyond just technically setting the EFN values – it must also provide information and guidance to enable consideration of EFNs in the context of natural flow variation and water allocation and use, similar to the considerations used for balancing use with flows in the water use planning process.
2. In a practical EFN-setting exercise, it will be important to understand the degree to which current licensed water uses are impacting streamflows. Facility and infrastructure operations that change water diversions and water releases on a daily or even hourly basis can have effects that are not detectable through the use of summary flow statistics such as mean monthly flows during the summer critical flow period (e.g., Schleppe and Larratt 2015). Many of the licenses are dated and may lack provisions governing factors such as ramping rates and maximum diversion rates, which have been shown to affect fish populations (e.g., BC Hydro Water Use Planning Studies such as Irvine et al. 2009). The new EFN-setting procedure will emphasize that water use in the Okanagan is not only about “the total quantity” of use, but also about “how” and “when” the water is used. A watershed with a relatively low diversion rate but poor operations may have a much greater impact on fish populations than a watershed with a higher diversion rate and optimized operations that mitigate effects on fish. BC Hydro has done extensive work that considers issues such as ramping rates and timing of flow augmentation, and has set minimum environmental flow targets to reduce effects on fish populations or functions that support fish (e.g., forage availability), all of which are considered important factors in an EFN-setting exercises.
3. It is desirable to be cost-effective without sacrificing technical rigor or the data that is needed to make an EFN decision.
4. The Okanagan is small and contains a relatively narrow range of stream morphologies, aquatic species of interest, and aquatic habitat, which may be able to be leveraged to advantage. Any leveraging of similarities between systems would require reasonable information on both physical characteristics and habitat characteristics (such as the spatial availability or quantity of habitat available).
5. Previous work can be leveraged (e.g., previous habitat analysis or biophysical habitat mapping such as Sensitive Habitat Inventory and Mapping (SHIM), previous EFN work, or previous streamflow measurement and modeling).
6. The EFN definition in the *Water Sustainability Act* refers to both the volume and timing of water flow required for proper functioning of the aquatic ecosystem. Proper functioning occurs when the flows are sufficient and properly timed for ecosystem functions - i.e., when the water flow and timing is in a range for the processes and species in the stream to allow natural life history patterns to occur (e.g., sufficient water for spawning or rearing fish or for food like benthic invertebrates for fish) to carry out life cycles that involve both terrestrial and aquatic stages. Natural flows vary beyond that range - low flows in dry conditions are not likely to satisfy the habitat preferences of fish or may reduce forage availability at key life history stages of fish. Flood conditions on the other hand can force species to seek refuge

elsewhere in the system (although in cases where extreme channelization has occurred these refugia may no longer be present).

7. It is necessary to consider other physical habitat features and other flow related factors that affect fish populations (e.g., floodplain and riparian condition, off channel habitat connectivity, sediment transport and channel maintenance) to ensure proper ecosystem function.
8. Fish periodicity for all species of interest in each tributary should be considered when setting EFNs, including species not currently present, if future re-introduction could be considered. Priority is usually given to the species and life stage with the highest flow requirements in any time period, as higher flows than required for some species life stages are on balance usually better than lower than required flows for others. Flow impacts for all species and life stages should be taken into account when setting the EFN values.
9. Streamflow varies hourly, daily, weekly, and annually depending upon hydrologic drivers such as weather patterns. The recommended EFN-setting methods should allow EFN values within years to provide a hydrological pattern that allows and supports the ecological functions that aquatic species and life stages need. The methods should also allow for between year variation in EFN.
10. The methods recommended herein should be flexible as to the most appropriate unit of time – monthly works well for winter months, but weekly would be more appropriate from mid-April to mid-July when flows change rapidly during freshet. It is important to note that hourly effects of water use may also affect fish, or food for fish (e.g. Schleppe and Larratt, 2015), and should be considered, but these concerns can be addressed through identification of the magnitude and timing of withdrawals within a monthly or weekly context.
11. The most appropriate spatial unit for the basic EFN is the entire stream from the mouth all the way up the mainstem and tributaries. The EFN regime must consider the most sensitive reaches of the stream, the identification of which may require data acquisition to rank stream habitat values between all reaches of consideration. It is possible that EFN considerations may be able to consider lower reaches of the stream in some cases, but in others the EFN may need to consider key reaches that occur in upstream locations where water availability varies with other key factors such as influence from tributaries or groundwater. For instance, the highest density of Rainbow Trout spawning likely occurs between 13 and 19 kilometers upstream in Mission Creek, rather than near the mouth (Wightman and Yaworski 1982).
12. During application of the field-based method outlined in Section 5.3.3, detailed habitat work will be carried out in stream reaches and habitat units within the reach. With the additional provisions for flow protection required for fish-bearing waters (2015 Environmental Flow Needs Policy), determination of fish-bearing status in any affected stream is an important task. Existing standards for establishing fish presence include the Fish Stream Identification Guidebook (BC MOF/ BC MOE 1998). Extensive mapping and inventory projects based on these methods have been previously undertaken in the forested uplands of the Okanagan. Knowledge of the complete extent of habitat recognizes that in

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addition to the highest value habitat, persistence of fish in areas of lower productive capacity is important for population level productivity and conservation. The level of field detail applied will be a function of the risk tolerance, and the characteristics and variability of the stream. The field work will identify both the availability and relative value of habitat, and the within-reach relationships between key habitat factors and flow. In essence, the objective is to ensure the EFNs are based on the highest relative value stream reaches, and the specific effects of flow variability on available habitat (i.e., WUW). Specific habitat work could be repeated in multiple habitat units and multiple reaches, and similar reaches should yield similar results, meaning field work can likely be limited to key reaches of highest relative habitat value. As such, initial detailed work would focus on identifying the highest value habitat in the stream and developing EFNs appropriate for those high value habitat areas. Detailed habitat work could be as simple as WUW transects in the reach identified as the most important single habitat unit (e.g., riffle or glide), or could include detailed habitat mapping and cross-sections across several key stream reaches known to provide important habitats for various life stages of fish, or known to provide ecological functions that support fish. In addition to the risk-based driver of the level of detail required, the level of detail needed will depend on key life stages of fish, the spatial availability of habitat, the relative importance within and between stream reaches, and the production values associated with the stream. If available or warranted, spatial habitat data such as SHIM can be used with simple rank indices to identify high value habitat locations in conjunction with other fisheries information in a spatial framework. This approach would allow for comparison both within and between stream reaches to identify the highest value areas to aid in EFN decision-making, particularly at the Expert Panel stage when EFN recommendations are being fine-tuned (see Hawes et al. [2011] for examples of a simple rank index approach that is currently being used by Fisheries and Oceans Canada for large rivers, or Schleppe [2010] - for lake shorelines - that could be adapted for use with this approach).

13. Standard Habitat Suitability Index (HSI) relationship-based habitat assessments like WUW often demonstrate the greatest useable width (optimal flow) at flow values that exceed median flows (i.e. at relatively high flows). Nevertheless, the HSI-based approach does demonstrate how habitat varies with flow, and it can therefore be used to focus attention on flow-related habitat impacts within the range of historical or expected flows, including flows smaller than median flows. This should allow specification of EFNs that are realistic and attainable.
14. Technical expert judgment, although less quantitative than some methods, can be as valuable and efficient at solving complex problems because of the complex interactions that occur in living systems, or because of the highly specific watershed factors that are important at governing fish populations that would require watershed specific models. Factors to inform expert judgment would include the spatial availability of habitat, the relative importance of a watershed to fish populations or system productivity, fish population estimates and their associated temporal variation, spawner enumerations and key locations, water temperature and temperature related issues, presence of barriers to fish passage such as falls, and the effects of previous habitat alteration on stream productivity.
15. By definition, EFNs are focused on ecological needs and do not balance ecological needs with water demands. Some previous EFN-setting exercises in the Okanagan and elsewhere have been

considered non-operational because they do not account for needed societal demands. Balancing demands with ecological needs is a valid consideration within a socio-economic context, but it needs to be done in a separate step, subsequent to the work of a technical EFN-setting regime. The focus of that 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. The scope of the present study is limited to providing technical recommendations. However, we recognize the need for broader consideration of other values before an EFN flow regime is adopted on an Okanagan stream. Another implication of this point is that the methods and criteria used in the technical EFN-setting approaches recommended herein must produce transparent and defensible EFN recommendations.

16. Fish habitat and streamflow regimes have been affected in some Okanagan streams over the past century, and it is not necessarily safe to assume that simply establishing an EFN flow regime that respects the historical natural flow patterns will be sufficient to protect present-day aquatic populations in streams where there has been some habitat degradation and/or loss.
17. Okanagan streams support meta-populations of fish, and do not necessarily function in isolation from one another. Fish that cannot gain access to their preferred stream may utilize adjacent streams. This factor should be acknowledged and accounted for in designing EFN-setting studies in the Okanagan.
18. Methods proposed herein should be considered in an adaptive management framework – and modified (if required) as improved techniques or additional data becomes available. If possible, allowance should be made to facilitate future amendments to adopted EFNs as new information becomes available.
19. Several useful ideas have been considered during the present assignment, but have not been explicitly included in the proposed methods. It is anticipated that many of these ideas, which are listed in Section 7, and require further examination, will help improve the proposed EFN-setting methods.

### 5.3 OUTLINE OF RECOMMENDED OKANAGAN EFN-SETTING METHODS

#### 5.3.1 Introduction

In this section, we describe an approach to EFN-setting that involves either a desktop EFN-setting method alone, or a desktop method followed by a field-based method. The desktop method is intended for use in setting initial EFNs for each stream, and the field-based method is intended for refining these initial EFNs in streams with higher risks due to existing or proposed water allocations, and for quantifying some of the habitat implications of water allocation that results in residual flows that are lower than EFNs. Examples and other supplemental information to further illustrate the recommended methods are provided in Appendices C and D, respectively.

The approach is characterized as a “moderately prescriptive guideline” to highlight the concepts that while the two recommended methods can be described as a sequence of steps in a flowchart, there is flexibility in

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the level of effort to apply within each of the method steps, and that experience and good judgment in hydrology and aquatic biology are required to execute the approach.

### 5.3.2 Outline of recommended Desktop EFN-setting Method – the “Okanagan Tennant Method”

The desktop method outlined herein is proposed to be known as the “Okanagan Tennant” method”. It is an adaptation of the B.C.-Modified Tennant method previously used in the Okanagan. It is recommended for setting initial EFN values for Okanagan streams, and includes an approach to understand the implications of flows lower than the EFNs. It will be useful for developing an initial understanding of the risks to aquatic habitat and ecological processes from existing and proposed water allocations relative to natural or naturalized flows, and will act as a useful starting step for setting EFNs in the Okanagan.

This section describes how to set an annual EFN flow regime that satisfies the EFN definition for proper functioning, and also considers the reality that flows will drop below EFNs in dry years.

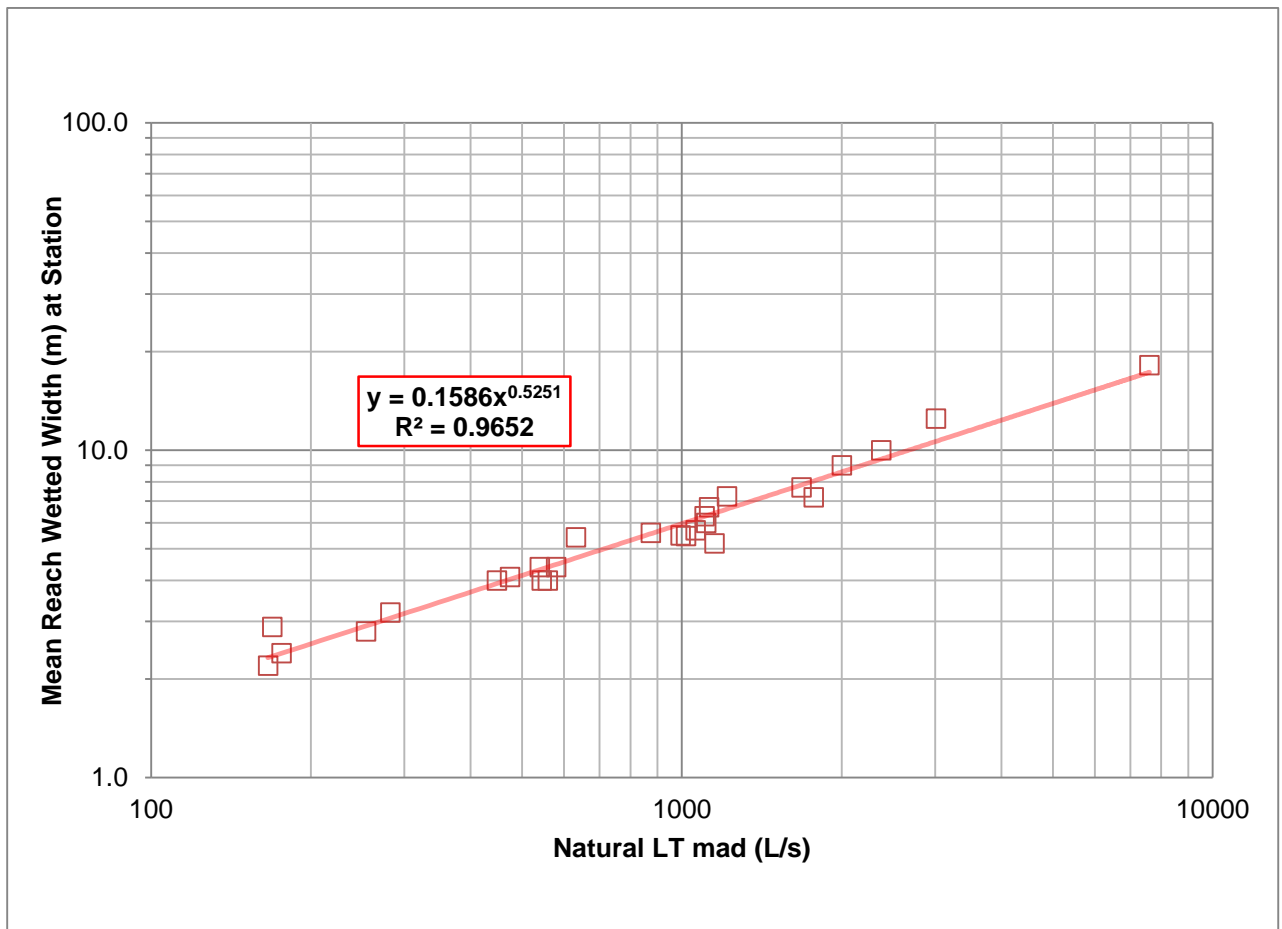
#### **Technical Basis for the Okanagan Tennant Method**

The Okanagan Tennant method is based on the B.C.-Modified Tennant method which has a history of use in the Okanagan (nhc 2001, 2003, 2005) and is well understood by FLNRO staff.

The Tennant method is sometimes viewed as overly simplistic and criticized for relying on percentages of a single flow statistic - long term mean annual discharge (LT mad). Despite the criticisms, the B.C.-Modified Tennant provides a good framework for setting basic EFN values in Okanagan streams. A strong relationship exists between LT mad and channel characteristics, as shown in Figure 5-1. In addition, the %LT mad values do consider fish life stage and provide for ecological functions, and there is considerable scientific evidence to support these percentages as appropriate. Examples of previous successful adaptations of this method in the Okanagan include:

- developing parallel sets of Tennant recommendations for dry, normal, and wet years to adjust to the inter-annual variation in flows in the Middle and Upper Vernon Creek watersheds (nhc 2003);
- using stream specific WUW analyses that account for habitat reductions for rearing and spawning habitats at lower than EFN flows to inform Water Use Planning processes (nhc 2005; Epp 2009); and
- using a multiplier of real-time flow data from Camp Creek to reduce Trout Creek EFN targets when the natural flows are lower than the Tennant EFNs (nhc 2005). A similar relationship was established for Mission Creek based on Pearson Creek (Epp 2010a), but requires re-establishment of a hydrometric station with real-time transmission on Pearson Creek.





**Figure 5-1**  
**Downstream hydraulic geometry (width) changes with LT mad in select Okanagan tributaries**  
**(source: Ptolemy, 2016d)**

An overview of the B.C.-Modified Tennant method was provided in Section 2.2.1, and the modifications recommended to revise the method to the Okanagan Tennant method are outlined in this Section. Further details on the Okanagan Tennant method are provided in Appendix C. A discussion paper titled “Draft: Using Limiting Factors to Link the Fish Periodicity Chart and Hydrologic Indices in an EFN Setting Procedure” by Richard McCleary of FLNRO (McCleary, 2016) is also included in Appendix C. This discussion paper provides an alternate approach to choosing the time periods for EFN analysis than outlined herein. A flow chart and description of the steps required to implement the method are provided in Section 6.

**Percent LT mad per Tennant Corresponds Well with Median Monthly Flows**

The B.C.-Modified Tennant method uses %LT mad to specify the flows that will meet the EFN requirements for applicable species life stages and ecological processes as per the instream presumptive flow standards in Table C-1 in Appendix C. As shown in Table C-2 in Appendix C, the B.C.-Modified Tennant approach

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typically provides monthly EFN values that are close to median monthly flows in Okanagan streams, except in the four highest flow months (April through July). This observation is consistent with the premise that aquatic populations and ecological processes in lower flow, or highly variable flow regimes have become adapted to the historic natural flow regime in each stream, i.e. the pre-European contact flow regime. Presumably, over the past few hundred years, prior to the start of the 20<sup>th</sup> century, Okanagan streams have been characterized by naturally variable flow regimes, with many years of low or very low flow occurring naturally. Because fish populations are still present and viable, it is likely safe to assume that the populations present today have adapted to this scenario. Under this premise, properly functioning aquatic ecosystems would be maintained in all streams under typical natural flow conditions (i.e., in which the negative consequences of low flow years are balanced by the benefits of higher flow years). This concept is consistent with the findings of researchers in Washington State, where juvenile salmonid productivity was not maximized at the optimal flow levels as predicted by physical habitat simulation, but rather productivity continued to increase at flows above the theoretical optimal flow - supporting the idea that in some habitats, more water equals more fish (Beecher et. al. 2010). It is worth noting, however, that habitat in many streams has been degraded or lost in recent decades, and streamflow regimes have also been affected. Accordingly, it is not necessarily safe to assume that simply establishing an EFN flow regime that respects the historical natural flow patterns will be sufficient to protect present-day aquatic populations in streams where there has been some habitat degradation and/or loss.

Based on the above observations, we recommend that percentile flows be incorporated into the basis for setting stream-specific Okanagan Tennant EFN values. In particular, we recommend monthly time steps for the eight months from August through March, and weekly time steps for April to July. This recommendation is based on the fact that streamflows change relatively slowly during August through March, but can change relatively quickly during the spring snowmelt and runoff period (April through July).

For each time step, both median monthly (August through March) or weekly (April through July) naturalized flows and the instream presumptive flow standards are considered. The applicable EFN will be the lower of the median flow for the time period and the applicable instream presumptive flow standard. The rationale for using the lower value is that the instream presumptive flow standards provide a generally adequate EFN value for the species / life stages and ecological functions even when median flows are higher, while median naturalized flows represent a functional stream specific EFN when median flows are lower than the instream presumptive flow standards.

Some of the flow requirements are of relatively short (weeks) to very short (days) duration as per the presumptive flow standards in Table C-1. The median flows will indicate when those flows should usually be expected for developing the weekly / monthly EFN values. It should be understood that because there is hydrological variation between years, the timing of short duration EFNs can be expected to vary, and this is acceptable as long as it occurs within the overall timing for that function of the fish periodicity (i.e., while weekly targets are set, the exact timing may shift forward or backward depending upon the year and interaction between weather patterns and the hydrological cycle). Additional thoughts regarding the integration of fish periodicity charts with hydrologic indices are provided in the discussion paper by McCleary (2016) in Appendix C.

Using median flows as a basis for the EFN values is transparent, and EFN values can be established for any time period (e.g., daily, weekly, monthly, or seasonally) based on calculating the percentile flows over the length of the period (e.g., weekly, bi-weekly, monthly). For most streams, residual flows (i.e., the current flows that reflect diversion and storage / storage release) will need to be naturalized prior to using percentile flows for setting flow targets. As such, a daily time step is less practical because it is unlikely that regulated flows can be naturalized precisely enough for a daily time step. Nonetheless, it should be recognized that there is a growing body of evidence from the B.C. hydropower industry that demonstrates that water control structures have the potential to impact fish populations or features that support fish populations (e.g., periphyton and invertebrates) at time intervals as short as hourly (e.g., Schleppe and Larratt 2015). Similar impacts have also been observed with water utility flow regulation in the Okanagan (e.g. Epp, 2010d), The impacts of very short term flow fluctuation within the longer EFN time steps can not be addressed within the EFN setting exercise, but could / should be considered in licensee-specific operating plans to make better use of water supplies.

Defaulting to median flows when lower than the instream presumptive flow standards means that the EFN as %LT mad will also vary from stream to stream in relation to the specific hydrology of each stream - factors like stream losses to groundwater in lower elevation reaches, earlier or later runoff due to factors such as elevation differences, bedrock influences on magnitude of base flows, and weather pattern differences are reflected in the observed streamflow patterns and will be inherent in the EFN values.

### **Operationally adjusting EFNs for Natural Flow Variation in Real Time**

EFNs set with the Okanagan Tennant method for water licensing purposes will exceed natural low flows for significant periods of each year in lower flow years because the EFN's will be set at median flows or instream presumptive flow standards that are close to median flows. This is an issue with using EFNs for operational considerations regardless of which method they are set with, because unless EFNs are set at unrealistically low values, they will sometimes exceed natural low flows.

We therefore recommend that EFNs for real-time management purposes be considered to be the lower of the EFN value set as per the recommendation above or the naturalized real-time flow. Variable EFNs set as the lower of the two will be more realistic for management purposes as the EFNs will then not exceed natural flows. Tables C-2 to C-5 in Appendix C document the variation from minimum to median monthly flows among several Okanagan streams with natural flow records, and demonstrate why EFNs will always exceed natural flows for some periods of time in some years, unless EFNs are varied operationally for the purpose of real time management.

Allowing EFNs to match naturally lower flows in dry years is most useful for setting realistic targets relative to existing water use and flow regulation in water use planning exercises and when considering regulatory water use reductions during low flow conditions.

Finally, it is important to recognize that allowing EFNs to match naturally lower flows in dry years for management purposes does not increase water availability for licensing. Residual flows after water allocation will still be compared to the naturalized flow and the full EFN flow used for allocation purposes to demonstrate the natural low flow impact plus any additional impact from allocations at the lower flows.

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### Assessing Impacts of Flows below EFN values

Methods to calculate variations in habitat and ecosystem function in relation to flow variation are recommended as part of the Okanagan WUW method described in Section 5.3.3. These methods can be used to show how habitat and ecological considerations vary with flow, which will be useful in demonstrating the natural variation and reduction in habitat / function at lower flows. This will also provide a context for evaluating the impacts of reduced flows through existing and proposed water allocations. It is understood that water withdrawals will result in flows below the EFN values at lower flows (unless the EFNs are set very low - below the lowest normal flow range). It is also understood that technically-recommended EFNs will be considered in the water allocation process by an Advisory Panel or regulatory agency. As such, the goal of an Okanagan EFN-setting exercise will be to set EFNs that meet the EFN definition in the *Water Sustainability Act*, and then identify the implications of reducing flows below EFN values, in order to facilitate informed recommendations by an Advisory Panel and/or a regulatory agency.

For the Okanagan Tennant method, a desktop approximation of the scale of impact due to flow reductions from existing and proposed water allocation can be determined by looking at the differences in %LT mad for various percentile flows for a standard period (e.g., 1981-2010). As stated previously, a reasonable premise is that aquatic populations are adapted to the natural (i.e. pre-European contact) flow regime in each stream, and the ecological processes are (or were if there is now significant flow alteration) also in balance with the natural flow regime. This suggests that the potential impact can be approximated by recalculating the %LT mad for the residual flows (i.e., after actual withdrawal and/or full allocation withdrawal [if different]) at each percentile and comparing that value to the natural / naturalized value to assess how much the hydrograph may have shifted over the standard period). This is similar to the Sustainable Boundary Approach method reviewed by Linnansaari et al. (2013). For example, a shift of the natural flow from a P50 (50<sup>th</sup> percentile) to a P40, or from a P25 to a P20 after allocation might be considered low risk because the residual flow is not largely different from that of the natural flow. A shift from a P50 to a P25, on the other hand, would likely be considered a high risk because the median residual flow has shifted the flows to a natural 1 in 4 year flow. Similarly, a shift from a P25 to P10 would also be considered high risk because the P25 residual flow would be equivalent to a natural 1 in 10 year low flow rather than a natural 1 in 4 year flow.

The comparison would be similar to the WUW reduction comparison demonstrated in Table D-1 and Figure D-2 (Appendix D). The flows columns in Table D-1 illustrate the lower residual flows at various percentiles for two allocation examples relative to the starting flow at each percentile, and can be compared directly for a tabular comparison. The values also could be plotted similar to the index flows in Figure D-2 for a visual comparison.

Percentile flows are very useful for water allocation decisions because they represent the range of historical flow that can be used to evaluate additional allocations against the natural flow regime. However, if implementing licensing with conditions or timing that are intended to vary with flow variability, reference to real-time hydrometric stations or other means such as drought indexes will need to be used to match current flow conditions to the percentiles in the historic record or standard period.

The comparisons need to consider the existing residual flow regime, the historic natural flow regime, and the flow regime that would result if all currently licensed water allocations were being used. It is important to differentiate between the volume of water that has been licensed for use and the volume that is actually used, because most of the large water utilities in the Okanagan use less than half of their allocated water. Actual use is required to naturalize residual flows, and determining impacts of existing water use. However, it is also important to evaluate the impacts of the allocated, but not currently utilized allocation, as part of any assessment of new applications. Proposed new allocations would then be subtracted from the residual flows and from the full withdrawal flow regime to consider the additional impact of a proposed new allocation.

For many streams in the Okanagan Basin, naturalized and residual flow regimes were developed for all watersheds and residual areas as part of the Okanagan Water Supply and Demand Project (Summit 2010). Since that study considered actual use data for the 1996-2006 period only, there is a need to update the information. Since flow naturalization is an important step in the recommended EFN-setting process, we have described a standard method for this purpose (in Section 6).

Water licence applications demonstrate a wide range of potential flow reductions. Large water utilities in the Okanagan generally have large upland reservoirs to store freshet flows for release during, summer, fall and winter months, which should help to achieve EFN targets during those seasons. While the most substantial effects of the larger water utilities may be most apparent during freshet flows, the potential effects of regulation like reservoir filling during lower than average periods are important to consider because these often correspond with key life history timing of important species such as Rainbow Trout migration and spawning. Domestic licences have very small impacts year round, and irrigation licences are seasonal (April to September) with the greatest demand in July and August when flows are critical for Rainbow Trout rearing. The impacts related to each new water licence application will need to have the proposed water use purpose quantified for each time period in order to complete a risk assessment.

Specific risk / impact categories based on the percentile comparison are not suggested at this time, but should be developed in future.

### **5.3.3 Outline of Recommended Field-based EFN-setting Method – the “Okanagan WUW Method”**

The recommended field-based method (i.e., the “Okanagan WUW method”) is recommended for use where further confidence in the results obtained through the Okanagan Tennant method is required. Results of the Okanagan WUW method will be used to refine recommendations derived through the Okanagan Tennant method, to provide additional information for consideration of EFNs, and to further evaluate the impacts of reducing flows below recommended EFN values. Section 6 provides advice on how to decide whether to apply the Okanagan Tennant method alone, or to add the Okanagan WUW method following completion of the Okanagan Tennant method, for each Okanagan tributary.

Details on the Okanagan WUW method are provided in Appendix D. A flow chart and description of the steps involved in applying the Okanagan WUW method are provided in Section 6.

### Technical Basis for Okanagan WUW Method

The proposed method for calculating how aquatic habitat varies with flow is based on the WUW habitat simulation technique. WUW analysis is a standard technique that has been conducted throughout B.C., including in Mission, Trout, Trepanier, Peachland, Powers, Middle Vernon, and Ellis creeks in the Okanagan, the adjacent Bessette Creek and tributaries in the Shuswap watershed, and the adjacent West Kettle, Kettle and Granby Rivers in the Kettle watershed. The method reflects some of the strengths of the Lewis et al. (2004) habitat assessment method, but is simpler and less time consuming to apply. WUW is calculated using depth and velocity measurements at intervals along transects located in the appropriate habitat units for the species and life stage of interest, in conjunction with HSI curves. The measurements and calculations are repeated for each transect over a range of flows, and the weighted useable widths are then plotted vs. flow to demonstrate the relationship. Typically, these plots result in a non-linear curve, and statistical modelling of the curve can provide a function with appropriate confidence intervals. There are many new techniques that can be used to derive an appropriate function for the WUW curve, that allow for consideration of error in the estimates.

The Okanagan WUW method does not require a full-scope habitat analysis, but rather focuses on riffle analyses for juvenile rearing and insect production, and on glide analyses for spawning, in areas identified as having the highest relative habitat values. These are critical habitat elements that vary with flow, and as such, changes in useable width in these areas can be used as an indicator of how habitat quantity and quality vary with flow. Choosing the most appropriate transect sites is important, so we recommend using existing habitat knowledge (such as SHIM or suitable habitat indices [e.g. Hawes et al. 2011] where available) to help select the optimal locations for analysis. Ultimately, the choices in site selection should be based on a thorough understanding of the relative importance of different stream reaches, with focus placed on the highest value stream reaches. As previously indicated, there are numerous rank indices that have been used by Fisheries and Oceans Canada and others to understand and rank relative habitat value that could be modified using SHIM or others types of spatial data (see Hawes et al. 2011 for Okanagan / Shuswap examples), where the level of data is commensurate with the fisheries production of the stream.

Choosing the level of effort to apply in the field (in particular, the choice of the number and the location of transects and the effort to apply to habitat characterization) would be determined by considering the risk tolerance of the Expert Panel or Advisory Panel on a case-by-case basis. More information reduces uncertainty and provides additional confidence in the outcomes, but adds time and cost. In addition, the level of detail required depends on technical factors such as the habitat values on the stream, the quantity of available habitat, the extent of habitat alteration, the production of the stream and the relationship between productivity and habitat available<sup>3</sup>, and the sensitivity of the fish population to imposed changes<sup>4</sup>.

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<sup>3</sup> For example, Deep Creek near Peachland has a very small area of available habitat, but is considered extremely productive.

<sup>4</sup> For example, imposed changes due to water allocation - in many watersheds, Kokanee production is currently recovering from all-time lows, meaning that focus on key spawning areas and their relative availability is key to where, when, and how many transects are needed to describe the system sufficiently to effectively promote recovery of these populations.

In cases where additional detail is required, the methods outlined by Lewis et al. (2004) could be used, or other methods that have been developed to assess and rank habitat on a spatial scale (e.g. Hawes et al. 2011). The concept of an Aquatic Habitat Index has been used in several planning processes in the Okanagan, Kootenays, and Shuswap, and has been developed in conjunction with project partners such as Fisheries and Oceans Canada. These methods are cost effective because they use both biophysical data (e.g., potential spawning habitat, large woody debris) and qualitative/quantitative spatial data (e.g., where fish actually spawn, where the high value rearing habitat is located), but do not build complex models.<sup>5</sup> In addition to being cost-effective, these methods allow for incorporation of expert opinion, which is a key component of the EFN approach recommended herein. While it is logical that this approach is transferable to Okanagan tributaries, as indicated in Section 7, we recommend that it be tested on at least one stream to confirm its suitability for Okanagan tributaries.

### **Key Locations for WUW application**

The Okanagan WUW method can be applied at any suitable location along the stream length, but the most important reaches to consider in the Okanagan are generally the high value reaches close to the main low elevation Okanagan lakes and the Okanagan River. This is where most of the Kokanee Salmon and adfluvial Rainbow Trout spawning occurs, and the flows in the lower reaches reflect the net result of all flow regulation and diversion related changes upstream. It is important to note that this is not always the case, and each system should be considered on a case by case basis to ensure that key habitats in upper reaches are afforded appropriate EFN consideration. Note that the reference herein to lower reaches does not specifically indicate the lowest reach. For example, as mentioned in Section 3.2, in Mission Creek the highest value habitat for adfluvial Rainbow Trout spawning begins between 10 and 13 km upstream of Okanagan Lake and extends to the natural fish migration barriers in Gallaghers Canyon (Wightman and Yaworski 1982).

The Okanagan WUW method does not directly consider land use related habitat alteration such as channelization, riparian vegetation removal, and loss of off-channel connections. It is recognized that those alterations are likely to have reduced habitat quantity and quality, but flow related impacts are in essence superimposed on those land use related impacts. In other words, flow reductions will reduce use of poor quality habitat when depths and velocities are reduced, similar to reductions in higher quality habitat when depths and velocities are reduced. The relative magnitude of the habitat reductions may not be equal, but they should be similar enough to retain the utility of this technique. However, this highlights that the most important habitat areas should be spatially identified during field data acquisition because these habitat units of higher value are currently in use and are critical to maintaining populations in systems where habitat alteration has effectively reduced the productive capacity of the stream (e.g., Mission Creek). It may also suggest that caution in EFN-setting in such circumstances is warranted, as the populations may be less robust than they were pre-disturbance.

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<sup>5</sup> A simple ranking of habitat can also be incorporated into other planning processes that affect fish and their habitats, such as Official Community Plans and Watershed Management Plans. For example, this process was used as part of a planning tool for the Shuswap River, where habitat was mapped, key habitat attributes such as riparian areas, floodplain areas, spawning areas, rearing areas were identified, and results were used to facilitate identification of key areas for watershed planning.

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### Relevance of Standard HSI curves

Habitat suitability varies with many physical, biological, and chemical characteristics of a stream, as well as characteristics of the fish (e.g. species, life stage, and size distribution). In the absence of stream-specific HSI curves for each stream, standard HSI curves for B.C. (including the Okanagan) have been developed. These were provided by Ptolemy (2016b), and are reproduced in Appendix E. The available HSI curves are as follows:

- Juvenile Rainbow Trout rearing (fry and parr life stages);
- Juvenile Steelhead rearing;
- Juvenile Salmon rearing (Coho and Chinook);
- Generic insect production for use in rearing (riffle) transects;
- Kokanee spawning;
- Rainbow Trout spawning;
- Chinook Salmon spawning;
- Coho Salmon spawning; and
- Steelhead Trout spawning for use in spawning (glide) transects.

The rearing HSI curves are for use in rearing (riffle) transects, and the spawning curves are for use in spawning (glide) transects.

Sockeye Salmon spawning HSI curves are notably missing from the standard B.C. HSI set. The HSI values for Sockeye Salmon spawning will likely lie between those for Kokanee (similar but generally smaller species) and Coho Salmon. As such, Sockeye Salmon requirements will be covered if both Kokanee and Coho Salmon are considered in a stream, but priority should be given to determining HSI values specific to Sockeye Salmon.

Because of size and other differences between the streams on which the B.C. standard HSI set was developed and Okanagan streams and Okanagan fish, relevance of such curves to the Okanagan has been questioned. As outlined in the next section, the Okanagan WUW method overcomes this potential issue by scaling habitat values from zero to one between a critically low flow and a functional higher flow, such that the chief consideration becomes relative rather than absolute change in flow and habitat. Accordingly, the B.C. standard HSI curves are appropriate for use with the Okanagan WUW method (for streams without stream-specific HSI curves).

However, there may be a desire to validate HSI curves to increase confidence in their applicability to Okanagan streams, and this potential knowledge gap is highlighted in Section 7. Finally, the influence of water temperature, substrate, cover, and other factors on habitat should be considered in setting EFNs – i.e. using HSI curves to determine useable habitat width based on depth and velocity preferences should not be the exclusive consideration.

### Modification to overcome tendency to recommend “optimal” flows

A criticism of habitat simulations like WUW is that the results indicate optimal habitat at flows that are well above the median – i.e., not usually naturally attainable unless conservation storage is developed for such



purposes. The high flows associated with optimal habitat do not invalidate the calculations – rather, they simply indicate that the species and life stage being considered could benefit from higher than median flows, or they may reflect an artifact of HSI curves for larger bodied fish (or some combination thereof). Herein, we propose a modification of the WUW technique to render it more useful by focussing only on the portion of the curve between the critical environmental flow threshold and a designated upper reference flow.

The critical environmental flow threshold is defined in Section 1 of the *Water Sustainability Act* as “the volume of water flow below which significant or irreversible harm to the aquatic ecosystem of the stream is likely to occur.” For the upper reference flow, we recommend the Okanagan Tennant method EFN if available, or the median monthly flow for August through March, and the median weekly flow for April through July as a starting point for consideration, where it can be adapted as necessary and applicable. For the critical environmental flow threshold, we initially recommend 5% LT mad, as the minimum monthly summer flow (naturalized) with the understanding that other, likely higher flows will apply to other species and life stages such as migration and spawning for large bodied fish. The difference in useable habitat using WUW between the two points can then be scaled from 0 to 1, and replotted against the range of percentile flows. This plot will demonstrate the percentage of habitat associated with any flow that is lower than the EFN due to either natural or allocation-related flow reduction as compared to the habitat at the median flow value. Both the upper reference and critical low flow can be adjusted on a case by case basis to adopt the most appropriate values.

There are also likely benefits to the aquatic environment of periodically achieving flows that exceed median flows because it is probable that during higher flow years, fish populations experience a benefit in production (e.g. Beecher et. al. 2010). This means that the benefits higher than average flows in some years could help offset production-related consequences that occur during periods when EFNs are not met. Currently, it is not known what benefits, or what magnitude of benefits, would result by providing additional flows on an infrequent basis. Nonetheless, this idea is plausible given the context of Okanagan streams and the life history of fish adapted to this region. Therefore, we have identified this issue for further study in Section 7.

In Appendix D we provide an illustrative example of this approach using data for Mission Creek.

### **Additional data collection to support “expert judgment” contribution**

We suggest that additional observations be made during field work to provide qualitative observations to round out the technical WUW analyses. Such additional considerations could include:

- Obtain a location-specific photographic record;
- Document the nature and degree of existing habitat alteration using SHIM or some other spatial habitat mapping alternative (if available);
- Obtain habitat and flow observations at very low flows, and use expert judgment to confirm or modify the initial assumption that 5% LT mad is an appropriate estimate for the critical environmental flow threshold in summer, and to develop recommendations for all relevant species and life stages in the stream. Also consider other relevant information on nearby similar streams,

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and other information such as traditional knowledge in developing the critical environmental flow thresholds.

- Obtain information to understand the degree to which the stream is important in supporting meta-populations of fish;
- Identify waterfalls and anthropogenic obstructions that restrict accessible habitat by using the B.C. Ministry of Environment's Fisheries Information Summary System (FISS) and using existing or updated SHIM to confirm existing or identify new obstructions not previously documented;
- Develop a judgment on the potential for temperature-related impacts on aquatic populations and the implications of temperature issues for EFNs;
- If the level of risk requires it, obtain additional detail and develop models (e.g., River 1-D or River 2-D) to better understand the relationships between flow, channel morphology, habitat, and biophysical characteristics (e.g., depth and velocity) to facilitate determination of an EFN and set a benchmark for the critically low flows and potentially the upper reference flows; and
- If the level of risk or fisheries production values warrants it, map and identify the quantity of available habitat to understand the importance and relative availability of habitat both within and between streams.

In addition, information on non-habitat factors that could be important to EFN-setting should be obtained, such as:

- Aquatic population estimates (historic and current);
- Spawner enumerations;
- Benthic productivity;
- Knowledge of the conservation status of the aquatic populations (historic and current);
- Evaluation of the role of managed flows in either positively or negatively affecting habitat conditions;
- Historical reports of flow related fish kills (e.g., the adfluvial rainbow mortality in Mission Creek due to extreme low flow in June 1992), as available from MOE's Cross-linked information resources (CLIR) database or from FLNRO / ONA files;
- The level of water allocation already present within the watershed or on a specific stream; and
- Knowledge of surface water and groundwater interactions throughout the watershed and specifically within the lower reaches of a watershed where high value aquatic habitat may be located.

### **Setting ecological function flows**

The maintenance of ecological function (including fluvial geomorphology and riparian character and unction) requires periodic flows near or exceeding bankfull flow. In EFN literature, such flows are usually specified in terms of %LT mad, similar to the way lower EFN flows are specified. Herein, we recommend setting ecological function flows using the same approach recommended by nhc (2001).

The B.C.-Modified Tennant method as used by nhc (2001) recommends flows of 100% LT mad in April and June, and 200% LT mad in May for maintenance of ecological functions such as sediment movement and

flushing, as well as other functions like off-channel connectivity. There is also a notation that for channel maintenance over the longer term, a maximum instantaneous flow of 500% LT mad is recommended. The instream flow presumptive standards in Table C-1 and the fish periodicity chart for Mission Creek in Appendix E provide additional detail on how much flow is required and for how long. The off-channel connectivity and riparian needs flows of >100% LT mad are recommended from the last week of April until the first week of July, and the channel maintenance flows of >400% LT mad are required for 1 to 2 days in May or June. A preliminary analysis of Mission Creek data (see Appendix D) provides an example of a potential method for evaluating water allocation impacts on the magnitude, timing, duration and frequency of high flows.

**Setting riffle passage flows**

Riffles represent the shallowest sections in the streams, and as such, can limit fish access to spawning areas if riffles become too shallow to allow fish passage. Reiser and Bjornn (1979) indicate the following as minimum passage depths for fish migrating to spawning areas, and recommend that at least 25% of the wetted channel width meet these minimum depths.

Chinook Salmon	0.24 m
Coho Salmon	0.18 m
Large Trout	0.18 m
Trout	0.12 m

For Okanagan purposes, Kokanee could be considered to have equivalent depth requirements as trout, and Sockeye Salmon would be similar to large trout and Coho Salmon.

WUW analyses measure depths in riffles over a range of flows and can be used to calculate 25th percentile depths as per the Reiser and Bjornn (1979) recommendations. Alternately, purpose specific riffle transects could be measured for this purpose, and could be included as part of the spatial mapping and ranking of habitats. Finally, these estimates could be used in conjunction with other factors such as minimum spawning depths and velocities to provide estimates of critically low flows, possibly in conjunction with appropriate one-or two dimensional river models.

The information reported by Reiser and Bjornn (1979) is relatively dated, but is still considered to be valid for general evaluation in the Okanagan. However, if available, stream specific spawner enumeration data could be compared to daily flow data to provide more definitive fish passage flows for Okanagan streams.

## 6 Implementation Steps and Relevant Information for Tributaries

Appendix E presents fish periodicity and HSI information relevant for all Okanagan tributaries. Appendices F through X present tributary-specific information for each of the 19 tributaries included in the present study. Each of these Appendices includes a comprehensive list of literature relevant to EFN-setting in that tributary, and a brief summary of information on hydrology, water use, and fish and aquatic habitat. Table 6-1 identifies the information that is available for each of the 19 selected tributaries.

Two high-level processes must be completed to customize and apply the recommend method(s) to the 19 Okanagan tributaries included in this study. The first process is to determine the most appropriate approach to use for the tributary (i.e., Okanagan Tennant alone or Okanagan Tennant followed by Okanagan WUW). The second process is to assemble and review the information available for the tributary and develop additional decision-making tools required to implement the method(s).

### 6.1 DETERMINING THE MOST APPROPRIATE EFN-SETTING APPROACH

A decision on the most appropriate approach to EFN-setting for each tributary should be made by the Expert and/or Advisory panels discussed in Section 3.1. Possible criteria that could be used to determine the method include:

- The number and volume of current licences to extract water for offstream use (i.e. to provide water for domestic, irrigation, or other purposes);
- The volume of storage (both licensed and in place) to support existing and future offstream allocations;
- The degree of streamflow alteration from natural conditions during critical and non-critical life stage periods (this is related to the above two points);
- The conservation status of resident and anadromous species currently, historically, or potentially present;
- The current level of habitat alteration and the potential to improve current habitat conditions;
- The current availability of habitat at a stream reach scale;
- The productivity of the system, and the relative importance of a watershed to maintenance of fish populations;
- Factors that are known to, or are likely to affect key life history stages and act as population level bottlenecks (i.e., if spawning habitat is considered a population limiting factor due to habitat alteration, then we should know where fish spawn, and how much habitat is available, with EFNs set based upon those key habitat areas because they are considered critical to maintenance of the population);
- Current and anticipated pressures on the water supply system; and
- The potential or known role of the stream in supporting meta-populations of Okanagan fish (i.e. its relevance in supporting fish in nearby tributaries).

**Table 6-1**  
**Summary of information relevant to EFN-setting in the 19 selected tributaries**

Tributary Name	Stream-specific Habitat Suitability Index	Sensitive Habitat Inventory and Mapping (SHIM)	Hydrometric Data		Stream-specific Fish Periodicity	Included in a Water Use Plan	Upstream Storage/ Flow Regulation	Previous EFN Investigations			
			Active Records	Historic Records				B.C.-Modified Tennant	BCIFN	WUW	Other
Coldstream Creek		✓	✓	✓			✓				✓
Equesis Creek				✓			✓	✓	✓		✓
Inkaneep Creek			✓	✓			✓		✓		✓
McDougall Creek		✓		✓			✓		✓		
McLean Creek				✓							
Mill Creek		✓		✓			✓	✓	✓		✓
Mission Creek		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Naramata Creek							✓	✓	✓		
Naswhito Creek				✓				✓	✓		✓
Penticton Creek			✓	✓			✓	✓	✓		✓
Powers Creek		✓		✓	✓		✓	✓	✓	✓	✓
Shingle Creek			✓	✓			✓		✓		✓
Shorts Creek				✓				✓	✓		✓
Shuttleworth Creek				✓					✓		
Trepanier Creek		✓	✓	✓	✓		✓	✓	✓	✓	✓
Trout Creek			✓	✓	✓	✓	✓	✓	✓	✓	✓
Vaseux Creek		✓	✓	✓					✓		
Vernon Creek		✓	✓	✓	✓		✓	✓	✓	✓	✓
Whiteman Creek			✓	✓				✓	✓		✓

nhc (2001) assessed the sensitivity of 21 selected Okanagan tributaries using indices to express the level of human activity within a watershed, as well as indices to express the state of a stream and its ability to resist change. These indices included a review of residual streamflows compared to conservation streamflows, summer and winter water demands and 7-day low flows, peak flows, forest harvesting, and watershed urbanization. Therefore, in addition to the criteria noted above, it is suggested that the Expert and/or Advisory panels consider using criteria from nhc (2001) to guide the determination of the EFN-setting method for the tributaries identified herein.

### 6.2 ASSEMBLING AND REVIEWING AVAILABLE INFORMATION AND DEVELOPING ADDITIONAL DECISION-MAKING TOOLS

Once the appropriate method for EFN-setting has been chosen, available information must be assembled and reviewed, and additional information must be collected or prepared to support implementation. The literature summary tables and other information developed for each of the 19 streams highlighted in Appendices F through X should be used to guide this process.

The following sections outline the steps to follow for the application of the Okanagan Tennant method and the Okanagan WUW method.

#### 6.2.1 Okanagan Tennant Method

For application of the Okanagan Tennant method, the information needed, and the steps to follow, are outlined in Figure 6-1 and below:

1. Define area and reach(es) of interest.
2. Conduct a literature review using the literature summary tables provided in Appendices F through X (focus on streamflow, water use, habitat alteration, fish species and life stages, fish habitat, and previous EFN-setting work) to determine what information is available for the tributary. Assemble available information.
3. Adopt fish periodicity chart for species / life stages of Interest (Appendix E).
4. Calculate naturalized long term mean annual discharge (LT mad).
5. Choose time steps (default to monthly from August to March and weekly from April to July) but consider other potentially relevant time steps based on data availability, flow variation and duration of environmental needs.
6. Review Instream Presumptive Flow Standards (Appendix C).
7. Set EFNs as % LT mad for applicable time periods, using fish periodicity and presumptive instream flow standards.

8. Convert EFN flows as % LT mad to flows as m<sup>3</sup>/s using the LT mad value for the point of interest.
9. Confirm applicability of presumptive flow standard based targets by comparing EFNs to fish, fish habitat and naturalized flow data as available. Modify EFNs if warranted.
10. Create four annual hydrographs for the most downstream point of interest.
  - Naturalized hydrograph (current flows with regulation effects removed)
  - Residual hydrograph (current flows)
  - Licensed hydrograph (flows that would result if all licensed water was used)
  - Proposed diversion hydrograph (Case 3 flows accounting for additional effect of proposed licence[s]). (This hydrograph would be created if the Okanagan Tennant method was being used in response to a water licence application.)
11. Calculate percentile flows for each time period for each hydrograph.
12. Convert percentile flows to % LT mad using the LT mad value for the point of interest.
13. Compare EFNs derived with the presumptive instream flow standards to percentile flows using hydrograph 1 (naturalized). Median monthly (or weekly) flows as EFN are recommended as an alternative to presumptive standards to customize EFN to each stream for non-freshet months, when median flows are less than the presumptive standards.
14. Compare EFNs to fish and fish habitat data and any historic EFN work to further confirm applicability of EFN presumptive standard and median flow based standards. Modify EFN values if warranted.
15. Quantify approximate impact of existing water use diversions on habitat by comparing hydrograph 2 (residual) percentile flows as % LT mad to percentile naturalized flows on hydrograph 1 (naturalized). Impact to habitat is not linear, but impact can be approximated by direct comparison of naturalized and residual percentile flows below the base EFNs. Two comparisons are recommended. First compare the percentage of residual flow vs. naturalized flow as % LT mad at each percentile for an approximation of the percent reduction in habitat. Second compare the residual vs naturalized percentile flows to determine which percentile naturalized flow the residual flow corresponds to (e.g., the P40 residual flow could now compare to the P30 or P20 naturalized flow) to demonstrate the shift in hydrograph after existing water diversions. Similar flows at similar percentiles indicate little impact. Significant differences between percentile flows indicate a much greater frequency of lower flows.
16. Repeat impact approximation by comparing hydrograph 3 (licensed) percentile flows which account for any unused licenced allocation not reflected in the current use to hydrographs 1 (naturalized) and 2 (residual). Unused allocation can be very significant as Okanagan water utilities often use less than 50% of allocation.

## 6 - Implementation Steps and Relevant Information for Tributaries

17. Repeat impact approximation by comparing hydrograph 4 (proposed diversion) percentile flows which account for additional allocation under consideration to licenced allocation not reflected in the current use to hydrographs 1 (naturalized), 2 (residual), and 3 (licensed).
18. Consider usefulness of short duration higher flows, and amend EFNs or provide technical advice on the potential inclusion of short duration higher flows into the managed flow regime.
19. Since the method will be used proactively (i.e., in advance of future applications for water diversions), provide technical guidance on the consequences of future flow reductions.
20. Before finalizing the Okanagan Tennant recommendations, review the “considerations for EFN-setting” provided in Section 5.2 of this report to determine if any final adjustment of the recommended values is warranted, and document the reasons for making any adjustments.



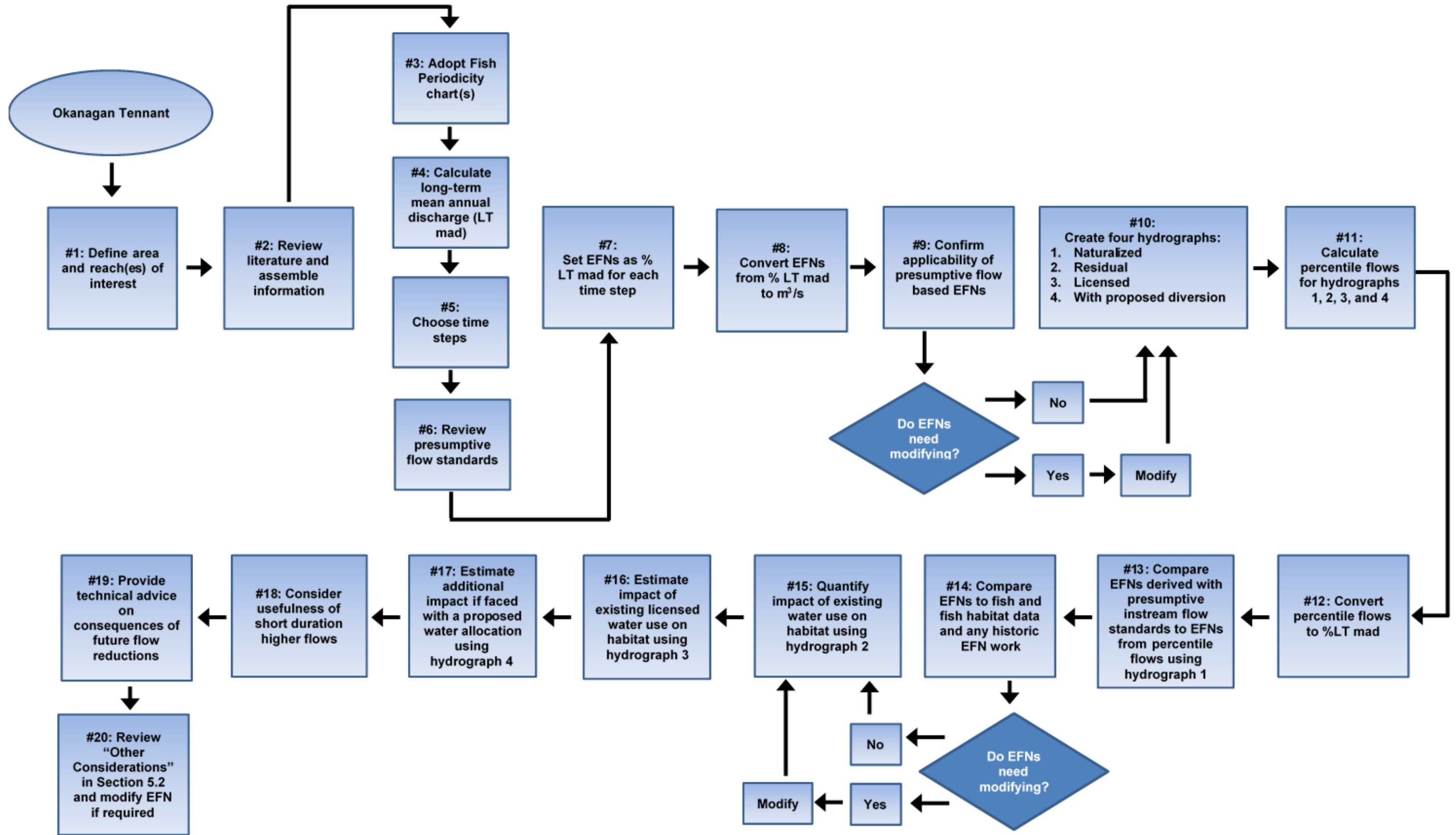


Figure 6-1  
Okanagan Tennant Implementation Steps

## 6 - Implementation Steps and Relevant Information for Tributaries

### Streamflow Naturalization Process:

This section summarizes the methods required to produce streamflow estimates to support the recommended EFN-setting methods for Okanagan tributaries. The required streamflow estimates are as follows:

- Case 1: Naturalized hydrograph (current flows with effects of flow regulation removed)
- Case 2: Residual hydrograph (current flows that reflect flow regulation);
- Case 3: Licensed hydrograph (flows under condition of maximum licensed water use); and
- Case 4: Proposed diversion hydrograph (Case 3 flows accounting for a future proposed water use).

If streamflows are natural (i.e. there is no water storage or withdrawal), Case 1 is the same as Case 2. Most Okanagan flow records are “Case 2” records. Case 4 streamflows would only be developed in a reactive EFN-setting exercise (i.e., one in which the EFN was being established in response to a licence application).

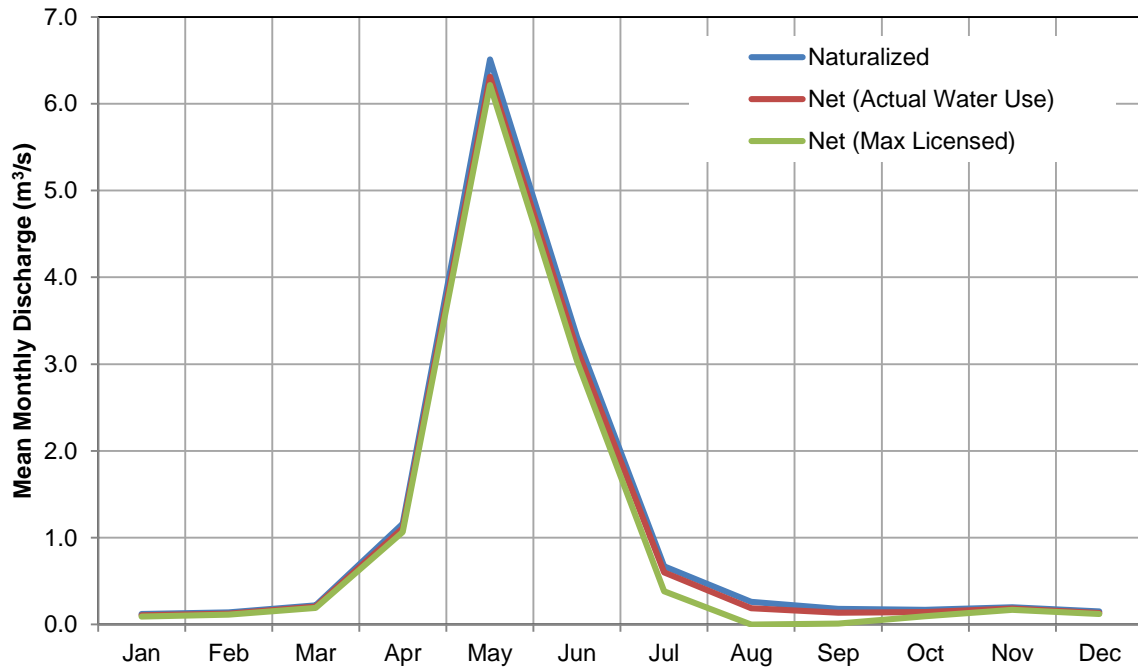
The steps to develop the streamflow estimates for the four cases identified above will depend on available streamflow records and their proximity to the EFN point-of-interest, available water use and management information, and the standard period and time-step required. As a result, EFN-setting exercises may vary between watersheds based on the information that is available.

The general steps to produce the required streamflow estimates are as follows:

- Assemble and evaluate available streamflow records for the target watershed, and select a standard period (e.g. the 1981-2010 climate normal period) for the analysis.
- Identify the location(s) within the watershed where streamflow records are available and identify the point(s)-of-interest where the EFN(s) will be defined.
- Ascertain whether the available streamflow records represent Case 1 or Case 2 conditions.
- Obtain current water use and water management information from previous studies or water purveyors; and obtain water license information from previous studies or the provincial government.
- Systematically review, fill data gaps, and/or scale available streamflow records to the respective EFN point(s)-of-interest as required for the respective time-steps (e.g. monthly for most of the year and weekly for April – July) outlined by the recommended EFN-setting methods (Section 5).
- Case 1: If natural streamflow records are not available, naturalize available net streamflow records (i.e. naturalize existing Case 2 streamflows) by accounting for water held or released from storage, and for water withdrawn and returned upstream of the respective EFN point(s)-of-interest. A consistent time-step (e.g. daily, weekly, monthly) is required between net streamflows and water use in order to naturalize streamflows.
- Case 3: Estimate net streamflows based on licensed use; using naturalized streamflows and the licensed storage and withdrawal quantities (considering storage and the timing of the licensed use) within the watershed. Distribute the total annual licensed quantities into required intervals (i.e. monthly, weekly, daily) using available water use information or assumed water use distributions (e.g. stockwatering water licensed use is evenly distributed throughout the year).
- Case 4: Estimate net streamflows for a future water use case of existing plus proposed licensed quantities. Obtain estimates of future proposed licensed use from the provincial government using

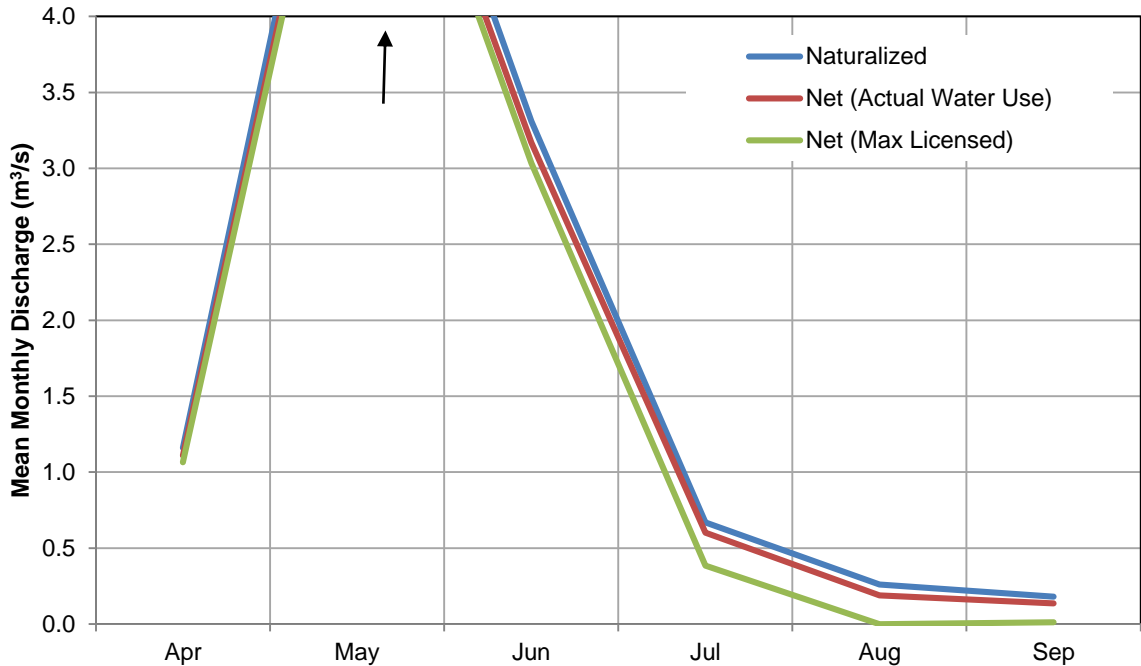
water license applications deemed to be under review or pending. Distribute the proposed licensed quantities into required intervals (i.e. monthly, weekly, daily) using available water use information or assumed water use distributions.

Example hydrographs of selected streamflow estimates to support the EFN-setting methods for Okanagan tributaries are provided in Figures 6-2 and 6-3.



**Figure 6-2**  
**Mean monthly discharge for Trepanier Creek at the mouth for 2003 (January to December) under naturalized and net (actual and licensed water use) streamflows (adapted from Summit [2004])**

## 6 - Implementation Steps and Relevant Information for Tributaries



**Figure 6-3**  
**Mean monthly discharge for Trepanier Creek at the mouth for 2003 during the irrigation season (April to September) under naturalized and net (actual and licensed water use) streamflows (adapted from Summit [2004])**

### 6.2.2 Okanagan WUW Method

The information needed and the steps to follow to complete the Okanagan WUW method are outlined in Figure 6-4. Some of these steps will have been completed during development of the Okanagan Tennant method estimates. The steps are as follows:

1. Complete Okanagan Tennant method to set base EFN for stream.
2. Define area and reach(es) of interest for more detailed habitat evaluation.
  - high value downstream reaches must be included to ensure that upstream EFN modifications following WUW do not compromise downstream values.
3. Confirm species and life stages of interest.
4. Assemble available information:
  - fish habitat assessments and SHIM data to document and rank habitat value to place transects at appropriate locations. Information to consider:
    - Fish spawning and / or rearing locations for species of interest.
    - Suitability of HSI tables / curves for species and life stages of interest.

5. Define the flow range of interest (e.g., critical environmental flow threshold at zero to median flow at one, or some other minimum and maximum for the month(s) or week(s) of interest). The critical EFN threshold (the index zero) will be based upon background information, implementation, and consideration of risks, with a default of 5% LT mad. The zero point for the index is intended to represent a point below which catastrophic consequences to fish populations may occur.
6. Determine field intensity level.
  - The level of effort to devote to field work is a function of risk tolerance, complexity of the system, fish species and life stages of importance, potential for restoration and / or level of historical anthropogenic alteration, and other factors. This consideration will influence the number of stream reaches and the number and locations of transects to use.
7. Select and pin transect locations.
  - use available information to select appropriate reaches.
  - locate transects in glides for spawning WUW.
  - locate transects in riffles for rearing WUW.
  - pin (e.g., nail in tree, anchor bolt in rock) the ends of each transect so that all measurements are repeated on the exact same cross-section.
  - survey locations to facilitate future development of flow models.
  - If possible, incorporate hydrometric stations for one field season to develop flow / channel morphology relationships.
8. Measure depths and velocities at each transect over a range of flows.
  - >20 verticals evenly spaced over wetted width.
  - photograph transect from upstream, downstream, and cross-section views.
  - ensure velocity meter used to measure verticals is appropriate for shallow depths and measurements in riffles.
  - repeat transect measurements 8 to 10 times over a range of flows from minimum to >100% LT mad if possible.
9. Obtain other field data as required to understand factors controlling aquatic populations.
10. Ensure applicable HSI curve(s) is (are) available.
11. Enter width, depth and velocity data into Excel template workbook or consider development of computer program using R (or other suitable alternative) to automate process. Process as follows:
  - template is constructed to carry out all basic WUW calculations, with data summaries and basic charts.
  - template also plots wetted width, mean depth, and mean velocity vs. flows. Useful for confirming glide / riffle hydraulic geometry, and understanding the WUW results.
12. Define the WUW vs. flow relationship for each applicable species / life stage.
  - If multiple transects for same species / life stage, results can be combined for average, and/or compared to demonstrate similarities and variances.

## 6 - Implementation Steps and Relevant Information for Tributaries

- derive formula for each WUW curve using appropriate statistics, likely in a nonlinear regression, with appropriate error measurements.
13. Compare Okanagan Tennant method EFN targets to the WUW results to fine tune EFNs. WUW results are:
- useful for showing the WUW changes over the entire range of flows, including optimal flow.
  - optimal WUW will generally occur at flows that are higher than median flow during the rearing and spawning periods.
  - inflection point on the curve can be used to suggest EFN target, but WUW curves do not implicitly define an EFN value.
  - greatest value is demonstrating how WUW (habitat quantity) changes with flow.
  - comparing Okanagan Tennant method EFN targets to the WUW results will show where the Tennant targets occur on the curve, and can be used as an indicator of whether or not the Okanagan Tennant method targets could/should be fine-tuned.
14. Convert WUW to index values by using the WUW formula to calculate WUW values for each percentile flow over the range of interest on the 4 hydrographs. WUW for minimum flow in the range of interest on hydrograph 1 (naturalized) defines 0 for the index, and WUW for maximum flow in the range of interest on hydrograph 1 (naturalized) defines 1. All other WUW values, including those for the other hydrographs are scaled according to naturalized hydrograph 0 and 1 values.
- a. Convert WUW to Index values over the range of interest using hydrograph 1 (naturalized).
  - b. Convert WUW to Index values over the range of interest using hydrograph 2 (residual).
  - c. Convert WUW to Index values over the range of interest using hydrograph 3 (licensed)
  - d. Convert WUW to Index values over the range of interest using hydrograph 4 (proposed diversion).
15. Plot index values against percentile flows to generate a series of WUW Index curves. Several series may need to be plotted when the life stages span several months as both natural flows and water use can vary significantly from month to month.
- a. Plot index values over range of interest using hydrograph 1 (naturalized).
  - b. Plot index values over range of interest using hydrograph 2 (residual).
  - c. Plot index values over range of interest using hydrograph 3 (licensed).
  - d. Plot index values over range of interest using hydrograph 4 (proposed diversion).
16. Provide technical advice on consequences of future flow reductions.
- the naturalized flow index demonstrates how habitat quantity varies within the natural range of flows, and with the percentiles indicating the frequency of the lower natural flows and reduced habitat.
  - comparing index values at each percentile demonstrates the reduction in habitat that is already occurring (residual index values) and the further reduction that will occur if additional water is allocated as per the unused licensing and additional allocation scenario(s).
  - comparing index values across the lines indicates the changes in percentiles that occur due to existing and proposed water use. The shift to lower percentiles approximates the decreasing return frequency of the naturalized flows.

- index comparison for naturalized, residual, and additional water use flows quantifies both the percentage of habitat reduction due to lower flows over the range of natural flow variation, and the decreasing return frequency of habitat quantities due to water allocation. Levels of acceptable change could be, but as yet have not been defined

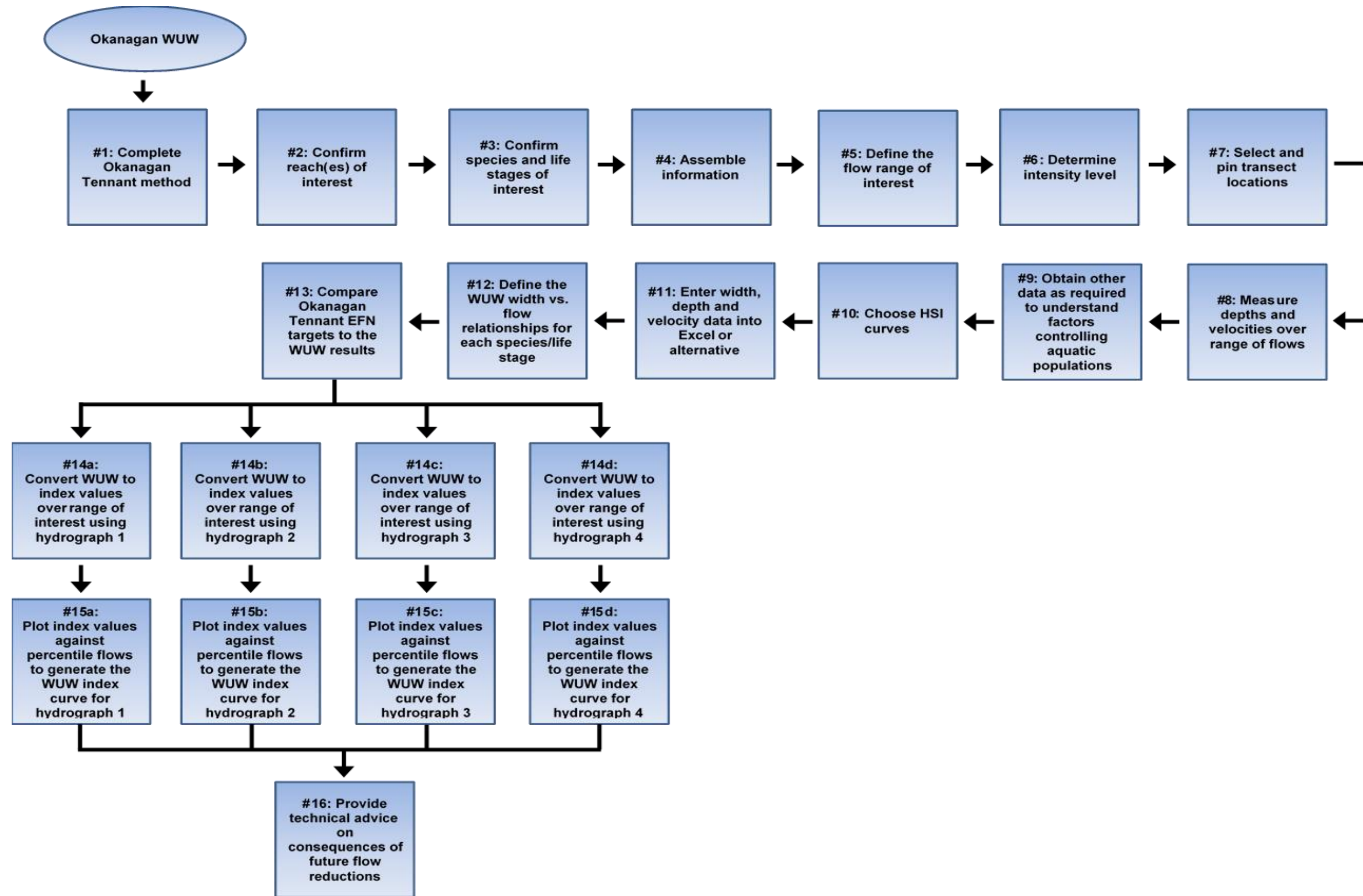


Figure 6-4  
Okanagan WUW Implementation Steps



## 7 Further Studies to Enhance the Okanagan Tennant and Okanagan WUW Methods

Before widespread adoption of the methods outlined in this report occurs, we recommend that the proponents (OBWB, ONA, and FLNRO) complete a demonstration project. The purpose of this demonstration project would be to apply the EFN-setting methods outlined herein on a selection of Okanagan streams, carefully document the steps taken, recommend process improvements, and issue a revised version of this document.

Other future investigations are recommended below, intended to improve the methods over time as new data is collected as part of an adaptive EFN-setting strategy. None of these future studies must be completed before the methods proposed herein are adopted.

Recommended future studies, listed approximately in order of importance and urgency, include:

- Develop a set of HSI curves for Sockeye Salmon, as HSI curves for B.C. for this species have not previously been developed.
- Conduct additional research for each stream to determine time-varying critical environmental flow thresholds that will meet the definition contained in the *Water Sustainability Act*, and provide the intended level of protection for each stream.
- Assess the frequency, magnitude, and duration of high flows needed to sustain ecological function in Okanagan streams, and the implications of not meeting these flows. This work would help to set EFNs and fine-tune the April through July EFN flow regimes recommended herein.
- Determine the benefits to the aquatic environment of periodically achieving flows that exceed default EFN flows, with a view to considering a future amendment of the methods outlined herein to incorporate such periodic higher flows into the EFN flow regime.
- Although existing B.C. standard HSI curves are considered relevant to the Okanagan, further study would be required to confirm their relevance. Given the degree of streamflow changes during the spring reservoir filling phase, and the potential for impacts to Rainbow Trout migration, spawning and incubation, improved knowledge of specific flow needs during this time would be beneficial. There are also considerable variations in the size of spring spawners from stream resident Rainbow Trout, to adfluvial Rainbow Trout and Steelhead Trout which should be considered.
- Develop a procedure to quantify the impacts / risks to fish and fish habitat associated with shifting the hydrograph such that lower flows occur with greater frequency (e.g., natural P5 or P10 flows correspond to higher percentile [e.g. P25] residual flows). The procedure could be based on correlating existing meso-habitat scale fish population and habitat data with hydrometric data to scale percentile flows from those that demonstrate population success to failure. Empirical data on actual fish movements using fence counts, radio telemetry, and stream walk information could also be correlated with hydrometric data to scale percentile flows for fish passage.
- Ongoing climate change may increase summer water temperatures in Okanagan streams, and the *Water Sustainability Act* recognizes that water temperature may become a limiting factor for fish. Additional study is required to enable quantitative consideration of this factor in water management decisions.

- Assess the methods currently used for detailed habitat characterization (e.g., Hawes et al. 2011; Lewis et al. 2004) and select and field-test the most appropriate method(s) for use in describing habitat in Okanagan tributaries to allow for a spatial assessment of relative habitat value and ensure site selection occurs at the most important locations.
- Explore the potential to employ Bayesian approaches or fuzzy logic to enhance our understanding of habitat-flow relationship within Okanagan streams in EFN determination.
- Assess the potential to leverage geomorphic similarities between Okanagan streams, with a view to reducing the level of field effort needed in stream reaches that are sufficiently similar to stream reaches that have been previously investigated.
- Because climate change, population growth, and other factors are influencing both water supply and water use, we recommend periodic re-evaluation of recommended EFNs to reflect updated knowledge of natural flow regimes, residual flow regimes, and licensed flow regimes, and of species' ability to adapt to these changes. Depending on the rate of change of these governing factors, the interval between re-evaluations could range from 5 to 20 years.
- Following adoption of EFN flow regimes, it is suggested that the outcomes be monitored to assess their effectiveness at protecting the aquatic ecosystem. Clear evaluation criteria should be developed for this purpose. The EFN flow regime should be re-evaluated following any investigation that determines that the recommend flows are not adequately protecting the aquatic environment.

## 8 Conclusions and Recommendations

This study is Phase 1 of an EFN-setting program for Okanagan tributaries. It was led by three key Okanagan organizations: OBWB, ONA, and FLNRO, and was conducted by an experienced consulting team of Okanagan-based professionals. Its objective was to recommend robust methods for determining EFNs in Okanagan tributaries. EFN-setting work in specific tributaries will be completed during future phases of the Okanagan EFN project.

By building on previously successful approaches and incorporating some innovative ideas, two EFN-setting methods were recommended by the consulting team. Amongst other attributes, the proposed methods will enable development of an EFN flow regime that meets the requirements of the *Water Sustainability Act*. Following initial development of the methods, review and comment was sought from a large and diverse group of individuals external to the consulting team; and the methods ultimately recommended herein are now believed to be broadly acceptable to key Okanagan water management organizations. Accordingly, the objectives of the study have been achieved.

For lower risk EFN-setting situations, the study recommends use of a desktop method termed the Okanagan Tennant method. For higher risk situations (such as for water allocation decision-making), the study recommends use of the Okanagan Tennant method followed by the field-based Okanagan Weighted Useable Width (WUW) method. Both the Okanagan Tennant method and the Okanagan WUW method are based on previously proven methods, with value-added refinements. The Okanagan WUW method does not prescribe a particular level of field intensity, but instead allows flexibility as a function of risk tolerance and other factors.

It is recommended that the study proponents (OBWB, ONA, and FLNRO) complete an evaluation of the EFN-setting methods recommended herein on two or three Okanagan tributaries, and refine them as necessary following the evaluation.

Several other recommendations for improving the methods are outlined in Section 7 of the report, and not repeated here.

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