FINAL REPORT

Okanagan Basin Water Board

Streamflow Datasets to Support the Application of the Okanagan Tennant Methods in Priority Okanagan Streams

September 2019

Associated Environmental

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Nelson Jatel, P.Ag.
Water Stewardship Director
Okanagan Basin Water Board
1450 KLO Rd.
Kelowna, BC V1W 3Z4

Re: FINAL REPORT - STREAMFLOW DATASETS TO SUPPORT THE APPLICATION OF THE OKANAGAN TENNANT METHOD IN PRIORITY OKANAGAN STREAMS

Dear Mr. Jatel:

Associated Environmental Consultants Inc. is pleased to provide this final report summarizing the methods and results of the streamflow datasets needed to support the application of the Okanagan Tennant method in 18 Okanagan tributaries. The datasets outlined within this report have been provided to the Okanagan Nation Alliance to use within the Okanagan Tennant method and to support setting environment flow needs within the respective tributaries.

If you have any questions, please contact the undersigned or Drew Lejbak at 250-826-9486.

Yours truly,
Associated Environmental Consultants Inc.

Drew Lejbak, M.Sc., M.Sc.
Senior Hydrologist

Reviewed by:

Paul Hague, B.Sc., RPF
Manager, Water and Earth Sciences

Acknowledgements

This report was completed by Associated Environmental Consultants Inc. (Associated) in partnership with Polar Geoscience Ltd. (Polar). The work was carried out under contract with the Okanagan Basin Water Board and BC Ministry of Forests, Lands, Natural Resource Operations, and Rural Development.

All analyses and conclusions remain the sole responsibility of Associated.

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Glossary

ALUI	Agriculture Land Use Inventory
BMID	Black Mountain Irrigation District
COP	City of Penticton
DOP	District of Peachland
EFN	Environmental Flow Needs
EFN point-of-interest	The location where streamflows are estimated for establishing EFNs (i.e., the furthest downstream EFN transect). This point-of-interest considers groundwater – surface water interaction across an alluvial fan between the apex of the alluvial fan and the furthest downstream EFN transect.
FLNRORD	BC Ministry of Forests, Lands, Natural Resource Operations, and Rural Development
GIS	Geographic Information System
GW/SW	Groundwater – surface water
LT mad	Long-term mean annual discharge
Maximum Licensed LT mad	Long-term mean annual discharge under maximum licensed streamflow conditions
Naturalized LT mad	Long-term mean annual discharge under naturalized streamflow conditions
OBWB	Okanagan Basin Water Board
OKIB	Okanagan Indian Band
ONA	Okanagan Nation Alliance
OWDM	Okanagan Water Demand Model
OWSDP	Okanagan Water Supply and Demand Project
RDOS	Regional District of Okanagan-Similkameen
Residual LT mad	Long-term mean annual discharge under residual streamflow conditions
SEKID	Southeast Kelowna Irrigation District
Streamflow point-of-interest	The location where streamflows are estimated (i.e., apex of alluvial fan). This point-of-interest does not consider groundwater – surface water interaction across an alluvial fan.
WSC	Water Survey of Canada

1 Introduction

1.1 BACKGROUND

As described in the report "Collaborative Development of Methods to Set Environmental Flow Needs in Okanagan Streams" (Associated 2016), the Okanagan Tennant method is the recommended method for setting initial environmental flow need (EFN) targets for streams in the Okanagan Basin. The Okanagan Tennant method is a desktop assessment involving several steps, which provides insight into the risks to aquatic habitat and ecological processes from existing and proposed water allocations relative to natural or naturalized flows. The specific steps of the Okanagan Tennant method are summarized in Figure 1-1.

Three of the steps in the Okanagan Tennant method require the compilation of specific streamflow datasets or statistics (Figure 1-1):

- Step 4 requires identification of the naturalized long-term mean annual discharge (LT mad).
- Step 10 requires identification of the annual hydrographs under three scenarios[1]:
    1. Naturalized (or natural) streamflow.
    2. Residual (or net) streamflow assuming current water withdrawals and management.
    3. Residual (or net) streamflow assuming water withdrawals and management are maximized under existing water licences.
- Step 11 requires the calculation of percentile streamflows (i.e., 50th percentile [median]) for each of the three scenarios noted under Step 10.

Prior to the application of the Okanagan Tennant method to Okanagan streams, the Okanagan Basin Water Board (OBWB) requested that Associated Environmental Consultants Inc. (Associated) assemble and critically evaluate all available streamflow records (i.e., measurements), estimates (i.e., modelled flows), and relevant reports, and provide tributary-specific recommendations for the development of the streamflow datasets required to complete Steps 4, 10, and 11. That assessment was completed by Associated (2017) and outlined a general approach for the development of streamflow datasets required to set EFNs in Okanagan tributaries using the Okanagan Tennant method; and provided specific steps for the development of streamflow datasets for 18 tributaries[2]. The recommended general and specific tributary approaches were reviewed and accepted by the OBWB, the Okanagan Nation Alliance (ONA), and the BC Ministry of Forests, Lands, Natural Resource Operations, and Rural Development (FLNRORD).

Subsequently, the OBWB and FLNRORD requested the development of streamflow datasets for the 18 Okanagan tributaries to support the application of the Okanagan Tennant method. This document is the final report presenting the streamflow datasets created for these tributaries, and the supporting methods used to create the datasets.

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[1] A fourth hydrograph is also required when assessing the impacts from a proposed diversion under a new water licence application. It is not identified here, since this hydrograph is to be completed by water authorization officers at a later date when assessing new applications for water licences.

[2] The 18 tributaries are Coldstream, Equesis, Inkaneep, McDougall, McLean, Mill (Kelowna), Mission, Naramata, Naswhito, Penticton, Powers, Shingle, Shorts, Shuttleworth, Trepanier, Trout, Vaseux, and Whiteman Creeks.

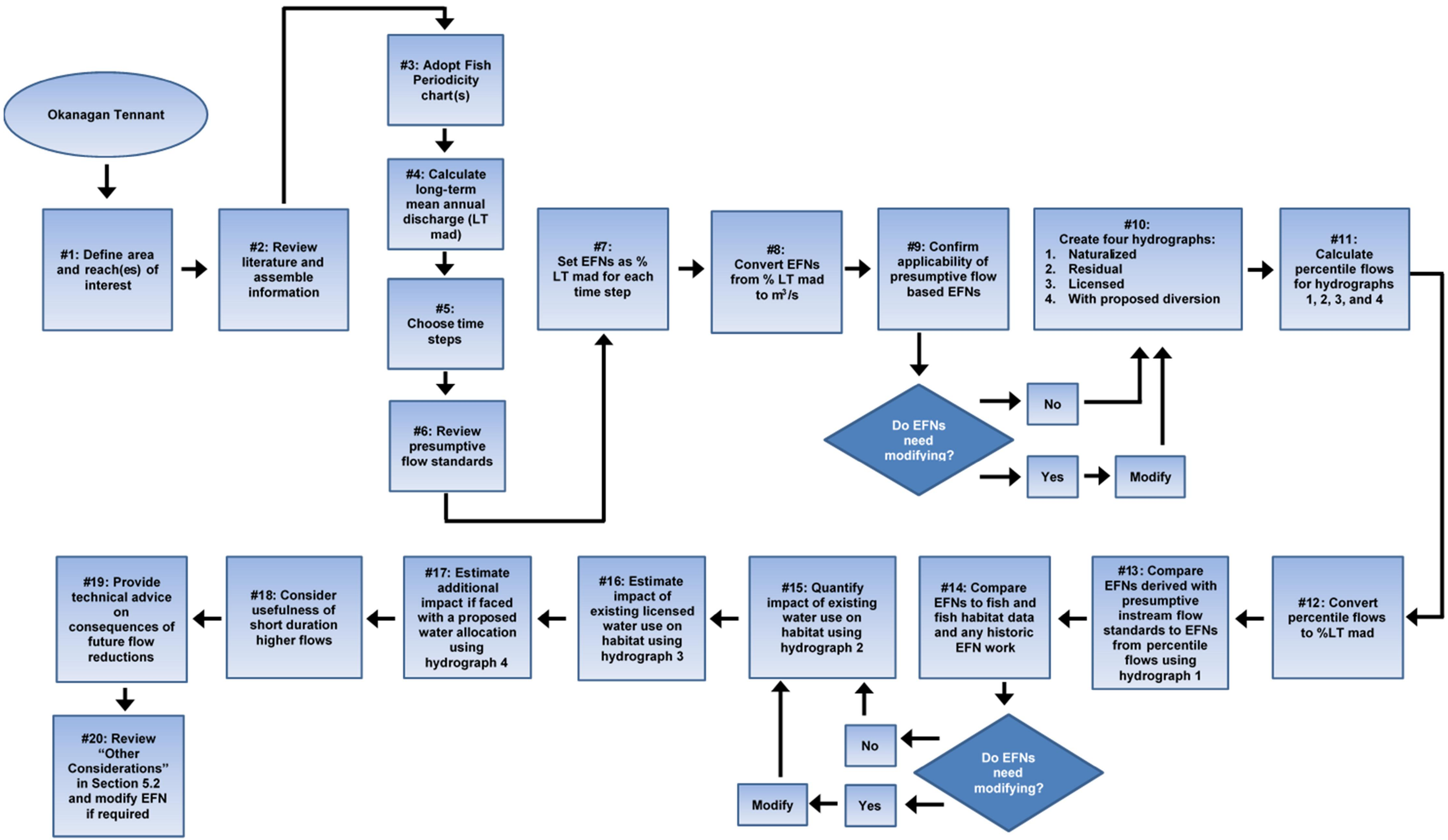


Figure 1-1 Okanagan Tennant method implementation steps (from Associated 2016)

1.2 OBJECTIVES

The scope of this project is to develop the necessary streamflow datasets for 18 Okanagan tributaries to support the application of the Okanagan Tennant method. As outlined by Associated (2017), the standard period for dataset development is 1996-2010 (n = 15 years).

The specific streamflow datasets to be developed for the 18 Okanagan tributaries for the standard period are as follows:

- naturalized long-term mean annual discharge (LT mad);
- mean weekly time-series of naturalized (or natural) streamflow (i.e., streamflow in the absence of any regulation[3]);
- mean weekly time-series of streamflow under current water use and management (i.e., residual streamflow);
- mean weekly time-series of streamflow assuming maximization of licensed storage and withdrawals (i.e., maximum licensed residual streamflow);
- summer (i.e., July 1 to September 30) 30-day low natural and residual streamflows under 1:2, 1:5, 1:10, and 1:20-year return periods; and
- winter (i.e., November 1 to March 31) 30-day low natural and residual streamflows under 1:2, 1:5, 1:10, and 1:20-year return periods.

The overall application of the Okanagan Tennant method is being completed by the ONA. Therefore, the calculation of respective percentile values (i.e., Figure 1-1 – Step 11) and the use/application of the respective streamflow datasets for Okanagan Tennant method purposes is outside the scope of this project.

Also, it is noted that based on discussions with the OBWB, ONA, FLNRORD in February 2019, the application of the Okanagan Tennant method by ONA will only require naturalized streamflows, while residual and maximum licensed streamflows will only be needed under selected cases. Therefore, for reporting herein, Associated has developed only the datasets needed by ONA for each tributary.

1.3 GEOGRAPHIC EXTENT

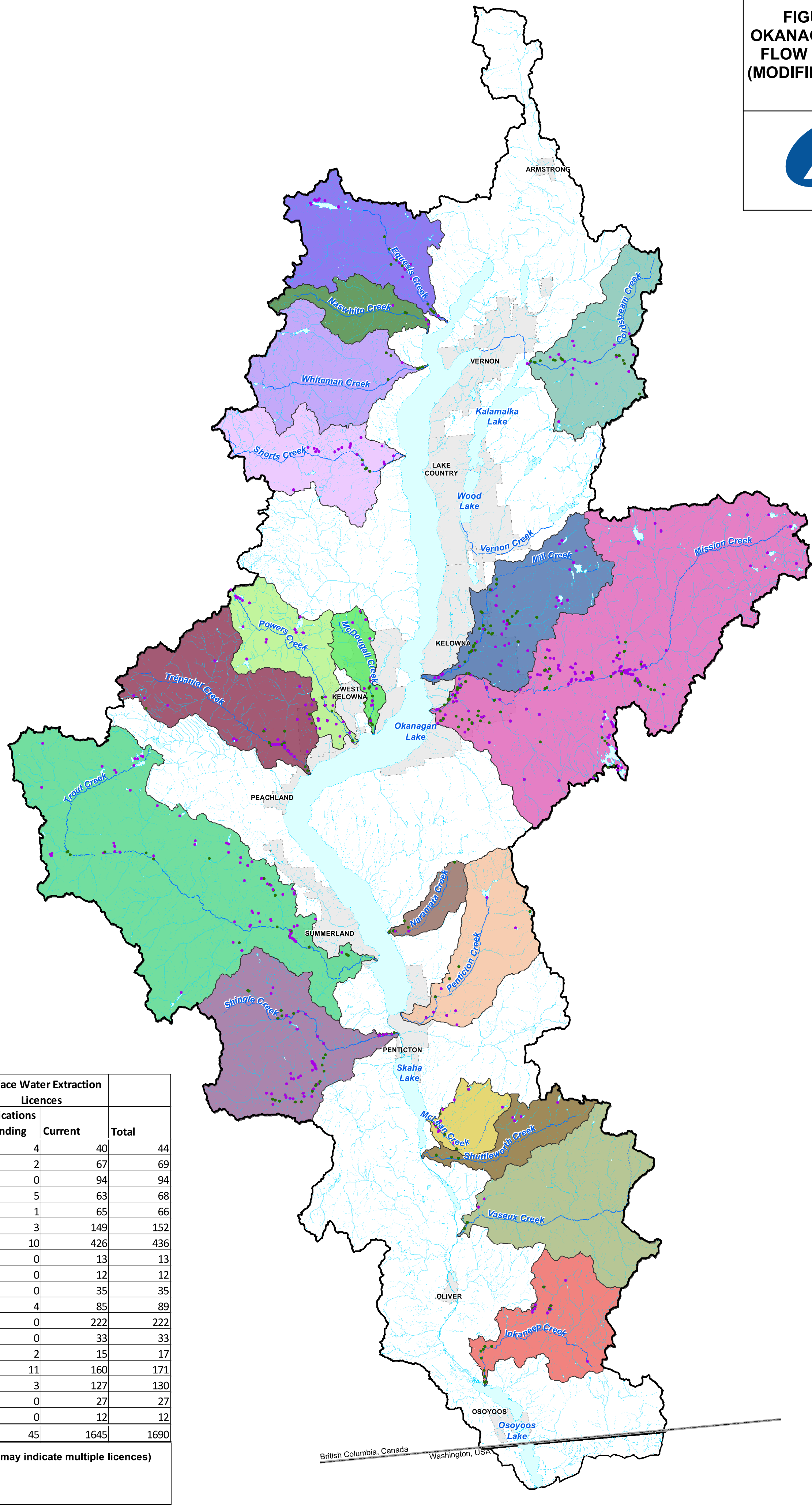
The 18 Okanagan tributaries are highlighted in Figure 1-2, and individual maps identifying the specific characteristics of each watershed are provided in respective sections within Section 3.

[3] The term *regulation* is used to describe any human influence on streamflow (e.g., water extraction, water diversion, and/or reservoir storage).

FIGURE 1-2: PRIORITY OKANAGAN ENVIRONMENTAL FLOW NEEDS TRIBUTARIES (MODIFIED FROM ASSOCIATED [2016])

Associated Environmental

Map produced by: BdJ
April 2017



Subbasin	Surface Water Extraction Licences: Applications & Pending	Current	Total
Coldstream Creek	4	40	44
Equesis Creek	2	67	69
Inkaneep Creek	0	94	94
McDougall Creek	5	63	68
McLean Creek	1	65	66
Mill Creek	3	149	152
Mission Creek	10	426	436
Naramata Creek	0	13	13
Naswhito Creek	0	12	12
Penticton Creek	0	35	35
Powers Creek	4	85	89
Shingle Creek	0	222	222
Shorts Creek	0	33	33
Shuttleworth Creek	2	15	17
Trepanier Creek	11	160	171
Trout Creek	3	127	130
Vaseux Creek	0	27	27
Whiteman Creek	0	12	12
Grand Total	45	1645	1690

Water licence points of diversion (may indicate multiple licences)

- Irrigation Use
- Other Use

1.4 STREAMFLOW DATASET POINTS-OF-INTEREST

Associated (2016) indicates that the point-of-interest for streamflow datasets used to support the Okanagan Tennant method is the location of the lowermost EFN transect (if established). However, since many Okanagan tributaries have well-defined alluvial fans, Associated (2017) recommended that the apex of the alluvial fan be considered as the streamflow point-of-interest for dataset development since (depending on stream and aquifer characteristics, as well as time of year), downstream of the apex there is a potential for streamflow gain or loss. Such gains and losses are stream-specific and have generally not been well quantified. Nevertheless, with knowledge of runoff generated within the drainage area upstream of the alluvial fan and estimates of the potential gain/loss on the fan, streamflow conditions at the lowermost EFN transect locations (i.e., EFN point-of-interest) can be estimated.

Therefore, for clarification of the points-of-interest terminology used in this document (from this point forward), the following definitions are noted:

- **Streamflow points-of-interest** – The location where streamflows are estimated (i.e., apex of alluvial fan). This point-of-interest does not consider groundwater – surface water interaction across an alluvial fan.
- **EFN points-of-interest** – The location where streamflows are estimated for establishing EFNs (i.e., the furthest downstream EFN transect). This point-of-interest considers groundwater – surface water interaction across an alluvial fan between the apex of the alluvial fan and the furthest downstream EFN transect.

2 Streamflow Dataset Development Methods

This section provides an overview of data sources and the methods used to develop streamflow datasets for the application of the Okanagan Tennant method within the 18 Okanagan tributaries.

2.1 WATERSHED SPECIFIC METHODS – ASSOCIATED (2017)

Associated (2017) outlined detailed methods for the development of streamflow datasets for the 18 Okanagan tributaries. The specific methods recommended for each tributary are provided in their respective tables in Appendix A.

The application of the recommended methods for each watershed are summarized in Sections 3 to 20.

2.2 DATA SOURCES AND HYDROLOGIC SCALING METHODS

2.2.1 Available Datasets

The following data sources (as noted in Appendix A) were used to support the development of streamflow datasets:

- Water Survey of Canada (WSC) hydrometric records;
- Okanagan Water Demand Model[4] (OWDM) output for applicable watershed water use areas;
- Water licence information available from FLNRORD (2018);
- Field hydrometric measurements collected by the ONA at established EFN transects; and
- Drainage areas and median elevations calculated using GIS and publicly available topography and stream network datasets from GeoBC (i.e., BC Freshwater Atlas).

2.2.2 Updated Regional Runoff Relations

As recommended by Associated (2017), provincial regional median elevation runoff relations (i.e., Obedkoff 1998) were updated to the 1996-2010 standard period to support the application of the Okanagan Tennant method. Normal annual runoff relations provide a reference against which independent streamflow estimates (e.g., on a weekly basis) for any given stream can be reconciled. However, it must be noted that the regional median elevation runoff relations were not used herein to specifically calculate LT mad at a streamflow or EFN point-of-interest. Instead, the relation(s) were used to support the scaling of hydrometric records at a WSC hydrometric station located within a watershed or nearby (if available) to a streamflow point-of-interest. The application of this method was used to account for any differences in unit discharge

[4] The OWDM was developed as part of the OWSDP (Summit 2010). The OWDM estimates current and future water demand within the Okanagan Basin for agricultural irrigation, outdoor irrigation (i.e., domestic, municipal, and golf courses), and indoor use (i.e., domestic and industrial-commercial-institutional [ICI]) purposes. The OWDM also includes an estimate of water supply transmission losses (i.e., 5% of total water demand). The OWDM is a modified version of the Agriculture Water Demand Model developed by van der Gulik et al. (2010). The OWDM is based on a Geographic Information System (GIS) database (i.e., Agriculture Land Use Inventory and BC Assessment land parcels). Within the OWDM, the estimated water demands are linked to respective water sources and water suppliers through the delineation of 'water use areas'. These areas match spatial water supplier distribution areas (with private water users grouped as 'other' within a watershed) and provide summaries of total water demand for individual water suppliers (Summit 2010).

relationships that may exist within a hydrologic zone and/or watershed between upper (i.e., headwaters) and lower (i.e., valley bottom) elevations.

A summary of the development of updated provincial regional median elevation runoff relations for hydrologic zones 14 (Northern Columbia Mountains), 15 (Fraser Plateau), 23 (Okanagan Highlands), and 24 (South Thompson Plateau) is provided in Appendix B.

Note that as part of the development of the updated regional runoff relations, gridded precipitation information for the spatial extent of the regional WSC hydrometric station watershed areas was also obtained to calculate a mean annual precipitation for the 1996-2010 standard period. The mean annual precipitation was plotted against mean annual runoff for each respective WSC hydrometric station for each hydrologic zone. The results found that there were no significant relationships between mean annual precipitation and runoff within respective hydrologic zones. As a result, no specific precipitation runoff relations were developed to support the scaling of hydrometric records within or between watersheds. Instead, runoff:precipitation ratios were used to generally review/confirm scaling factors obtained from the updated regional median elevation runoff relations. A summary of the runoff:precipitation ratios is provided in Appendix B.

2.2.3 Temporal Period Adjustment Factor

For establishing EFNs using the Okanagan Tennant method, Associated (2017) recommended that for the purposes of streamflow dataset development, the 1996-2010 (n = 15 year) period be adopted. This period was recommended because of the lack of information on water management within the Okanagan Basin specifically pertaining to upland reservoir operations prior to 1996. In addition, Agriculture and Agri-Foods Canada noted that the Agricultural Land Use Inventory (ALUI) (that the OWDM uses to support water demand estimates) is insufficient to reflect land use conditions within the Okanagan Basin prior to the mid-1990’s.

However, following review of some initial draft streamflow datasets for some Okanagan Basin tributaries, the ONA expressed concern over the summer streamflow estimates based on the 1996-2010 period. Specifically, the ONA noted that based on historic knowledge, the initial estimates of naturalized streamflows for the summer period (August to September) were suspected to generally underestimate the streamflows experienced in recent historical times that are known to support fish population needs.

Following review of the available long-term data within the Okanagan Basin, it was determined that the 1996-2010 period summer runoff represented a drier period relative to recorded long-term conditions (1971-2014). Thus, the 1971-2014 period was identified to provide an unbiased period of dry and wet climatic and streamflow conditions. However, since Associated (2017) outlined specific methods to develop weekly streamflows for the 1996-2010 period, datasets were still development using those methods, but the resultant streamflow datasets were adjusted to 1971-2014 conditions using weekly ratios (because actual water use information and land use spatial coverages are not generally available prior to the mid-1990s).

The range of mean weekly ratios between the 1971-2014 and 1996-2010 periods were developed for four natural streamflow WSC hydrometric stations located in the Okanagan Basin (i.e., Coldstream, Whiteman, Camp, and Vaseux Creeks). For application purposes, the most appropriate weekly ratios from the individual WSC hydrometric station were applied on a watershed-by-watershed basis (i.e., Whiteman Creek weekly ratios were used to adjust streamflow datasets for Whiteman Creek and other watersheds where appropriate [i.e., Naswhito Creek, Equesis Creek]). The streamflow dataset adjustment factors were applied to naturalized streamflow datasets (i.e., LT Mad and mean weekly streamflows) developed following Associated (2017), while the adjustment is carried through for the development of the residual and maximum licensed streamflow datasets. Thus, 15 years (i.e., 1996-2010, but re-named to Year 1 to Year 15) of streamflows were still created.

A complete summary of the temporal period adjustment factor is provided in Appendix C and individually described for each watershed summary in Sections 3 to 20.

2.2.4 Low Streamflow Statistical Methods

The summer (i.e., July 1 to September 30) and winter (i.e., November 1 to March 31) 30-day low natural and residual streamflows under 1:2, 1:5, 1:10, and 1:20-year return periods were determined by first calculating the minimum four-week moving mean weekly discharge for each year of the adjusted 1996-2010 standard period[5]. The minimum values were then fit to each of the following four frequency distributions: Pearson type III, log Pearson type III, log normal, and Gumbel. Following this, the general procedure for estimating individual return period streamflows involved visually assessing the goodness-of-fit of the data to each distribution, with poor fits excluded. Based on review of each distribution, it was concluded for each watershed that all distribution types fitted the data reasonably well; therefore, the results from all four distributions were averaged and used to calculate average values (and 95% confidence limits).

2.3 DATA ERROR AND DATA QUALITY RATING

To support the assessment of data reliability (associated with the method used) and uncertainty (i.e., error) for the streamflow datasets that were developed, Associated (2017) recommended a data error and quality rating framework (Table 2-1). This framework was applied herein to provide an indication of the reliability of the estimated streamflow datasets.

[5] Given the weekly resolution of streamflow datasets developed to support the application of the Okanagan Tennant Method, 30-day low streamflow statistics (typically based on daily streamflow data) were approximated using four-week low streamflow statistics based on weekly streamflow data.

Table 2-1 Data error and data quality rating framework for rating estimated streamflow datasets developed for application of the Okanagan Tennant method (from Associated 2017)

Rating	Data Error	Data Quality
A	≤10%	• Streamflows available entirely from measurements at streamflow and/or EFN point-of-interest (or at least a location very close). • Water use/diversion information is available. • Reservoir regulation records or information is available.
B	>10% and ≤25%	• Streamflows available from a combination of measurements and modelling within a watershed either at, or scaling to, a streamflow and/or EFN point-of-interest. • Water use/diversion information available from a combination of measurements and modelling. • Reservoir regulation records or information available from a combination of measurements and modelling.
C	>25% and ≤50%	• Streamflows estimated from modelling using information from a nearby representative watershed and scaling to a streamflow and/or EFN point-of-interest. • Water use/diversion information available from modelling. • Reservoir regulation information available from modelling.
D	>50%	• Streamflows estimated from modelling using information from a nearby watershed (but with limited similarities) and scaling to a streamflow and/or EFN point-of-interest. • Water use/diversion information estimated. • Reservoir regulation information estimated.

3 Equesis Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-1) for Equesis Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 3-1 provides an overview map of the watershed with the specific data sources, delineated sub-watersheds, ONA EFN transects, and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix D.

3.1 NATURALIZED STREAMFLOWS

Weekly naturalized streamflows for Equesis Creek at the streamflow point-of-interest were estimated following the approach outlined in Appendix A using discontinued hydrometric records from Ewer Creek near the Mouth (WSC No. 08NM176) extended to the 1996-2010 standard period using hydrometric records from the nearby Whiteman Creek above Bouleau Creek (WSC No. 08NM174). Specifically, the record for Ewer Creek was extended to the standard period using the long-term mean weekly unit discharge relation established for the overlapping period of record between WSC No. 08NM174 and 08NM176 (Appendix D).

Following the approach described above, a modification was made to the methods outlined in Appendix A. Specifically, for the development of the necessary streamflow datasets, the Equesis Creek watershed was divided into two sub-watersheds: 1) Pinaus Lake watershed and 2) Equesis Creek watershed to streamflow point-of-interest (minus Pinaus Lake watershed) (Figure 3-1). This division was completed to support the development of the regulated streamflow datasets to allow for the consideration of reservoir management (Section 3.2). This approach is consistent to that previously used by Letvak (1983) to assess water supply availability within the Equesis Creek watershed.

The Ewer Creek records were then scaled to the drainage area extents of both sub-watersheds but adjusted to represent different drainage areas with different median elevations. Specifically, the updated regional runoff relation for hydrologic zone 15 (Fraser Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between the Pinaus Lake watershed (i.e., 37.3 km^2; median elevation = 1,288 m), Equesis Creek watershed to streamflow point-of-interest (minus Pinaus Lake watershed) (i.e., 163.8 km^2; median elevation = 1,213 m), and Ewer Creek at WSC No. 08NM176 (i.e., 51.5 km^2; median elevation = 1,453 m). The ratios used for adjustment purposes were 0.67 for the Pinaus Lake watershed and 0.56 for the Equesis Creek watershed to streamflow point-of-interest (minus Pinaus Lake watershed). The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 15 (Appendix B). Streamflows at the streamflow point-of-interest were then assumed to be the sum of both sub-watersheds, which assumes no streamflow routing influence due to the weekly time-step modelled.

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Whiteman Creek weekly scaling ratios (Appendix C).

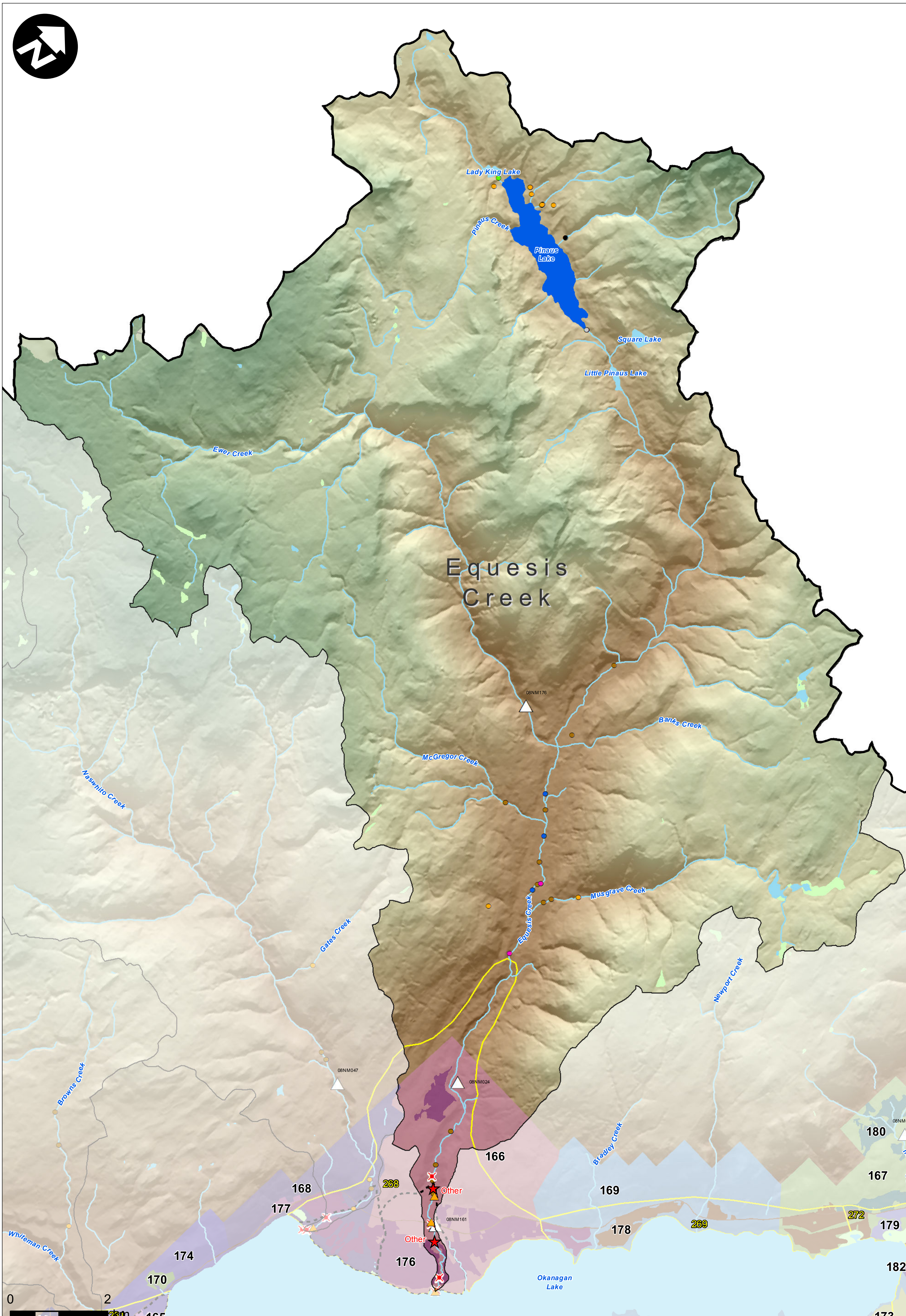


Figure 3-1: Map of Equesis Creek watershed (from Associated 2017)

OBWB

Application of Okanagan Tennant Method in Okanagan Streams

Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. The ONA installed three hydrometric stations along the alluvial fan (i.e., from the apex to the mouth) (Figure 3-1). However, Okanagan Indian Band (OKIB) ditch diversions are present on the fan, which limits the understanding of natural continuous streamflow gains/losses, since the diversions are not gauged. To address this limitation, the ONA collected corresponding manual streamflow measurements at selected EFN transects on the alluvial fan (Table 3-1; Figure 3-1) and the results suggested that for the dates measured, the Equesis Creek channel gained water for the portion monitored. However, due to the limited spatial understanding of streamflow gains/losses across the entire alluvial fan and unclear impact of seasonal variation (if any), it was deemed more appropriate to consider a gain/loss value equivalent to zero across the entire fan. This is consistent with the approach recommended by Summit (2009a) in support of hydrologic modelling of the Equesis Creek watershed during the Okanagan Water Supply and Demand Project (OWSDP).

Table 3-1 Summary of discharge measurements collected by the ONA across the Equesis Creek alluvial fan

Date	ONA EFN Transect[1,2] – Discharge (m^3/s)	
	Glide 2 (Upstream)	Glide 1a (Downstream)
19-Jun-2017	1.67	1.79
27-Jun-2017	1.14	1.29
06-Jul-2017	0.815	0.940
17-Jul-2017	0.574	0.689
04-Aug-2017	0.375	0.440
28-Aug-2017	0.285	0.340
29-Sep-2017	0.207	0.275

Note:
1. Refer to Figure 3-1 for location of EFN transects.
2. Distance between Glide 2 and Glide 1a is approximately 275 m.

3.2 RESIDUAL STREAMFLOWS

3.2.1 Background Water Use and Reservoir Management Information

For Equesis Creek watershed, residual streamflows are a result of licensed water withdrawals by OKIB and private residents, as well as through Pinaus Lake reservoir management (by OKIB). Prior to dataset development, the OKIB was contacted to discuss data availability and general operation of the Pinaus Lake outlet structure. The results of the discussion were as follows:

- No information is available on actual withdrawals by OKIB, but the large ditch diversion located near the apex of the alluvial fan is only operated during the spring, summer, and fall to support irrigation. There are also two ditch diversions below Westside Road (on the alluvial fan) that are operated year-round (Louis, K., pers. comm, 2018).

- The Pinaus Lake dam, which was replaced approximately two years ago by FLNRORD and OKIB, has not been used to manage releases from the lake yet, since the lake was drawn down significantly to support dam construction and has yet to recover to spill levels (Louis, R., pers. comm., 2018).
- Prior to replacement of the Pinaus Lake dam, the previous dam outlet gate had been stuck in the open position; therefore, limited management of the lake was completed by OKIB (Louis, R., pers. comm., 2018).

Besides discussions with the OKIB, no other actual water use or management information was identified.

3.2.2 Pinaus Lake Watershed – Outflows

Based on discussions with OKIB, the recent replacement of the Pinaus Lake dam introduces a challenge moving forward for establishing EFNs within the watershed, since the standard period for streamflow dataset development is prior to the-new dam. However, since the new dam outlet structure has yet to be operated, it was deemed more appropriate at this time (for the application of the Okanagan Tennant method) to develop residual streamflow datasets for Equesis Creek that consider the original dam and outlet structure. Thus, the development of residual streamflows for the Pinaus Lake watershed (Section 3.2.1) uses the outlet structure (i.e., fish ladder port, outlet pipe, and spillway) documented by MOE (1979a).

To estimate residual streamflows for the Pinaus Lake watershed, a Pinaus Lake water balance spreadsheet model was developed for the standard period. The following datasets and assumptions were included within the model:

- Natural inflows into Pinaus Lake for the standard period were equivalent to those estimated in Section 3.1.
- Water licences (issued only for domestic purposes) located on contributing tributaries/springs to the lake were assumed to be used during May to September (for recreation property use) up to their maximum licensed volumes under a consistent weekly diversion rate. No other water licences are located within the Pinaus Lake watershed.
- Total monthly precipitation on the surface of Pinaus Lake was estimated using ClimateWNA[6] and split into a weekly time-step using the weekly precipitation pattern observed at the Silver Creek climate station (Meteorological Service of Canada Station No. 1167337; located approximately 25 km northeast of Pinaus Lake).
    - Precipitation in the form of rain was added to the lake surface between April (starting on Week 14) and November (ending on Week 46, when ice was assumed to be present).
    - Between mid-November (Week 47) and mid-March (Week 16) precipitation was assumed to be in the form of snow and accumulated on the frozen lake surface. Of the accumulated snowpack, 10% was assumed to be lost to sublimation during the winter period and the remaining snow was assumed to melt during the month of April (each year), assuming the

[6] http://www.climatewna.com/

following melting schedule: Week 14 = 20%, Week 15 = 20%, Week 16 = 50%, and Week 17 = 10%.

- Total monthly evaporation from Pinaus Lake was estimated using ClimateWNA. The monthly values were divided into a weekly time-step using a smoothing function (i.e., LOESS). Limited (or no) evaporation was assumed to occur from the lake between November and March.
- Groundwater seepage losses form the lake were assumed to be negligible.
- Pinaus Lake storage capacity was assumed to be equivalent to the values summarized by MOE (1979b).
- The Pinaus Lake outlet structure included the following, as identified by MOE (1979a):
    - o Rectangular fish ladder port = 0.41 m wide x 0.13 m high;
    - o Gated outlet = 0.762 m (30-inch) diameter pipe; and
    - o Spillway = 6.53 m long, 0.305 m wide

Following the above, due to the lack of available information on historic lake management and outlet structure operations by the OKIB, lake outflows were estimated assuming that the lake was managed each year to have the fish ladder port submerged continuously. Under this assumption, the lake would generally be managed to maintain approximately 50% storage capacity under low streamflow periods.

No Pinaus Lake water level or outflow information was available for comparison to the modelled output. However, G.G. Oliver and Associates (2003) noted that the annual lake drawdown is approximately 1.2 m. A summary of the lake water levels and outflows for the standard period are presented in Appendix D. The results suggest that the annual water level fluctuation for Pinaus Lake for the standard period is 0.70 m to 0.90 m.

3.2.3 Equesis Creek to Streamflow Point-of-Interest (minus Pinaus Lake watershed)

To estimate residual streamflows within Equesis Creek to the streamflow point-of-interest (minus Pinaus Lake watershed), the following was completed:

- Natural streamflows to the streamflow point-of-interest for the adjusted standard period were equivalent to those estimated in Section 3.1.
- Water use within the sub-watershed was assumed equivalent to the OWDM outputs for water use areas: 176 (OKIB Reserve 1 [ID 3]), 166 (OKIB Reserve 1 [ID 10]), and 192 (Other_Node 8) (Figure 3-1). To support the use of the OWDM output, the following assumptions were included for each water use area:
    - o Summit (2010) identified water use area 176 to be sourced by groundwater. However, the presence of irrigation ditches on the alluvial fan (and within the spatial extent of water use area 176) suggested an error by Summit (2010). Therefore, it was assumed that water use area 176 was serviced by surface water.
    - o Summit (2010) identified water use area 166 to be sourced by surface water. However, based on the findings for water use area 176, it was assumed that groundwater supplied water use area 166.
    - o Total water demand for water use area 192 was reduced by 8.6% (recommended by Summit [2010]) to remove estimated groundwater use within the spatial extent of the water use area.
- Raw OWDM output for irrigation water demands was supplemented as follows:

  - For selected years, the OWDM includes a Week 0 to account for field watering by farmers at the end of season to increase soil moisture to field capacity. Thus, water demands estimated for years with Week 0 were assumed to occur evenly in September (i.e., Weeks 36 to 39) to consider the end of season watering.
  - A 10% irrigation system loss was assumed.
  - The weekly water demand values were smoothed using the LOESS function, and the timing of irrigation water use was limited to April through September (i.e., licensed period of use).
- Domestic and stockwatering water use estimates for water use area 199 were reduced by 72.5% to account for most of the water licences issued within the Pinaus Lake watershed.
- The OKIB are licensed to divert water for irrigation and stockwatering at six points-of-diversion above and on the alluvial fan (i.e., water licences C023319, F015510, and F015511). Based on discussions with OKIB (Section 3.2.1), for water use area 176, 75% of irrigation water demand was assumed to occur above the apex of the fan, while the remainder (i.e., 25%) occurred on the fan. In addition, all stockwatering was assumed to occur on the fan.

3.2.4 Equesis Creek at EFN Point-of-Interest

To estimate residual streamflows within Equesis Creek at the EFN point-of-interest, the streamflows estimated in Sections 3.2.2 and 3.2.3 were summed. The estimated water demands for water use area 176 (for the fan area only) (Section 3.2.3) were then removed from the streamflows and streamflow gains/losses across the fan were consistent to that assumed in Section 3.1.

The resultant residual streamflows for the adjusted standard period were compared to streamflows recorded by WSC No. 08NM161 (Equesis Creek near the Mouth; Period of record: 1969-1982). The comparison indicated that although different time periods were compared, the general magnitude of the residual streamflows was consistent with that previously measured by the WSC. See Appendix D for a visual comparison.

3.3 MAXIMUM LICENSED STREAMFLOWS

To estimate maximum licensed streamflows within Equesis Creek at the EFN point-of-interest, the same steps to estimate residual streamflows outlined in Section 3.2 were used, but the OWDM output was scaled to maximum licensed volumes for the respective water use purposes and corresponding periods of use. This assumed that the weekly water use distribution pattern (predicted by the OWDM for each year of the standard period) was the same between residual and maximum licensed conditions.

Also, due to the lack of available information on historic lake management and outlet structure operations by the OKIB, under maximum licensed streamflow conditions, it was still assumed that lake outflows were estimated assuming that the lake was managed each year to have the fish ladder port submerged continuously. Note that this assumption results in periods of zero streamflows at the EFN point-of-interest during selected years (Appendix D), but due to the lack of available information on Pinaus Lake management operations and strategies (i.e., balancing priorities of fish port releases versus downstream demand), this assumption was considered reasonable to support EFN development.

3.4 SUMMARY OF THE THREE STREAMFLOW DATASETS

A summary of naturalized, residual, and maximum licensed streamflows at the streamflow and EFN points-of-interest is provided digitally in Appendix C. A comparison of LT mad values estimated herein and by others for Equesis Creek watershed are summarized in Table 3-2 and estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 3-3. Of note, the residual low streamflow statistics reported in Table 3-3 are higher than naturalized conditions due to storage releases by OKIB from Pinaus Lake.

Lastly, following the data error and quality rating framework (Table 2-1), the naturalized streamflow datasets are given a rating of B (i.e., data error >10% and ≤25%), while a rating of D (i.e., data error >50%) is given to the residual and maximum licensed streamflows. The latter rating is due to the lack of available hydrometric records (for the standard period) at the points-of-interest, the number of assumptions required to estimate water use within the watershed, and the uncertainty about Pinaus Lake management.

Table 3-2 Summary of LT mad values estimated for Equesis Creek watershed

	LT mad estimates for Equesis Creek watershed						
	Summit (2009a)	**Ptolemy (2016)**	**Obedkoff (1998)**	**NHC (2001)**	**Letvak (1983)**	**OK Basin Agreement (1974)**	**This Study**
Time Period	1996-2006	Unknown	1961-1990	1961-1995	1972-1979	Ave Year (1970)	Adjusted 1996-2010
Point-of-Interest	Mouth	Mouth	Mouth	Mouth	Mouth	Mouth	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	0.743	1.11	0.678	0.700	0.645	0.657	0.700
Residual LT mad (m^3/s)	-	-	-	-	-	-	0.690
Max Licensed LT mad (m^3/s)	-	-	-	-	-	-	0.590

Table 3-3 Summary of summer and winter period low streamflow statistics at Equesis Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.103	0.161
Summer 1:5-year return period 30 Day Low Streamflow	0.059	0.109
Summer 1:10-year return period 30 Day Low Streamflow	0.045	0.090
Summer 1:20-year return period 30 Day Low Streamflow	0.037	0.078
Winter 1:2-year return period 30 Day Low Streamflow	0.091	0.114
Winter 1:5-year return period 30 Day Low Streamflow	0.059	0.079
Winter 1:10-year return period 30 Day Low Streamflow	0.046	0.062
Winter 1:20-year return period 30 Day Low Streamflow	0.037	0.050

4 Naswhito Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-2) for Naswhito Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 4-1 provides an overview map of the watershed with the specific data sources, ONA EFN transects, and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix E.

4.1 NATURALIZED STREAMFLOWS

For Naswhito Creek naturalized streamflows, a modification was made to the methods outlined in Appendix A after ONA expressed concerns over low streamflow values estimated for the summer period (August to September) even after the temporal period adjustment factor (Section 2.2.3) was applied.

Specifically, weekly naturalized streamflows for Naswhito Creek at the streamflow point-of-interest were estimated following the approach outlined in Appendix A, but estimates only used scaled Ewer Creek near the Mouth (WSC No. 08NM176) data extended to the 1996-2010 standard period (from Section 3.1). This is a modification from the approach outlined in Appendix A, which recommends that the average between the Ewer Creek records and actual records from nearby Whiteman Creek above Bouleau Creek (WSC No. 08NM174) be used for estimation purposes. This modification was applied based on actual hydrometric records collected on Naswhito Creek in 2016-2018, which suggested that the unit discharge for the Naswhito Creek watershed was better reflected by Ewer Creek than Whiteman Creek.

Following the approach described above, the Ewer Creek records were scaled to the drainage area for Naswhito Creek at the streamflow point-of-interest (i.e., 83.7 km^2), but adjusted to represent the different median elevations. Specifically, the updated regional runoff relation for hydrologic zone 15 (Fraser Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between the Naswhito Creek point-of-interest (i.e., 83.7 km^2; median elevation = 1,311 m) and Ewer Creek at WSC No. 08NM176 (i.e., 51.5 km^2; median elevation = 1,453 m). The ratio used for adjustment purposes was 0.71 for the Ewer Creek scaled streamflows to the Naswhito Creek streamflow point-of-interest. The estimated weekly time series was then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 15 (Appendix B).

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Whiteman Creek weekly scaling ratios (Appendix C).

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Figure 4-1: Map of Naswhito Creek watershed (from Associated 2017)

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Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. The ONA installed one hydrometric station on the alluvial fan, approximately 500 m from the mouth (Figure 4-1) and collected corresponding manual streamflow measurements at selected EFN transects on the alluvial fan (Table 4-1; Figure 4-1). The results suggested that for the dates measured, the Naswhito Creek channel lost water for the portion of the creek that was monitored. The average loss across the fan, measured by ONA for July to September 2017, was 0.011 m^3/s, which is equivalent to 0.019 $m^3/s/km$ (between EFN transects). The results were consistent with that recommended by Summit (2009a) for considering streamflow gains/losses across the Naswhito Creek alluvial fan (i.e., 0.014 $m^3/s/km$). Therefore, it was assumed that the average loss that the ONA measured (i.e., 0.011 m^3/s) was representative for the entire distance between the streamflow and EFN points-of-interest for all seasons and the standard period.

Table 4-1 Summary of discharge measurements collected by the ONA on the Naswhito Creek alluvial fan

Date	ONA EFN Transect[1,2] – Discharge (m^3/s)	
	Glide 2 (Upstream)	Glide 1a (Downstream)
14-Jul-17	0.226	0.215
25-Jul-17	0.149	0.139
15-Aug-17	0.093	0.083
06-Sep-17	0.060	0.048

Note:
1. Refer to Figure 4-1 for location of EFN transects.
2. Distance between Glide 2 and Glide 1a is approximately 550 m.

4.2 RESIDUAL STREAMFLOWS

4.2.1 Background Water Use Information

For Naswhito Creek watershed, residual streamflows are a result of licensed water withdrawals by OKIB and private residents. Prior to dataset development, the OKIB was contacted to discuss water use data. The results of the discussion were as follows:

- No information is available on actual withdrawals by OKIB.
- The OKIB identified that Naswhito Creek sometimes dries up (i.e., zero streamflows) for select reaches across the Naswhito Creek alluvial fan (Marchand, pers. comm., 2018).

Besides discussions with the OKIB, no other actual water use or management information was identified.

4.2.2 Naswhito Creek to Streamflow Point-of-Interest

To estimate residual streamflows within Naswhito Creek to the streamflow point-of-interest, the following approach was taken:

- Natural streamflows to the streamflow point-of-interest for the adjusted standard period were assumed to be equivalent to those estimated in Section 4.1.
- Water use within the watershed was assumed equivalent to the OWDM outputs for water use areas 168 (OKIB Reserve 1 [ID 12]) and 92 (Other_Node 10) (Figure 4-1).
- Raw OWDM output for irrigation water demands was supplemented as follows:
    - For selected years, the OWDM includes a Week 0 to account for field watering by farmers at the end of season to increase soil moisture to field capacity. Thus, water demands estimated for years with Week 0 were assumed to occur evenly in September (i.e., Weeks 36 to 39) to consider the end of season watering.
    - A 10% irrigation system loss was assumed.
    - The weekly water demand values were smoothed using the LOESS function and timing of irrigation water use was limited to April and September (i.e., licensed period of use).
- Under water licences C122431 and C122432, a private individual is licensed to divert water into a dugout (127,048 m^3/yr) between April 1 (Week 14) and June 30 (Week 26) (for storage purposes) to support irrigation between April and September. No information is available on the dugout diversion, so it was assumed that water is diverted out of the creek evenly (up to the maximum licensed volume) between Weeks 14-26 each year. Following this, no water demand from the creek was assumed for the remainder of the irrigation season (i.e., July to September) at point-of-diversion, as water would be drawn out of the dugout for irrigation purposes.

4.2.3 Naswhito Creek at EFN Point-of-Interest

To estimate residual streamflows within Naswhito Creek at the EFN point-of-interest, estimated water demands for water use area 168 (for the fan area only) (Section 4.2.3) were removed from the streamflows and streamflow gains/losses across the fan were consistent to that assumed in Section 4.1. See Appendix E for estimated residual streamflows at the EFN point-of-interest.

No historic WSC records are available for comparison to estimated residual streamflows. However, streamflow records were available for a hydrometric station operated by ONA on the alluvial fan (near Glide 2) (Figure 4-1) for 2016-2018. The resultant residual streamflows for the adjusted standard period were compared to streamflows recorded by the ONA and the comparison indicated that although different time periods were compared, the general magnitude of the residual streamflows was consistent with that recorded by the ONA. See Appendix E for a visual comparison.

4.3 MAXIMUM LICENSED STREAMFLOWS

To estimate maximum licensed streamflows within Naswhito Creek at the EFN point-of-interest, the same steps to estimate residual streamflows outlined in Section 4.2 were used, but the OWDM output was scaled to maximum licensed volumes for the respective water use purposes and corresponding periods of use. This assumed that the weekly water use distribution pattern (predicted by the OWDM for each year of the standard period) was the same between residual and maximum licensed conditions.

4.4 SUMMARY OF THE THREE STREAMFLOW DATASETS

A summary of naturalized, residual, and maximum licensed streamflows at the streamflow and EFN points-of-interest is provided digitally in Appendix E. A comparison of LT mad values estimated herein and by others for Naswhito Creek watershed are summarized in Table 4-2 and estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 4-3.

Lastly, following the data error and quality rating framework (Table 2-1), the resultant datasets are given a rating of C (i.e., data error >25% and ≤50%). This is due to the lack of historic hydrometric records for the watershed, as well as the number of assumptions required to estimate water use.

Table 4-2 Summary of LT mad values estimated for Naswhito Creek watershed

	LT mad estimates for Naswhito Creek watershed				
	Summit (2009a)	**Ptolemy (2016)**	**Obedkoff (1998)**	**NHC (2001)**	**This Study**
Time Period	1996-2006	Based on one year of data (1921)	1961-1990	1961-1995	Adjusted 1996-2010
Point-of-Interest	Mouth	Mouth	Mouth	Mouth	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	0.337	0.448	0.358	0.310	0.363
Residual LT mad (m^3/s)	-	-	-	-	0.357
Max Licensed LT mad (m^3/s)	-	-	-	-	0.331

Table 4-3 Summary of summer and winter period low streamflow statistics at Naswhito Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.045	0.040
Summer 1:5-year return period 30 Day Low Streamflow	0.021	0.016
Summer 1:10-year return period 30 Day Low Streamflow	0.013	0.008
Summer 1:20-year return period 30 Day Low Streamflow	0.009	0.003
Winter 1:2-year return period 30 Day Low Streamflow	0.038	0.038
Winter 1:5-year return period 30 Day Low Streamflow	0.020	0.020
Winter 1:10-year return period 30 Day Low Streamflow	0.014	0.014
Winter 1:20-year return period 30 Day Low Streamflow	0.009	0.009

5 Vaseux Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-3) for Vaseux Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 5-1 provides an overview map of the watershed with the specific data sources, ONA EFN transects, and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix F.

5.1 NATURALIZED STREAMFLOWS

Weekly naturalized streamflows for Vaseux Creek at the streamflow point-of-interest were estimated following the approach outlined in Appendix A using discontinued hydrometric records from Vaseux Creek above Dutton Creek (WSC No. 08NM015) extended to the 1996-2010 standard period using hydrometric records from the nearby Vaseux Creek above Solco Creek (WSC No. 08NM171). Specifically, the record for Vaseux Creek above Dutton Creek was extended to the standard period using the long-term mean weekly unit discharge relation established for the overlapping period of record between WSC No. 08NM171 and 08NM015 (Appendix E).

The Vaseux Creek above Dutton Creek (WSC No. 08NM015) records were then scaled to the drainage area of the streamflow point-of-interest but adjusted to represent the different drainage area with a different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 24 (South Thompson Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between Vaseux Creek at WSC No. 08NM015 (254.8 km^2; median elevation = 1,600 m) and Vaseux Creek at streamflow point-of-interest (291.8 km^2; median elevation = 1,571 m). The ratio used for adjustment purposes was 0.93. The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 24 (Appendix B).

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Vaseux Creek weekly scaling ratios (Appendix C).

Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. The ONA installed one hydrometric station on the alluvial fan, approximately 500 m from the mouth near the location of the discontinued WSC hydrometric station – Vaseux Creek near the Mouth (WSC No. 08NM246; Period of record – 2006 to 2010) (Figure 5-1). The ONA also collected corresponding manual streamflow measurements at selected EFN transects on the alluvial fan (Table 5-1; Figure 5-1). The results suggested that for the dates measured, the Vaseux Creek channel lost and gained water across the small portion (i.e., 55 m) of the fan monitored.

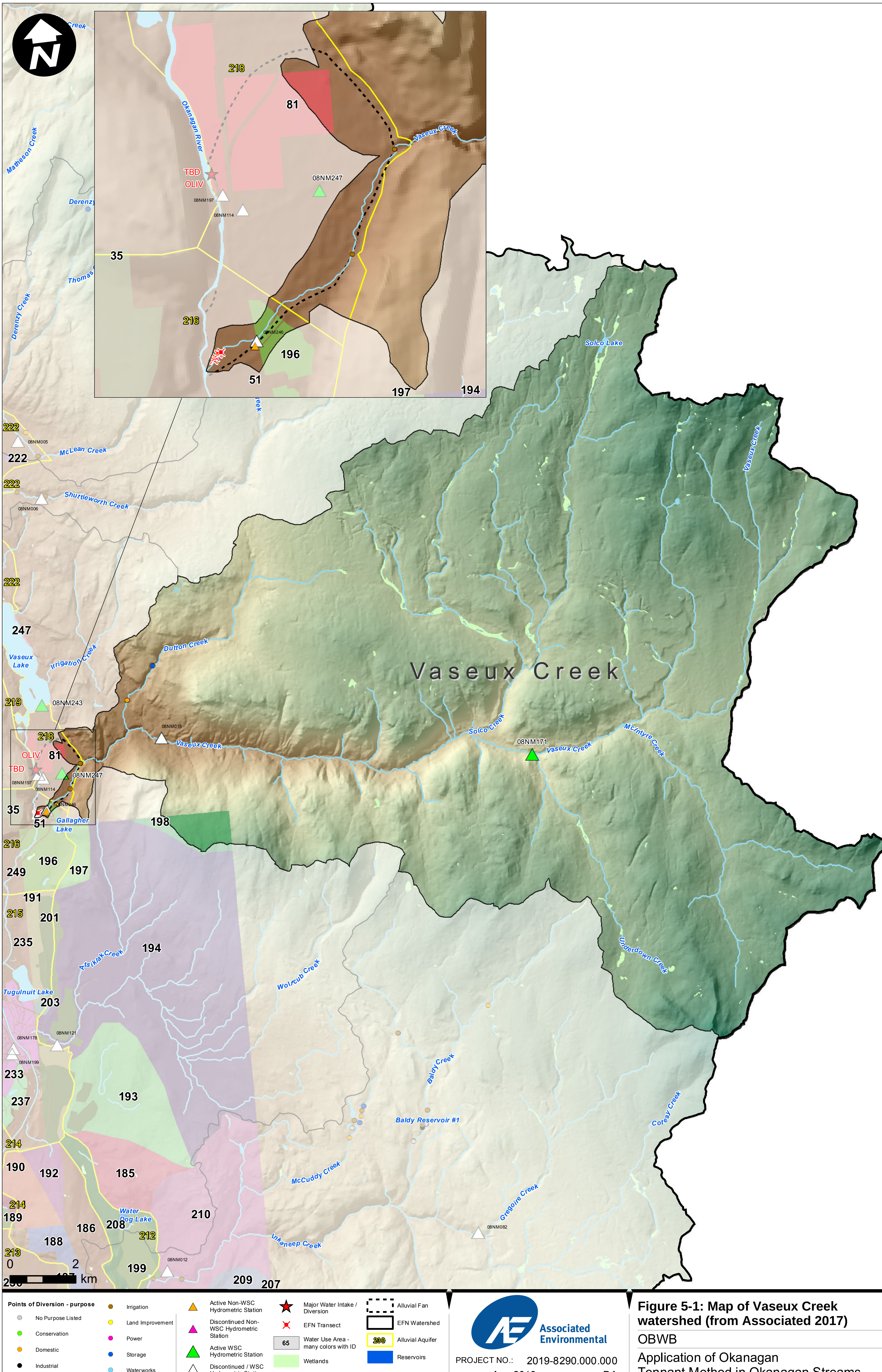

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Figure 5-1: Map of Vaseux Creek watershed (from Associated 2017)

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Table 5-1 Summary of discharge measurements collected by the ONA across the Vaseux Creek alluvial fan

Date	ONA EFN Transect[1,2] – Discharge (m³/s)	
	VAS40GL (Upstream)	VAS0GL (Downstream)
10-Aug-16	0.152	0.131
16-Jun-17	2.80	2.84
26-Jun-17	1.14	1.32
06-Jul-17	0.336	0.372
12-Jul-17	0.224	0.204
20-Jul-17	0.126	0.108
17-Aug-17	0.032	0.022

Note:
1. Refer to Figure 5-1 for location of EFN transects.
2. Distance between VAS40GL and VAS20GL is approximately 55 m.

However, although the ONA measured gains and losses across the fan, it was for a small channel length (i.e., 55 m) in comparison to the entire length of the fan (i.e., approximately 2.3 km). Therefore, to estimate streamflow gains/losses across the entire fan to the EFN point-of-interest, the difference between the estimated residual streamflows at the EFN point-of-interest (i.e., residual streamflows at streamflow point-of-interest minus the on fan water use – Section 4.2) and the records at Vaseux Creek near the Mouth (WSC No. 08NM246) for corresponding years (2006-2010) was calculated[7]. The results found that the median difference between the two points-of-interest for the overlapping records was a streamflow loss of 0.166 m^3/s. As a result, since the ONA measured values were limited spatially across the fan and there is limited information on Vaseux Creek's alluvial fan characteristics, it was assumed that the calculated median difference in residual streamflows between the streamflow point-of-interest and Vaseux Creek near the Mouth was a reasonable estimate of streamflow losses across the fan for all seasons and the standard period.

5.2 RESIDUAL STREAMFLOWS

5.2.1 Background Water Use Information

For Vaseux Creek watershed, residual streamflows are a result of licensed water withdrawals by private residents. Prior to dataset development, FLNRORD was contacted to determine whether water use

[7] Estimated residual streamflow values during the winter period were used as a threshold to estimate streamflow gains/losses across the alluvial fan since ONA identified that no on fan diversions operated during the winter.

information for the watershed was available, but no response was received. Therefore, it was assumed that no information is publicly available on actual withdrawals within Vaseux Creek watershed.

The ONA was also contacted and provided the following information:

- There is a diversion canal located approximately 2 km upstream from the creek confluence (with the Okanagan River) that diverts a portion of streamflow year round in a holding reservoir and any unused water is returned to the creek downstream. The volume of water diverted and returned throughout the year is unknown (ONA 2011; McGrath, pers. comm, 2019).
- There is a second diversion on the alluvial fan approximately 2.5 km upstream from the creek confluence (with the Okanagan River) that diverts a portion of the streamflow through a side channel and then through a control structure. No water is returned to the creek and the volume of water diverted is unknown (ONA 2011; McGrath, pers. comm., 2019).

5.2.2 Vaseux Creek to Streamflow Point-of-Interest

To estimate residual streamflows within Vaseux Creek to the streamflow point-of-interest, the following approach was taken:

- Natural streamflows to the streamflow point-of-interest for the adjusted standard period were assumed to be equivalent to those estimated in Section 5.1.
- Water use within the watershed was assumed equivalent to the OWDM outputs for water use area 147 (Other_Node 66) (Figure 5-1). In addition, total water demand for water use area 147 was reduced by 14.3% (as recommended by Summit [2010]) to remove estimated groundwater use within the spatial extent of the water use area.
- Water use area 147 encompasses the entire watershed; therefore, to divide OWDM outputs into above-alluvial fan and on-alluvial fan withdrawals, the spatial distribution of water licensed volumes was assumed representative of water withdrawals, as follows:
  - Domestic water demands – 40% above the alluvial fan and 60% on the alluvial fan.
  - Irrigation water demands – 23% above the alluvial fan and 77% on the alluvial fan.
  - Stockwatering – 100% on the alluvial fan.
- Raw OWDM output for irrigation water demands was supplemented as follows:
  - For selected years, the OWDM includes a Week 0 to account for field watering by farmers at the end of season to increase soil moisture to field capacity. Thus, water demands estimated for years with Week 0 were assumed to occur evenly in September (i.e., Weeks 36 to 39) to consider the end of season watering.
  - A 10% irrigation system loss was assumed.
  - The weekly water demand values were smoothed using the LOESS function and timing of irrigation water use was limited to April and September (i.e., licensed period of use).
- Under water licence C050403, a private individual is licensed to divert 98,678 m^3/yr of water for storage purposes into a dugout between October 1 (Week 40) and June 15 (Week 14) to support irrigation between April and September. No information is available on the dugout diversion, so it was assumed that water is diverted out of the creek evenly (up to the maximum licensed volume) between Weeks 40-14 each year. Following this, no water withdrawals from the creek was assumed for the remainder of the irrigation season (i.e., mid-June to September) at the point-of-diversion, as stored water would be drawn out of dugout for irrigation purposes.

5.2.3 Vaseux Creek at EFN Point-of-Interest

To estimate residual streamflows within Vaseux Creek at the EFN point-of-interest, two approaches were used, as follows:

- For available hydrometric records between 2006 and 2010, recorded streamflows at Vaseux Creek near the Mouth (WSC No. 08NM246) were used to represent residual streamflows at the EFN point-of-interest, but adjusted to long-term conditions.
- For all periods when WSC No. 08NM246 streamflow records were not available, estimated water demands for water use area 147 (for the fan area only) (Section 5.2.3) were removed from the estimated streamflows at the streamflow point-of-interest and streamflow gains/losses across the fan were considered consistent with that assumed in Section 5.1.

Note that although ONA identified the two large diversions on the alluvial fan (Section 5.2.1), no specific information is available on the volume/rate of water diverted and/or returned. Therefore, understanding that the diversions are canals, it was assumed that each diversion diverted water up to their maximum licensed capacity for their respective periods of use.

See Appendix F for estimated residual streamflows at the EFN point-of-interest.

The resultant residual streamflows for the adjusted standard period were compared to streamflows recorded by WSC No. 08NM246 (Vaseux Creek near the Mouth; Period of record: 2006-2010). The comparison indicated that although different time periods were compared, the general magnitude of the residual streamflows was consistent with that previously measured by the WSC (including several periods of zero streamflows).

5.3 MAXIMUM LICENSED STREAMFLOWS

To estimate maximum licensed streamflows within Vaseux Creek at the EFN point-of-interest, the same steps to estimate residual streamflows outlined in Section 5.2 were used, but the OWDM output was scaled to maximum licensed volumes for the respective water use purposes and corresponding periods of use. This assumed that the weekly water use distribution pattern (predicted by the OWDM for each year of the standard period) was the same between residual and maximum licensed conditions.

5.4 SUMMARY OF THE THREE STREAMFLOW DATASETS

A summary of naturalized, residual, and maximum licensed streamflows at the streamflow and EFN points-of-interest is provided digitally in Appendix F. A comparison of LT mad values estimated herein and by others for Vaseux Creek watershed are summarized in Table 5-2 and estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 5-3.

Lastly, following the data error and quality rating framework (Table 2-1), the resultant datasets are given a rating of C (i.e., data error >25% and ≤50%). This is due to the presence of hydrometric records at or near points-of-interest, but these records are limited for the entire standard period, so large uncertainty exists and several assumptions were used to estimate streamflow gains/losses across the alluvial fan.

Table 5-2 Summary of LT mad values estimated for Vaseux Creek watershed

	LT mad estimates for Vaseux Creek watershed			
	Summit (2009a)	Ptolemy (2016)	Obedkoff (1998)	This Study
Time Period	1996-2006	Unknown	1961-1990	Adjusted 1996-2010
Point-of-Interest	Mouth	Mouth	Mouth	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	1.53	1.53	1.43	1.29
Residual LT mad (m^3/s)	-	-	-	1.26
Max Licensed LT mad (m^3/s)	-	-	-	1.26

Table 5-3 Summary of summer and winter period low streamflow statistics at Vaseux Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.042	0.030
Summer 1:5-year return period 30 Day Low Streamflow	0.008	0.003
Summer 1:10-year return period 30 Day Low Streamflow	0.003	0.000
Summer 1:20-year return period 30 Day Low Streamflow	0.002	0.000
Winter 1:2-year return period 30 Day Low Streamflow	0.002	0.002
Winter 1:5-year return period 30 Day Low Streamflow	0.000	0.000
Winter 1:10-year return period 30 Day Low Streamflow	0.000	0.000
Winter 1:20-year return period 30 Day Low Streamflow	0.000	0.000

6 Whiteman Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-4) for Whiteman Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 6-1 provides an overview map of the watershed with the specific data sources, ONA EFN transects, and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix G.

6.1 NATURALIZED STREAMFLOWS

Weekly naturalized streamflows for Whiteman Creek at the streamflow point-of-interest were estimated following the approach outlined in Appendix A using actual records from nearby Whiteman Creek above Bouleau Creek (WSC No. 08NM174).

The Whiteman Creek records were scaled to the drainage area extent for the Whiteman Creek streamflow point-of-interest (i.e., 202.1 km^2), but adjusted to represent a different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 15 (Fraser Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between the Whiteman Creek point-of-interest (202.1 km^2; median elevation = 1,414 m) and Whiteman Creek at WSC No. 08NM174 (107.3 km^2; median elevation = 1,434 m). The ratio used for adjustment purposes were 0.95. The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 15 (Appendix B).

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Whiteman Creek weekly scaling ratios (Appendix C).

Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. The ONA installed one hydrometric station on the alluvial fan, approximately 500 m from the mouth (Figure 6-1), and collected corresponding manual streamflow measurements at selected EFN transects on the alluvial fan (Table 6-1; Figure 6-1). The results suggested that for the dates measured, the Whiteman Creek channel generally lost water for the portion that was monitored. However, due to the limited spatial understanding of streamflow gains/losses across the entire alluvial fan and unclear seasonal variation (if any), it was deemed more appropriate to consider a gain/loss value equivalent to zero across the entire fan. This is consistent with the approach recommended by Summit (2009a) in support of hydrologic modelling of the Whiteman Creek watershed during the OWSDP.

Figure 6-1: Map of Whiteman Creek watershed (from Associated 2017)

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Table 6-1 Summary of discharge measurements collected by the ONA across the Whiteman Creek alluvial fan

Date	ONA EFN Transect[1,2] – Discharge (m^3/s)	
	Glide 2 (Upstream)	Glide 1 (Downstream)
15-Aug-16	0.249	0.190
31-Aug-16	0.128	0.125
14-Jun-17	2.864	2.900
26-Jun-17	1.354	1.199
05-Jul-17	0.904	0.686
14-Jul-17	0.618	0.436
25-Jul-17	0.411	0.296
15-Aug-17	0.254	0.182
06-Sep-17	0.190	0.113

Note:
1. Refer to Figure 6-1 for location of EFN transects.
2. Distance between Glide 2 and Glide 1 is approximately 725 m.

6.2 RESIDUAL STREAMFLOWS

6.2.1 Background Water Use Information

For Whiteman Creek watershed, residual streamflows are a result of licensed water withdrawals by OKIB and private residents. Prior to dataset development, the OKIB was contacted to discuss water use data, but no information was available on actual withdrawals.

Besides discussions with the OKIB, no other actual water use information was identified.

6.2.2 Whiteman Creek to Streamflow Point-of-Interest

To estimate residual streamflows within Whiteman Creek to the streamflow point-of-interest, the following approach was taken:

- Natural streamflows to the streamflow point-of-interest for the adjusted standard period were assumed to be equivalent to those estimated in Section 6.1.
- Water use within the watershed was assumed to be equivalent to the OWDM outputs for water use areas 174 (OKIB Reserve 1 [ID 18]) and 96 (Other_Node 14) (Figure 6-1). Note that water use area 174 only withdrawals water from the alluvial fan, while water use area 96 withdrawals water within the watershed above the alluvial fan.

- Raw OWDM output for Whiteman Creek watershed indicates that no irrigation occurs within the watershed and water use is limited to domestic and stockwatering purposes only.

6.2.3 Whiteman Creek at EFN Point-of-Interest

To estimate residual streamflows within Whiteman Creek at the EFN point-of-interest, estimated water demands for water use area 174 (for the fan area only) (Section 4.2.3) were removed from the streamflows and streamflow gains/losses across the fan were consistent to that assumed in Section 6.1. See Appendix G for estimated residual streamflows at the EFN point-of-interest.

No historic WSC records are available for comparison to estimated residual streamflows and ONA hydrometric records (for 2017) were not available at the time of reporting.

6.3 MAXIMUM LICENSED STREAMFLOWS

To estimate maximum licensed streamflows within Whiteman Creek at the EFN point-of-interest, the same steps to estimate residual streamflows outlined in Section 6.2 were used, but domestic water use was assumed equivalent to the maximum licensed volume. In addition, although no irrigation was predicted by the OWDM for Whiteman Creek watershed, water licences for irrigation purposes have been issued. To account for irrigation water licences, the weekly irrigation water use distribution pattern for Naswhito Creek watershed (from the OWDM) was assumed representative of an upstream alluvial fan water use pattern for Whiteman Creek, while the Equesis Creek watershed (on the alluvial fan) irrigation water use pattern was assumed representative of alluvial fan water use for Whiteman Creek. This also assumed that the weekly water use distribution pattern (predicted by the OWDM for Equesis and Naswhito Creeks for each year of the standard period) was the same between residual and maximum licensed conditions.

6.4 SUMMARY OF THE THREE STREAMFLOW DATASETS

A summary of naturalized, residual, and maximum licensed streamflows at the streamflow and EFN points-of-interest is provided digitally in Appendix G. A comparison of LT mad values estimated herein and by others for Whiteman Creek watershed are summarized in Table 6-2 and estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 6-3.

Lastly, following the data error and quality rating framework (Table 2-1), the resultant datasets are given a rating of B (i.e., data error >10% and ≤25%). This is due to the presence of hydrometric records within the headwaters of the watershed, but several assumptions related to water use and streamflow gains/losses across the alluvial fan were required.

Table 6-2 Summary of LT mad values estimated for Whiteman Creek watershed

	LT mad estimates for Whiteman Creek watershed				
	Summit (2009a)	Ptolemy (2016)	Obedkoff (1998)	NHC (2001)	This Study
Time Period	1996-2006	Unknown	1961-1990	1961-1995	Adjusted 1996-2010
Point-of-Interest	Mouth	Mouth	Mouth	Mouth	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	1.07	1.15	1.03	1.28	1.09
Residual LT mad (m^3/s)	-	-	-	-	1.09
Max Licensed LT mad (m^3/s)	-	-	-	-	1.07

Table 6-3 Summary of summer and winter period low streamflow statistics at Whiteman Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.108	0.108
Summer 1:5-year return period 30 Day Low Streamflow	0.057	0.056
Summer 1:10-year return period 30 Day Low Streamflow	0.042	0.041
Summer 1:20-year return period 30 Day Low Streamflow	0.033	0.032
Winter 1:2-year return period 30 Day Low Streamflow	0.098	0.098
Winter 1:5-year return period 30 Day Low Streamflow	0.060	0.060
Winter 1:10-year return period 30 Day Low Streamflow	0.046	0.046
Winter 1:20-year return period 30 Day Low Streamflow	0.037	0.037

7 Shorts Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-5) for Shorts Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 7-1 provides an overview map of the watershed with the specific data sources and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix H.

Note that for this watershed, ONA did not conduct any fieldwork to support the setting of EFNs. Thus, it was assumed that the EFN point-of-interest for this watershed was the mouth.

7.1 NATURALIZED STREAMFLOWS

For Shorts Creek naturalized streamflows, a modification was made to the methods outlined in Appendix A after a review of the OWDM results indicated very minimal water use within the watershed. In addition, discussions with individuals with experience conducting assessments within the watershed indicated that unit discharge runoff measured in nearby Whiteman Creek was likely higher (than Shorts Creek) under low streamflow conditions due to the lack of large canyon geomorphology and general bedrock topography that is present within the Shorts Creek watershed (Dobson, pers. comm., 2019).

Following the above, weekly naturalized streamflows for Shorts Creek at the streamflow point-of-interest were estimated using discontinued hydrometric records from Shorts Creek at the Mouth (WSC No. 08NM151)[8] extended to the 1996-2010 standard period using hydrometric records from the nearby Whiteman Creek above Bouleau Creek (WSC No. 08NM174). Specifically, the record for Shorts Creek was extended to the standard period using the mean weekly unit discharge relation established for the overlapping period of record between WSC No. 08NM174 and 08NM151 (i.e., 1971-1982) (Appendix H). This approach was different than that outlined in Appendix A (which recommended to scale the Whiteman Creek hydrometric records only) but was judged to better capture the actual streamflow characteristics.

Following the above, the Shorts Creek records were scaled to the drainage area for Shorts Creek at the streamflow point-of-interest (i.e., 185 km^2), but adjusted to represent the different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 15 (Fraser Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between the Shorts Creek point-of-interest (185 km^2; median elevation = 1,423 m) and Shorts Creek at WSC No. 08NM151 (184 km^2; median elevation = 1,424 m). The ratio used for adjustment purposes was 0.994. The estimated weekly time series was then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 15 (Appendix B).

[8] WSC No. 08NM151 was reported by the WSC to record regulated streamflow conditions; however, upon review of the WSC station description form, there was no note of upstream regulation. In addition, upon review of OWDM results for Shorts Creek watershed, the amount of land use present within the watershed is very small. Thus, it was deemed that the WSC No. 08NM151 records reflected natural (or near natural) streamflow conditions.

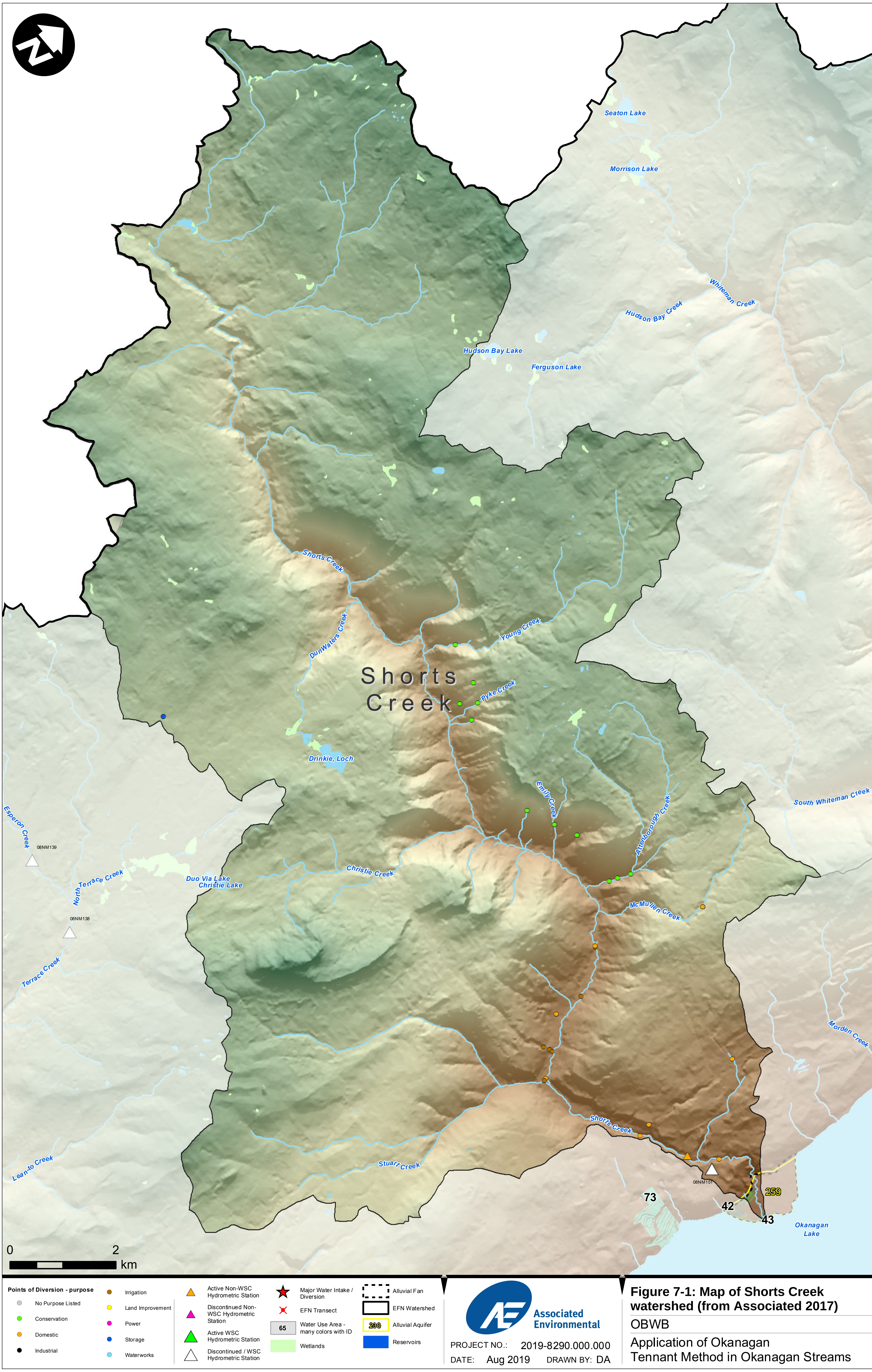

Figure 7-1: Map of Shorts Creek watershed (from Associated 2017)

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The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Whiteman Creek weekly scaling ratios (Appendix C).

Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. No field measurements were available to estimate streamflow gains/losses across the fan, so the approach recommended by Summit (2009a) was adopted. Summit (2009a) recommended that streamflow losses across the Shorts Creek alluvial fan were equivalent to 0.014 m^3/s/km. Therefore, with an alluvial fan channel length of 1.02 km (measured from apex to mouth), the estimated streamflow loss across the fan was estimated to 0.014 m^3/s. This loss was considered representative for the entire distance between the streamflow and EFN points-of-interest for all seasons and the standard period.

7.2 RESIDUAL STREAMFLOWS

7.2.1 Background Water Use Information

For Shorts Creek watershed, residual streamflows are a result of licensed water withdrawals by private residents; however, no information is publicly available on actual withdrawals within the watershed.

Besides the private residents, the City of West Kelowna is licensed to divert water from Shorts Creek into the Lambly Creek watershed through the DunWaters Diversion (under water licence C119359). The City of West Kelowna was contacted about the diversion and the following information was provided:

- The diversion was constructed in 2009 and the time when the diversion is opened/closed depends mostly on the timing of spring snowmelt and accessibility to the diversion. The diversion is generally operated from the last week of May or first week of June until June 30th. The volume diverted depends on the volume of water needed to fill Big Horn Reservoir within the Lambly Creek watershed. The volume is not measured as there is no weir structure(Hillis, pers. comm., 2019).

7.2.2 Shorts Creek to Streamflow Point-of-Interest

To estimate residual streamflows within Shorts Creek to the streamflow point-of-interest, the following approach was taken:

- Natural streamflows to the streamflow point-of-interest for the adjusted standard period were assumed to be equivalent to those estimated in Section 7.1.
- Water use within the watershed was assumed to be equivalent to the OWDM outputs for water use area 98 (Other_Node 16) (Figure 7-1). In addition, total water demand for water use area 147 was reduced by 4.9% (as recommended by Summit [2010]) to remove estimated groundwater use within the spatial extent of the water use area.
- Raw OWDM output for the Shorts Creek watershed indicates that no irrigation occurs within the watershed and water use is limited to domestic indoor, domestic outdoor, and stockwatering purposes only.
- Raw OWDM output for domestic outdoor water demands was supplemented as follows:
    - For selected years, the OWDM includes a Week 0 to account for outdoor watering by residents at the end of season to increase soil moisture to field capacity. Thus, water

  - demands estimated for years with Week 0 were assumed to occur evenly in September (i.e., Weeks 36 to 39) to consider the end of season watering.
  - The weekly water demand values were smoothed using the LOESS function, and the timing of domestic outdoor water use was generally limited to April and September (i.e., period of use).
- Under water licence C119359, the City of West Kelowna is licensed to divert water for storage purposes into Lambly Creek watershed (and into Big Horn Reservoir) through the DunWaters Diversion between April 1 (Week 14) and June 30 (Week 26). However, based on available information (Section 7.2.1), it was assumed that the diversion is operational each year between Weeks 22 to 26. Following this, based on superseded water licence C039007, the DunWaters Diversion was identified to account for 45% of the total licensed storage volume[9]. Thus, without actual records of diversion volumes, it was assumed that the City of West Kelowna diverted the water evenly (up to the estimated total licensed storage volume) between Weeks 22-26 each year.

7.2.3 Shorts Creek at EFN Point-of-Interest

To estimate residual streamflows within Shorts Creek at the EFN point-of-interest, streamflow gains/losses across the fan were consistent to that assumed in Section 7.1 and no water use or water licences were identified on the alluvial fan. See Appendix H for estimated residual streamflows at the EFN point-of-interest.

Streamflow records were available for a hydrometric station operated by ONA near Westside Road (Figure 4-1) for 2014-2017. The resultant residual streamflows for the adjusted standard period were compared to streamflows recorded by the ONA. The comparison indicated that although different time periods were compared, the general magnitude of the residual streamflows was consistent with that recorded by the ONA, but the timing of the spring freshet differed. However, upon further review, for the available period of record, the timing of the freshet in 2015 and 2016 was earlier than normal when compared to available records in other nearby watersheds (e.g., Whiteman Creek). See Appendix H for a visual comparison.

7.3 MAXIMUM LICENSED STREAMFLOWS

To estimate maximum licensed streamflows within Shorts Creek at the EFN point-of-interest, the same steps to estimate residual streamflows outlined in Section 7.2 were used, but domestic water use was assumed to be equivalent to the maximum licensed volume. In addition, although no irrigation was predicted by the OWDM for Shorts Creek watershed, water licences for irrigation purposes have been issued. To account for irrigation water licences, the weekly irrigation water use distribution pattern for Whiteman Creek watershed (from the OWDM) was assumed representative of an upstream alluvial fan water use pattern for Shorts Creek, while no water use on the fan was considered since no water licences are present. This also assumed that the weekly water use distribution pattern (predicted by the OWDM [for Whiteman Creek] for each year of the standard period) was the same between residual and maximum licensed conditions.

[9] Water licence C119359 includes diversion contributions into Big Horn Reservoir by the DunWaters Diversion, North Terrace Creek, and Christie Creek. Based on superseded water licence C039007, the diversion contributions are as follows: 45% DunWaters Diversion, 45% North Terrace Creek, and 10% Christie Creek.

7.4 SUMMARY OF THE THREE STREAMFLOW DATASETS

A summary of naturalized, residual, and maximum licensed streamflows at the streamflow and EFN points-of-interest is provided digitally in Appendix H. A comparison of LT mad values estimated herein and by others for Shorts Creek watershed are summarized in Table 7-1 and estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 7-2.

Lastly, following the data error and quality rating framework (Table 2-1), the resultant datasets are given a rating of B (i.e., data error >10% and ≤25%). This is due to the presence of historic WSC hydrometric records within the watershed, but several assumptions related to water use and streamflow gains/losses across the alluvial fan were required.

Table 7-1 Summary of LT mad values estimated for Shorts Creek watershed

	LT mad estimates for Shorts Creek watershed						
	Summit (2009a)	Ptolemy (2016)	Obedkoff (1998)	NHC (2001)	OK Basin Agreement (1974)	Tredger (1988)	This Study
Time Period	1996-2006	Unknown	1961-1990	1961-1995	Ave Year (1970)	1969-1982	Adjusted 1996-2010
Point-of-Interest	Mouth	WSC 08NM151	Mouth	Mouth	Mouth	WSC 08NM151	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	1.32	1.02	1.00	1.30	1.28	1.06	1.01
Residual LT mad (m^3/s)	-	-	-	-	-	-	0.992
Max Licensed LT mad (m^3/s)	-	-	-	-	-	-	0.979

Table 7-2 Summary of summer and winter period low streamflow statistics at Shorts Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.029	0.028
Summer 1:5-year return period 30 Day Low Streamflow	0.006	0.006
Summer 1:10-year return period 30 Day Low Streamflow	0.003	0.002
Summer 1:20-year return period 30 Day Low Streamflow	0.002	0.001
Winter 1:2-year return period 30 Day Low Streamflow	0.035	0.032
Winter 1:5-year return period 30 Day Low Streamflow	0.013	0.012
Winter 1:10-year return period 30 Day Low Streamflow	0.005	0.005
Winter 1:20-year return period 30 Day Low Streamflow	0.004	0.004

8 Inkaneep Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-6) for Inkaneep Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 8-1 provides an overview map of the watershed with the specific data sources, ONA EFN transects, and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix I.

8.1 NATURALIZED STREAMFLOWS

Weekly naturalized streamflows for Inkaneep Creek at the streamflow point-of-interest were estimated following the approach outlined in Appendix A, using several methods as follows:

- Actual residual streamflow records from Inkaneep Creek near the Mouth (WSC No. 08NM200) (which is located at the apex of fan – i.e., streamflow point-of-interest) were available for 2006-2010 (of the standard period).
- No information was available on water use for the watershed (Section 8.2.1), so the available WSC No. 08NM200 records were naturalized by adding estimated water use to the residual streamflows using data available from the OWDM as follows:
    - Water use within the watershed was assumed to be equivalent to the OWDM outputs for water use area 159 (Other_Node 78) (Figure 8-1). In addition, total water demand for water use area 159 was reduced by 14.6% (as recommended by Summit [2010]) to remove estimated groundwater use within the spatial extent of the water use area.
    - Water use area 159 encompasses the entire watershed; therefore, to divide OWDM outputs into above-alluvial fan and on-alluvial fan withdrawals, the spatial distribution of water licensed volumes was assumed representative of water withdrawals as follows:
        - Domestic water demands – 100% above the alluvial fan.
        - Unsupported by storage irrigation water demands – 88.7% above the alluvial fan and 11.3% on the alluvial fan.
        - Stockwatering – 100% above the alluvial fan.
    - Raw OWDM output for irrigation water demands was supplemented as follows:
        - For selected years, the OWDM includes a Week 0 to account for field watering by farmers at the end of season to increase soil moisture to field capacity. Thus, water demands estimated for years with Week 0 were assumed to occur evenly in September (i.e., Weeks 36 to 39) to consider the end of season watering.
        - A 10% irrigation system loss was assumed.
        - The weekly water demand values were smoothed using the LOESS function and the timing of irrigation water use was limited to April and September (i.e., licensed period of use).
    - Diversions to support storage licences were assumed to occur evenly each year between May 1 (Week 18) and June 30 (Week 26) up to the maximum licensed storage volume. No diversions were assumed to occur after June 30 and all stored water was used to support all respective licensed (and OWDM) water demands downstream.

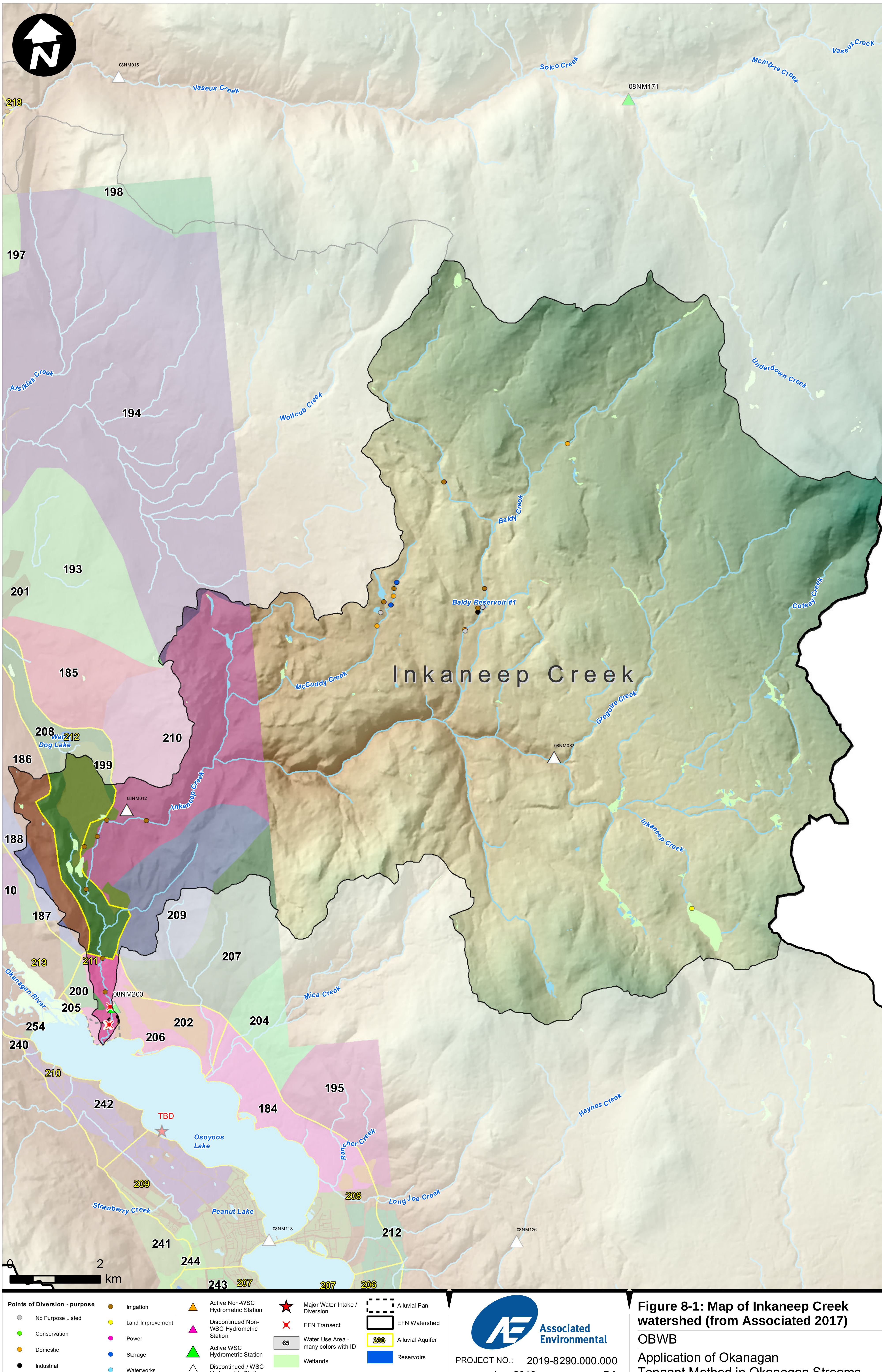

Figure 8-1: Map of Inkaneep Creek watershed (from Associated 2017)

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Application of Okanagan Tennant Method in Okanagan Streams

Following the approach described above, weekly naturalized unit discharges for Inkaneep Creek at the streamflow point-of-interest (i.e., WSC No. 08NM200) for 2006 to 2010 were compared to nearby WSC hydrometric stations (i.e., Vaseux Creek – WSC No. 08NM171, Camp Creek – WSC No. 08NM134) using natural streamflows for the overlapping period. Upon comparison of overlapping records, the naturalized streamflows for Inkaneep Creek had the strongest relationship with Vaseux Creek (WSC No. 08NM171). Thus, the record for Inkaneep Creek was extended to the standard period using the mean weekly unit discharge relation (Appendix I) and the Vaseux Creek (WSC No. 08NM171) streamflow records.

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Vaseux Creek weekly scaling ratios (Appendix C).

Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. With WSC No. 08NM200 located at the apex of the fan, corresponding manual streamflow measurements collected by the ONA at selected EFN transects on the alluvial fan were compared (Table 8-1; Figure 8-1). The results suggested that for the dates measured, the Inkaneep Creek channel generally lost water for the portion that was monitored. The average loss across the fan, based on measurements collected by the ONA m in August 2016 and July 2017, was 0.014 m^3/s, which is equivalent to 0.028 $m^3/s/km$ (between WSC No. 08NM200 and EFN transect INK30GL). The results were higher than those recommended by Summit (2009a) for considering streamflow gains/losses across the Inkaneep Creek alluvial fan (i.e., 0.014 $m^3/s/km$). Without additional information available, it was assumed that the average loss that ONA measured (i.e., 0.014 m^3/s) was representative for the entire distance between the streamflow and EFN points-of-interest for all seasons and the standard period.

Table 8-1 Comparison of discharge measurements across the Inkaneep Creek alluvial fan monitored by the WSC and ONA

Date	WSC No. 08NM200 (Upstream) – Mean Daily Discharge (m^3/s)	ONA EFN Transect[1,2] – Inst. Discharge (m^3/s)	
		INK30GL2016 (Downstream)	INK20GL2016 (Downstream)
17-Aug-16	0.036	0.023	0.031
15-Jun-17	0.944	0.951	1.01
23-Jun-17	0.555	0.500	0.500
11-Jul-17	0.157	0.139	0.119
26-Jul-17	0.092	0.080	0.041
14-Nov-17	0.182	-	0.171
24-Nov-17	0.233	-	0.250

Note:
1. Refer to Figure 8-1 for location of EFN transects.
2. Distance between INK30GL and INK20GL is approximately 10 m and no water intakes were reported by ONA. WSC No. 08NM200 is located approximately 400 m upstream of the EFN transects.

8.2 RESIDUAL STREAMFLOWS

8.2.1 Background Water Use Information

For the Inkaneep Creek watershed, residual streamflows are a result of licensed water withdrawals by private residents and the Osoyoos Indian Band; however, no information is publicly available on actual withdrawals within the watershed.

The ONA was contacted and provided the following information:

- There was a diversion on Inkaneep Creek located just upstream of WSC No. 08NM200 that withdrew a large proportion of the streamflow during the summer months in some years. The diversion was dismantled in 2016, but at the time of dismantling, the streamflows downstream doubled. Therefore, it is expected that some inconsistent streamflow patterns recorded at WSC No. 08NM200 prior to 2016 are likely related to the water diversion immediately upstream.

8.2.2 Inkaneep Creek to Streamflow Point-of-Interest

To estimate residual streamflows within Inkaneep Creek to the streamflow point-of-interest (for the period not previously recorded by WSC No. 08NM200), estimated water use was removed from the naturalized streamflows calculated in Section 8.1. Water use was estimated using the OWDM output following the methods outlined in Section 8.1.

8.2.3 Inkaneep Creek at EFN Point-of-Interest

To estimate residual streamflows within Inkaneep Creek at the EFN point-of-interest, streamflow gains/losses across the fan and on the fan and water use estimates were consistent to that assumed in Section 8.1. See Appendix I for estimated residual streamflows at the EFN point-of-interest.

8.3 MAXIMUM LICENSED STREAMFLOWS

To estimate maximum licensed streamflows within Inkaneep Creek at the EFN point-of-interest, the same steps to estimate residual streamflows outlined in Section 8.1 and 8.2 were used, but the OWDM output was scaled to maximum licensed volumes for the respective water use purposes and corresponding periods of use. This assumed that the weekly water use distribution pattern (predicted by the OWDM for each year of the standard period) was the same between residual and maximum licensed conditions.

8.4 SUMMARY OF THE THREE STREAMFLOW DATASETS

A summary of naturalized, residual, and maximum licensed streamflows at the streamflow and EFN points-of-interest is provided digitally in Appendix I. A comparison of LT mad values estimated herein and by others for Inkannep Creek watershed are summarized in Table 8-2 and estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 8-3.

Lastly, following the data error and quality rating framework (Table 2-1), the resultant datasets are given a rating of C (i.e., data error >25% and ≤50%). This is due to the presence of some WSC hydrometric records within the watershed, but several assumptions related to water use and streamflow gains/losses across the alluvial fan were required.

Table 8-2 Summary of LT mad values estimated for Inkaneep Creek watershed

	LT mad estimates for Inkaneep Creek watershed				
	Summit (2009a)	Ptolemy (2016)	Obedkoff (1998)	Eby (1985)	This Study
Time Period	1996-2006	Unknown	1961-1990	1921-1929	Adjusted 1996-2010
Point-of-Interest	Mouth	WSC No. 08NM200	WSC No. 08NM200	WSC No. 08NM012[1]	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	0.481	1.14	0.488	0.225	0.362
Residual LT mad (m^3/s)	-	-	-	-	0.333
Max Licensed LT mad (m^3/s)	-	-	-	-	0.267

Note:
1. WSC No. 08NM012 = Inkaneep Creek near Oliver (Lower Station); Period of Record = 1919-1950. See Figure 8-1 for location.

Table 8-3 Summary of summer and winter period low streamflow statistics at Inkaneep Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.081	0.079
Summer 1:5-year return period 30 Day Low Streamflow	0.036	0.033
Summer 1:10-year return period 30 Day Low Streamflow	0.019	0.015
Summer 1:20-year return period 30 Day Low Streamflow	0.016	0.009
Winter 1:2-year return period 30 Day Low Streamflow	0.071	0.071
Winter 1:5-year return period 30 Day Low Streamflow	0.051	0.051
Winter 1:10-year return period 30 Day Low Streamflow	0.043	0.043
Winter 1:20-year return period 30 Day Low Streamflow	0.038	0.038

9 Shuttleworth Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-7) for Shuttleworth Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 9-1 provides an overview map of the watershed with the specific data sources, ONA EFN transects, and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix J.

9.1 NATURALIZED STREAMFLOWS

For Shuttleworth Creek naturalized streamflows, a modification was made to the methods outlined in Appendix A after it was determined that the EFN point-of-interest (i.e., EFN transect SHW20SCR2016) was at the location of discontinued hydrometric station WSC No. 08NM149 (Shuttleworth Creek at the Mouth; Period of Record = 1970-1971 and 2006-2010).

Weekly naturalized streamflows for Shuttleworth Creek at the streamflow point-of-interest were estimated using two different methods, as follows:

- For 1996-2005, weekly naturalized streamflows for Shuttleworth Creek at the streamflow point-of-interest were estimated following the approach outlined in Appendix A using actual records from nearby Vaseux Creek above Solco Creek (WSC No. 08NM171). The Vaseux Creek records were scaled to the drainage area extent of the Shuttleworth Creek streamflow point-of-interest (i89.0 km^2), but adjusted to represent a different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 24 (Southern Thompson Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between the Shuttleworth Creek point-of-interest (89.0 km^2; median elevation = 1,543 m) and Vaseux Creek at WSC No. 08NM171 (117.5 km^2; median elevation = 1,694 m). The ratio used for adjustment purposes was 0.70. The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 24 (Appendix B).
- For 2006-2010, actual residual streamflow records from Shuttleworth Creek near the Mouth (WSC No. 08NM149) (which is located at the EFN point-of-interest) were available. No information was available on water use for the watershed (Section 9.2.1), so the available WSC No. 08NM149 records were naturalized by adding estimated water use (to the residual streamflows) available from the OWDM as follows:
    - Water use within the watershed was assumed to be equivalent to the OWDM outputs for water use area 142 (Other_Node 60) (Figure 9-1). In addition, total water demand for water use area 142 was reduced by 70.3% (as recommended by Summit [2010]) to remove estimated groundwater use within the spatial extent of the water use area.
    - Water use area 142 encompasses the entire watershed; however, no water licences are present on the alluvial fan between the streamflow and EFN points-of-interest. Thus, all water demands are considered to occur above the streamflow point-of-interest.

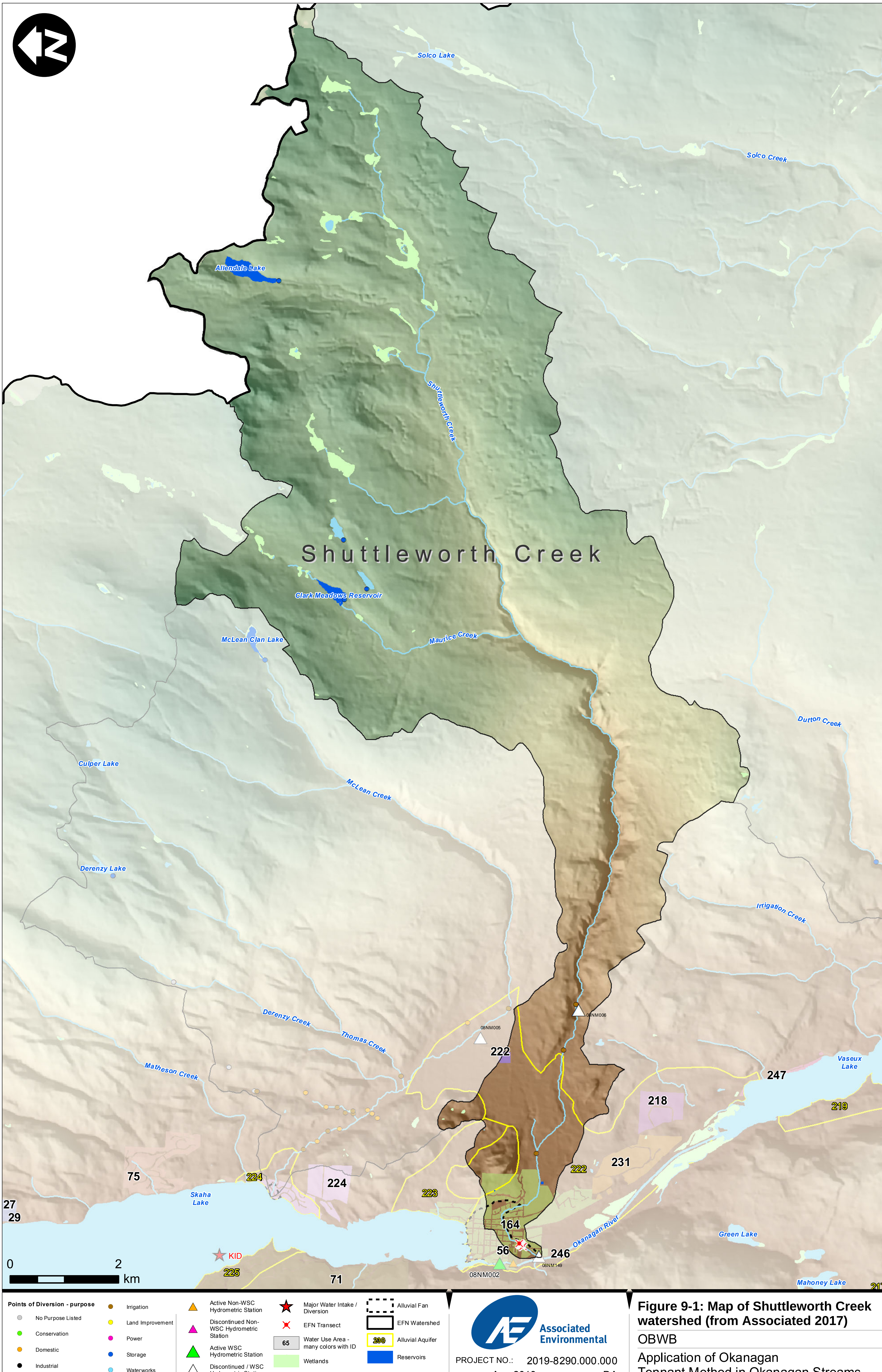

Figure 9-1: Map of Shuttleworth Creek watershed (from Associated 2017)

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- o Raw OWDM output for irrigation and domestic outdoor water demands were supplemented as follows:
  - For selected years, the OWDM includes a Week 0 to account for field watering by farmers and private residents at the end of season to increase soil moisture to field capacity. Thus, water demands estimated for years with Week 0 were assumed to occur evenly in September (i.e., Weeks 36 to 39) to consider the end of season watering.
  - A 10% irrigation system loss was assumed for irrigation water demands.
  - The weekly water demand values were smoothed using the LOESS function and timing of irrigation water use was limited to April and September (i.e., licensed period of use) for both irrigation and domestic outdoor water demands.
- o Diversions to support storage licences were assumed to occur each year between October 1 (Week 40) and June 15 (Week 25) up to the maximum licensed storage volume. The pattern of storage inflows was assumed equal to the pattern of natural streamflows for the respective weeks for each year recorded on Vaseux Creek at WSC No. 08NM171. No diversions were assumed to occur after June 15 and all stored water was assumed to be used to support all respective licensed (and OWDM) water demands downstream with no water being released beyond water demand needs (as noted in Section 9.2.1).

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Vaseux Creek weekly scaling ratios (Appendix C).

Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. The ONA installed one hydrometric station on the alluvial fan (at Maple Street – approximately 500 m downstream from the apex of the fan) (Figure 9-1). The ONA also collected corresponding manual streamflow measurements at selected EFN transects on the alluvial fan (Table 9-1; Figure 9-1) and the results suggested that for the dates measured, the Shuttleworth Creek channel generally lost water for the portion that was monitored. However, due to the limited spatial understanding of streamflow gains/losses across the entire alluvial fan, unclear seasonal variation (if any), and the accuracy of the hydrometric station records, it was deemed more appropriate to consider a gain/loss value equivalent to what Summit (2009a) recommended (0.014 $m^3/s/km$) to support hydrologic modelling of Shuttleworth Creek watershed during the OWSDP. Thus, with an alluvial fan channel length of approximately 1.5 km (measured from apex to EFN transect SHW20SCR2016), the estimated streamflow loss across the fan was estimated to 0.021 m^3/s. This loss was considered representative for the entire distance between the streamflow and EFN points-of-interest for all seasons and the standard period. This value was applied to the estimated dataset for the 1996-2005 period outlined above, while no value was applied to the 2006-2010 period since the WSC records already accounted for streamflow gains/losses across the fan.

Table 9-1 Comparison of discharge measurements across the Shuttleworth Creek alluvial fan monitored by the ONA

Date	ONA Hydrometric Station (Upstream) – Mean Daily Discharge (m^3/s)	ONA EFN Transect[1,2] – Inst. Discharge (m^3/s)	
		SHWGL502016 (Downstream)	SHWGL302016 (Downstream)
27-Oct-16	-	0.095	0.097
10-May-17	3.07	2.64	2.57
19-Jun-17	0.343	0.253	0.291
28-Jun-17	0.161	0.107	0.117
07-Jul-17	0.030	0.015	0.010
18-Apr-18	0.224	0.158	0.140
25-Apr-18	0.410	0.443	0.476
04-May-18	2.20	3.07	3.31

Note:
1. Refer to Figure 9-1 for location of EFN transects.
2. Distance between Glide 50 and Glide 30 is approximately 20 m and no water intakes were reported by ONA. The ONA hydrometric station at Maple Street is located approximately 600 m upstream of the EFN transects.

9.2 RESIDUAL STREAMFLOWS

9.2.1 Background Water Use Information

For Shuttleworth Creek watershed, residual streamflows are a result of licensed water withdrawals by private residents; however, no information is publicly available on actual withdrawals within the watershed.

A few selected water licencees were contacted and provided the following information:

- Allendale Water User's Community includes three water licensees. Water management involves two reservoirs (Allendale and Clarke Meadows) and water is stored until it is needed for irrigation purposes. Water is released downstream where it is piped into a balancing reservoir as needed, to later be piped to irrigate fields. All releases from the reservoirs are to meet irrigation needs at the time (Mavety, pers. comm., 2018).
    - On a normal year, 50% or less of the licensed amount is used by one licensee, while another indicated that their full licensed volume is used.
    - Of the water used, approximately 75-80% occurs between mid-June to the first week of August.

9.2.2 Shuttleworth Creek to Streamflow Point-of-Interest

To estimate residual streamflows within Shuttleworth Creek to the streamflow point-of-interest (for the period not previously recorded by WSC No. 08NM149), estimated water use was removed from the naturalized streamflows calculated in Section 9.1. Water use was estimated using the OWDM output following the methods outlined in Section 9.1.

9.2.3 Shuttleworth Creek to EFN Point-of-Interest

To estimate residual streamflows within Shuttleworth Creek at the EFN point-of-interest, streamflow gains/losses across the fan were assumed to be consistent to those described inSection 9.1, and no water use or water licences were identified on the alluvial fan. See Appendix J for estimated residual streamflows at the EFN point-of-interest.

Streamflow records were available for a hydrometric station operated by ONA at Maple Street (Figure 9-1) for 2017-2018. The resultant residual streamflows for the adjusted standard period were compared to streamflows recorded by the ONA and the comparison indicated that although different time periods were compared, the general magnitude of the residual streamflows was consistent with that recorded by the ONA. See Appendix J for a visual comparison.

9.3 MAXIMUM LICENSED STREAMFLOWS

To estimate maximum licensed streamflows within Shuttleworth Creek at the EFN point-of-interest, the same steps to estimate residual streamflows outlined in Section 9.1 and 9.2 were used, but the OWDM output was scaled to maximum licensed volumes for the respective water use purposes and corresponding periods of use. This assumed that the weekly water use distribution pattern (predicted by the OWDM for each year of the standard period) was the same between residual and maximum licensed conditions.

9.4 SUMMARY OF THE THREE STREAMFLOW DATASETS

A summary of naturalized, residual, and maximum licensed streamflows at the streamflow and EFN points-of-interest is provided digitally in Appendix J. A comparison of LT mad values estimated herein and by others for Shuttleworth Creek watershed are summarized in Table 9-2 and the estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 9-3.

Lastly, following the data error and quality rating framework (Table 2-1), the resultant datasets are given a rating of C (i.e., data error >25% and ≤50%). This is due to the presence of some WSC hydrometric records within the watershed, but several assumptions related to water use and streamflow gains/losses across the alluvial fan were required.

Table 9-2 Summary of LT mad values estimated for Shuttleworth Creek watershed

	LT mad estimates for Shuttleworth Creek watershed			
	Summit (2009a)	Ptolemy (2016)	Obedkoff (1998)	This Study
Time Period	1996-2006	Unknown	1961-1990	Adjusted 1996-2010
Point-of-Interest	Mouth	Mouth	Mouth	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	0.361	0.485	0.423	0.436
Residual LT mad (m^3/s)	-	-	-	0.407
Max Licensed LT mad (m^3/s)	-	-	-	0.406

Table 9-3 Summary of summer and winter period low streamflow statistics at Shuttleworth Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.049	0.043
Summer 1:5-year return period 30 Day Low Streamflow	0.020	0.012
Summer 1:10-year return period 30 Day Low Streamflow	0.010	0.002
Summer 1:20-year return period 30 Day Low Streamflow	0.006	0.000
Winter 1:2-year return period 30 Day Low Streamflow	0.028	0.022
Winter 1:5-year return period 30 Day Low Streamflow	0.010	0.003
Winter 1:10-year return period 30 Day Low Streamflow	0.004	0.001
Winter 1:20-year return period 30 Day Low Streamflow	0.002	0.000

10 McDougall Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-8) for McDougall Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 10-1 provides an overview map of the watershed with the specific data sources, ONA EFN transects, and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix K.

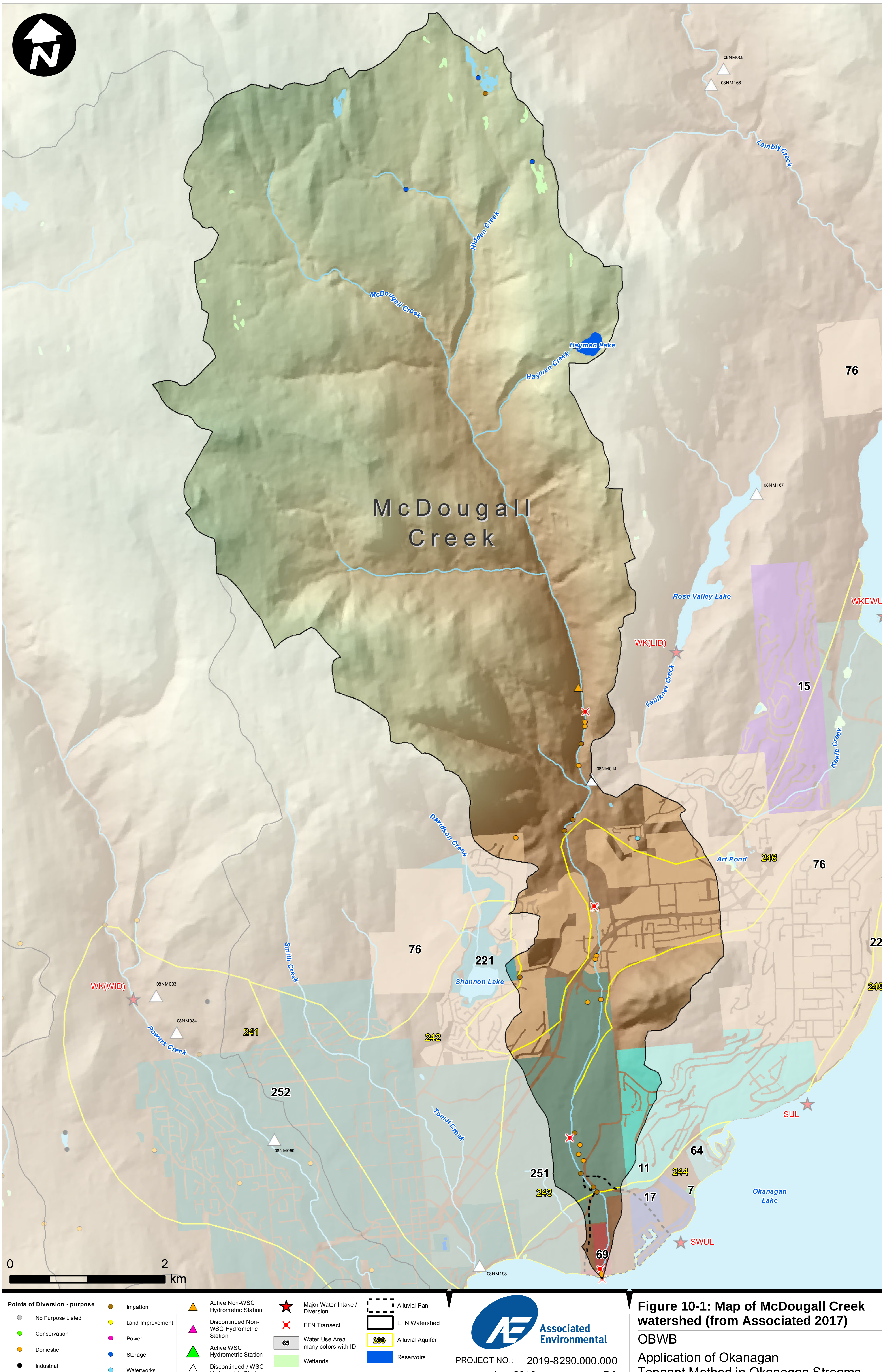
10.1 NATURALIZED STREAMFLOWS

For McDougall Creek naturalized streamflows, a modification was made to the methods outlined in Appendix A after ONA expressed concerns over low streamflow values estimated for the summer period (August to September) even after the temporal period adjustment factor (Section 2.2.3) was applied.

Specifically, weekly naturalized streamflows for McDougall Creek at the streamflow point-of-interest were estimated following the approach outlined in Appendix A, but using the average between scaled Daves Creek near Rutland (WSC No. 08NM137) extended to the 1996-2010 standard period and actual (1996-2010) scaled Camp Creek at Mouth near Thirsk (WSC No. 08NM134) records. This is a modification from that outlined in Appendix A, which recommends that extended Daves Creek records be used for estimation purposes. This modification was applied based on actual hydrometric records collected on McDougall Creek in 2017-2018, which indicated that the unit discharge for McDougall Creek watershed was better reflected by the average of the Daves and Camp Creek estimates. Also, McDougall Creek is located close to several provincial hydrologic zone divides, so the use of two WSC hydrometric stations (located in different hydrologic zones) was deemed to better capture the general streamflow characteristics of McDougall Creek watershed.

Specifically, weekly naturalized streamflows for McDougall Creek at the streamflow point-of-interest were estimated using discontinued hydrometric records from Daves Creek (WSC No. 08NM137) extended to the 1996-2010 standard period using hydrometric records from the nearby Whiteman Creek above Bouleau Creek (WSC No. 08NM174). Specifically, the record for Daves Creek was extended to the standard period using the mean weekly unit discharge relation established for the overlapping period of record between WSC No. 08NM137 and 08NM174 (Appendix K).

The Daves Creek records were then scaled to the McDougall Creek point-of-interest, but adjusted to represent different drainage areas with different median elevations. Specifically, the updated regional runoff relation for hydrologic zone 23 (Okanagan Highland) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between Daves Creek at WSC 08NM137 (31.6 km^2; median elevation = 1,316 m) and McDougall Creek watershed at the streamflow point-of-interest (52.8 km^2; median elevation = 1,182 m). The ratio used for adjustment purposes was 0.73. The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 23 (Appendix B).



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PROJECT NO.: 2019-8290.000.000

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Figure 10-1: Map of McDougall Creek watershed (from Associated 2017)

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Similarly, the Camp Creek records were scaled to the McDougal Creek point-of-interest, but were also adjusted to represent different drainage areas and median elevations. The updated regional runoff relation for hydrologic zone 24 (Southern Thompson Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between Camp Creek at WSC 08NM134 (34.7 km^2; median elevation = 1,456 m) and McDougall Creek watershed at the streamflow point-of-interest (52.8 km^2; median elevation = 1,182 m). The ratio used for adjustment purposes was 0.52. The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 23 (Appendix B).

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Camp Creek weekly scaling ratios (Appendix C).

Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. The ONA installed one hydrometric station on the alluvial fan, approximately 100 m from the mouth (Figure 10-1). The ONA also collected corresponding manual streamflow measurements at selected EFN transects on the alluvial fan (Table 10-1; Figure 10-1) and the results suggested that for the dates measured, the McDougall Creek channel generally lost water for the portion that was monitored. However, small water intakes operated by Westbank First Nation (WFN) are present on the fan, which limit an understanding of natural continuous streamflow gains/losses, since the water diversions are not gauged. Therefore, due to the limited spatial understanding of streamflow gains/losses across the entire alluvial fan, unclear seasonal variation (if any), and the unknown volume of water being diverted by WFN, it was deemed more appropriate to consider a gain/loss value equivalent to zero across the entire fan.

Table 10-1 Comparison of discharge measurements across the McDougall Creek alluvial fan monitored by the ONA

Date	ONA EFN Transect[1,2] – Discharge (m^3/s)	
	Glide 2 (Upstream)	Glide 1 (Downstream)
01-Sep-16	0.019	0.014
14-Nov-16	0.163	0.156
29-May-17	0.668	0.821
06-Jun-17	0.439	0.449
12-Jun-17	0.296	0.318
20-Jun-17	0.159	0.171
28-Jun-17	0.082	0.077
30-Jun-17	0.076	0.099
03-Jul-17	0.074	0.063
12-Jul-17	0.045	0.053
24-Jul-17	0.024	0.026
03-Aug-17	0.020	0.014

Note:
1. Refer to Figure 10-1 for location of EFN transects.
2. Distance between Glide 2 and Glide 1 is approximately 1.8 km.

10.2 RESIDUAL STREAMFLOWS

10.2.1 Background Water Use Information

For McDougall Creek watershed, residual streamflows are a result of licensed water withdrawals by WFN and private residents. Prior to dataset development, the ONA was contacted to discuss water use data, but no information was available on actual withdrawals.

The ONA did identify that McDougall Creek generally dries up naturally between Highway 97 for approximately 1-2 km downstream before water re-surfaces. This is generally observed under low streamflow conditions.

10.2.2 McDougall Creek to Streamflow Point-of-Interest

To estimate residual streamflows within McDougall Creek to the streamflow point-of-interest, the following approach was taken:

- Natural streamflows to the streamflow point-of-interest for the adjusted standard period were assumed to be equivalent to those estimated in Section 10.1.
- Water use within the watershed was assumed to be equivalent to the OWDM outputs for water use areas 221 (Shannon Lake Golf Course) and 109 (Other_Node 26) (Figure 10-1). The total water demand for water use areas 221 and 109 were reduced by 50% and 18.9%, respectively, as recommended by Summit (2010) to remove estimated groundwater use within the spatial extent of the water use area.
- Raw OWDM output for irrigation water demands was supplemented as follows:
    - For selected years, the OWDM includes a Week 0 to account for field watering by farmers/golf course operators at the end of season to increase soil moisture to field capacity. Thus, water demands estimated for years with Week 0 were assumed to occur evenly in September (i.e., Weeks 36 to 39) to consider the end of season watering.
    - A 10% irrigation system loss was assumed.
    - The weekly water demand values were smoothed using the LOESS function and the timing of irrigation water use was limited to April through September (i.e., licensed period of use).
- There are several storage licences present within McDougall Creek watershed. Diversions to support storage licences were assumed to occur each year between respective periods: October 1 (Week 40) and June 15 (Week 25) or April 1 (Week 15) and June 15 (Week 25) up to the maximum licensed storage volume. The pattern of storage inflows was assumed equal to the pattern of natural McDougall Creek streamflows (Section 10.1) for the respective weeks for each year. No diversions were assumed to occur after June 15 and all stored water was released evenly between April 1 (Week 14) and September 30 (Week 49) to be consistent with licensed use.
- The WFN are licensed to divert water for irrigation and domestic purposes at 10 points-of-diversion, with two located on the alluvial fan (i.e., water licence F009758). No information was available on actual WFN water use, so it was assumed that 80% of the WFN water demand occurs above the apex of the fan, while the remainder (i.e., 20%) occurs on the fan.

10.2.3 McDougall Creek at EFN Point-of-Interest

To estimate residual streamflows within McDougall Creek at the EFN point-of-interest, streamflow gains/losses across the fan were consistent to that assumed in Section 10.1, and water use on the alluvial fan was estimated as outlined in Section 10.2.2. See Appendix K for estimated residual streamflows at the EFN point-of-interest.

Streamflow records were available for a hydrometric station operated by ONA near the mouth of McDougall Creek (Figure 10-1) for 2017-2018. The resultant residual streamflows for the adjusted standard period were compared to streamflows recorded by the ONA and the comparison indicated that although different time periods were compared, the general magnitude of the residual streamflows was consistent with that recorded by the ONA. See Appendix K for a visual comparison.

10.3 MAXIMUM LICENSED STREAMFLOWS

To estimate maximum licensed streamflows within McDougall Creek at the EFN point-of-interest, the same steps to estimate residual streamflows outlined in Section 10.2 were used, but the OWDM output was scaled to maximum licensed volumes for the respective water use purposes and corresponding periods of use. This assumed that the weekly water use distribution pattern (predicted by the OWDM for each year of the standard period) was the same between residual and maximum licensed conditions.

10.4 SUMMARY OF THE THREE STREAMFLOW DATASETS

A summary of naturalized, residual, and maximum licensed streamflows at the streamflow and EFN points-of-interest is provided digitally in Appendix K. A comparison of LT mad values estimated herein and by others for McDougall Creek watershed are summarized in Table 10-2 and the estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 10-3.

Lastly, following the data error and quality rating framework (Table 2-1), the resultant datasets are given a rating of C (i.e., data error >25% and ≤50%). This is due to the presence of limited WSC hydrometric records within the watershed and the need to use several assumptions to consider water use and streamflow gains/losses across the alluvial fan.

Table 10-2 Summary of LT mad values estimated for McDougall Creek watershed

	LT mad estimates for McDougall Creek watershed						
	Summit (2004)	Summit (2009a)	Ptolemy (2016)	NHC (2001)	Obedkoff (1998) – Zone 23	Obedkoff (1998) – Zone 15	This Study
Time Period	1961-1995	1996-2006	Unknown	1961-1995	1961-1990	1961-1990	Adjusted 1996-2010
Point-of-Interest	Mouth	Mouth	Mouth	Mouth	EFN Point-of-Interest	EFN Point-of-Interest	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	0.119	0.089	0.232	0.118	0.113	0.161	0.132
Residual LT mad (m^3/s)	-	-	-	-	-	-	0.107
Max Licensed LT mad (m^3/s)	-	-	-	-	-	-	0.094

Table 10-3 Summary of summer and winter period low streamflow statistics at McDougall Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.024	0.025
Summer 1:5-year return period 30 Day Low Streamflow	0.018	0.013
Summer 1:10-year return period 30 Day Low Streamflow	0.015	0.009
Summer 1:20-year return period 30 Day Low Streamflow	0.014	0.007
Winter 1:2-year return period 30 Day Low Streamflow	0.023	0.018
Winter 1:5-year return period 30 Day Low Streamflow	0.018	0.012
Winter 1:10-year return period 30 Day Low Streamflow	0.016	0.010
Winter 1:20-year return period 30 Day Low Streamflow	0.015	0.009

11 Naramata Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-9) for Naramata Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 11-1 provides an overview map of the watershed with the specific data sources and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix L.

Note that for this watershed, ONA did not conduct any fieldwork to support the setting of EFNs. Thus, it was assumed that the EFN point-of-interest for this watershed was the mouth.

11.1 NATURALIZED STREAMFLOW

Weekly naturalized streamflows for Naramata Creek at the streamflow point-of-interest were estimated following the approach outlined in Appendix A using discontinued hydrometric records from Bellevue Creek near Okanagan Mission (WSC No. 08NM035) extended to the 1996-2010 standard period using hydrometric records from the nearby Vaseux Creek above Solco Creek (WSC No. 08NM171). Specifically, the record for Bellevue Creek was extended to the standard period using the mean weekly unit discharge relation established for the overlapping period of record between WSC No. 08NM035 and 08NM171 (Appendix L).

The Bellevue Creek records were then scaled to the Naramata Creek streamflow point-of-interest but adjusted to represent a different drainage area with a different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 24 (Southern Thompson Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between Bellevue Creek at WSC No. 08NM035 (72.7 km^2; median elevation = 1,541 m) and Naramata Creek watershed to streamflow point-of-interest (40.4 km^2; median elevation = 1,431 m). The ratios used for adjustment purposes was 0.77. The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 24 (Appendix B).

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Vaseux Creek weekly scaling ratios (Appendix C).

Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. No field measurements were available to estimate streamflow gains/losses across the fan. Therefore, due to the limited spatial understanding of streamflow gains/losses across the entire alluvial fan and unclear seasonal variation (if any), a gain/loss value equivalent to zero across the entire fan was assumed.

Figure 11-1: Map of Naramata Creek watershed (from Associated 2017)

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11.2 RESIDUAL STREAMFLOWS

11.2.1 Background Water Use Information

For Naramata Creek watershed, residual streamflows are largely a result of licensed water withdrawals by private residents and the Regional District of Okanagan-Similkameen (RDOS). No information is publicly available on actual withdrawals by private residents within the watershed.

The RDOS holds water licences on Naramata Creek for irrigation and waterworks purposes. These licences traditionally supported water use by the RDOS from their South Intake on Naramata Creek (Figure 11-1), which was used to supply water for the community of Naramata and local farmers. However, after 2007, the RDOS constructed a new intake in Okanagan Lake, and stopped full time operation of the South Intake on Naramata Creek.

Prior to the construction of the Okanagan Lake water intake, water within Naramata Creek was supplemented by the Chute-Robinson-Naramata Creek diversion (Summit 2009b). This diversion represents an inter-basin diversion as follows:

- Water is diverted from the Chute Creek watershed via a diversion ditch into Elinor Lake, located within Robinson Creek watershed.
- Water flowing in Robinson Creek is either diverted into the highline diversion (into Naramata Creek watershed) or extracted by the North Intake (located near the mouth of Robinson Creek) by the RDOS.
- The highline diversion adds water directly to Naramata Creek approximately 100 m upstream from the South Intake. Most of the water in Naramata Creek is extracted by the South Intake; however, due to conservation flow requirements, a portion of the streamflow (which includes natural runoff and the diverted volume from Robinson Creek watershed) is left since Naramata Creek can dry up in the summer.

Through discussions with the RDOS, the typical season for diversion of water into Naramata Creek was from July to the end of October (Palmer, pers. comm., 2019). Naramata Creek would be monitored visually and when a drop in streamflows was observed, the diversion would be opened for the season. The RDOS also identified that operators would try to maintain a minimum amount of water flowing back (after withdrawals at the South Intake) into Naramata Creek (Palmer, pers. comm., 2019). No records are available for the volume of water diverted into Naramata Creek by the highline diversion, but total monthly volumes withdrawn by the South Intake between 1996-2005 were provided by the RDOS (Appendix L).

The RDOS also identified even though the South Intake is no longer in operation, the RDOS is still operating the highline diversion in the same manner, with all diverted water into Naramata Creek directly supplementing streamflows (Palmer, pers. comm., 2019).

11.2.2 Naramata Creek to Streamflow Point-of-Interest

To estimate residual streamflows within Naramata Creek to the streamflow point-of-interest, the following approach was taken:

- Natural streamflows to the streamflow point-of-interest for the adjusted standard period were assumed to be equivalent to those estimated in Section 11.1.
- Water use within the watershed was assumed to be equivalent to the OWDM outputs for water use area 124 (Other_Node 40) (Figure 11-1). The total water demand for water use area 124 was reduced by 50% (as recommended by Summit [2010]) to remove estimated groundwater use within the spatial extent of the water use area.
- Water use area 45 (i.e., the area serviced by the RDOS South Intake) was not considered, since the water intake is not currently in operation.
- Water use area 124 encompasses the entire watershed; therefore, to divide OWDM outputs into above-alluvial fan and on-alluvial fan withdrawals, the spatial distribution of water licensed volumes was assumed representative of water withdrawals as follows:
    - Domestic indoor water demands – 100% on the alluvial fan.
    - Irrigation and domestic outdoor water demands – 70.3% above the alluvial fan and 29.7% on the alluvial fan.
- Raw OWDM output for irrigation and domestic outdoor water demands were supplemented as follows:
    - For selected years, the OWDM includes a Week 0 to account for field watering by farmers and private residents at the end of season to increase soil moisture to field capacity. Thus, water demands estimated for years with Week 0 were assumed to occur evenly in September (i.e., Weeks 36 to 39) to consider the end of season watering.
    - A 10% irrigation system loss was assumed for irrigation water demands.
    - The weekly water demand values were smoothed using the LOESS function and timing of irrigation water use was limited to April and September (i.e., licensed period of use) for both irrigation and domestic outdoor water demands.
- With no information available on the volume of water diverted into Naramata Creek by the highline diversion, the following diversion operation was assumed:
    - The diversion was in operation from July 1st to October 31st (as noted by the RDOS – Section 11.2.1).
    - The median monthly water withdrawals at the South Intake between 1996-2005 (recorded by the RDOS – Appendix L) for the respective months were assumed to reflect the volume of water diverted by the highline diversion[10]. This resulted in water diversions as follows: July – 0.070 m^3/s, August – 0.080 m^3/s, September – 0.050 m^3/s, and October – 0.020 m^3/s.

11.2.3 Naramata Creek to EFN Point-of-Interest

To estimate residual streamflows within Naramata Creek at the EFN point-of-interest, streamflow gains/losses across the fan were consistent to those assumed in Section 11.1, and water use on the alluvial fan was considered as outlined in Section 11.2.2. See Appendix L for estimated residual streamflows at the EFN point-of-interest.

[10] As noted in Section 11.2.1, the RDOS tried to maintain minimum streamflows past the South Intake, so it was assumed that water diverted into Naramata Creek by the highline diversion was equivalent to the volume withdrawn at the South Intake and that Naramata Creek provided enough water naturally to meet the respective minimum streamflows.

No hydrometric records (active or historic) are available for comparison of estimated residual streamflows within Naramata Creek. However, the results indicated that the residual streamflows are higher than naturalized streamflows during the summer and fall periods. This is a result of the additional water diverted into Naramata Creek by the highline diversion.

11.3 MAXIMUM LICENSED STREAMFLOWS

To estimate maximum licensed streamflows within Naramata Creek at the EFN point-of-interest, the same steps to estimate residual streamflows outlined in Section 11.2 were used, but the OWDM output was scaled to maximum licensed volumes for the respective water use purposes and corresponding periods of use. This assumed that the same weekly water use distribution pattern (predicted by the OWDM for each year of the standard period) was the same between residual and maximum licensed conditions.

Although RDOS water use (at the South Intake) was not considered when estimating residual streamflows, the RDOS water licences are still active, so they were considered when estimating the maximum licensed streamflow.

11.4 SUMMARY OF THE THREE STREAMFLOW DATASETS

A summary of naturalized, residual, and maximum streamflows at the streamflow and EFN points-of-interest is provided digitally in Appendix L. A comparison of LT mad values estimated herein and by others for Naramata Creek watershed are summarized in Table 11-1 and the estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 11-2.

Lastly, following the data error and quality rating framework (Table 2-1), the naturalized streamflow dataset is given a rating of C (i.e., data error >25% and ≤50%) and the residual and maximum licensed streamflow datasets a rating of D (i.e., >50%). This is due to no WSC hydrometric records available within the watershed, the need to use several assumptions to consider water use and streamflow gains/losses across the alluvial fan, and the need to estimate the volume of water diverted into Naramata Creek by the highline diversion.

Table 11-1 Summary of LT mad values estimated for Naramata Creek watershed

	LT mad estimates for Naramata Creek watershed					
	Summit (2009a)	Ptolemy (2016)	Obedkoff (1998)	NHC (2001)	Coulson (1982)	This Study
Time Period	1996-2006	Unknown	1961-1990	1961-1995	Unknown	Adjusted 1996-2010
Point-of-Interest	Mouth	Mouth	Mouth	Unknown	Unknown	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	0.129	0.250	0.141	0.100	0.091	0.157
Residual LT mad (m^3/s)	-	-	-	-	-	0.173
Max Licensed LT mad (m^3/s)	-	-	-	-	-	0.136

Table 11-2 Summary of summer and winter period low streamflow statistics at Naramata Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.012	0.047
Summer 1:5-year return period 30 Day Low Streamflow	0.006	0.040
Summer 1:10-year return period 30 Day Low Streamflow	0.004	0.037
Summer 1:20-year return period 30 Day Low Streamflow	0.002	0.036
Winter 1:2-year return period 30 Day Low Streamflow	0.009	0.009
Winter 1:5-year return period 30 Day Low Streamflow	0.005	0.005
Winter 1:10-year return period 30 Day Low Streamflow	0.004	0.004
Winter 1:20-year return period 30 Day Low Streamflow	0.003	0.003

12 Mission Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-10) for Mission Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 12-1 provides an overview map of the watershed with the specific data sources and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix M.

Note that for this watershed, FLNRORD identified that the EFN point-of-interest for this watershed would be Mission Creek near East Kelowna (WSC No. 08NM116.

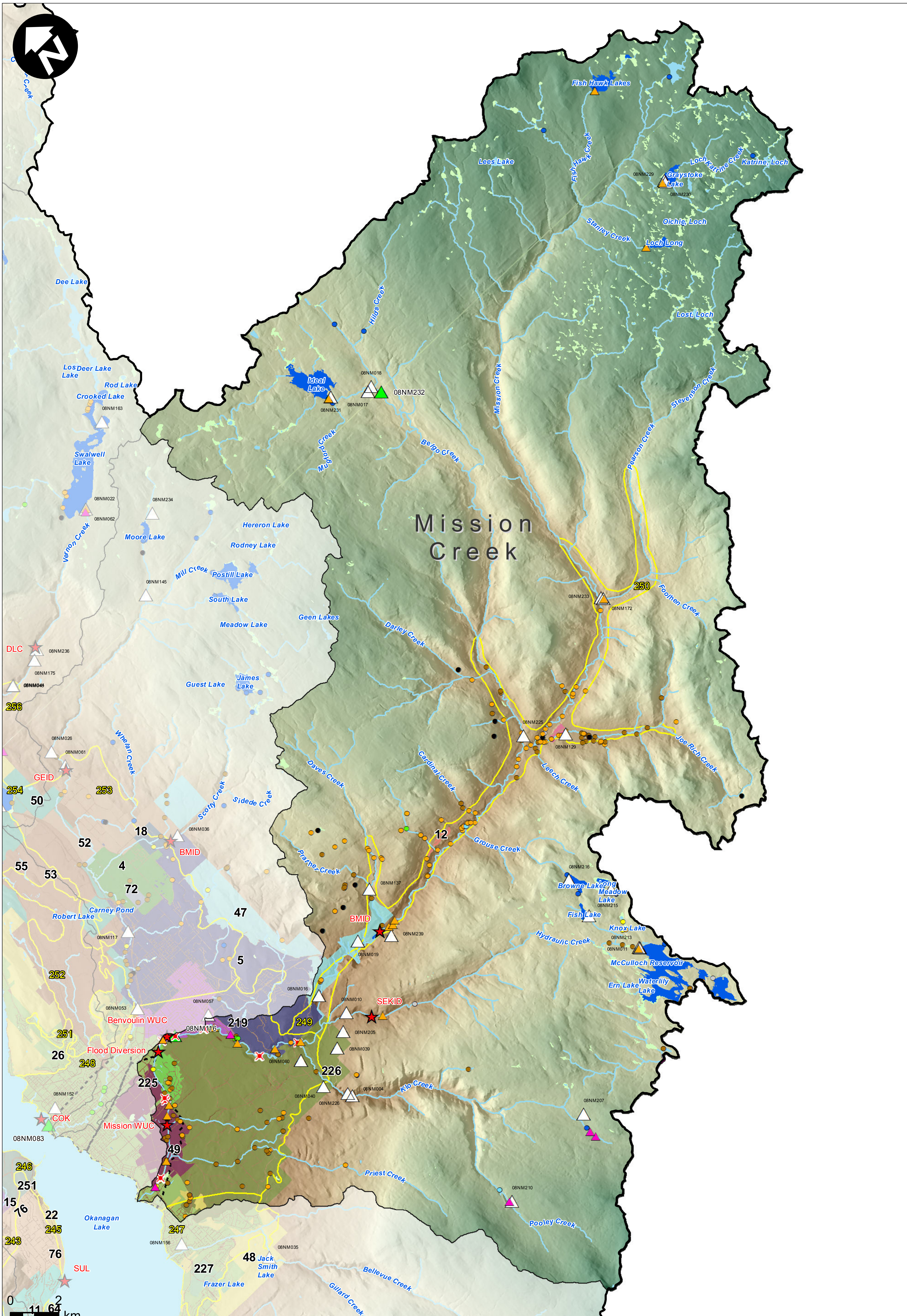
12.1 NATURALIZED STREAMFLOW

Actual residual streamflow records from Mission Creek (WSC No. 08NM116) (i.e., EFN point-of-interest) are available, and some water use and reservoir management information is available for the watershed (Section 12.2.1). Therefore, following the methods outlined in Appendix A, the available WSC No. 08NM116 records were initially naturalized by adding water use (to the residual streamflows) available from actual records and the OWDM, as well as considering the upland reservoir operations by Black Mountain Irrigation District (BMID) and Southeast Kelowna Irrigation District (SEKID).

However, upon review of the initial naturalized streamflow results, the ONA expressed concerns over low streamflow values estimated for the summer period (August to September) even after the temporal period adjustment factor (Section 2.2.3) was applied. Due to the substantial level of water management within the watershed, the estimated low streamflow concerns were identified to likely be related to the several assumptions needed to consider upland reservoir management by BMID and SEKID and the conversion of total monthly water use into weekly values. Thus, a modification to the methods outlined in Appendix A was applied to improve the naturalized streamflow estimates.

Based on the approach described above, weekly naturalized streamflows for Mission Creek at the streamflow point-of-interest were estimated using discontinued hydrometric records from Pearson Creek[11] near the Mouth (WSC No. 08NM172) extended to the 1996-2010 standard period using hydrometric records from the nearby West Kettle River near McCulloch (WSC No. 08NN015). Specifically, the record for Pearson Creek was extended to the standard period using the mean weekly unit discharge relation established for the overlapping period of record between WSC No. 08NM172 and 08NN015 (Appendix M).

[11] Pearson Creek is a tributary to Mission Creek that is not influenced by water use or management within the watershed.



Points of Diversion - purpose

- No Purpose Listed
- Conservation
- Domestic
- Industrial
- Irrigation
- Land Improvement
- Power
- Storage
- Waterworks

- Active Non-WSC Hydrometric Station
- Discontinued Non-WSC Hydrometric Station
- Active WSC Hydrometric Station
- Discontinued / WSC Hydrometric Station
- Major Water Intake / Diversion
- EFN Transect
- 65 Water Use Area - many colors with ID
- Wetlands
- Alluvial Fan
- EFN Watershed
- 290 Alluvial Aquifer
- Reservoirs

Associated Environmental

PROJECT NO.: 2019-8290.000.000

DATE: Aug 2019 DRAWN BY: DA

Figure 12-1: Map of Mission Creek watershed (from Associated 2017)

OBWB

Application of Okanagan Tennant Method in Okanagan Streams

The Pearson Creek records were then scaled to the Mission Creek streamflow point-of-interest but adjusted to represent a different drainage area with a different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 23 (Okanagan Highland) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between Pearson Creek at WSC No. 08NM172 (73.2 km^2; median elevation = 1,572 m) and Mission Creek watershed to streamflow point-of-interest (785.9 km^2; median elevation = 1,393 m). The ratio used for adjustment purposes was 0.65. The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 23 (Appendix B).

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Vaseux Creek weekly scaling ratios (Appendix C).

For the Mission Creek watershed, WSC No. 08NM116 is located close to the apex of the alluvial fan, so the streamflow and EFN points-of-interest are considered the same location. Therefore, gains/losses across the alluvial fan are not considered further.

Natural streamflow records were available for Pearson Creek at WSC No. 08NM172 for 1970-1987 and at the same location for 2004-2005, 2008-2009, and 2015-2016 from a third-party data collector. The resultant naturalized unit discharge for Mission Creek (at the EFN point-of-interest) for the adjusted standard period were compared to unit discharges recorded by the WSC and third-party data collector. The comparison indicated that although different time periods were compared, the general magnitude of the unit discharges were consistent with natural unit discharges previously recorded within the Mission Creek watershed. See Appendix M for a visual comparison.

12.2 RESIDUAL STREAMFLOWS

12.2.1 Background Water Use Information

For the Mission Creek watershed, residual streamflows are a result of licensed water withdrawals by private residents, BMID, and SEKID and by upland reservoir operations by BMID and SEKID. No information was available on private resident water user, but BMID and SEKID were contacted and provided the following information:

- BMID reservoir operator notes outlining timing of historical water storage and volume releases from Fish Hawk, Graystoke, and Belgo Reservoirs from 1993-2009.
- Mean daily releases from McCulloch Reservoir between 1998 and 2010 and total monthly water withdrawals from Hydraulic Creek from 1995 to 2018 (provided by SEKID).

In addition to the above information, total monthly water withdrawals at the BMID water intake on Mission Creek were reported by KJWC (2012) for 1992-2010.

Also, as outlined within the Mission Creek Water Use Plan (WMC 2010), fishery flow targets at WSC No. 08NM116 and minimum streamflow releases at the BMID and SEKID water intakes are summarized as follows:

- Minimum streamflow releases:
  - BMID = 0.500 m^3/s
  - SEKID = 0.031 m^3/s
- Fishery Flow Targets at WSC No. 08NM116:
  - July and August = 2.25 m^3/s;
  - September = 1.90 m^3/s; and
  - October = 1.50 m^3/s.

Based on the above information, residual streamflows measured at WSC No. 08NM116 include streamflow supplementation by BMID and SEKID at certain times of the year to ensure that minimum streamflows and/or fishery flows are met.

12.2.2 Mission Creek at EFN Point-of-Interest

Residual streamflows within Mission Creek at the EFN point-of-interest are considered equivalent to those measured at WSC No. 08NM116. Hydrometric records are available for 1949-present at the WSC hydrometric station; therefore, actual records are available for the long-term adjustment period (i.e., 1971-2014) and provide an unbiased period of dry and wet climatic and streamflow conditions (Section 2.2.3). Thus, a 15-year residual streamflow dataset was not developed, since it was deemed more appropriate to allow ONA to use the actual long-term hydrometric records to support EFN-setting. However, for comparison purposes, the median weekly residual streamflow for 1971-2014 was calculated and included in Appendix M.

12.3 MAXIMUM LICENSED STREAMFLOWS

Maximum licensed streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

12.4 SUMMARY OF STREAMFLOW DATASETS

A summary of naturalized and residual streamflows at the EFN points-of-interest is provided digitally in Appendix M. A comparison of LT mad values estimated herein and by others for Mission Creek watershed are summarized in Table 12-1 and the estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 12-2. As noted in Section 12.2.1, streamflows within Mission Creek are supplemented at certain times of the year to meet Mission Creek Water Use Plan requirements. Therefore, residual streamflows can be higher than naturalized streamflows in some years.

Lastly, following the data error and quality rating framework (Table 2-1), the naturalized and residual streamflow datasets are given a rating of B (i.e., data error >10% and ≤25%) and A (i.e., data error ≤10%), respectively. This is due to a WSC hydrometric records available at the EFN point-of-interest that measures residual streamflows, but insufficient water management information available to directly estimate naturalized streamflows using the residual streamflow information.

Table 12-1 Summary of LT mad values estimated for Mission Creek watershed

	LT mad estimates for Mission Creek watershed								
	Summit (2009a)	**Ptolemy (2016)**	**NHC (2001)**	**WMC (2010)**	**MOE (2000)**	**Reksten (undated)**	**OK Basin Agreement (1974)**	**Obedkoff (1998)**	**This Study[1]**
Time Period	1996-2006	Unknown	1961-1995	1954-2004	Unknown	1949-1964	Average Year	1961-1990	Adjusted 1996-2010
Point-of-Interest	Mouth	WSC 08NM116	Mouth	WSC 08NM116	WSC 08NM116	Mouth	Mouth	WSC 08NM116	WSC 08NM116
Naturalized LT mad (m^3/s)	7.82	6.92	11.6	7.50	8.17	6.33	5.56	7.47	6.35
Residual LT mad (m^3/s)	-	-	-	-	-	-	-	-	6.28
Max Licensed LT mad (m^3/s)	-	-	-	-	-	-	-	-	-

Note:
1. Naturalized LT mad = adjusted 1996-2010 period, while residual LT mad = actual recorded LT mad for 1971-2014 measured at WSC No. 08NM116.

Table 12-2 Summary of summer and winter period low streamflow statistics at Mission Creek EFN point-of-interest

Streamflow Statistic[1]	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	1.10	1.23
Summer 1:5-year return period 30 Day Low Streamflow	0.578	0.866
Summer 1:10-year return period 30 Day Low Streamflow	0.430	0.760
Summer 1:20-year return period 30 Day Low Streamflow	0.340	0.701
Winter 1:2-year return period 30 Day Low Streamflow	0.702	0.783
Winter 1:5-year return period 30 Day Low Streamflow	0.507	0.545
Winter 1:10-year return period 30 Day Low Streamflow	0.461	0.459
Winter 1:20-year return period 30 Day Low Streamflow	0.444	0.401

Note:

1. Naturalized low streamflow statistics calculated using adjusted 1996-2010 estimates, while residual statistics calculated using actual 1917-2014 records measured at WSC No. 08NM116.

13 Penticton Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-11) for Penticton Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 13-1 provides an overview map of the watershed with the specific data sources and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix N.

Note that for this watershed, ONA did not conduct any fieldwork to support the setting of EFNs. Thus, it was assumed that the EFN point-of-interest for this watershed was the mouth.

13.1 NATURALIZED STREAMFLOW

For Penticton Creek naturalized streamflows, a modification was made to the methods outlined in Appendix A after streamflow values estimated for the summer period (August to September) were deemed too low even after the temporal period adjustment factor (Section 2.2.3) was applied.

Specifically, the modification for the development of the necessary streamflow datasets included the division of the watershed into three sub-watersheds: 1) Greyback Lake watershed, 2) Penticton Creek watershed to streamflow point-of-interest (minus Greyback Lake watershed), and 3) Penticton Creek watershed between the streamflow point-of-interest and the mouth (Figure 13-1). This division was completed to support the development of the regulated streamflow datasets to allow for the consideration of reservoir management (Section 13.2).

For the Greyback Lake sub-watershed, weekly naturalized streamflows were estimated using hydrometric records from Two Forty (WSC No. 08NM240) and Two Forty One (WSC No. 08NM241) Creeks near Penticton that both have data for the 1996-2010 standard period. Both creeks directly flow into Greyback Lake, so the average mean weekly unit discharge between both WSC hydrometric stations was used to scale to the drainage area extent of the sub-watersheds but adjusted to represent a different drainage area with a different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 24 (Southern Thompson Plateau) (Appendix B) and Two Forty and Two Forty One Creeks was used to adjust the ratio of the predicted normal annual runoff for the Greyback Lake watershed (30.8 km^2; median elevation = 1,704 m). The ratio used for adjustment purposes was 0.92. The estimated weekly time series was then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 15 (Appendix B).

Figure 13-1: Map of Penticton Creek watershed (from Associated 2017)

OBWB

Application of Okanagan Tennant Method in Okanagan Streams

Following the approach described above, weekly naturalized streamflows for Penticton Crek watershed to streamflow point-of-interest (minus Greyback Lake watershed) and Penticton Creek watershed between streamflow-point-of-interest and mouth were estimated using hydrometric records from Vasuex Creek above Solco Creek (WSC No. 08NM171). The Vaseux Creek records were scaled to the drainage area extents of each sub-watershed, but adjusted to represent a different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 24 (Southern Thompson Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between the Penticton Creek streamflow point-of-interest (minus Greyback Lake watershed) (144.2 km^2; median elevation = 1,559 m), Penticton Creek watershed between streamflow-point-interest and mouth (4.2 km^2; median elevation = 429 m), and Vaseux Creek at WSC No. 08NM171 (117.5 km^2; median elevation = 1,694 m). The ratios used for adjustment purposes were 1.04 (Penticton Creek streamflow-point-of-interest [minus Greyback Lake watershed]) and 0.07 (Penticton Creek between streamflow point-of-interest and mouth). The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 24 (Appendix B).

Streamflows at the streamflow point-of-interest were then assumed to be the sum the Greyback Lake watershed outflows and the estimated Penticton Creek to streamflow point-of-interest (minus Greyback Lake watershed) streamflows – which assume no streamflow routing influence due to the weekly time-step modelled.

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Vaseux Creek weekly scaling ratios (Appendix C).

Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. No field measurements were available to estimate streamflow gains/losses across the fan. Therefore, due to the limited spatial understanding of streamflow gains/losses across the entire alluvial fan and unclear seasonal variation (if any), a gain/loss value equivalent to zero across the entire fan was assumed.

13.2 RESIDUAL STREAMFLOWS

13.2.1 Background Water Use Information

For Penticton Creek watershed, residual streamflows are a result of licensed water withdrawals by the City of Penticton (COP) and private residents, as well as through Greyback Lake reservoir management (by COP). Prior to dataset development, the COP was contacted to discuss data availability and a review of a technical assessment completed by Associated (2018) to support the development of a Penticton drought management plan was conducted. The results of the discussion and review were as follows:

- Greyback Lake storage is managed by the COP to ensure adequate water supply is available to downstream users and aquatic resources. Under normal conditions, Greyback Lake is managed under two settings: (1) winter and (2) summer. The two settings are summarized by the City of Penticton (2014) as follows:
  - Winter Setting (November 15 to April 15) – gate (i.e., 8” gate) is set to provide enough water within Penticton Creek for potable usage, Water Treatment Plant (WTP) operations, and fall Kokanee Salmon spawning.

  - Summer Setting (April 16 to November 14) – gate (i.e., 24" gate open and 8" gate closed, or 24" and 8" gates open proportionally) is set to provide enough water within Penticton Creek for potable and irrigation usage and WTP operations.
  - Total reservoir storage volume for Greyback Lake was monitored manually between 1980-2015 and since 2016 is now monitored continuously through COP's supervisory control and data acquisition (SCADA) system.
- The Campbell Mountain Diversion dam supports the diversion of water through a tunnel to supply the North Penticton Irrigation System. The diversion is only operational during the irrigation season (i.e., April to September).
- The Penticton #2 dam was designed to support the diversion of water to the WTP. The diversion operates as required year-round, based on the requirements of the WTP for blending of water from different sources and distribution purposes. The dam was designed as a flow-through system, with water diverted as necessary and the remainder spilling to maintain streamflow.
- Total monthly diversions for the North Penticton Irrigation System are available for 2004-2016. Since the Campbell Mountain Diversion is only used for irrigation purposes, water is typically only diverted between April and October, with the months of July and August typically being the highest.
- Total monthly Penticton Creek diversions for the WTP are available for 2009-2016. The water diversions vary throughout the year largely due to the WTPs blending of water with Okanagan Lake diversions; however, approximately 55% of the diverted water is used between April and September.
- Currently there are no provincially regulated fishery flow requirements for Penticton Creek. However, COP has implemented a year-round minimum streamflow criteria of 0.231 m^3/s downstream of the WTP intake, which is monitored by the City's hydrometric station at Nanaimo Avenue (Associated 2018). Historic hydrometric datasets are available for the hydrometric station from 2001 to 2016; however, COP identified that the quality of the datasets was unknown (Firlotte, pers. comm., 2019). The minimum streamflow criteria has been implemented to limit sedimentation at the WTP intake.

13.2.2 Greyback Lake Watershed – Outflows

To estimate residual streamflows for the Greyback Lake watershed, a Greyback Lake water balance spreadsheet model was developed for the adjusted standard period. The following datasets and assumptions were included within the model:

- Natural inflows into Greyback Lake for the adjusted standard period were equivalent to those estimated in Section 3.1.
- Total monthly precipitation on the surface of Greyback Lake was estimated using ClimateWNA and split into a weekly time-step using the weekly precipitation pattern observed at the Penticton Airport climate station (Meteorological Service of Canada Station No. 1126150; located approximately 25 km southwest of Greyback Lake).
  - Precipitation in the form of rain was added to the lake surface between April (starting on Week 14) and November (ending on Week 46, when ice was assumed to be present).
  - Between mid-November (Week 47) and mid-March (Week 16) precipitation was assumed to be in the form of snow and accumulated on the frozen lake surface. Of the accumulated snowpack, 10% was assumed to be lost to sublimation during the winter period and the remaining snow was assumed to melt during the month of April (each year), assuming the

following melting schedule: Week 14 = 20%, Week 15 = 20%, Week 16 = 50%, and Week 17 = 10%.

- Total monthly evaporation from Greyback Lake was estimated using ClimateWNA. The monthly values were divided into a weekly time-step using a smoothing function (i.e., LOESS). Limited (or no) evaporation was assumed to occur from the lake between November and March.
- Groundwater seepage losses form the lake were assumed to be negligible.
- Greyback Lake storage capacity was assumed to be equivalent to the values recorded manually by COP.
- The operation of the Greyback Lake outlet structure followed that as outlined by City of Penticton (2014) and summarized in Section 13.2.1.

Greyback Lake water level records were available to support model development. In addition, the WSC operated a hydrometric station downstream of Greyback Lake (i.e., WSC No. 08NM168; Penticton Creek above Dennis Creek) that included available records for the standard period (1996-1999). A summary of the lake water levels and outflows for the adjusted standard period are presented in Appendix N. The results suggest that the modelled streamflow releases from Greyback Lake are generally consistent with the measured streamflows recorded by WSC No. 08NM168).

13.2.3 Penticton Creek to Streamflow Point-of-Interest (minus Greyback Lake watershed)

To estimate residual streamflows within Penticton Creek to the streamflow point-of-interest (minus Greyback Lake watershed), the following approach was taken:

- Natural streamflows to the streamflow point-of-interest for the adjusted standard period were assumed to be equivalent to those estimated in Section 13.1.
- Actual water use records available from COP were used for the WTP (Penticton Creek supply only) between 2000-2010. For the period of missing record (i.e., 1996-1999), the median weekly water use recorded between 2000-2010 was assumed representative due to the uncertainty of the amount of blending of Okanagan Lake and Penticton Creek water that occurred during that period.
- Actual water records available from COP were used from the North Penticton Irrigation System between 2004-2010. For the period of missing records (i.e., 1996-2003), the total annual water use estimated by the OWDM for water use area 30 (City of Penticton [System ID 4]) was split into weekly values assuming that the median weekly irrigation distribution records by COP for 2004-2010 was generally representative of the North Penticton Irrigation System during 1996-2003.
- Water use within the remainder of the sub-watershed was assumed equivalent to the OWDM outputs for water use area 130 (Other_Node 46) (Figure 13-1). The total water demand for water use area 130 was reduced by 48.4%, as recommended by Summit (2010), to remove estimated groundwater use within the spatial extent of the water use area.
- Raw OWDM output for irrigation water demands (for water use areas 30 and 130) was supplemented as follows:
    - For selected years, the OWDM includes a Week 0 to account for field watering by farmers at the end of season to increase soil moisture to field capacity. Thus, water demands estimated for years with Week 0 were assumed to occur evenly in September (i.e., Weeks 36 to 39) to consider the end of season watering.
    - A 10% irrigation system loss was assumed.

- The weekly water demand values were smoothed using the LOESS function and the timing of irrigation water use was limited to April through September (i.e., licensed period of use).

13.2.4 Penticton Creek at EFN Point-of-Interest

To estimate residual streamflows within Penticton Creek at the EFN point-of-interest, the streamflows estimated in Sections 13.2.2 and 13.2.3 were summed and the streamflows estimated for Penticton Creek between the streamflow point-of-interest and the mouth (Section 13.1) were also added. No off-stream water licences have been issued along the Penticton Creek alluvial fan. Also, streamflow gains/losses across the alluvial fan were consistent to those assumed in Section 13.1.

The resultant residual streamflows for the adjusted standard period were compared to streamflows recorded by COP at Nanaimo Avenue (Period of record: 2001-2016). The comparison indicated that although different time periods were compared, the general magnitude of the residual streamflows was consistent with that previously measured by COP. See Appendix N for a visual comparison.

13.3 MAXIMUM LICENSED STREAMFLOWS

Maximum licensed streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

13.4 SUMMARY OF STREAMFLOW DATASETS

A summary of naturalized and residual streamflows at the EFN points-of-interest is provided digitally in Appendix N. A comparison of LT mad values estimated herein and by others for Penticton Creek watershed are summarized in Table 13-1 and the estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 13-2. As noted in Section 13.2.1, COP has implemented a year-round minimum streamflow criteria of 0.231 m^3/s within Penticton Creek downstream of the WTP intake. Therefore, residual streamflows can be higher than naturalized streamflows in some years.

Lastly, following the data error and quality rating framework (Table 2-1), the naturalized and residual streamflow datasets are given a rating of B (i.e., data error >10% and ≤25%). This is due to COP hydrometric records available near the EFN point-of-interest that measure residual streamflows, but insufficient water management information available to directly estimate naturalized streamflows due to the significant instream channel work that has been completed on Penticton Creek between the WTP and the mouth.

Table 13-1 Summary of LT mad values estimated for Penticton Creek watershed

	LT mad estimates for Penticton Creek watershed						
	Summit (2009a)	**Ptolemy (2016)**	**NHC (2001)**	**Obedkoff (1998)**	**Rodgers and Kreuder (1963)**	**OK Basin Agreement (1974)**	**This Study**
Time Period	1996-2006	Unknown	1961-1995	1961-1990	1930-1960	Average Year	Adjusted 1996-2010
Point-of-Interest	Mouth	Mouth	Mouth	Mouth	Mouth	Mouth	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	0.518	2.00	1.35	0.971	1.68	1.36	1.16
Residual LT mad (m^3/s)	-	-	-	-	-	-	1.15
Max Licensed LT mad (m^3/s)	-	-	-	-	-	-	-

Table 13-2 Summary of summer and winter period low streamflow statistics at Penticton Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.104	0.381
Summer 1:5-year return period 30 Day Low Streamflow	0.064	0.309
Summer 1:10-year return period 30 Day Low Streamflow	0.052	0.280
Summer 1:20-year return period 30 Day Low Streamflow	0.045	0.258
Winter 1:2-year return period 30 Day Low Streamflow	0.086	0.295
Winter 1:5-year return period 30 Day Low Streamflow	0.059	0.222
Winter 1:10-year return period 30 Day Low Streamflow	0.052	0.189
Winter 1:20-year return period 30 Day Low Streamflow	0.048	0.164

14 Coldstream Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-12) for Coldstream Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 14-1 provides an overview map of the watershed with the specific data sources and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix O.

14.1 NATURALIZED STREAMFLOWS

For Coldstream Creek naturalized streamflows, several modifications were made to the methods outlined in Appendix A after streamflow values estimated for the summer and winter periods were deemed too low after review of historic streamflows recorded near the EFN point-of-interest by the WSC, even after the temporal period adjustment factor (Section 2.2.3) was applied.

Specifically, a modification for the development of the necessary streamflow datasets included the division of the watershed into two sub-watersheds: 1) King Edward Lake watershed and 2) Coldstream Creek watershed to streamflow point-of-interest (minus King Edward Lake watershed) (Figure 14-1). This division was completed to support the development of the regulated streamflow datasets to allow for the consideration of reservoir management (Section 14.2).

Following the approach described above, weekly naturalized streamflows for the King Edward Lake watershed were estimated using hydrometric records from Coldstream Creek above Municipal Intake (WSC No. 08NM142), which has data available for the 1996-2010 standard period. The Coldstream Creek records were then scaled to the King Edward Lake watershed but adjusted to represent a different drainage area with a different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 23 (Okanagan Highlands) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between Coldstream Creek at WSC No. 08NM142 (61.9 km^2; median elevation = 1,132 m) and King Edward Lake watershed (6.6 km^2; median elevation = 1,405 m). The ratio used for adjustment purposes was 1.93. The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 23 (Appendix B).

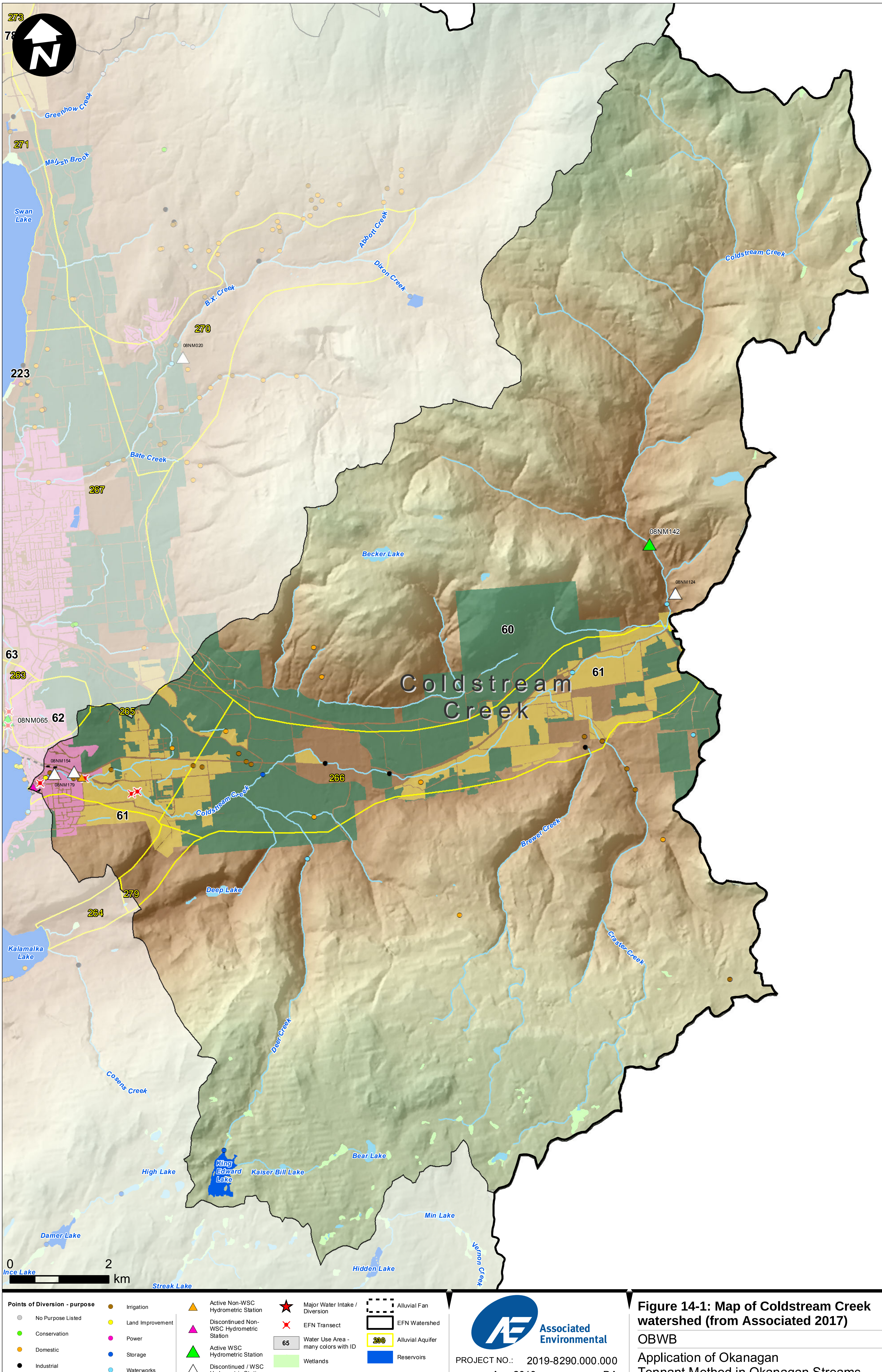


Figure 14-1: Map of Coldstream Creek watershed (from Associated 2017)

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For the Coldstream Creek watershed to streamflow point-of-interest (minus King Edward Lake watershed), weekly naturalized streamflows were estimated using hydrometric records from Coldstream Creek above Municipal Intake (WSC No. 08NM142). However, upon further review of the period of overlapping record (i.e., 1971-1982) between WSC No. 08NM142 and Coldstream Creek above Kalavista Diversion (WSC No. 08NM179)[12], it was apparent that WSC No. 08NM179 recorded higher unit discharges during the summer and winter periods than that in the headwaters (i.e., WSC No. 08NM142). The higher unit discharges measured at WSC No. 08NM179 were assumed to be a result of groundwater contribution from the large valley floor present within the watershed. Following this, the following was completed to estimate streamflows at the streamflow point-of-interest (minus King Edward Lake watershed):

- For peak to intermediate streamflow conditions between mid-April (Week 15) to mid-July (Week 29), streamflows were estimated using hydrometric records from WSC No. 08NM142, which has data available for the 1996-2010 standard period. The Coldstream Creek records were then scaled to the streamflow point-of-interest (minus King Edward Lake watershed) but adjusted to represent a different drainage area with a different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 23 (Okanagan Highlands) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between Coldstream Creek at WSC No. 08NM142 (i61.9 km^2; median elevation = 1,132 m) and the streamflow point-of-interest (98.7 km^2; median elevation = 1,027 m). The ratio used for adjustment purposes was 0.78. The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 23 (Appendix B).
- For low streamflow conditions between late July (Week 30) to early April (Week 14), a mean weekly unit discharge relationship was established between the period of overlapping record for WSC No. 08NM142 and 08NM179 (i.e., 1971-1982) (Appendix O). The relation was then used to estimate streamflows for the standard period using available WSC No. 08NM142 records scaled to the streamflow point-of-interest (minus King Edward Lake watershed).

Streamflows at the streamflow point-of-interest were then assumed to be the sum of both the King Edward Lake watershed outflows and the estimated Coldstream Creek to streamflow point-of-interest (minus King Edward Lake watershed) streamflows – which assume no streamflow routing influence due to the weekly time-step modelled.

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Coldstream Creek weekly scaling ratios (Appendix C).

Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. The ONA installed one hydrometric station approximately 400 above the mouth (Figure 14-1). The ONA also collected corresponding manual streamflow measurements at selected EFN transects on the alluvial fan (Table 14-1; Figure 14-1) and the results suggested that for the dates measured, the Coldstream Creek channel generally lost water for the portion monitored. However, small private water intakes are present between EFN transects, which limit an understanding of natural continuous streamflow gains/losses, since the water diversions are not gauged. Therefore, due to the limited spatial understanding of streamflow gains/losses across the entire alluvial fan, unclear seasonal

[12] WSC No. 08NM179 is located on the alluvial fan (Figure 14-1) and was noted by the WSC to record residual streamflows.

variation (if any), and the volume of water being diverted, it was deemed more appropriate to consider a gain/loss value equivalent to zero across the entire fan.

Table 14-1 Comparison of discharge measurements across the Coldstream Creek alluvial fan monitored by the ONA

Date	ONA EFN Transect[1,2] – Discharge (m^3/s)	
	Glide 2 (Upstream)	Glide 1 (Downstream)
08-Aug-16	0.299	0.299
04-Oct-16	0.407	0.415
06-Apr-17	0.964	1.01
07-Jun-17	1.93	1.77
16-Jun-17	1.35	1.27
23-Jun-17	1.01	0.933
30-Jun-17	0.793	0.717
07-Jul-17	0.603	0.597
18-Jul-17	0.527	0.414
09-Aug-17	0.369	0.348
24-Aug-17	0.308	0.289

Note:
1. Refer to Figure 14-1 for location of EFN transects.
2. Distance between Glide 2 and Glide 1 is approximately 275 m.

Streamflow records were available for a hydrometric station operated by ONA at McClounie Road (Figure 14-1) for 2017-2018. Although the ONA hydrometric station recorded residual streamflows, the naturalized streamflows for the adjusted standard period were compared to streamflows recorded by the ONA and the comparison indicated that although different time periods and streamflow conditions were compared, the general magnitude of the naturalized streamflows was consistent with that recorded by the ONA. See Appendix O for a visual comparison.

14.2 RESIDUAL STREAMFLOWS

Residual streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

14.3 MAXIMUM LICENSED STREAMFLOWS

Maximum licensed streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

14.4 SUMMARY OF STREAMFLOW DATASETS

A summary of naturalized streamflows at the EFN points-of-interest is provided digitally in Appendix O. A comparison of LT mad values estimated herein and by others for Coldstream Creek watershed are summarized in Table 14-2 and estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 14-3.

Lastly, following the data error and quality rating framework (Table 2-1), the naturalized streamflow dataset was given a rating of B (i.e., data error >10% and ≤25%). This is due to availability of WSC hydrometric records within the headwaters, but insufficient information available to fully quantify the groundwater contribution to streamflows through the large valley present in the lower portion of the watershed.

Table 14-2 Summary of LT mad values estimated for Coldstream Creek watershed

	LT mad estimates for Coldstream Creek watershed			
	Ptolemy (2016)	**Obedkoff (1998) – Zone 23**	**Obedkoff (1998) – Zone 15**	**This Study**
Time Period	Unknown	Unknown	1961-1990	Adjusted 1996-2010
Point-of-Interest	WSC 08NM179	EFN Point-of-Interest	EFN Point-of-Interest	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	0.788	0.946	0.457	0.748
Residual LT mad (m^3/s)	-	-	-	-
Max Licensed LT mad (m^3/s)	-	-	-	-

Table 14-3 Summary of summer and winter period low streamflow statistics at Coldstream Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.360	-
Summer 1:5-year return period 30 Day Low Streamflow	0.317	-
Summer 1:10-year return period 30 Day Low Streamflow	0.302	-
Summer 1:20-year return period 30 Day Low Streamflow	0.292	-
Winter 1:2-year return period 30 Day Low Streamflow	0.248	-
Winter 1:5-year return period 30 Day Low Streamflow	0.201	-
Winter 1:10-year return period 30 Day Low Streamflow	0.180	-
Winter 1:20-year return period 30 Day Low Streamflow	0.165	-

15 Mill Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-13) for Mill Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 15-1 provides an overview map of the watershed with the specific data sources and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix P.

Note that for this watershed, ONA did not conduct any fieldwork to support the setting of EFNs. Thus, it was assumed that the EFN point-of-interest for this watershed was the mouth.

15.1 NATURALIZED STREAMFLOW

For Mill Creek naturalized streamflows, a modification was made to the methods outlined in Appendix A after streamflow values estimated for the summer period (August to September) were deemed too low even after the temporal period adjustment factor (Section 2.2.3) was applied.

Specifically, the modification for the development of the necessary streamflow datasets included the division of the watershed into an upper watershed area and lower (valley) watershed area to the streamflow point-of-interest. The upper watershed area included: 1) Upper Mill Creek watershed to Old Vernon Road, 2) Whelan Creek watershed to Old Vernon Road, 3) Scotty Creek watershed to Old Vernon Road, and 4) residual upland area contributing to valley floor (Figure 15-1). The lower watershed area included the large valley floor of the watershed (Figure 15-1). This division was completed, similar to Coldstream Creek (Section 13), because it is locally known that peak streamflows are largely driven by upland snowmelt runoff, while low streamflows are supplied by groundwater contributions along the valley floor.

Following the above, weekly naturalized streamflows for the upper watershed areas were estimated using discontinued hydrometric records from Daves Creek (WSC No. 08NM137) extended to the 1996-2010 standard period using hydrometric records from the nearby Whiteman Creek above Bouleau Creek (WSC No. 08NM174). Specifically, the record for Daves Creek was extended to the standard period using the mean weekly unit discharge relation established for the overlapping period of record between WSC No. 08NM137 and 08NM174. This dataset was developed to support streamflow development for McDougall Creek watershed (Section 10).

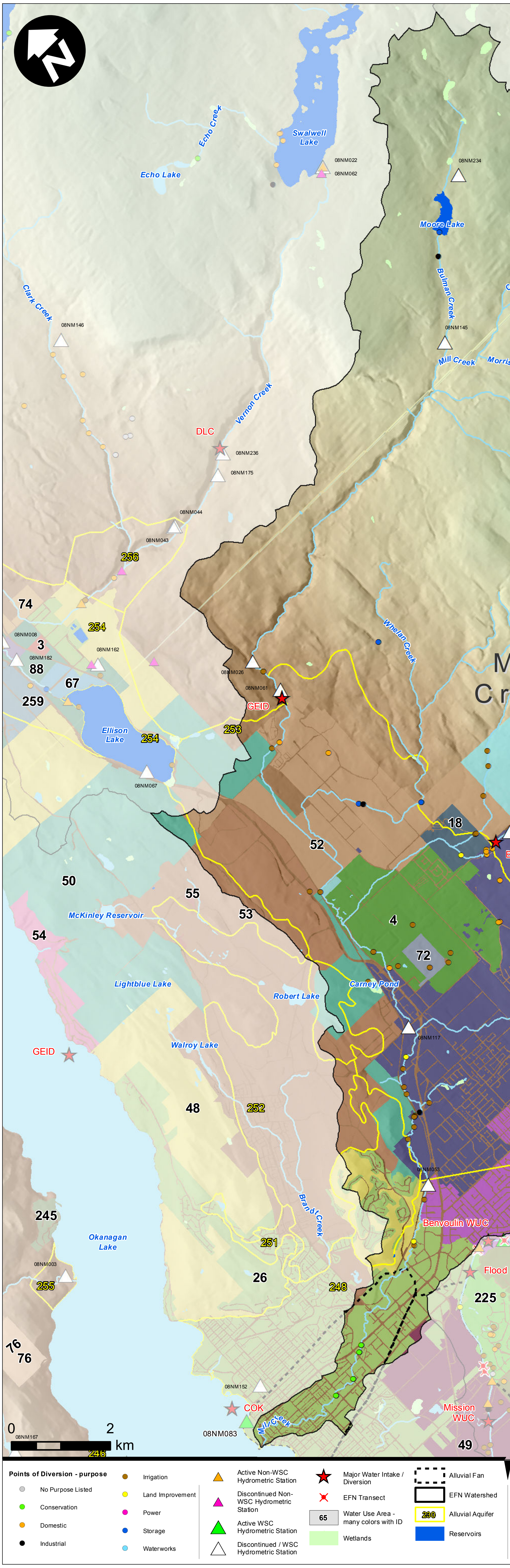

Figure 15-1: Map of Mill Creek watershed (from Associated 2017)

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The Daves Creek records were then scaled to the upper watershed areas but adjusted to represent different drainage areas with a different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 24 (Southern Thompson Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between Daves Creek at WSC No. 08NM137 (31.6 km^2; median elevation = 1,316 m) and the upper watershed areas as follows:

- Upper Mill Creek watershed to Old Vernon Road (77.5 km^2; median elevation = 1,392 m) ratio adjustment was 1.20.
- Whelan Creek at Old Vernon Road (24.7 km^2; median elevation = 1,016 m) ratio adjustment was 0.49.
- Scotty Creek at Old Vernon Road (39.8 km^2; median elevation = 1,313 m) ratio adjustment was 0.99.
- Residual upland area contributing to valley floor (39.6 km^2; median elevation = 640 m) ratio adjustment was 0.20.

The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 24 (Appendix B). Contributing streamflows to the lower (valley) watershed area were then assumed to be the sum of all four upland area watersheds – which assume no streamflow routing influence due to the weekly time-step modelled.

For the lower (valley) watershed area to the streamflow point-of-interest, upon review of the period of overlapping record (i.e., 1950-1953 and 1970-1975) between Kelowna (Mill) Creek near Kelowna (Lower Station) (WSC No. 08NM053) and Kelowna (Mill) Creek at Rutland Station (WSC No. 08NM117)[13], it was apparent that during peak streamflows both hydrometric stations recorded similar peak streamflow magnitudes (and timing), but during the summer and winter periods, WSC No. 08NM053 (downstream of WSC No. 08NM117) consistently recorded higher streamflows. With limited tributary contribution present between WSC No. 08NM053 and 08NM117, it was assumed that the higher streamflows downstream were a result of groundwater contribution from the large valley floor present within the watershed.

Following the approach described above, a mean weekly discharge relationship was established between the period of overlapping record for WSC No. 08NM053 and 08NM117 (i.e., 1950-1953 and 1970-1975) (Appendix P). It was then assumed that the total streamflows estimated for the upper watershed area were similar to those historically recorded at WSC No. 08NM117. The mean weekly discharge relationship between WSC No. 08NM053 and 08NM117 was then used to estimate streamflows at the historic location of WSC No. 08NM053. However, upon further review of the estimate streamflows at WSC No. 08NM053, it was deemed that the streamflows were consistently low in comparison to historic records. This was likely a result of the lack of available information on groundwater contribution between the Kelowna Airport and the location of WSC No. 08NM117. Thus, a comparison of the baseflow period (i.e., late November [Week 48] to early March [Week 9]) between the estimated naturalized streamflows for the standard period and the available dataset for WSC No. 08NM053 (i.e., 1950-1996), indicated that the mean weekly difference was approximately 0.130 m^3/s. This value was then added to the estimated streamflows at WSC No. 08NM053 and the resultant values were assumed to be the same at the streamflow point-of-interest (due to no information available on additional groundwater contributions between points-of-interest).

[13] WSC No. 08NM053 is located approximately 15 km downstream WSC No. 08NM117 with limited water licences and tributaries present between hydrometric station locations.

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Coldstream Creek weekly scaling ratios (Appendix C).

Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. No field measurements were available to estimate streamflow gains/losses across the fan. Therefore, due to the limited spatial understanding of streamflow gains/losses across the entire alluvial fan and unclear seasonal variation (if any), a gain/loss value equivalent to zero across the entire fan was assumed.

15.2 RESIDUAL STREAMFLOWS

Residual streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

15.3 MAXIMUM LICENSED STREAMFLOWS

Maximum licensed streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

15.4 SUMMARY OF STREAMFLOW DATASETS

A summary of naturalized streamflows at the EFN points-of-interest is provided digitally in Appendix P. A comparison of LT mad values estimated herein and by others for the Mill Creek watershed are summarized in Table 15-1 and the estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 15-2.

Lastly, following the data error and quality rating framework (Table 2-1), the naturalized streamflow dataset was given a rating of C (i.e., data error >25% and ≤50%). This is due to availability of WSC hydrometric records within the headwaters, but insufficient information available to fully quantify the groundwater contribution to streamflows through the large valley present in the lower portion of the watershed.

Table 15-1 Summary of LT mad values estimated for Mill Creek watershed

	LT mad estimates for Mill Creek watershed						
	Summit (2009a)	**Ptolemy (2016)**	**NHC (2001)**	**Obedkoff (1998) – Zone 24**	**Obedkoff (1998) – Zone 15**	**OK Basin Agreement (1974)**	**This Study**
Time Period	1996-2006	Unknown	1961-1995	1961-1990	1961-1990	Average Year	Adjusted 1996-2010
Point-of-Interest	Mouth	08NM053	Mouth	Mouth	Mouth	Mouth	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	0.840	0.935	1.16	0.355	0.504	0.666	0.744
Residual LT mad (m^3/s)	-	-	-	-	-	-	-
Max Licensed LT mad (m^3/s)	-	-	-	-	-	-	-

Table 15-2 Summary of summer and winter period low streamflow statistics at Mill Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.266	-
Summer 1:5-year return period 30 Day Low Streamflow	0.216	-
Summer 1:10-year return period 30 Day Low Streamflow	0.198	-
Summer 1:20-year return period 30 Day Low Streamflow	0.187	-
Winter 1:2-year return period 30 Day Low Streamflow	0.257	-
Winter 1:5-year return period 30 Day Low Streamflow	0.218	-
Winter 1:10-year return period 30 Day Low Streamflow	0.202	-
Winter 1:20-year return period 30 Day Low Streamflow	0.189	-

16 Trout Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-14) for Trout Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 16-1 provides an overview map of the watershed with the specific data sources and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix Q.

Note that for this watershed, ONA did not conduct any fieldwork to support the setting of EFNs. Thus, it was assumed that the EFN point-of-interest for this watershed was the mouth.

16.1 NATURALIZED STREAMFLOWS

For Trout Creek naturalized streamflows, a modification was made to the methods outlined in Appendix A after streamflow values estimated for the summer period (August to September) were deemed too low even after the temporal period adjustment factor (Section 2.2.3) was applied.

Specifically, weekly naturalized streamflows for Trout Creek at the streamflow point-of-interest were estimated following the approach outlined in Appendix A, but using the average between scaled Bull Creek near Crump (WSC No. 08NM133) extended to the 1996-2010 standard period and actual (1996-2010) scaled Camp Creek at Mouth near Thirsk (WSC No. 08NM134) records. This is a modification from the methods outlined in Appendix A, which recommend that extended Bull Creek records be used for estimation purposes. This modification was applied because Bull and Camp creeks are located within the Trout Creek watershed, and therefore better reflect streamflows within the mainstem creek.

For Bull Creek (WSC No. 08NM133), the historic streamflows were extended to the 1996-2010 standard period using hydrometric records from the nearby Camp Creek at Mouth near Thirsk (WSC No. 08NM134). Specifically, the record for Bull Creek was extended to the standard period using the mean weekly unit discharge relation established for the overlapping period of record between WSC No. 08NM133 and 08NM134 (Appendix Q).

The Bull and Camp Creek records were then scaled to the Trout Creek streamflow point-of-interest, but adjusted to represent different drainage areas with different median elevations. Specifically, the updated regional runoff relation for hydrologic zone 24 (Southern Thompson Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between Bull Creek at WSC No. 08NM133 (45.9 km^2; median elevation = 1,547 m), Camp Creek at WSC No. 08NM34 (34.7 km^2; median elevation = 1,456 m), and Trout Creek watershed at the streamflow point-of-interest (745.3 km^2; median elevation = 1,393 m). The ratios used for adjustment purposes were 0.69 and 0.87, respectively. The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 24 (Appendix B).

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Camp Creek weekly scaling ratios (Appendix C).

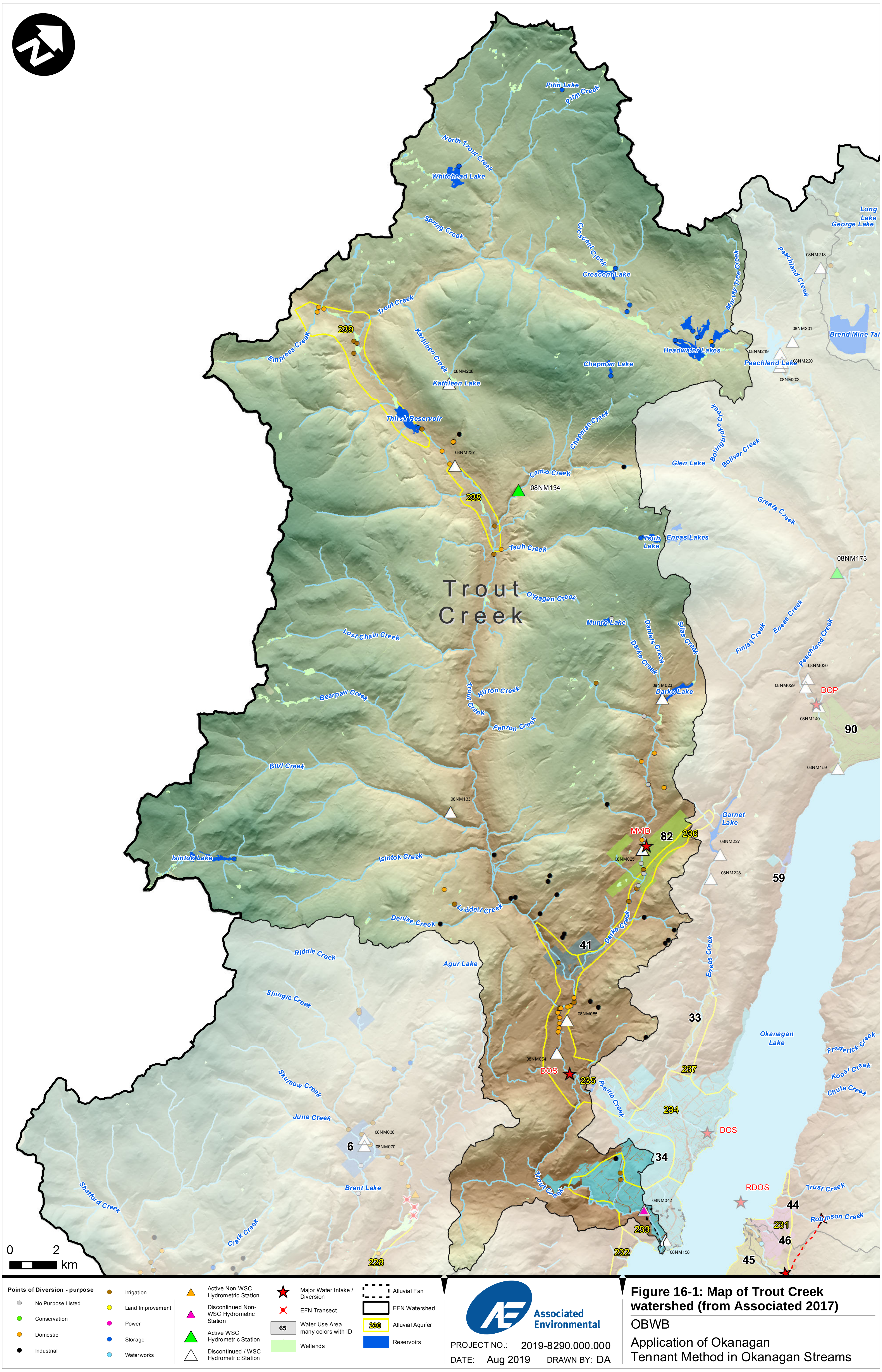

Figure 16-1: Map of Trout Creek watershed (from Associated 2017)

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Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. No field measurements were available to estimate streamflow gains/losses across the fan. However, WMC (2005) reported natural streamflow losses of up to 0.040 m^3/s within Trout Creek, so this loss was assumed to occur across the entire alluvial fan to the EFN point-of-interest.

16.2 RESIDUAL STREAMFLOWS

Residual streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

16.3 MAXIMUM LICENSED STREAMFLOWS

Maximum licensed streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

16.4 SUMMARY OF STREAMFLOW DATASETS

A summary of naturalized streamflows at the EFN points-of-interest is provided digitally in Appendix Q. A comparison of LT mad values estimated herein and by others for Trout Creek watershed are summarized in Table 16-1 and the estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 16-2.

Lastly, following the data error and quality rating framework (Table 2-1), the naturalized streamflow dataset was given a rating of B (i.e., data error >10% and ≤25%). This is due to availability of active WSC hydrometric records within the headwaters and discontinued records available for the lower elevations, but the need to use assumptions for streamflow gains/losses across the alluvial fan.

Table 16-1 Summary of LT mad values estimated for Trout Creek watershed

	LT mad estimates for Trout Creek watershed[1]								
	Summit (2009a)	**Ptolemy (2016)**	**NHC (2001)**	**WMC (2005)**	**NHC (2004)**	**Letvak (1989)**	**OK Basin Agreement (1974)**	**Obedkoff (1998)**	**This Study**
Time Period	1996-2006	Unknown	1961-1995	1938-2002	Unknown	1970-1982	Average Year	1961-1990	Adjusted 1996-2010
Point-of-Interest	Mouth	Mouth	Mouth	Mouth; excluding Darke Creek	Mouth	Mouth	Mouth	WSC 08NM116	Mouth
Naturalized LT mad (m^3/s)	2.08	3.01	2.65	2.89	2.89	2.56	2.13	2.60	2.17
Residual LT mad (m^3/s)	-	-	-	-	-	-	-	-	-
Max Licensed LT mad (m^3/s)	-	-	-	-	-	-	-	-	-

Note:

1. Other studies not referenced in table (due to page spacing) include: Agua (2008) – Naturalized LT Mad = 2.64 m^3/s (estimated at District of Summerland water intake); and Reksten (1971) – Naturalized LT Mad = 1.98 m^3/s (estimated at mouth).

Table 16-2 Summary of summer and winter period low streamflow statistics at Trout Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.512	-
Summer 1:5-year return period 30 Day Low Streamflow	0.368	-
Summer 1:10-year return period 30 Day Low Streamflow	0.311	-
Summer 1:20-year return period 30 Day Low Streamflow	0.272	-
Winter 1:2-year return period 30 Day Low Streamflow	0.401	-
Winter 1:5-year return period 30 Day Low Streamflow	0.312	-
Winter 1:10-year return period 30 Day Low Streamflow	0.283	-
Winter 1:20-year return period 30 Day Low Streamflow	0.265	-

17 McLean Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-15) for McLean Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 17-1 provides an overview map of the watershed with the specific data sources and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix R.

Note that for this watershed, ONA did not conduct any fieldwork to support the setting of EFNs. Thus, it was assumed that the EFN point-of-interest for this watershed was the mouth.

17.1 NATURALIZED STREAMFLOWS

Weekly naturalized streamflows for McLean Creek at the streamflow point-of-interest were estimated following the approach outlined in Appendix A using actual records from nearby Vaseux Creek above Solco Creek (WSC No. 08NM171). The Vaseux Creek records were scaled to the drainage area extent of the McLean Creek streamflow point-of-interest (i.e., 63.1 km^2), but adjusted to represent a different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 24 (Southern Thompson Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between the McLean Creek point-of-interest (63.1 km^2; median elevation = 1,243 m) and Vaseux Creek at WSC No. 08NM171 (117.5 km^2; median elevation = 1,694 m). The ratio used for adjustment purposes was 0.34. The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 24 (Appendix B).

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Vaseux Creek weekly scaling ratios (Appendix C).

Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. No field measurements were available to estimate streamflow gains/losses across the fan. Therefore, due to the limited spatial understanding of streamflow gains/losses across the entire alluvial fan, unclear seasonal variation (if any), and small alluvial fan length (i.e., approximately 250 m), a gain/loss value equivalent to zero across the entire fan was assumed.

Lastly, natural streamflow records were available for McLean Creek near Okanagan Falls (WSC No. 08NM005) for the period 1921-1926. The resultant naturalized streamflows for the adjusted standard period were compared to streamflows recorded by WSC No. 08NM005 and the comparison indicated that although different time periods were compared, the general magnitude of the naturalized streamflows was consistent with that recorded historically by the WSC. See Appendix R for a visual comparison.

17.2 RESIDUAL STREAMFLOWS

Residual streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

Figure 17-1: Map of McLean Creek watershed (from Associated 2017)

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17.3 MAXIMUM LICENSED STREAMFLOWS

Maximum licensed streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

17.4 SUMMARY OF STREAMFLOW DATASETS

A summary of naturalized streamflows at the EFN points-of-interest is provided digitally in Appendix R. A comparison of LT mad values estimated herein and by others for the McLean Creek watershed are summarized in Table 17-1 and the estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 17-2.

Lastly, following the data error and quality rating framework (Table 2-1), the naturalized streamflow dataset was given a rating of C (i.e., data error >25% and ≤50%). This is due to no recent WSC hydrometric records available within the watershed and the need to assume streamflow gains/losses across the alluvial fan.

Table 17-1 Summary of LT mad values estimated for McLean Creek watershed

	LT mad estimates for Trout Creek watershed		
	Ptolemy (2016)	**Obedkoff (1998)**	**This Study**
Time Period	Unknown	1961-1990	Adjusted 1996-2010
Point-of-Interest	Mouth	Mouth	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	0.122	0.150	0.167
Residual LT mad (m^3/s)	-	-	-
Max Licensed LT mad (m^3/s)	-	-	-

Table 17-2 Summary of summer and winter period low streamflow statistics at McLean Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.023	-
Summer 1:5-year return period 30 Day Low Streamflow	0.012	-
Summer 1:10-year return period 30 Day Low Streamflow	0.008	-
Summer 1:20-year return period 30 Day Low Streamflow	0.005	-
Winter 1:2-year return period 30 Day Low Streamflow	0.017	-
Winter 1:5-year return period 30 Day Low Streamflow	0.012	-
Winter 1:10-year return period 30 Day Low Streamflow	0.010	-
Winter 1:20-year return period 30 Day Low Streamflow	0.009	-

18 Trepanier Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-16) for Trepanier Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 18-1 provides an overview map of the watershed with the specific data sources and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix S.

Note that for this watershed, ONA did not conduct any fieldwork to support the setting of EFNs. Thus, it was assumed that the EFN point-of-interest for this watershed was the mouth.

18.1 NATURALIZED STREAMFLOWS

For Trepanier Creek naturalized streamflows, a modification was made to the methods outlined in Appendix A after discussions with Brenda Mines personnel, who noted that as part of their mine water management program, water has been released into Trepanier Creek from 1997 to present (Rodier, pers. comm., 2019). Also, based on previous experience within the watershed by a local consultant, it was identified that streamflow contribution to Trepanier Creek below the District of Peachland (DOP) water intake was minor (Epp, pers. comm., 2019).

Specifically, the modification for the development of the necessary streamflow datasets included the division of the watershed into two sub-watersheds: 1) Trepanier Creek watershed to WSC No. 08NM041 (minus the Brenda Mines site), and 2) Trepanier Creek watershed to streamflow point-of-interest (minus upland watershed area) (Figure 18-1). This division was completed to consider the influence of Brenda Mines and the different watershed area streamflow contributions.

Figure 18-1: Map of Trepanier Creek watershed (from Associated 2017)

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Following the approach described above, weekly naturalized streamflows for Trepanier Creek at the streamflow point-of-interest were estimated as follows:

- Actual residual streamflow records from Trepanier Creek near Peachland (WSC No. 08NM041) (which is located above the DOP water intake) were available for the standard period.
- Some information was available on water use for the watershed (Section 18.2.1), so the available WSC No. 08NM041 records were naturalized by adding/removing water use, water releases and diversions, and upland storage (to the residual streamflows) as follows:
    - Water use above WSC No. 08NM041 was assumed to be equivalent to the OWDM outputs for water use area 113 (Other_Node 30) (Figure 18-1). In addition, total water demand for water use area 113 was reduced by 16.4% (as recommended by Summit [2010]) to remove estimated groundwater use within the spatial extent of the water use area. The water use estimates were refined as follows (and added to the WSC No 08NM041 hydrometric records):
        - Water use area 113 encompasses the entire watershed; therefore, to divide OWDM outputs into only above WSC No. 08NM041 withdrawals, the spatial distribution of water licensed volumes was assumed to be representative of water withdrawals as follows:
            - Domestic water demands – 12.9% above WSC No. 08NM041.
            - Irrigation water demands –
                - Unsupported by storage = 3.9% above WSC No. 08NM041; and
                - Supported by storage = 26.8% above WSC No. 08NM041.
        - Raw OWDM output for irrigation water demands was supplemented as follows:
            - For selected years, the OWDM includes a Week 0 to account for field watering by farmers at the end of season to increase soil moisture to field capacity. Thus, water demands estimated for years with Week 0 were assumed to occur evenly in September (i.e., Weeks 36 to 39) to consider the end of season watering.
            - A 10% irrigation system loss was assumed.
            - The weekly water demand values were smoothed using the LOESS function and the timing of irrigation water use was limited to April and September (i.e., licensed period of use).
    - Under water licence C107625, the DOP is licensed to divert water into Peachland Creek watershed for storage purposes through the MacDonald Creek diversion between April 1 (Week 14) and June 15 (Week 24). However, as outlined in Section 18.2.1, the diversion has not been operated since 2009 and no diversion records are available. Therefore, the pattern of diversion for 1996-2008 was assumed to be equal to the pattern of streamflow recorded by Trepanier Creek (WSC No. 08NM041) for the respective weeks for each year up to the maximum licensed diversion volume. No diversions were assumed to occur after June 15^{th} each year. The estimated diversion values were added to the WSC 08NM041 hydrometric records.
    - Silver Lake releases recorded by DOP in 2006 (Weeks 36-38) and 2007 (Week 38) (Section 18.2.1) were removed from the WSC No. 08NM041 hydrometric records.
    - Mine water released into Trepanier Creek by Brenda Mines was accounted for using actual and estimated release records from 1998-2010 (Section 18.2.1).

Based on the above, weekly naturalized streamflows for Trepanier Creek watershed at WSC No. 08NM041 (minus the Brenda Mines site) for the standard period were estimated. In addition, for select weeks in 2006, 2007, 2009, and 2010, WSC No. 08NM041 was missing data. Therefore, estimated naturalized unit discharges for Trepanier Creek watershed at WSC No. 08NM041 for the standard period were compared to nearby Camp Creek – WSC No. 08NM134. A strong relationship was found; therefore, the missing weeks for Trepanier Creek watershed at WSC No. 08NM041 were estimated for the standard period using the mean weekly unit discharge relation (Appendix S) and the Camp Creek (WSC No. 08NM134) streamflow records.

The Trepanier Creek records were scaled to the drainage area extent of the natural watershed area that includes Brenda Mines, but adjusted to represent a different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 24 (Southern Thompson Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between Trepanier Creek watershed at WSC No. 08NM041 (minus the Brenda Mines site) (177.1 km^2; median elevation = 1,348 m) and Trepanier Creek watershed at WSC No. 08NM041 (including the Brenda Mines site) (183.9 km^2; median elevation = 1,365 m). The ratio used for adjustment purposes was 1.04. The estimated weekly time series was then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 24 (Appendix B).

The Trepanier Creek naturalized streamflow records were then used to estimate the Trepanier Creek watershed to streamflow point-of-interest (minus upland watershed area) contributions. Specifically, the updated regional runoff relation for hydrologic zone 24 (Southern Thompson Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between Trepanier Creek at WSC No. 08NM041 (including the Brenda Mines site) (183.9 km^2; median elevation = 1,365 m) and Trepanier Creek watershed to streamflow point-of-interest (minus upland watershed area) (75.6 km^2; median elevation = 1,003 m). The ratio used for adjustment purposes was 0.44. The estimated weekly time series was then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 24 (Appendix B).

Streamflows at the streamflow point-of-interest were then assumed to be the sum of both the Trepanier Creek watershed at WSC No. 08NM041 (including the Brenda Mines site) and the estimated Trepanier Creek watershed to streamflow point-of-interest (minus upland watershed area) streamflows – which assume no streamflow routing influence due to the weekly time-step modelled.

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Camp Creek weekly scaling ratios (Appendix C).

Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. Obedkoff (1990) reported streamflow losses of 0.110 m^3/s (summer) and 0.160 m^3/s (winter) for a 7.5 km length of the Trepanier Creek channel between the DOP water intake and the mouth; however, the loss estimates included both natural streamflows and water use. The results were higher than that recommended by Summit (2009a) for considering streamflow gains/losses across the Trepanier Creek alluvial fan (i.e., 0.014 $m^3/s/km$). However, because of the Trepanier Creek bedrock waterfall located at the apex of the alluvial fan, it was assumed that any natural streamflow losses upstream would be recovered at the fan apex. Thus, it was deemed more appropriate to consider a gain/loss value equivalent to what Summit (2009a) recommended to support hydrologic modelling of Trepanier Creek watershed during the OWSDP. Thus, with an alluvial fan channel length of approximately 0.95 km (measured from apex to mouth), the streamflow loss across the fan was estimated to be 0.013 m^3/s. This loss was considered representative for the entire distance between the streamflow and EFN points-of-interest for all seasons and the standard period.

Lastly, residual streamflow records were available for Trepanier Creek at the Mouth (WSC No. 08NM155) for the period 1969-1981. The resultant naturalized streamflows for the adjusted standard period were compared to streamflows recorded by WSC No. 08NM155 and the comparison indicated that although different time periods and streamflow types were compared, the general magnitude of the naturalized streamflows was consistent with that recorded historically by the WSC. See Appendix S for a visual comparison.

18.2 RESIDUAL STREAMFLOWS

18.2.1 Background Water Use Information

For Trepanier Creek watershed, residual streamflows above and below WSC No. 08NM041 are a result of licensed water withdrawals by private residents, mine water releases by Brenda Mines, the MacDonald Creek inter-basin transfer operated by the DOP, and by upland reservoirs operated by the DOP and private residents. No information was available on private resident water use, but DOP and Brenda Mines were contacted and provided the following information:

- DOP provided total monthly water withdrawals at the DOP water intake on Trepanier Creek for 1989-present.
- DOP identified that Silver Lake is not managed on an annual basis, but water will be released from the lake during dry years if requested by FLNRORD. For the standard period, DOP documented releases from Silver Lake for selected weeks in 2006 (n = 3 weeks) and 2007 (n = 1 week) (Grundy, pers. comm., 2019).
- DOP identified that the MacDonald Creek inter-basin transfer was in operation until 2009, but no records of diversion volumes and/or timing were available (Grundy, pers. comm., 2019). The MacDonald Creek inter-basin transfer diverted water into Peachland Creek watershed to support irrigation needs.
- Brenda Mines identified that the mine site is a closed system and that all water is captured on site within ponds (Rodier, pers. comm., 2019). Thus, a portion of the natural watershed area for Trepanier Creek has been removed.
- Brenda Mines identified that mine water releases into the Trepanier Creek watershed have occurred from 1998 to present. The total daily volumes released have been recorded and were provided (Rodier, pers. comm., 2019).

In addition to the information listed above, no lake management was reported to occur on Lacoma Lake and as a result, the lake was largely a flow through system (Dobson, pers. comm., 2019) for the standard period.

18.2.2 Trepanier Creek at Streamflow and EFN points-of-interest

Residual streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

18.3 MAXIMUM LICENSED STREAMFLOWS

Maximum licensed streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

18.4 SUMMARY OF STREAMFLOW DATASETS

A summary of naturalized streamflows at the EFN points-of-interest is provided digitally in Appendix S. A comparison of LT mad values estimated herein and by others for Trepanier Creek watershed are summarized in Table 18-1 and the estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 18-2.

Lastly, following the data error and quality rating framework (Table 2-1), the naturalized streamflow dataset was given a rating of B (i.e., data error >10% and ≤25%). This is due to actual residual WSC hydrometric records available within the watershed, but the need to assume water use and inter-basin diversions and streamflow gains/losses across the alluvial fan.

Table 18-1 Summary of LT mad values estimated for Trepanier Creek watershed

	LT mad estimates for Trepanier Creek watershed						
	Summit (2009a)	**Ptolemy (2016)**	**NHC (2001)**	**Obedkoff (1998) – Zone 24**	**Summit (2004)**	**OK Basin Agreement (1974)**	**This Study**
Time Period	1996-2006	Unknown	1961-1995	1961-1990	2003	Average Year	Adjusted 1996-2010
Point-of-Interest	Mouth	Mouth	Mouth	Mouth	Mouth	Mouth	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	1.22	1.23	1.15	0.659	1.09	1.10	1.28
Residual LT mad (m^3/s)	-	-	-	-	1.03	-	-
Max Licensed LT mad (m^3/s)	-	-	-	-	0.953	-	-

Table 18-2 Summary of summer and winter period low streamflow statistics at Trepanier Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.263	-
Summer 1:5-year return period 30 Day Low Streamflow	0.177	-
Summer 1:10-year return period 30 Day Low Streamflow	0.149	-
Summer 1:20-year return period 30 Day Low Streamflow	0.133	-
Winter 1:2-year return period 30 Day Low Streamflow	0.213	-
Winter 1:5-year return period 30 Day Low Streamflow	0.158	-
Winter 1:10-year return period 30 Day Low Streamflow	0.137	-
Winter 1:20-year return period 30 Day Low Streamflow	0.123	-

19 Powers Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-17) for Powers Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 19-1 provides an overview map of the watershed with the specific data sources and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix T.

Note that for this watershed, ONA did not conduct any fieldwork to support the setting of EFNs. Thus, it was assumed that the EFN point-of-interest for this watershed was the mouth.

19.1 NATURALIZED STREAMFLOWS

For Powers Creek naturalized streamflows, a modification was made to the methods outlined in Appendix A after it was identified that Lambly Lake and the Alocin Creek inter-basin transfer were not part of the natural watershed area. The lake (and contributing area) was added to Powers Creek watershed after a second dam was constructed on the lake to allow West Kelowna to store and release water to their Powers Creek water intake, while the Alcoin Creek inter-basin diversion transfers water into the Powers Creek watershed from the Nicola River watershed (OK Basin Agreement 1974).

Specifically, the modification for the development of the necessary streamflow datasets included the division of the watershed into a natural watershed area (124.6 km^2; median elevation = 1,299 m) and a separate residual watershed area (145.0 km^2; median elevation = 1,308 m) to the streamflow point-of-interest.

Weekly naturalized streamflows for Powers Creek (natural watershed) at the streamflow point-of-interest were estimated following the approach outlined in Appendix A but modified to only use naturalized records from nearby Trepanier Creek near Peachland (WSC No. 08NM041) (Section 18.1). The Trepanier Creek naturalized records were scaled to the drainage area extent of the Powers Creek (natural watershed) streamflow point-of-interest (124.6 km^2), but adjusted to represent a different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 24 (Southern Thompson Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between the Powers Creek (natural watershed) point-of-interest (124.6 km^2; median elevation = 1,299 m) and Trepanier Creek at WSC No. 08NM041 (minus Mines site) (177.1 km^2; median elevation = 1,348 m). The ratio used for adjustment purposes was 0.89. The estimated weekly time series were then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 24 (Appendix B).

The resultant streamflows at the streamflow point-of-interest were then adjusted to long-term conditions using the Camp Creek weekly scaling ratios (Appendix C).

Points of Diversion - purpose
No Purpose Listed
Conservation
Domestic
Industrial
Irrigation
Land Improvement
Power
Storage
Waterworks
Active Non-WSC Hydrometric Station
Discontinued Non-WSC Hydrometric Station
Active WSC Hydrometric Station
Discontinued / WSC Hydrometric Station
Major Water Intake / Diversion
EFN Transect
65 Water Use Area - many colors with ID
Wetlands
Alluvial Fan
EFN Watershed
290 Alluvial Aquifer
Reservoirs

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Figure 19-1: Map of Powers Creek watershed (from Associated 2017)

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Streamflows at the streamflow point-of-interest were then reviewed to consider gains/losses across the alluvial fan to the EFN point-of-interest. No field measurements were available to estimate streamflow gains/losses across the fan. Therefore, due to the limited spatial understanding of streamflow gains/losses across the entire alluvial fan and unclear seasonal variation (if any), a gain/loss value equivalent to zero across the entire fan was assumed. A gain/loss value of zero was also recommended by Summit (2009a) to support hydrologic modelling of Powers Creek watershed during the OWSDP.

Lastly, residual streamflow records were available for Powers Creek at the Mouth (WSC No. 08NM157) for the period 1969-1982 and for Powers Creek at Gellatly Road (third-party dataset) for the period 2004-2008). The resultant naturalized streamflows for the adjusted standard period were compared to streamflows recorded by WSC No. 08NM157 and available third-party records. The comparison indicated that although different time periods and streamflow types were compared, the general magnitude of the naturalized streamflows was consistent with that recorded historically. See Appendix T for a visual comparison.

19.2 RESIDUAL STREAMFLOWS

Residual streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

19.3 MAXIMUM LICENSED STREAMFLOWS

Maximum licensed streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

19.4 SUMMARY OF STREAMFLOW DATASETS

A summary of naturalized streamflows at the EFN points-of-interest is provided digitally in Appendix T. A comparison of LT mad values estimated herein and by others for the Powers Creek watershed are summarized in Table 19-1 and the estimated low streamflow statistics (at the EFN point-of-interest) are summarized in Table 19-2.

Lastly, following the data error and quality rating framework (Table 2-1), the naturalized streamflow dataset was given a rating of C (i.e., data error >25% and ≤50%). This is due to no recent WSC hydrometric records available prior to the inclusion of Lambly Lake and the Alocin Creek inter-basin transfer within the watershed, and the need to assume streamflow gains/losses across the alluvial fan.

Table 19-1 Summary of LT mad values estimated for Powers Creek watershed

	LT mad estimates for Powers Creek watershed							
	Summit (2004)	**Summit (2009a)**	**Ptolemy (2016)**	**NHC (2001)**	**Obedkoff (1998) – Zone 24**	**Letvak (1981)**	**OK Basin Agreement (1974)**	**This Study**
Time Period	1961-1995	1996-2006	Unknown	1961-1995	1961-1990	Unknown	Average Year	Adjusted 1996-2010
Point-of-Interest	Mouth	Mouth	Mouth	Mouth	EFN Point-of-Interest	West Kelowna Intake	Mouth	EFN Point-of-Interest
Naturalized LT mad (m^3/s)	0.920	0.817	1.15	0.920	0.341	-	0.540	0.643
Residual LT mad (m^3/s)	-	-	-	-	-	0.825	-	-
Max Licensed LT mad (m^3/s)	-	-	-	-	-	-	-	-

Table 19-2 Summary of summer and winter period low streamflow statistics at Powers Creek EFN point-of-interest

Streamflow Statistic	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.137	-
Summer 1:5-year return period 30 Day Low Streamflow	0.094	-
Summer 1:10-year return period 30 Day Low Streamflow	0.080	-
Summer 1:20-year return period 30 Day Low Streamflow	0.072	-
Winter 1:2-year return period 30 Day Low Streamflow	0.113	-
Winter 1:5-year return period 30 Day Low Streamflow	0.085	-
Winter 1:10-year return period 30 Day Low Streamflow	0.074	-
Winter 1:20-year return period 30 Day Low Streamflow	0.067	-

20 Shingle Creek Watershed

Expanding upon the methods summarized in Appendix A (i.e., Table A-18) for Shingle Creek, this section provides an overview of the specific methods used to develop streamflow datasets and the corresponding results. Figure 20-1 provides an overview map of the watershed with the specific data sources, ONA EFN transects, and identified points-of-interest. All scaling relationships and resultant streamflow datasets are provided digitally in Appendix U.

20.1 NATURALIZED STREAMFLOWS

For Shingle Creek naturalized streamflows, a modification was made to the methods outlined in Appendix A after it was identified that ONA had established two EFN points-of-interest within the watershed: 1) Upper EFN point-of-interest = EFN transect SHG10SCR2016, and 2) Lower EFN point-of-interest = EFN transect SCR1002016) (Figure 20-1).

Specifically, the modification for the development of the necessary streamflow datasets at the two EFN points-of-interest included the division of the watershed into four sub-watersheds: 1) Upper Shingle Creek to EFN point-of-interest, 2) Upper Shingle Creek at confluence, 3) Brent-Farleigh Lakes watershed, and 4) Shatford Creek to Shingle Creek watershed streamflow point-of-interest (minus Upper Shingle Creek and Brent-Farleigh Lakes watershed) (Figure 20-1). This division was also completed to support the development of the regulated streamflow datasets (to be completed at a later date) to allow for the consideration of reservoir management.

For the Upper Shingle Creek to EFN point-of-interest sub-watershed, weekly naturalized streamflows were estimated using hydrometric records from Shatford Creek near Penticton[14] (WSC No. 08NM037) and Shingle Creek above Kaleden Diversion (WSC No. 08NM038). Specifically, the record for Shingle Creek at WSC No 08NM038 was extended to the standard period using the mean weekly unit discharge relation established for the overlapping period of record between WSC No. 08NM037 and 08NM134 (Appendix U). The estimated Shingle Creek at WSC 08NM134 (45.4 km^2; median elevation = 1,532 m) records were used to adjust the ratio of the predicted normal annual runoff for the Upper Shingle Creek watershed to EFN point-of-interest (118.4 km^2; median elevation = 1,282 m). The ratio used for adjustment purposes was 0.55. The estimated weekly time series was then reconciled with the LT mad (for the standard period) for the updated regional runoff relation for hydrologic zone 24 (Appendix B).

[14] WSC No. 08NM037 was reported by the WSC to record regulated streamflow conditions; however, upon review of the WSC station description form, there was no note of upstream regulation. In addition, there are limited water licenses present upstream. Thus, it was deemed that the WSC No. 08NM037 records reflected natural (or near natural) streamflow conditions.

Points of Diversion - purpose
- No Purpose Listed
- Conservation
- Domestic
- Industrial
- Irrigation
- Land Improvement
- Power
- Storage
- Waterworks

- Active Non-WSC Hydrometric Station
- Discontinued Non-WSC Hydrometric Station
- Active WSC Hydrometric Station
- Discontinued / WSC Hydrometric Station
- Major Water Intake / Diversion
- EFN Transect
- 65 Water Use Area - many colors with ID
- Wetlands
- Alluvial Fan
- EFN Watershed
- 290 Alluvial Aquifer
- Reservoirs

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Figure 20-1: Map of Shingle Creek watershed (from Associated 2017)

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For estimating streamflows at the Shingle Creek streamflow point-of-interest (and the Lower EFN point-of-interest), the Shatford Creek at WSC No. 08NM037 and Shingle Creek at WSC 08NM038 records were scaled to the respective watershed areas but adjusted to represent different drainage areas with a different median elevation. Specifically, the updated regional runoff relation for hydrologic zone 24 (Southern Thompson Plateau) (Appendix B) was used to adjust the ratio of predicted normal annual runoff between Shatford Creek at WSC No. 08NM037 (45.4 km^2; median elevation = 1,532 m) and Shingle Creek at WSC 08NM038 (118.4 km^2; median elevation = 1,282 m) as follows:

- Upper Shingle Creek at confluence (132.5 km^2; median elevation = 1,233 m) ratio adjustment was 0.49 (using Shingle Creek at WSC No. 08NM038).
- Brent-Farleigh Lakes watershed (21.4 km^2; median elevation = 775 m) ratio adjustment was 0.17 (using Shatford Creek at WSC No. 08NM037).
- Shatford Creek to Shingle Creek watershed streamflow point-of-interest (minus Upper Shingle Creek and Brent-Farleigh Lakes watershed) (142.3 km^2; median elevation = 1,323 m) ratio adjustment was 0.99.

Streamflows at the streamflow point-of-interest were then assumed to be the sum of the above three sub-watershed areas – which assume no streamflow routing influence due to the weekly time-step modelled.

The resultant streamflows at the Upper Shingle Creek EFN point-of-interest and the Shingle Creek streamflow point-of-interest were then adjusted to long-term conditions using the Camp Creek weekly scaling ratios (Appendix C).

Streamflows were then reviewed to consider gains/losses at the two EFN points-of-interest as follows:

- For the Upper Shingle Creek EFN point-of-interest, since the point-of-interest is located mid-watershed, no streamflow gains/losses were assumed.
- For the Lower Shingle Creek EFN point-of-interest, the ONA collected manual streamflow measurements at selected EFN transects on the alluvial fan (Table 20-1; Figure 20-1) and the results suggested that for the dates measured, the Shingle Creek channel generally gained water for the portion monitored. However, due to the limited spatial understanding of streamflow gains/losses across the entire alluvial fan and unclear seasonal variation (if any), it was deemed more appropriate to consider a gain/loss value equivalent to zero across the entire fan.

Lastly, residual streamflow records were available for Shingle Creek at the Mouth (WSC No. 08NM150) for the period 1969-1982 and for Shingle Creek at Lower Irrigation Dam and at Gabriel Fields (from ONA) for the period 2016-2018. The resultant naturalized streamflows for the adjusted standard period were compared to the respective streamflows recorded by the WSC and ONA. The comparison indicated that although different time periods and streamflow types were compared, the general magnitude of the naturalized streamflows was consistent with that recorded historically. See Appendix U for a visual comparison.

Table 20-1 Summary of discharge measurements collected by the ONA across the Shingle Creek alluvial fan

Date	ONA EFN Transect[1,2] – Discharge (m^3/s)	
	Irrigation Dam (Upstream)	Hatchery (Downstream)
14-Dec-12	0.140	0.200
8-Mar-13	0.040	0.170
4-Jun-13	3.610	2.720
12-Jun-13	2.720	2.910
13-Apr-16	1.494	1.462
4-May-16	3.641	3.765
16-Jun-16	0.890	0.860
23-Jun-16	0.742	0.823

Note:

1. Refer to Figure 20-1 for location of EFN transects.
2. Distance between Glide 2 and Glide 1a is approximately 1.9 km.

20.2 RESIDUAL STREAMFLOWS

Residual streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

20.3 MAXIMUM LICENSED STREAMFLOWS

Maximum licensed streamflows for the adjusted standard period have not be calculated at this time. They are to be completed at a later date.

20.4 SUMMARY OF STREAMFLOW DATASETS

A summary of naturalized streamflows at the EFN points-of-interest is provided digitally in Appendix U. A comparison of LT mad values estimated herein and by others for the Shingle Creek watershed are summarized in Table 20-2 and the estimated low streamflow statistics (at the EFN points-of-interest) are summarized in Table 20-3.

Lastly, following the data error and quality rating framework (Table 2-1), the naturalized streamflow dataset was given a rating of B (i.e., data error >10% and ≤25%). This is due to actual residual WSC hydrometric records available within the headwaters of the watershed, but the need to assume streamflows at several other locations within the watershed, as well as the need to assume streamflow gains/losses across the alluvial fan.

Table 20-2 Summary of LT mad values estimated for Shingle Creek watershed

	LT mad estimates for Powers Creek watershed				
	Summit (2009a)	**Ptolemy (2016)**	**Obedkoff (1998) – Zone 24**	**This Study**	
Time Period	1996-2006	Unknown	1961-1990	Adjusted 1996-2010	
Point-of-Interest	Mouth	Mouth	Lower EFN Point-of-Interest	Upper EFN Point-of-Interest	Lower EFN Point-of-Interest
Naturalized LT mad (m^3/s)	0.654	0.744	0.733	0.272	0.641
Residual LT mad (m^3/s)	-	-	-	-	-
Max Licensed LT mad (m^3/s)	-	-	-	-	-

Table 20-3 Summary of summer and winter period low streamflow statistics at Upper and Lower Shingle Creek EFN points-of-interest

Streamflow Statistic	Upper EFN Point-of-Interest		Lower EFN Point-of-Interest	
	Naturalized (m^3/s)	Residual (m^3/s)	Naturalized (m^3/s)	Residual (m^3/s)
Summer 1:2-year return period 30 Day Low Streamflow	0.036	-	0.110	-
Summer 1:5-year return period 30 Day Low Streamflow	0.021	-	0.067	-
Summer 1:10-year return period 30 Day Low Streamflow	0.016	-	0.052	-
Summer 1:20-year return period 30 Day Low Streamflow	0.013	-	0.043	-
Winter 1:2-year return period 30 Day Low Streamflow	0.020	-	0.063	-
Winter 1:5-year return period 30 Day Low Streamflow	0.015	-	0.047	-
Winter 1:10-year return period 30 Day Low Streamflow	0.013	-	0.042	-
Winter 1:20-year return period 30 Day Low Streamflow	0.012	-	0.040	-

21 Summary and Recommendations

21.1 SUMMARY

The Okanagan Tennant method is the recommended method for setting initial EFN targets for streams in the Okanagan Basin. The Okanagan Tennant method is a desktop assessment involving several steps that provides insight into the risks to aquatic habitat and ecological processes from existing and proposed water allocations relative to natural or naturalized flows.

To apply the Okanagan Tennant method, the following streamflow datasets and statistics are required:

- naturalized long-term mean annual discharge (LT mad);
- mean weekly time-series of naturalized (or natural) streamflow (i.e., streamflow in the absence of any regulation, which is a term used to describe human influence on streamflow including water extraction, water diversion, and/or reservoir storage);
- mean weekly time-series of streamflow under current water use and management (i.e., residual streamflow);
- mean weekly time-series of streamflow assuming maximization of licensed storage and withdrawals (i.e., maximum licensed residual streamflow);
- summer (i.e., July 1 to September 30) 30-day low natural and residual streamflows under 1:2, 1:5, 1:10, and 1:20-year return periods; and
- winter (i.e., November 1 to March 31) 30-day low natural and residual streamflows under 1:2, 1:5, 1:10, and 1:20-year return periods.

Associated (2017) outlined a general approach for the development of streamflow datasets required to set EFNs in Okanagan tributaries using the Okanagan Tennant method; and provided specific steps for the development of streamflow datasets for 18 Okanagan tributaries. This document summarizes the streamflow datasets developed for the respective watersheds and the supporting methods and assumptions used to develop the datasets for the adjusted standard period (1996-2010). Note that for most watersheds, only naturalized streamflow datasets were developed because residual and maximum licensed streamflows are only needed by the ONA for EFN-setting for select cases, and will be completed at a later date.

21.2 RECOMMENDATIONS

There is a reasonable degree of confidence in the streamflow datasets developed herein to support the application of the Okanagan Tennant method; however, several estimates and assumptions were required due to the limitations (or absence) of site-specific information. Therefore, to improve and/or confirm the streamflow datasets, we recommend the following:

- Continue hydrometric monitoring at established EFN hydrometric stations under low, moderate, and high streamflows for a period deemed sufficient to capture low and high-water years. This information is critical to confirm the magnitude of streamflow datasets estimated herein.
- Complete detailed investigations into surface water gains/losses across alluvial fans. For most of the Okanagan EFN watersheds, some information is available to inform analysis of surface water / groundwater interactions across alluvial fans, but interactions are unique to each alluvial fan and can vary spatially, as well as seasonally. Since the Okanagan Tennant method recommends the

setting of EFNs at the lowest EFN transect (which is generally near the mouth of most watersheds), an accurate characterization of surface water / groundwater interactions is necessary to ensure that any recommended EFN streamflow thresholds are appropriate. To confirm surface water / groundwater interactions across alluvial fans, the following should be completed:
    - Review available aerial imagery to confirm extents of alluvial fans.
    - Review available well logs to estimate geologic and sediment extents across the alluvial fans.
    - Install hydrometric stations at strategic locations on the alluvial fans (e.g., apex of alluvial fan, EFN point-of-interest) to assess gains/losses across the fan.
    - Document water intakes and/or ditch diversions across the alluvial fans. For any identified diversions, talk to owners/operators about volumes withdrawn/diverted and timing. If no information is available, consider monitoring (e.g., installation of hydrometric station on ditch diversion).
    - Document groundwater wells across the alluvial fans. For any identified wells, talk to owners about volumes withdrawn and timing. For each well, review drawdown and capture zone topology.
- Complete a water licence rationalization assessment within each watershed to confirm whether issued water licences are in use.

In addition to the general recommendations noted above, the following watershed-specific recommendations are also provided to help improve confidence in the estimated streamflow datasets:
- Equesis Creek watershed
    - Continue hydrometric monitoring at the three EFN hydrometric stations.
    - The ditch diversions (i.e., one near apex of alluvial fan and two on the alluvial fan) should be monitored to determine/confirm volumes of water diverted during all seasons.
    - Due to the presence of a new dam on Pinaus Lake and limited lake management operations by OKIB, a lake operations management plan should be established that considers EFN requirements downstream.
    - Due to vehicle access limitations to Pinaus Lake, install a real-time hydrometric station on Pinaus Lake to support OKIB with lake management operations.
- Naswhito Creek watershed
    - Due to zero streamflows estimated at the EFN point-of-interest, install a hydrometric station at or near the apex of the alluvial fan and continue monitoring at the existing EFN hydrometric station to confirm surface / groundwater interactions and zero streamflows (calculated) on the alluvial fan.
    - Due to the uncertainty of actual water use within the watershed, conduct surveys with private water licence holders to confirm if and/or when water is being diverted in the watershed.
- Vaseux Creek watershed
    - Due to the large alluvial fan and regular periods of zero streamflow recorded by the WSC (at WSC Station No. 08NM246), install a hydrometric station at or near the apex of the alluvial fan and continue monitoring at the existing EFN hydrometric station to confirm the magnitude of seasonal surface / groundwater interactions. In addition, monitor the ditch diversion (and return flow) that is present on the alluvial fan.

- Whiteman Creek watershed
  - Due to the assumptions required to consider surface water / groundwater interactions across the alluvial fan, install a hydrometric station at or near the apex of the alluvial fan and continue monitoring at the existing EFN hydrometric station to confirm the magnitude of seasonal surface / groundwater interactions.
- Shorts Creek watershed
  - Continue monitoring at the existing hydrometric station maintained by the ONA.
  - Due to the uncertainty of actual irrigation water use within the watershed, conduct surveys with private water licence holders to confirm if and/or when water is being diverted in the watershed.
- Inkaneep Creek watershed
  - Encourage the WSC to continue hydrometric monitoring at WSC No. 08NM200.
  - Due to the uncertainty of actual water use and storage operations within the watershed, conduct surveys with private water licence holders and the Osoyoos Indian Band to confirm if and/or when water is being diverted/stored/released in the watershed.
  - Due to the assumptions required to consider surface water / groundwater interactions across the alluvial fan, continue conducting streamflow measurements at the existing EFN transects to confirm the magnitude of seasonal surface / groundwater interactions in comparison to streamflows recorded at WSC No. 08NM200.
- Shuttleworth Creek watershed
  - Continue monitoring at the existing hydrometric station maintained by the ONA, or initiate discussions with the WSC about the option of re-activating WSC No. 08NM179.
  - Due to the assumptions required to consider surface water / groundwater interactions across the alluvial fan, continue conducting streamflow measurements at the existing EFN transects to confirm the magnitude of seasonal surface / groundwater interactions in comparison to streamflows recorded by the ONA upstream at Maple Street.
- McDougall Creek
  - Continue monitoring at the existing hydrometric station maintained by the ONA.
  - Due to the uncertainty of actual water use and storage operations within the watershed, conduct surveys with private water licence holders and the WFN to confirm if and/or when water is being diverted/stored/released in the watershed.
  - Due to the assumptions required to consider surface water / groundwater interactions across the alluvial fan, install a hydrometric station at or near the apex of the alluvial fan and continue monitoring at the existing EFN hydrometric station to confirm the magnitude of seasonal surface / groundwater interactions. This will also require that all diversions by the WFN on the alluvial fan be recorded/documented.
- Naramata Creek watershed
  - Conduct fieldwork to confirm that the EFN point-of-interest is the mouth of the creek or identify a more appropriate location.
  - Due to no active or historic hydrometric monitoring of Naramata Creek, install a hydrometric station at or near the apex of the alluvial fan and one near the EFN point-of-interest. These hydrometric stations will help confirm streamflow estimates, surface / groundwater interactions, and on fan water use.

    - Due to the assumptions needed to estimate streamflow supplementation by the highline diversion, install a hydrometric station within the diversion or collect manual measurements at selected times throughout the year to confirm the timing of diversions and volumes of water diverted.
- Mission Creek watershed
    - Due to the uncertainty of actual water use and reservoir management within the watershed, encourage water purveyors to continue and/or begin monitoring water diversion volumes and reservoir water levels and releases.
    - There are several inter-basin (e.g., Stirling Creek) and intra-basin (e.g., Hilda Creek) transfers within the Mission Creek watershed. Understanding the transfer of water within the watershed is important to understand water management and the influence on streamflow timing. Therefore, it is recommended that water purveyors be encouraged to document water transfers and timing (and volumes).
    - Install a hydrometric station on Pearson Creek near WSC No. 08NM172. Monitoring at this location provides an understanding the natural streamflow timing of Mission Creek watershed and historic information from this location was used by the Mission Creek Water Use Plan (WMC 2010) to set fishery flow targets on Mission Creek.
- Penticton Creek watershed
    - Conduct fieldwork to confirm that the EFN point-of-interest is the mouth of the creek or identify a more appropriate location.
    - Since the COP is actively recording streamflows at Nanaimo Avenue, encourage them to confirm the data quality of the available hydrometric records to ensure that standard procedures are being used to collect the streamflow dataset.
    - Once preliminary EFN values have been established, confirm that the EFN values are generally consistent and/or meet the goals of the Penticton Creek Restoration Plan.
- Coldstream Creek watershed
    - Continue monitoring at the existing hydrometric station maintained by the ONA. Due to the uncertainty of actual water use and storage operations within the watershed, as well as the likely large groundwater contribution along the Coldstream Creek valley, this hydrometric station will ensure that actual streamflow records are available to confirm magnitudes of streamflows, particularly during critical fish periodicity windows.
    - Due to the assumptions required to consider surface water / groundwater interactions across the alluvial fan, continue conducting streamflow measurements at the existing EFN transects to confirm the magnitude of seasonal surface / groundwater interactions in comparison to streamflows recorded by the ONA hydrometric station. This will also require that all diversions on the alluvial fan be recorded/documented.
- Mill Creek Watershed
    - Conduct fieldwork to confirm that the EFN point-of-interest is the mouth of the creek or identify a more appropriate location. A large portion of the lower reaches of Mill Creek are channelized through the City of Kelowna. Therefore, it is recommended that fieldwork be conducted to confirm the most appropriate EFN point-of-interest location (i.e., mouth or other).
    - Due to the uncertainty of groundwater contributions to streamflow throughout the lower watershed area, develop a strategic hydrometric monitoring program to record streamflows

from the upland watershed area, as well as streamflows at several locations in the lower watershed area to begin to quantify groundwater contributions along the valley floor.

- It is understood that the City of Kelowna is currently monitoring streamflows on Upper Mill Creek above the Kelowna Airport and on Scotty Creek. At a minimum, it is recommended that a hydrometric station be installed at the location of WSC No. 08NM053 to capitalize on the long history of record previous collected.

- Trout Creek Watershed
  - Conduct fieldwork to confirm that the EFN point-of-interest is the mouth of the creek or identify a more appropriate location.
  - Given the lack of hydrometric information available for Trout Creek, consider re-installing a hydrometric station at Trout Creek near the Mouth (WSC No. 08NM158) and/or Trout Creek below Thirsk Lake (WSC No. 08NM237). These locations would provide important information on residual streamflows within the Trout Creek watershed, as well as help confirm naturalized streamflow estimates.
  - Install a hydrometric station at or near the apex of the alluvial fan and at the location of historic WSC No. 08NM158 (see above) to confirm surface / groundwater interactions across the alluvial fan.
- McLean Creek watershed
  - Conduct fieldwork to confirm that the EFN point-of-interest is the mouth of the creek or identify a more appropriate location.
  - Due to no active and very limited historic hydrometric monitoring of McLean Creek, install a hydrometric station at or near the apex of the alluvial fan and one near the EFN point-of-interest. These hydrometric stations will help confirm streamflow estimates and surface / groundwater interactions.
- Trepanier Creek watershed
  - Conduct fieldwork to confirm that the EFN point-of-interest is the mouth of the creek or identify a more appropriate location.
  - Due to the assumption used to estimate streamflow gains/losses across the alluvial fan to the EFN point-of-interest, install a hydrometric station at or near the apex of the alluvial fan and at the location of historic WSC No. 08NM155 to confirm surface / groundwater interactions across the alluvial fan. This will also require that all diversions on the alluvial fan be recorded/documented.
- Powers Creek watershed
  - Conduct fieldwork to confirm that the EFN point-of-interest is the mouth of the creek or identify a more appropriate location.
  - With the lack of hydrometric information available for Powers Creek, consider re-installing a hydrometric station at Powers Creek near the Mouth (WSC No. 08NM157) and/or Powers Creek below Westbank Diversion (WSC No. 08NM059). These locations would provide important information on residual streamflows within the Powers Creek watershed, as well as help confirm naturalized streamflow estimates.
  - Due to the assumption used to estimate streamflow gains/losses across the alluvial fan to the EFN point-of-interest, install a hydrometric station at or near the apex of the alluvial fan and at the location of historic WSC No. 08NM157 (see above) to confirm surface / groundwater interactions across the alluvial fan. This will also require that all diversions on the alluvial fan be recorded/documented.

- Shingle Creek watershed
  - Continue monitoring at the existing hydrometric stations maintained by the ONA. Due to the uncertainty of actual water use and storage operations within the watershed, these hydrometric stations will ensure that actual streamflow records are available to confirm magnitudes of streamflows, particularly during critical fish periodicity windows.
  - Due to the assumptions required to consider surface water / groundwater interactions across the alluvial fan, continue conducting streamflow measurements at the existing EFN transects to confirm the magnitude of seasonal surface / groundwater interactions in comparison to streamflows recorded by the ONA hydrometric station. This will also require that all diversions on the alluvial fan be recorded/documented.

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Appendix A – Recommended Methods for Streamflow Dataset Development (from Associated 2017)

Table A-1 Summary information and recommended approach for developing streamflow datasets for Equesis Creek (from Associated 2017)

Stream:	**Equesis Creek**	**Overall data confidence:**	High
Drainage area (km²):	203.5	**Latitude, Longitude:**	50.28 N, -119.40 E
Median elevation (m):	1,173	**Provincial hydrologic zone:**	15
Minimum elevation (m):	342 +/-		
Maximum elevation (m):	1,778		

Watershed description:

Equesis Creek is located on the west side of Okanagan Lake near northwest arm of the lake. The upper portion of the watershed drains a gently sloping plateau and includes Pinaus Lake, Little Pinaus Lake, Lady King Lake, and Square Lake. Land use on the plateau consists primarily of forest harvesting, but also includes outdoor recreation (e.g., fishing). Below about an elevation of 1,300 m, the watershed drains moderately steep eastward-facing slopes. Approximately half way down from the plateau, the relatively large tributary of Ewer Creek enters from the southwest. At about an elevation of 500 m, Equesis Creek crosses a terrace consisting of thick unconsolidated deposits that supports an alluvial aquifer. Near Okanagan Lake, Equesis Creek flows through the Okanagan Indian Band I.R. No. 1 and onto a large alluvial fan that has merged with one near the mouth of Naswhito Creek. Agriculture is the principal land use activity downstream of Ewer Creek.

Hydrometric data:

Station	Nat / Reg	Period of record	Drainage area (km²)	Median elev. (m)	Notes
Water Survey of Canada:					
Equesis Creek near Vernon (08NM024)	Reg.	1911-1926	179	-	-
Equesis Creek near the Mouth (08NM161)	Reg.	1969-1982	199	1,173	Continuous record 1977-1982
Ewer Creek near the Mouth (08NM176)	Nat.	1971-1986	52.8	1,470	Continuous record 1972-1986
Others:					
Equesis Creek near the Mouth	Reg.	2016-present	-	-	EFN station operated by ONA. Installed in August 2016
Equesis Creek at Westside Rd.	Reg.	2016-present	-	-	EFN station operated by ONA. Installed in August 2016
Equesis Creek below Upstream Diversion	Reg,	2016-present	-	-	EFN station operated by ONA. Installed in August 2016

Water suppliers / users: Okanagan Indian Band

Storage licences / reservoirs:

Reservoir	Water Supplier	Licensed Storage (ML/year)
Pinaus Lake[1]	Okanagan Indian Band	1,961.2[2]
	Juergen Holder (Private)	98.7
	Total:	**2,059.9**

Notes: The Okanagan Indian Band and FLNRO jointly manage Pinaus Lake to supplement natural streamflows when needed (Dobson 2008). There is a pending licence (C020099) for storage in Pinaus Lake for 123.3 ML/year.

Inter-basin transfers: None

Water Use Areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
166	Okanagan Indian Band Reserve 1	10	100
176	Okanagan Indian Band Reserve 1	3	0
192	OTHER_Node 8_Equesis Creek (mouth)	8	91.4

According to Dobson (2008), the areas not supplied by groundwater in the Equesis Creek watershed, south part of Residual Area W-2, and north part of Residual Area W-3 are supplied or likely to be supplied by Equesis Creek.

Based on field observations by ONA and FLNRO, there are two relatively large licensed water diversions feeding open ditches along the lower portion of Equesis Creek. This potential loss of water should be considered, if not accounted for, in streamflow estimation described below. Available diversion information for the ditches is likely limited; however, the ONA may have obtained field measurements and/or measured ditch dimensions that may be useful to volumes of water diverted.

Groundwater – surface water interaction:

There is potential that Equesis Creek is fed by groundwater along its lower reaches (NHC 2001). Groundwater gain/loss across the alluvial fan may be estimated using the recent streamflow measurements by the ONA at different locations on the fan (i.e., a limited record). However, if these records are not deemed reliable at this time, gains/losses on the fan should be conservatively assumed zero.

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Weekly streamflows for Equesis Creek at the apex of the alluvial fan should be based on the records from the following two stations: Ewer Creek near the mouth (08NM176) and Whiteman Creek above Bouleau Creek (08NM174). The former record represents natural streamflow from a higher location within the Equesis Creek watershed, but does not include streamflows during the period of interest (1996-2010). The latter station has one of the most complete long-term natural streamflow records on the west side of the Okanagan Basin (less than 10 km south of Equesis Creek). Since Ewer Creek is located within the Equesis Creek watershed, it provides the most reliable indicator of natural streamflow patterns in Equesis Creek. However, to use the record from Ewer Creek, two main steps are required:

1) The record for Ewer Creek needs to be extended to represent 1996-2010. This can be accomplished by identifying long-term weekly relations between Ewer Creek and Whiteman Creek. Summit (2009a) found a high correlation between the unit discharges of these two streams for the overlapping period of 1972 to 1986. This relation can be used to predict the Ewer Creek unit discharge for 1996-2010.

2) The predicted streamflows for Ewer Creek (1996-2010) need to be adjusted to represent a larger drainage[3] with a lower median elevation. The adjustment is based on the ratio of predicted normal annual runoffs (from a revised Figure 3-3) between Equesis Creek at the apex of alluvial fan and Ewer Creek near the mouth. Summit (2009a) identified this ratio as 0.52 for the 1996-2006 period; this means that on average, unit discharge of Equesis Creek (near the mouth) is about 52% of that at Ewer Creek.

The estimated weekly time series for Equesis Creek would then be reconciled with the LT mad (for 1996-2010) identified by the updated regional runoff relations (i.e., updated version of Figure 3-3). As a rough check, the final time series should be reviewed against the records at Equesis Creek near the mouth (08NM161) and Equesis Creek streamflows recorded by the ONA, recognizing that these records represent different periods and may be influenced by flow regulation. Streamflows at the streamflow point-of-interest (i.e., on the alluvial fan) should then be adjusted according to the expected gain/loss between the fan apex and the EFN point-of-interest. This gain/loss may be estimated using the recent streamflow measurements by the ONA at different locations on the fan (i.e., a limited record) or assumed zero. Any gains/losses can be assumed uniform throughout the year (unless there is data to the contrary), even though it is likely to vary seasonally with the elevation of groundwater table. Following this, weekly naturalized streamflows LT mad can then be calculated at the EFN point-of-interest.

Residual Streamflows Under Current Water Use and Management

Weekly residual streamflows for Equesis Creek under current water use and management should be estimated by summing the naturalized streamflow and the following:

1) Expected weekly net flow (+ or -) associated with upland storage reservoir operation (i.e., Pinaus Lake with a total licensed storage of approximately 2,060 ML). The Okanagan Indian Band and/or FLNRO should be contacted to identify patterns of reservoir operation and obtain reservoir/water use information (if available); if this information proves difficult to obtain, an assumed fill and release schedule along with the total licensed storage should be used.

2) Expected weekly water extraction upstream of the streamflow and EFN points-of-interest. This information will be based on the OWDM and the estimated demands associated with the water use areas identified above (i.e., Okanagan Indian Band I.R. No. 1, and "Other").

Residual Streamflows Assuming Maximum Licence Use

Weekly residual streamflows for Equesis Creek under maximum water use should be estimated in a similar way as for the current water use and management. The primary difference is that estimated demands from the OWDM would be replaced by the estimated total licensed extraction upstream of the point-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.

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[1] Water licenses are registered under Equesis Creek.

[2] Total of three licenses.

[3] Unless stated otherwise, all hydrologic estimates are based on unit discharge calculations; therefore, streamflows between two drainages with different areas may be compared.

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Table A-2 Summary information and recommended approach for developing streamflow datasets for Naswhito Creek (from Associated 2017)

Stream:	**Naswhito Creek**	**Overall data confidence:**	Moderate
Drainage area (km²):	86.5	**Latitude, Longitude:**	50.27, -119.44
Median elevation (m):	1242	**Provincial hydrologic zone:**	15
Minimum elevation (m):	342 +/-		
Maximum elevation (m):	1835		

Watershed description:

Naswhito Creek is located on the west side of Okanagan Lake, between Equesis Creek to the north and Whiteman Creek to the south. Above 1,200 m, Naswhito Creek drains a relatively small area of gently sloping plateau. Below that elevation, the watershed is characterized by moderately steep slopes and a deeply incised valley. Below 500 m, the creek flows over a large terrace of glacial sediments then crosses an alluvial fan (that merges with the fan of Equesis Creek) before draining into Okanagan Lake. Forestry is the primary land use in the upper watershed, with agricultural lands located within the lower reaches and adjacent to Okanagan Lake. Okanagan Indian Band I.R. No. 1 is situated on the alluvial fan at the mouth of the creek.

Hydrometric data:

Station	Nat / Reg	Period of record	Drainage area (km²)	Median elev. (m)	Notes
Water Survey of Canada:					
Naswhito Creek near Ewing's Landing (08NM047)	Nat.	1921	81.8	-	-
Others:					
Naswhito Creek near the Mouth	Reg.	2016-present	-	-	EFN Station operated by ONA. Installed in August 2016

Water suppliers / users:

The Okanagan Indian Band, the main water user within the Naswhito Creek watershed, use water from Naswhito Creek for irrigation and domestic purposes. However, none of this is supported by storage. One other private water licensee also uses water from Naswhito Creek for domestic and irrigation purposes, but holds a licence for storage.

Storage licences / reservoirs:

Reservoir	Water Supplier	Licensed Storage (ML/year)
Naswhito Creek	Geen (Private)	128.0[4]
	Total:	**128.0**

Note that there are multiple irrigation dams (some supported by storage water licences) that divert water for irrigation purposes on Naswhito Creek (Wightman and Taylor 1978); however, streamflows within Naswhito Creek are reported to be unsupported by storage (Dobson 2008).

Inter-basin transfers:

A licensed water diversion was constructed on the south fork of Naswhito Creek to divert water into Browns Creek, but this diversion is no longer active (Dobson 1999).

Water Use Areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
168	Okanagan Indian Band Reserve 1	12	100
92	OTHER_Node 10_Naswhito Creek (mouth)	10	100

Groundwater – surface water interaction

Summit (2009a) identified that Naswhito Creek likely loses water to groundwater and estimated that streamflow is lost to groundwater at a rate of 0.014 m^3/s per km of channel across the alluvial fan.

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Weekly streamflows for Naswhito Creek at the apex of the alluvial fan should be based on the records from two stations: Ewer Creek near the mouth (08NM176) and Whiteman Creek above Bouleau Creek (08NM174). The former record represents natural streamflow from a slightly higher location within the Equesis Creek watershed (directly north of Naswhito Creek), but does not include streamflows during the period of interest (1996-2010). The latter station has one of the most complete long-term natural streamflow records on the west side of the Okanagan Basin (directly south of Naswhito Creek). The following steps are required to develop naturalized streamflow estimates:

1) To use the record from Ewer Creek (08NM176):

a) The record for Ewer Creek (08NM176) needs to be extended to represent 1996-2010. This can be accomplished by identifying long-term weekly relations between Ewer Creek (08NM176) and Whiteman Creek (08NM174). Summit (2009a) found a high correlation between the unit discharges of these two streams for the overlapping period of 1972 to 1986. This relation can be used to predict the Ewer Creek (08NM176) unit discharge for 1996-2010.

b) The predicted streamflows for Ewer Creek (1996-2010) need to be adjusted to represent Naswhito Creek at the fan apex (i.e., a larger drainage with a lower median elevation). The adjustment is based on the ratio of predicted normal annual runoffs (from a revised Figure 3-3) between Naswhito Creek at the fan apex and Ewer Creek near the mouth.

2) To use the record from Whiteman Creek (08NM174), the unit weekly discharge should be scaled according to the ratio of predicted normal annual runoffs (from a revised Figure 3-3) between Naswhito Creek at the fan apex and Whiteman Creek above Bouleau Creek (08NM174).

3) Since Naswhito Creek is well represented by both Ewer Creek (to the north) and Whiteman Creek (to the south), these two weekly time series (scaled to reflect Naswhito Creek at the fan apex) can be averaged.

4) The estimated weekly time series for Naswhito Creek at the fan apex would then be reconciled with the LT mad (for 1996-2010) identified by the updated regional runoff relations (i.e., updated version of Figure 3-3).

5) Streamflows at the streamflow point-of-interest (i.e., on the alluvial fan) should then be adjusted according to the expected gain/loss between the fan apex and the EFN point-of-interest. Gains/losses can be assumed uniform throughout the year (unless there is data to the contrary), even though it is likely to vary seasonally with the elevation of the groundwater table. This can be confirmed or updated using field information collected by the ONA.

6) As a check, the final time series should be reviewed against the available records (albeit short) at Naswhito Creek near the mouth (ONA) and reports (e.g., NHC 2001), recognizing that these estimates represent different periods and may be influenced by flow regulation.

Residual Streamflows Under Current Water Use and Management

Weekly residual streamflows for Naswhito Creek under current water use and management should be estimated by summing the naturalized streamflow and the following:

1) Expected weekly net flow (+ or -) associated with the relatively minor upland storage. An assumed fill and release schedule along with the total licensed storage should be used.

2) Expected weekly water extraction upstream of the EFN point-of-interest. This information can be based on estimated demands associated with the water use areas identified above using the OWDM.

Residual Streamflows Assuming Maximum Licence Use

Weekly residual streamflows for Whiteman Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary difference is that estimated demands from the OWDM would be replaced by the estimated total licensed extraction upstream of the EFN point-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.

References:

Useful References to support the Development of Streamflow Datasets

Dobson Engineering Ltd. (Dobson). 2008. Water Management and Use Study. Prepared for Okanagan Basin Water Board, December 2008.

Northwest Hydraulic Consultants Ltd. (NHC). 2001. Hydrology, Water Use, and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, BC. Prepared for BC Fisheries, Fisheries Management Branch, August 2001.

Summit Environmental Consultants Ltd. (Summit). 2009a. Surface Water Hydrology and Hydrologic Modelling Study – "State of the Basin" Report. Prepared for the OBWB, September 2009.

Wightman, J.C., and G.D. Taylor. 1978. Overview and rating of production capabilities and enhancement opportunities for rainbow trout and kokanee in tributaries to upper Okanagan basin lakes. Fish Habitat Improvement Section, Fish and Wildlife Branch, Ministry of Recreation and Conservation, Victoria, BC.

[4] Includes two water licenses.

Table A-3 Summary information and recommended approach for developing streamflow datasets for Vaseux Creek (from Associated 2017)

Stream:	**Vaseux Creek**	**Overall data confidence:**	High
Drainage area (km^2):	294.3	**Latitude, Longitude:**	49.24, -119.53
Median elevation (m):	1,535	**Provincial hydrologic zone:**	23 (10%), 24 (90%)
Minimum elevation (m):	317		
Maximum elevation (m):	2,301		

Watershed description:

The Vaseux Creek watershed is located east of Vaseux Lake and Okanagan River between Shuttleworth Creek to the north and Wolfcub and Inkaneep Creek to the south. Vaseux Creek and its tributary, Solco Creek, drain a gently sloping plateau above 1,500 m elevation. Downslope, the creek has incised deeply into the surrounding plateau to form a steep-sided canyon. Prior to draining into Okanagan River, Vaseux Creek streamflows across a large alluvial fan on the valley bottom. The plateau has been extensively logged. The Vaseux Bighorn National Wildlife Area is located at the lower end of the creek. The land use at the south end of the alluvial fan is industrial and residential.

Hydrometric data:

Station	Nat / Reg	Period of record	Drainage area (km^2)	Median elev. (m)	Notes
Water Survey of Canada:					
Vaseux Creek above Dutton Creek (08NM015)	Nat.	1919-1982	255	1591	-
Vaseux Creek near the Mouth (08NM246)	Nat.	2006-2010	296	1535	Some missing data
Vaseux Creek above Solco Creek (08NM171)	Nat.	1970-present	117	1680	Continuous record. Real-time.
Others:					
Vaseux Creek near the mouth	Nat.	2016-present	296	1535	EFN Station operated by ONA. Installed in August 2016. Real-time.

Water suppliers / users:

There are no major water suppliers extracting water from Vaseux Creek; however, there are several privately held water licences including those for irrigation and domestic purposes. With no developed storage, natural streamflows in summer are often low. The Oliver canal that originates on the Okanagan River crosses through this watershed, but no water is diverted from the canal in this drainage.

Storage licences / reservoirs:

Reservoir / Stream	Water Supplier	Licensed Storage (ML/year)
Dutton Creek	Casorso (Private)	98.7
	Total:	**98.7**

Inter-basin transfers: None

Water use areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
147	OTHER_Node 66_Vaseux Creek (mouth)	66	85.7

Surface water – groundwater interaction:

Vaseux Creek likely loses water to groundwater and estimated that streamflow is lost to groundwater at a typical rate of 0.014 m^3/s per km of channel on the alluvial fan (Summit 2009a).

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Weekly streamflows for Vaseux Creek at the apex of the alluvial fan should be based on the records from the following stations: Vaseux Creek above Solco Creek (08NM171), Vaseux Creek above Dutton Creek (08NM015), and Vaseux Creek near the Mouth (08NM246). The first of these records represent natural streamflow from a higher location within the Vaseux Creek watershed. It also is one of the most complete long-term natural streamflow records in southeast Okanagan Basin. The second hydrometric record is at a lower location (i.e., closer to the streamflow point-of-interest); however, its record ends in 1982 (prior to the period of interest). The third record is closest to the streamflow point-of-interest; however, it is only four years and includes some gaps. To use these records to develop naturalized streamflows, the following steps are required:

1) Unit discharge values for both Vaseux Creek above Solco (08NM171) and Vaseux Creek above Dutton Creek (08NM105) should be reviewed and the overlapping records compared. The latter station better reflects streamflow patterns near the apex of Vaseux Creek, but unfortunately records for the period 1996-2010 are not available. To estimate what the streamflows for Vaseux Creek above Dutton Creek (08NM105) were for 1996-2010, weekly relations should be identified between the two hydrometric records over the 1971-1982 period. These ratios provide a basis for estimating Vaseux Creek above Dutton Creek (08NM105) streamflow from the record of Vaseux Creek above Solco Creek (08NM171) record.

2) To reflect conditions of Vaseux Creek at the fan apex, it is necessary to scale the synthesized record at Vaseux Creek above Dutton Creek (08NM105) down to reflect the slightly lower unit discharge at the fan apex. According to previous regional runoff relations (Summit 2009a), Vaseux Creek unit discharge values are approximately 8% lower at the mouth than at above Dutton Creek. Based on updated regional relations (i.e., updated Figure 3-3) this value will be reassessed.

3) The estimated weekly time series for Vaseux Creek at the apex would then be reconciled with the LT mad (for 1996-2010) identified by the updated regional runoff relations (i.e., updated version of Figure 3-3).

4) Since Vaseux Creek flows across an alluvial fan and aquifer, the assumed streamflow losses (noted above) should be applied.

5) Several checks should be made. This includes comparison of the estimated streamflows with streamflow records at Vaseux Creek at the mouth (08NM246); recognizing there may be some streamflow regulation effect and/or groundwater interaction reflected in this record. Additional checks should be made with previous estimates by others (e.g., Coulson 1978, NHC 2001) recognizing that different periods of interest can influence results.

Residual Streamflows Under Current Water Use and Management

Weekly residual streamflows for Vaseux Creek under current water use and management should be estimated by summing the naturalized streamflow and the following:

1) Expected weekly net flow (+ or -) associated with the relatively minor upland storage. An assumed fill and release schedule along with the total licensed storage should be used.

2) Expected weekly water extraction upstream of the streamflow and EFN points-of-interest. This information will be based on the OWDM and the estimated demands associated with the water use areas identified above, as well as any information available from the ONA who have detailed knowledge of the watershed.

Residual Streamflows Assuming Maximum Licence Use

Weekly residual streamflows for Vaseux Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary difference is that estimated demands from the OWDM would be replaced by the estimated total licensed extraction upstream of the EFN point-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.

References:

Useful References to support the Development of Streamflow Datasets

Coulson, C.H. 1978. Vaseux Creek Water Supply for April 15 to June 15.

Dobson Engineering Ltd. (Dobson). 2008. Water Management and Use Study. Prepared for Okanagan Basin Water Board, December 2008.

Dobson Engineering Ltd. 1999. Watershed Assessment Report for the Vaseux Creek Watershed. Final Report, Parts 1, 2, and 3. Prepared for Weyerhaeuser Canada Ltd., March 1999.

Letvak, D.B. 1988. Runoff in Okanagan Valley 1983-87. Memorandum dated May 3, 1988. BC Ministry of Environment and Parks, Water Management Branch. File S2109, Study 272.

Northwest Hydraulic Consultants Ltd. (NHC). 2001. Hydrology, Water Use, and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, BC. Prepared for BC Fisheries, Fisheries Management Branch, August 2001.

Summit Environmental Consultants Inc. (Summit). 2009a. Surface Water Hydrology and Hydrologic Modelling Study – "State of the Basin" Report. Prepared for the OBWB, September 2009.

Table A-4 Summary information and recommended approach for developing streamflow datasets for Whiteman Creek (from Associated 2017)

Stream:	**Whiteman Creek**	**Overall data confidence:**	High
Drainage area (km^2):	202.5	**Latitude, Longitude:**	50.23 N, -119.44 E
Median elevation (m):	1,340	**Provincial hydrologic zone:**	15
Minimum elevation (m):	342 +/-		
Maximum elevation (m):	2,039		

Watershed description:

Whiteman Creek is located on the west side of Okanagan Lake in the northern portion of the Okanagan Basin. It is located between Naswhito Creek to the north and Shorts Creek to the south. Whiteman Creek drains a gently sloping plateau above an elevation of about 1,400 m. Downslope, the creek flows through steep-sided hillslopes. The principal tributary to Whiteman Creek is Bouleau Creek, which drains the northern half of the watershed. Bouleau Creek is fed by Bouleau Lake situated at an elevation of about 1,375 m. Near an elevation of about 550 m, Whiteman Creek flows over a large terrace of glacial sediments before reaching a large alluvial fan at Okanagan Lake. The main land use within the upper watershed is forestry, with agriculture and urban development in the lower reaches.

Hydrometric data:

Station	Nat / Reg	Period of record	Drainage area (km^2)	Median elev. (m)	Notes
Water Survey of Canada:					
Whiteman Creek above Bouleau Creek (08NM174)	Nat.	1971-present	109	1,450	Continuous record. Drainage area is based on Obedkoff (1998); WSC reports a drainage area of 112 km^2.
Whiteman Creek near Vernon (08NM046)	Reg.	1920-1970	197	1,340	Seasonal record; Median elevation assumed similar to Whiteman Creek at the mouth (ONA hydrometric station).
Whiteman Creek at the Mouth (08NM180)	Reg.	1970-1972	197	1,340	Drainage area assumed similar to hydrometric station 08NM046. Median elevation assumed similar to Whiteman Creek at the mouth (ONA hydrometric station).
Others:					
Whiteman Creek near the Mouth	Reg.	2016-present	-	1,340	EFN station operated by ONA. Installed in August 2016

Water suppliers / users:

The Okanagan Indian Band is the primary water supplier within the Whiteman Creek watershed (Dobson 2008). There are approximately 12 current water licences within the Whiteman Creek watershed.

Storage licences / reservoirs:

Reservoirs	Water Supplier	Licensed Storage (ML/year)
None	-	-

Inter-basin transfers: None

Water use areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
174	Okanagan Indian Band Reserve 1	18	100
96	OTHER_Node 14_Whiteman Creek (mouth)	14	100

Groundwater – surface water interaction:

Whiteman Creek is likely an influent stream (i.e., gaining streamflow from groundwater in the lower reaches) (NHC 2001). However, there is speculation of no net change in streamflow along the lower reaches (Summit 2009a). Unless further information becomes available, no net change in surface streamflows across the fan should be assumed.

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Weekly streamflows for Whiteman Creek at the apex of the alluvial fan should be based on the record from Whiteman Creek above Bouleau Creek (08NM174). This record represents natural streamflow from a slightly higher location within the Whiteman Creek watershed. It also is one of the most complete long-term natural streamflow records on the west side of the Okanagan Basin. The following steps are suggested to develop naturalized streamflow:

1) Fill the gap in the record at hydrometric station 08NM174 during spring and summer 1997. This can be done by inspecting natural streamflow records from all WSC hydrometric stations that have overlapping records and specifically with records for the missing period in 1997. The record at Camp Creek at mouth near Thirsk (08NM134) was identified as most suitable given its similar pattern of streamflows. Weekly relations can be identified between the two stations to estimate the missing data at Whiteman Creek (08NM174).

2) The complete weekly record of natural streamflows at Whiteman Creek above Bouleau Creek (08NM174) should be scaled to reflect the lower unit discharge at fan apex. According to previous regional runoff relations (Summit 2009a), normal annual runoff at the mouth is about 81% of the value at the hydrometric station (08NM174); this value should be reassessed based on revised normal runoff curves (e.g., Figure 3-3). Final weekly time series should then be reconciled with the regionally based normal annual runoff, and if necessary a small scaling may be required.

3) There is potential that Whiteman Creek is fed by groundwater along its lower reaches (NHC 2001). However, since there is no solid information on groundwater gains, it should be conservatively assumed that no streamflow gain occurs. This assumption may be revised as new information emerges (e.g., following hydrometric monitoring by ONA).

4) As a check, the final streamflow time series should be reviewed against the available record of regulated streamflows at the hydrometric stations Whiteman Creek near Vernon (08NM046) and Whiteman Creek at the mouth (08NM180); however, direct validation of the estimates is limited by the period of record at the mouth (pre-1972) and the unknown volume of water actually withdrawn from the creek during the period of streamflow record. Additional checks should also be made against previous estimates (e.g., Letvak 1980, NHC 2001), recognizing that different periods of interest can influence results.

Residual Streamflows Under Current Water Use and Management

Weekly residual streamflows for Whiteman Creek under current water use and management should be estimated by summing the naturalized streamflow and the expected weekly water extraction upstream of the streamflow and EFN points-of-interest. This information will be based on the OWDM and the estimated demands associated with the water use areas identified above (i.e., Okanagan Indian Band I.R. No. 1, and "Other").

Residual Streamflows Assuming Maximum Licence Use

Weekly residual streamflows for Whiteman Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary difference s that estimated demands from the OWDM would be replaced by the estimated total licensed extraction upstream of the EFN point-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.

References:

Useful References to support the Development of Streamflow Datasets

Dobson Engineering Ltd. (Dobson). 2008. Water Management and Use Study. Prepared for Okanagan Basin Water Board, December 2008.

Letvak, D.B. 1980. Annual Runoff Estimates for West Side of Okanagan Valley, BC. BC Ministry of Environment. January 1980.

Northwest Hydraulic Consultants Ltd. (NHC). 2001. Hydrology, Water Use, and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, BC. Prepared for BC Fisheries, Fisheries Management Branch, August 2001.

Summit Environmental Consultants Inc. (Summit). 2009a. Surface Water Hydrology and Hydrologic Modelling Study – "State of the Basin" Report. Prepared for the OBWB, September 2009.

Table A-5 Summary information and recommended approach for developing streamflow datasets for Shorts Creek (from Associated 2017)

Stream:	Shorts Creek	Overall data confidence:	Moderate
Drainage area (km²):	185.6	Latitude, Longitude:	50.13, -119.49
Median elevation (m):	1,350	Provincial hydrologic zone:	15
Minimum elevation (m):	342 +/-		
Maximum elevation (m):	1,903		

Watershed description:

Shorts Creek is located on the west side of Okanagan Lake between Whiteman Creek to the north and Lambly Creek to the south. The Shorts Creek watershed includes Dunwaters Creek and several other tributaries including Stuart, Wilson, McMullen, Attenborough, Hamilton, Emily, Christie, Godwin, Pyke, Tarrant, and Young Creeks (Wildstone Resources Ltd. 1997). The watershed drains gently sloping plateau at elevations above about 1,400 m. Below this, the creek flows over a series of waterfalls through a relatively steep-sided canyon, which makes a relatively abrupt s-shaped bend as it approaches Okanagan Lake. The mouth of Shorts Creek flows across a large alluvial fan and into Okanagan Lake. The alluvial fan is the site of some residences and Fintry Provincial Park. Forest harvesting occurs in the uplands with residential and Fintry Provincial Park located on the lower slopes and alluvial fan near the mouth.

Hydrometric data:

Station	Nat / Reg	Period of record	Drainage area (km^2)	Median elev. (m)	Notes
Water Survey of Canada:					
Shorts Creek at the Mouth (08NM151)	Reg.[5]	1969-1982	185	-	Continuous record
Others:					
Shorts Creek upstream of Westside Road	Reg.	2014-present	-	-	Continuous Record. Operated by ONA.

Water suppliers / users:

Several private water licences are held within the Shorts Creek watershed for domestic, irrigation or stockwatering purposes. As of 2009, the City of West Kelowna diverted water from Dunwaters Creek (a tributary to Shorts Creek) to Lambly Creek. Fintry Provincial Park is located near the mouth of the Shorts Creek and is supplied by groundwater.

Storage licences / reservoirs:

Reservoir / Stream	Water Supplier	Licensed Storage (ML/year)
Dunwaters Creek*	City of West Kelowna (Lakeview System)	1480.2

Notes: *This storage licence is associated with a diversion to Lambly Creek.

Inter-basin transfers:

Since 2009 the City of West Kelowna has operated a diversion from Dunwaters Creek (a tributary to Shorts Creek) to Lambly Creek. The volume and timing of this inter-basin transfer is unknown. It is recommended that the City of West Kelowna be contacted to determine this information.

Water use areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
98	OTHER_Node 16_Shorts Creek (mouth)	16	95.1

Groundwater – surface water interaction:

Summit (2009a) identified that Shorts Creek likely loses water to groundwater and estimated that streamflow is lost to groundwater at a rate of 0.014 m^3/s per km of channel on the alluvial fan.

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Weekly streamflows for Shorts Creek at the apex of the alluvial fan should be based on the records from: Whiteman Creek above Bouleau Creek (08NM174) and Shorts Creek at the mouth (08NM151). This former record represents natural streamflow from a slightly higher location within the adjacent Whiteman Creek watershed. It also is one of the most complete long-term natural streamflow records on the west side of the Okanagan Basin. The Shorts Creek record is regulated and ends prior to the period of interest. Nevertheless, it provides useful information to understand local streamflow patterns. The following steps are required to develop naturalized streamflows:

1) Based on comparison of Shorts Creek at mouth (08NM151) with Whiteman Creek above Bouleau Creek (08NM174), it can be assumed that Shorts Creek at the fan apex is well represented by Whiteman Creek above Bouleau Creek (08NM174). It is recommended that the weekly unit discharges be scaled slightly down according to the normal annual runoff relations between the two locations. This should be followed by reconciling the normal annual runoff based on the weekly time series with that based on the regional relations (i.e., updated Figure 3-3).

2) Summit (2009a) identified a potential discrepancy between Whiteman Creek and Shorts Creek during the fall and winter baseflow period, when streamflows in Whiteman Creek were consistently above those in Shorts Creek. While the extraction of water from Shorts Creek may explain some of the discrepancy, it is more likely that relative groundwater contributions to Whiteman Creek are greater. This is consistent with NHC (2001), and suggests that Whiteman Creek is likely an influent stream, while Shorts Creek may or may not be effluent. To address any discrepancy, it is recommended that the ONA hydrometric record since 2014 be reviewed against the Whiteman Creek records of the same period. The results of this comparison may be used to refine the final weekly time-series, specifically during low and moderate flows[6].

3) As indicated above, Shorts Creek likely losses water along the lowermost portion of the creek as it flows across an alluvial fan and aquifer. Streamflow losses (noted above) should therefore applied to the gross streamflow estimates at the fan apex.

4) As a check, the final time series should be reviewed against previous estimates (e.g., Letvak, 1980, NHC, 2001), recognizing that different periods of interest can influence results.

Residual Streamflows Under Current Water Use and Management

Weekly residual streamflows for Shorts Creek under current water use and management should be estimated by summing the naturalized streamflow and the following:

1) Expected weekly water extraction upstream of the streamflow and EFN points-of-interest. This information should be based on the OWDM and the estimated demands associated with the water use areas identified above.

Residual Streamflows Assuming Maximum Licence Use

Weekly residual streamflows for Shorts Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary difference is that estimated demands from the OWDM would be replaced by the estimated total licensed extraction upstream of the EFN point-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.

References:

Useful References to support the Development of Streamflow Datasets

Dobson Engineering Ltd. (Dobson). 2008. Water Management and Use Study. Prepared for Okanagan Basin Water Board, December 2008.

Dobson Engineering Ltd. 1990. Shorts Creek – Assessment of Alternatives to Enhance Okanagan Lake Fishery. September, 1990.

Letvak, D. B. 1980. Annual Runoff Estimates for West Side of Okanagan Valley. BC Ministry of Environment. January, 1980.

Northwest Hydraulic Consultants Ltd. (NHC). 2001. Hydrology, Water Use, and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, BC. Prepared for BC Fisheries, Fisheries Management Branch, August 2001.

Summit Environmental Consultants Inc. (Summit). 2009a. Surface Water Hydrology and Hydrologic Modelling Study – "State of the Basin" Report. Prepared for the OBWB, September 2009.

Wildstone Resources Ltd. 1997. Overview Fish Habitat Assessment Procedure – Equesis, Naswhito, Whiteman and Shorts Creek Watershed. Prepared for Okanagan Indian Band. April, 1997.

[5] Although this station is considered regulated by the WSC, the degree of regulation is likely modest. According to Dobson (2008), annual water use from Shorts Creek is 38 ML, which is estimated to be about 0.09% of the annual runoff of Shorts Creek. As a result, the hydrometric record on Shorts Creek is close to natural (Summit 2009a).

[6] We understand that the high streamflows are likely less reliable in the ONA record of Shorts Creek upstream of Westside Road.

Table A-6 Summary information and recommended approach for developing streamflow datasets for Inkaneep Creek (from Associated 2017)

Stream:	**Inkaneep Creek**	**Overall data confidence:**	High
Drainage area (km²):	227 est.	**Latitude, Longitude:**	49.07 E, -119.51 N
Median elevation (m):	1,227	**Provincial hydrologic zone:**	24
Minimum elevation (m):	276		
Maximum elevation (m):	2,312		

Watershed description: Inkaneep Creek is located on the east side of the Okanagan valley and flows into Osoyoos Lake less than 10 km north of the US border. The main tributaries of Inkaneep Creek include McCuddy, Baldy, Gregoire, and Coteay Creeks. Inkaneep Creek and its tributaries drain a gently sloping plateau above 1,000 m elevation. Below that elevation, the creek has eroded a steep canyon into bedrock-dominated slopes. At about 460 m elevation, Inkaneep Creek flows onto a large relict fan, then cuts through glaciofluvial terraces before draining onto the modern alluvial fan at Osoyoos Lake. Land use in the watershed includes logging in the uplands and agriculture (e.g., vinyards) along the lower 6 km of Inkaneep Creek, as well as further upstream on McCuddy Creek. The lower portion of the watershed lies within Osoyoos Indian Band I.R. No. 1.

Hydrometric data:

Station	Nat / Reg	Period of record	Drainage area (km²)	Median elev. (m)	Notes
Water Survey of Canada:					
Inkaneep Creek near the mouth (08NM200)	Reg.	1973; 2006-present	227	1,227	Continuous record. Some rating curve issues. Relatively little water use upstream of gauge.
Inkaneep Creek near Oliver, Lower Station (08NM012)	Nat.	1911-1950	164	-	Seasonal record 1920-29 and 1941-50
Inkaneep Creek near Oliver, Upper Station (08NM082)	Nat.	1941-1977	70.4	-	Seasonal record 1941-1950

Water suppliers / users: The Osoyoos Indian Band (OIB) is the major water user within the Inkaneep Creek watershed. The OIB uses water predominantly for irrigation purposes within the watershed (Dobson 2008). The OIB hold licences on Inkaneep Creek totalling 2,733 ML/year, which equates to roughly an average of 0.2 m³/s between May to September – a value which is considerably more than what is currently estimated as demand (see below – Associated [2016]).

Storage licences / reservoirs:

Reservoirs/Stream	Water Supplier	Licensed Storage (ML/year)
Arminius Springs	Ross (Private)	18.5
	Tulak (Private)	*
Baldy Creek	Lual Orchards Ltd.	13.0[7]
	McGibbon (Private)	11.1
	Weins (Private)	1.9
Baldy Creek (West Fork)	Hayes (Private)	18.5
	Lual Orchards Ltd.	*
	Mann (Private)	*
	Tulak (Private)	*
	Wiens (Private)	*
Baldy Reservoir No. 1	Lual Orchards Ltd.	255.1[8]
	Schroeder (Private)	37.0
Inkaneep Creek (Waterdog Lake)	Osoyoos Indian Band	246.7
McCuddy Creek	Lual Orchards Ltd.	206.0[9]
	Mann (Private)	24.7[10]
	Tulak (Private)	12.3
	Wiens (Private)	12.3
	Total:	**857.1**

Notes: *Alternate water source under licence. Quantity is accounted for under another stream. Cassidy (Waterdog) Lake is filled by a diversion from Inkaneep Creek. There is no outlet to this lake (i.e., flows do not return to Inkaneep Creek) and the OIB use the lake water to irrigate surrounding agricultural land. Most of the other agricultural irrigation requirements are met by using water from Osoyoos Lake.

Inter-basin transfers: None

Water use areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
199	Osoyoos Indian Band	23	100
159	OTHER_Node 78_Inkaneep Creek (mouth)	78	86.4

Notes: Associated (2016) reports typical monthly demand from Inkaneep Creek based on the OWDM as follows: April <0.001 m³/s, May = 0.004 m³/s, June 0.006 m³/s, July = 0.008 m³/s, Aug = 0.008 m³/s, Sep = 0.004 m³/s.

Groundwater – surface water interaction: Inkaneep Creek likely loses water to groundwater along its alluvial fan. The estimated loss to groundwater is 0.014 m³/s per km of channel on the alluvial fan (Summit 2009a).

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Weekly streamflows for Inkaneep Creek at the apex of the alluvial fan should be based on the following hydrometric stations: Inkaneep Creek near the mouth (08NM200) and Vaseux Creek above Solco Creek (08NM171). The former station represents regulated streamflows at the apex of the fan; however, the degree of regulation is modest. The latter record has one of the most complete long-term natural streamflow records in the south Okanagan. The following steps are required to develop naturalized streamflow estimates:

1) The record at Inkaneep Creek near the mouth (08NM200) is located at the apex of the fan; however, the record is influenced by regulation. To naturalize the available record (2006 to present), the OWDM should be used to determine the pattern of extractions upstream of the hydrometric station. These extractions should be added to the record to estimate the naturalized streamflow. (Since no reservoir storage or inter-basin transfer occurs in the watershed, these can be ignored).

2) A weekly relation between the naturalized record for Inkaneep Creek at the mouth (08NM200) and the long-term record of Vaseux Creek above Solco Creek (08NM171) should be identified based on the overlapping period of record. This relation can then be used to estimate the naturalized streamflows for Inkaneep Creek at the mouth (08NM200) prior to 2006 (i.e., between 1996-2006).

3) The estimated weekly time series for Inkaneep Creek would then be reconciled with the LT mad (for 1996-2010) identified by the updated regional runoff relations (i.e., updated version of Figure 3-3).

4) Streamflows at the streamflow point-of-interest (i.e., on the alluvial fan) should then be adjusted according to the expected gain/loss between the fan apex and the EFN point-of-interest. Summit (2009a) identified a likely loss (noted above). Such losses can be assumed uniform throughout the year (unless there is data to the contrary), even though it is likely to vary seasonally with the elevation of groundwater table. Following this, weekly naturalized streamflows LT mad can then be calculated at the EFN point-of-interest.

Residual Streamflows Under Current Water Use and Management

Since the hydrometric station Inkaneep Creek near the mouth (08NM200) is located at the apex of the alluvial fan, weekly residual streamflows for Inkaneep Creek under current water use and management is directly provided by the hydrometric record. Unfortunately, this record will provide only the data for 2006-2010. To estimate the residual streamflows between 1996 and 2006, the following needs to be removed from the naturalized streamflow:

1) Expected weekly water withdrawals upstream of the streamflow and EFN points-of-interest. This information will be based on the OWDM and the estimated demands associated with the water use areas identified above (i.e., Osoyoos Indian Band and "Other").

Residual Streamflows Assuming Maximum Licence Use

Weekly residual streamflows for Inkaneep Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary differences are that all estimates (1996-2010) will be based on subtracting the estimated total licensed extraction upstream of the EFN point-of-interest from the naturalized streamflow. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.

[7] Includes three water licences.

[8] Includes three water licences.

[9] Includes multiple water licences and points of diversion.

[10] Includes two points of diversion.

References:	Useful References to Support the Development of Streamflow Datasets Associated Environmental Consultants Inc. 2016. Irrigation Water Demand – Inkaneep Creek Watershed. Prepared for the Ministry of Forests, Lands, and Natural Resource Operations. Dobson Engineering Ltd. (Dobson). 2008. Water Management and Use Study: Phase 2 Okanagan Water Supply and Demand Project. Prepared for Okanagan Basin Water Board. March 2008. Eby, J.R. 1985. Inkaneep Creek Irrigation Study – Osoyoos Indian Reserve No. 1. BC Ministry of Environment. Obedkoff, W. 1986. Inkaneep Creek Irrigation Study. Northwest Hydraulic Consultants Ltd. (NHC). 2001. Hydrology, Water Use, and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, BC. Prepared for BC Fisheries, Fisheries Management Branch, August 2001. Summit Environmental Consultants Ltd. (Summit). 2009a. Surface Water Hydrology and Hydrologic Modelling Study – “State of the Basin” Report. Prepared for the OBWB, September 2009.

Table A-7 Summary information and recommended approach for developing streamflow datasets for Shuttleworth Creek (from Associated 2017)

Stream:	Shuttleworth Creek	Overall Data Confidence:	Moderate
Drainage area (km²):	90.0	Latitude, Longitude:	49.34
Median elevation (m):	1,379	Provincial hydrologic zone:	24
Minimum elevation (m):	334		
Maximum elevation (m):	1,885		

Watershed description:

Shuttleworth Creek is located on the east side of the Okanagan valley south of Ellis Creek and north of Vaseux Creek. Shuttleworth Creek drains into the Okanagan River at Okanagan Falls. Above an elevation of 1,200 m, the creek drains gently sloping plateau. Downslope, the creek flows through a steep canyon. On the valley bottom near Okanagan Falls, Shuttleworth Creek flows through remnants of glaciofluvial terraces then over a short length of modern floodplain and alluvial fan. The mid and upper slopes of the sub-basin support timber harvesting. Land-use on the lower slopes and valley bottom consists of residential development and agriculture.

Hydrometric data:

Station	Nat / Reg	Period of record	Drainage area (km²)	Median elev. (m)	Notes
Water Survey of Canada:					
Shuttleworth Creek at the Mouth (08NM149)	Reg.	1969-1971; 2006-2010	89.9	1379	Continuous record; drainage area determined by GIS; Lots of missing data
Shuttleworth Creek near Okanagan Falls (08NM006)	Reg.	1921-1964	85.2	-	Seasonal record
Others:					
Shuttleworth Creek downstream Maple Street	Reg.	2016-present	-	-	EFN Station operated by ONA. Installed in August 2016.

Water suppliers / users:

Okanagan Falls Irrigation District is the main water purveyor operating near Shuttleworth Creek watershed. However, due to the lack of storage within the watershed, most water is sourced from surrounding areas (i.e. groundwater), outside of the watershed. Several water licences (from three points of diversion) on Shuttleworth Creek are privately held for irrigation and domestic purposes.

Storage licences / reservoirs:

Reservoir	Water Supplier	Licensed Storage (ML/year)
Clark Creek (Little Clarke Lake, non-regulated)	Allendale WUC	774.6
Clark Creek (Big Clake Lake, non-regulated)	Allendale WUC	*
Clark Meadows Reservoir	Allendale WUC	*
Kilmer Creek (Allandale Lake, regulated)	Allendale WUC	*
	Total:	**774.6**

Note that water allocated to Allendale WUC is associated with multiple points of diversion. The dams on Clarke Meadows Reservoir and Allandale Lake are currently being considered for decommission by ONA.

Inter-basin transfers: None

Water use areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
142	OTHER_Node 60_Shuttleworth Creek (mouth)	60	29.7

Groundwater – surface water interaction:

Summit (2009a) identified that Shuttleworth Creek likely loses water to groundwater and estimated that streamflow is lost to groundwater at a rate of 0.014 m^3/s per km of channel on the alluvial fan.

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Weekly streamflows for Shuttleworth Creek at the apex of the alluvial fan should be based on the record from: Vaseux Creek above Solco Creek (08NM171). This record represents natural streamflow from a slightly higher location within an adjacent watershed to the south. It also is one of the most complete long-term natural streamflow records in the southeast portion of the Okanagan Basin. The following steps are required to develop naturalized streamflows:

1) Use Vaseux Creek above Solco Creek (08NNM171) as a surrogate for Shuttleworth Creek at the fan apex, given its close proximity and watershed characteristics. Recorded streamflows in Vaseux Creek (08NM171) should be scaled down to account for the difference in median catchment elevation and thus normal annual runoff. This scaling factor was identified by Summit (2009a) as 0.836; however, it should be re-assessed once updated regional runoff relations (Figure 3-3) are identified.

2) Weekly time series should then be reconciled with the regionally based normal annual runoff, and if necessary a small additional scaling may be required.

3) There is potential that Shuttleworth Creek loses surface flow to groundwater across its alluvial fan. The rate of loss noted above can be applied assuming constant loss throughout the year.

4) The relatively short regulated record (2006-2010) at the mouth of Shuttleworth Creek should be naturalized by accounting for the relatively small volume of water used for storage upstream, and the volumes extracted from the creek to support the water use area identified above. This information is available from the OWDM. Once the naturalized four-year record is identified, it should be compared with the estimated time-series based on Vaseux Creek. If justified, some adjustments may be made to the time-series to reconcile with the naturalized Shuttleworth Creek record at the mouth.

4) As a check, the final time series should be reviewed against previous estimates (e.g., NHC 2001), recognizing that different periods of interest can influence results.

Residual Streamflows Under Current Water Use and Management

Weekly residual streamflows for Shuttleworth Creek under current water use and management should be estimated by summing the naturalized streamflow and the following:

1) Expected weekly net flow (+ or -) associated with the relatively minor upland storage. An assumed fill and release schedule along with the total licensed storage should be used.

2) Expected weekly water extraction upstream of the stream and EFN points-of-interest. This information will be based on the OWDM and the estimated demands associated with the water use areas identified above, as well as through discussions with the ONA who have detailed knowledge of this watershed.

Residual Streamflows Assuming Maximum Licence Use

Weekly residual streamflows for Shuttleworth Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary difference is that estimated demands from the OWDM would be replaced by the estimated total licensed extraction upstream of the EFN point-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.

References:

Useful References to support the Development of Streamflow Datasets

Dobson Engineering Ltd. (Dobson). 2008. Water Management and Use Study. Prepared for Okanagan Basin Water Board, December 2008.

Northwest Hydraulic Consultants Ltd. (NHC). 2001. Hydrology, Water Use, and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, BC. Prepared for BC Fisheries, Fisheries Management Branch, August 2001.

Summit Environmental Consultants Inc. (Summit). 2009a. Surface Water Hydrology and Hydrologic Modelling Study – "State of the Basin" Report. Prepared for the OBWB, September 2009.

Table A-8 Summary information and recommended approach for developing streamflow datasets for McDougall Creek (from Associated 2017)

Stream:	**McDougall Creek**	**Overall data confidence:**	Moderate
Drainage area (km^2):	53.5	**Latitude, Longitude:**	49.82 E, -119.60 N
Median elevation (m):	1,071	**Provincial hydrologic zone:**	15 (11%), 24 (89%)
Minimum elevation (m):	342 +/-		
Maximum elevation (m):	1,456		
Watershed description:	McDougall Creek is a small, south-flowing stream on the west side of Okanagan Lake within the City of West Kelowna and Westbank First Nation Tsinstikeptum I.R. No. 9. The watershed drains a small area of plateau above 1,200 m. Below this elevation, the creek is incised. The lower portion of the creek crosses a gently sloped terrace before flowing into Okanagan Lake. Land-use in the watershed includes forest harvesting in the uplands and a mix of urban development (i.e., residential and commercial land use) and agriculture in the lower reaches.		

Hydrometric data:

Station	Nat / Reg	Period of record	Drainage area (km^2)	Median elev. (m)	Notes
Water Survey of Canada:					
McDougall Creek near Westbank (08NM014)	Reg.	1920-1929	48.9	-	Incomplete record.
Others:					
McDougall Creek at Bartley Rd.	Reg.	2016-present	-	-	EFN Station operated by ONA. Installed in August 2016
McDougall Creek near the Mouth	Reg.	2016-present	-	-	EFN Station operated by ONA. Installed in August 2016

Water suppliers / users: City of West Kelowna and private water licensees.

Storage licences / reservoirs:

Reservoir / Stream	Water Supplier	Licensed Storage (ML/year)	Developed Storage
23 Acre Marsh	Russell & Doreen Ensign (Private)	160.4	
Allan Creek (Lake)	Ruth Yeulett (Private)	18.5	
	Westside Country Estates Ltd. (Private)	11.8	
Hayman Creek (Lake)	City of West Kelowna	13.8	
	Paynters Orchard Meadows Ltd. (Private)	7.3	
	Westside Country Estates Ltd. (Private)[11]	45.4	
	Ruth Yeulett (Private)	40.1	
Hidden Creek (Lake)	Russell & Doreen Ensign (Private)	41.9	
McDougall Creek[12]	Westside Country Estates Ltd. (Private)	123.3	
	Raphael & Denise Kathleen Cross Thomas (Private)	24.7	
	Total:	**487.2**	

Most licences for storage are to support irrigation on private land.

Inter-basin transfers: Stored water in the McDougall Creek watershed is used to irrigate private lands in the watershed and supplies water to Shannon Lake (Dobson 2008). Shannon Lake is the source of water for Shannon Lake Golf Course (Dobson 2008).

Water use areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
221	Shannon Lake Golf Course	1	50
109	OTHER_Node 26_McDougall Creek (mouth)	26	81.1

Groundwater – surface water interaction: McDougall Creek likely loses water to groundwater and estimated that streamflow is lost to groundwater at a rate of 0.014 m^3/s per km of channel on the alluvial fan (Summit 2009a).

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Weekly streamflows for McDougall Creek at the apex of the alluvial fan should be based on the following WSC hydrometric stations: Greata Creek near the mouth (08NM173) (within the Peachland Creek watershed), and Daves Creek near Rutland (08NM137) (within the Mission Creek watershed). The former station has an excellent long-term natural streamflow record (1971-present) that is representative of west-central Okanagan, including McDougall Creek. The latter record on Daves Creek, which only covers 1965-1986, is however an even more accurate indicator of streamflow patterns in McDougall Creek, since it is at the same latitude and has a similar physiography and aspect. The following steps are required to develop naturalized streamflow estimates:

1) Scale the weekly (natural) streamflows of Greata Creek near the mouth (08NM173) according to the ratio of expected normal annual runoff between McDougall and Greata Creeks (i.e., using a revised Figure 3-3). Due to elevational differences, the normal annual runoff in Greata Creek is expected to be slightly lower than McDougall Creek. To accurately represent McDougall Creek, Summit (2009a) indicated that Greata Creek streamflows should be increased by a factor of 1.169; this value would require revision based on new relations (e.g., Figure 3-3).

2) Since Daves Creek is a good surrogate of McDougall Creek it is desirable to identify the general hydrologic patterns from that record, even though the period of record is prior to 1996-2010. To do so, weekly-based relations between the scaled Greata Creek streamflows (i.e., first approximation of McDougall Creek streamflows) and the natural record for Daves Creek near Rutland (08NM137) should be identified using the overlapping period of record (1971-1986). These relations can then be used to estimate a revised (second) approximation of the streamflows for McDougall Creek at the apex for 1996-2010. As an additional check, the natural streamflow record at Testalinden Creek in the Canyon (08NM164) may also be reviewed. However, it has a mixed record with continuous records between 1969 and 1979 and seasonal records from 1980 to 1986.

3) The estimated weekly time series for McDougall Creek would then be reconciled with the normal annual runoff (for 1996-2010) identified by the updated regional runoff relations (i.e., updated version of Figure 3-3).

4) Streamflows at the streamflow point-of-interest (i.e., on the alluvial fan) should then be adjusted according to the expected gain/loss between the fan apex and the EFN point-of-interest. Summit (2009a) has identified a likely loss (noted above). Such losses can be assumed uniform throughout the year (unless there is data to the contrary), even though it is likely to vary seasonally with the elevation of groundwater table. This can be confirmed or updated based on field information collected by the ONA.

5) As a check, the weekly streamflow and LT mad estimates should be compared with other investigations (e.g., Summit 2004, NHC 2001, Ptolemy 2016) and available ONA hydrometric station records.

Residual Streamflows Under Current Water Use and Management

Weekly residual streamflows for McDougall Creek under current water use and management should be estimated by summing the naturalized streamflow and the following:

1) Expected weekly net flow (+ or -) associated with upland storage reservoir operation. Since there are several storage licences held in the watershed, it is important to distinguish those reservoirs with control structures that can influence downstream streamflows from those that are simply off-stream storage structure (i.e., no streamflow is returned to stream). To identify patterns of reservoir operation and obtain reservoir/water use information (if available) it would be desirable to contact the City of West Kelowna and a selection of the larger water licensees. If this information proves difficult to obtain, an assumed fill and release schedule along with the total licensed storage will be used; and

2) Expected weekly water extraction upstream of the EFN point-of-interest. This information will be based on the OWDM and the estimated demands associated with the water use areas identified above (i.e., Shannon Lake Golf Course and "Other").

Residual Streamflows Assuming Maximum Licence Use

Weekly residual streamflows for McDougall Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary differences are that all weekly estimates (1996-2010) will be based on subtracting the estimated total licensed extraction upstream of the EFN point-of-interest from the naturalized streamflow. The assumed weekly distribution of water licences would be identified, by purpose, using the estimated demand patterns from the OWDM.

[11] Includes two licences.

[12] Streamflows from McDougall Creek are routed to Shannon Lake.

References:	Useful References to support the Development of Streamflow Datasets Barr, L.J. 1988. Okanagan Region Low Flow Estimates. Memorandum dated May 20, 1988. Ministry of Environment and Parks, Water Management Branch. Dobson Engineering Ltd. (Dobson). 2008. Water Management and Use Study: Phase 2 Okanagan Water Supply and Demand Project. Prepared for Okanagan Basin Water Board. March 2008. Letvak, D.B. 1980. Annual Runoff Estimates for West Side of Okanagan Valley, B.C. Ministry of Environment. January 1980. Northwest Hydraulic Consultants Ltd. (NHC). 2001. Hydrology, Water Use, and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, BC. Prepared for BC Fisheries, Fisheries Management Branch, August 2001. Summit Environmental Consultants Ltd. (Summit). 2009a. Surface Water Hydrology and Hydrologic Modelling Study – "State of the Basin" Report. Prepared for the OBWB, September 2009. Summit Environmental Consultants Ltd. 2004. Trepanier Landscape Unit Water Management Plan. Prepared for Regional District of Central Okanagan and BC Ministry of Sustainable Resource Management, June 2004. Summit Environmental Consultants Ltd. 1996. McDougall Creek Watershed Assessment. Prepared for Heartland Economics Ltd. and Westbank First Nation. Project 536. March 1996.

Table A-9 Summary information and recommended approach for developing streamflow datasets for Naramata Creek (from Associated 2017)

<table>
<tr><td>Stream:</td><td>Naramata Creek</td><td>Overall data confidence:</td><td>Low</td></tr>
<tr><td>Drainage area (km²):</td><td>41.8</td><td>Latitude, Longitude:</td><td>49.60, -119.60</td></tr>
<tr><td>Median elevation (m):</td><td>1,330</td><td>Provincial hydrologic zone:</td><td>24</td></tr>
<tr><td>Minimum elevation (m):</td><td colspan="3">342 +/-</td></tr>
<tr><td>Maximum elevation (m):</td><td colspan="3">1,906</td></tr>
<tr><td>Watershed description:</td><td colspan="3">Naramata Creek is a southwest flowing stream on the east side of Okanagan Lake 11 km north of the City of Penticton near the community of Naramata. The creek is approximately 12.7 km long and drains a gently sloping plateau above 1,200 m elevation. Below this elevation, the creek has carved a steep canyon into the hillside. Between the 500 m elevation and Okanagan Lake, Naramata Creek has incised through two terraces, one comprising glaciofluvial sediments and the other glaciolacustrine sediments. Logging occurs on the plateau and the terraces near the lake support agriculture and residential land uses.</td></tr>
<tr><td>Hydrometric data:</td><td colspan="3">
<table>
<tr><th>Station</th><th>Nat / Reg</th><th>Period of record</th><th>Drainage area (km²)</th><th>Median elev. (m)</th><th>Notes</th></tr>
<tr><td>None</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
</table>
</td></tr>
<tr><td>Water suppliers / users:</td><td colspan="3">The RDOS (operating as the Naramata Water Utility) maintains a water intake (referred to as the North Intake) on Naramata Creek. The North Intake is part of the Chute-Robinson-Naramata Creek diversion system that was historically used to supply water to the community of Naramata. However, the intake has not been used for potable water supply purposes since 2006 due to a switch to an Okanagan Lake system. The North Intake on Naramata Creek is still being maintained by the RDOS and is currently being considered as a potential irrigation water supply source (EBA 2010). Although no longer operational, the South Intake is located on Naramata Creek approximately 3 km upstream from the mouth, as well, the high line diversion adds water to Naramata Creek approximately 100 m upstream of the South Intake. There are 10 current water licences within the Naramata Creek watershed, all but one are held by the RDOS.</td></tr>
<tr><td>Storage licences / reservoirs:</td><td colspan="3">
<table>
<tr><th>Reservoir</th><th>Water Supplier</th><th>Licensed Storage (ML/year)</th></tr>
<tr><td>None</td><td>-</td><td>-</td></tr>
</table>
Note that there are no storage reservoirs within the Naramata Creek watershed; however, as part of the Chute-Robinson-Naramata Creek diversion system, three reservoirs within Chute and Robinson Creek watersheds have historically been used to support water supply requirements for the community of Naramata through a series of diversion ditches. The reservoirs include Big Meadow Reservoir (Chute Creek watershed) and Elinor and Naramata Lakes (Robinson Creek watershed).</td></tr>
<tr><td>Inter-basin transfers:</td><td colspan="3">Water from Chute and Robinson Creeks is transferred into the Naramata Creek watershed by the Chute-Robinson-Naramata Creek diversion system. RDOS (1982) summarizes the diversion system as follows: 1) water is diverted from Chute Creek watershed via a diversion ditch into Elinor Lake (located within the Robinson Creek watershed); 2) water flowing within Robinson Creek is either diverted into the high line diversion (into Naramata Creek watershed) or extracted by the North Intake (located near the mouth of Robinson Creek) by the RDOS; and 3) the high line diversion adds water directly to Naramata Creek upstream of the RDOS's South Intake. The high line diversion is generally operational from July to September.
Summit (2009b) estimated water transfers into Naramata Creek by the Chute-Robinson-Naramata Creek diversion system for 1996-2006.</td></tr>
<tr><td>Water use areas:</td><td colspan="3">
<table>
<tr><th>Water Use Area ID</th><th>Water Supplier</th><th>System ID</th><th>% of total from this source</th></tr>
<tr><td>45</td><td>Former Naramata Irrigation District</td><td>2</td><td>50</td></tr>
<tr><td>124</td><td>OTHER_Node 40_Naramata Creek (mouth)</td><td>40</td><td>50</td></tr>
</table>
</td></tr>
<tr><td>Groundwater – surface water interaction:</td><td colspan="3">Summit (2009a) identified that Naramata Creek likely loses water to groundwater and estimated that streamflow is lost to groundwater at a rate of 0.014 m³/s per km of channel across the alluvial fan.</td></tr>
<tr><td>Suggested methodology for weekly streamflow estimation:</td><td colspan="3">
Naturalized Streamflows and LT mad
Weekly streamflows for Naramata Creek at the apex of the alluvial fan should be based on the records from the following two stations: Vaseux Creek above Solco Creek (08NM171) and Bellevue Creek near Okanagan Mission (08NM035)[13]. The former represents natural streamflow from a higher location within the Vaseux Creek watershed (south of Naramata Creek). It is however one of the most complete long-term natural streamflow records in southeast Okanagan. The second hydrometric station, which is considered representative of streamflow patterns in Naramata Creek (Summit 2009a), is located just north of Naramata Creek; however, its record runs from 1968 to 1985 (i.e., ending prior to the period of interest). The following steps are required to develop naturalized streamflow estimates:
1) To use the record from Bellevue Creek (08NM035):
a) The record for Bellevue Creek needs to be extended to represent 1996-2010. This can be accomplished by identifying long-term weekly relations between Bellevue Creek (08NM035) and Vaseux Creek (08NM171). Summit (2009a) found a high correlation between the unit discharges of these two streams for the overlapping period of 1971-1986. This relation can be used to predict the Bellevue Creek unit discharge for 1996-2010.
b) The predicted unit streamflows for Bellevue Creek (1996-2010) should then be scaled to represent Naramata Creek at the fan apex (i.e., a smaller drainage with a slightly lower median elevation). The adjustment is based on the ratio of predicted normal annual runoffs (from a revised Figure 3-3) between Naramata Creek at the fan apex and Bellevue Creek near Okanagan Mission (08NM035).
2) To use the record from Bellevue Creek (08NM035), the unit weekly discharge should be scaled according to the ratio of predicted normal annual runoffs (from a revised Figure 3-3) between Bellevue Creek at the fan apex and Naramata Creek at the fan apex.
3) The estimated weekly time series for Naramata Creek at the fan apex would then be reconciled with the LT mad (for 1996-2010) identified by the updated regional runoff relations (i.e., updated version of Figure 33-3) and scaled if necessary.
4) Streamflows at the streamflow point-of-interest (i.e., on the alluvial fan) should then be adjusted according to the expected gain/loss between the fan apex and the EFN point-of-interest. Gains/losses can be assumed uniform throughout the year (unless there are data to the contrary), even though it is likely to vary seasonally with the elevation of groundwater table.
5) As a check, the final time series should be reviewed against the available reports (e.g., NHC 2001; Obedkoff 1982a,b), recognizing that these estimates represent different periods and may be influenced by streamflow regulation.
Residual Streamflows Under Current Water Use and Management
Weekly residual streamflows for Naramata Creek under current water use and management should be estimated by summing the naturalized streamflow and the following:
1) Expected weekly net imports from Chute and Robinson Creeks. The RDOS should be contacted for any records they may have. Otherwise some estimates are available from Summit (2009b).
2) Expected weekly water extraction upstream of streamflow and EFN points-of-interest. This information can be based on estimated demands associated with the water use areas identified above using the OWDM.
Residual Streamflows Assuming Maximum Licence Use
Weekly residual streamflows for Naramata Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary difference is that estimated demands from the OWDM would be replaced by the estimated total licensed extraction upstream of the EFN point-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.
</td></tr>
</table>

[13] Median elevation of Bellevue Creek at the mouth is 1,384 m.

References:	
	References EBA Engineering Consultants Ltd. (EBA). 2010. Dam Safety Review Summary Report – Naramata Dams. Prepared for Regional District of Okanagan-Similkameen. December 21, 2010. Regional District of Okanagan Similkameen (RDOS). 1982. Naramata Irrigation District: Water Supply Study. Summary Draft Report. August 1982. Useful References to support the Development of Streamflow Datasets Barlow, D.P. 1994. Naramata Fan Study (with Robinson and Chute Creeks). BC Ministry of Environment, Lands and Parks, Water Management Division. December 1994. Bomford, T. 1996. A letter concerning the history of Naramata Creek pre-1990 by local Ted Bomford. Ecocat Report ID 38530. Dobson Engineering Ltd. (Dobson). 2008. Water Management and Use Study. Prepared for Okanagan Basin Water Board, December 2008. Matthews, S. 2003. Notes on Fish/Habitat Values and Potential Impacts Associated with Various Water Supply Scenarios in Naramata Creek. Naramata Environmental Roundtable – Sustainable Community Series Water Maters – December 2003. Northwest Hydraulic Consultants Ltd. (NHC). 2001. Hydrology, Water Use, and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, BC. Prepared for BC Fisheries, Fisheries Management Branch, August 2001. Obedkoff, W. 1987. Naramata Creek Peak Flow Estimates. Memorandum dated September 16, 1987. BC Ministry of Environment and Parks, Water Management Branch. File S2106, Study 263. Obedkoff, W. 1982a. Memorandum re. Naramata Irrigation District Study Tributary Annual Runoff Estimates. Obedkoff, W. 1982b. Naramata Irrigation District Study, Tributary Annual Runoff Estimates, BC Ministry of Environment, Lands and Parks, Water Management Branch, Victoria, File 0256957. Summit Environmental Consultants Ltd. (Summit). 2009a. Surface Water Hydrology and Hydrologic Modelling Study – “State of the Basin” Report. Prepared for the OBWB, September 2009. Summit Environmental Consultants Ltd. (Summit). 2009b. Assessment of estimates of Okanagan Basin water diversion and imports and sewage return flows provided by Dobson Engineering Ltd. (2008). Internal document, Reference 7200-004.06. Summit Environmental Consultants Ltd. (Summit). 1995. Naramata and Robinson Creeks Stream Assessment. Prepared for BC Ministry of Environment, Lands and Parks, December 1995.

Table A-10 Summary information and recommended approach for developing streamflow datasets for Mission Creek (from Associated 2017)

Stream:	Mission Creek	**Overall Data Confidence:**	High
Drainage area (km²):	845.1	**Latitude, Longitude:**	49.84, -119.49
Median elevation (m):	1,345	**Provincial hydrologic zone:**	15 (5%), 23 (76%), 24 (19%)
Minimum elevation (m):	342 +/-		
Maximum elevation (m):	2,170		
Watershed description:	Mission Creek is the largest watershed in the Okanagan Basin, and it flows from the eastern side of the Basin through Kelowna and into Okanagan Lake. It includes several large tributaries including Pearson, Joe Rich, Belgo, Hydraulic, and KLO Creeks. These drain gently sloping plateau above elevations of about 1200 m. Mid slopes are moderately steep to steep. Mission Creek flows through a steep canyon in the vicinity of Hydraulic and KLO Creeks, and then flows on to a large alluvial fan in the Kelowna area. This fan coalesces with the fans of Mill (Kelowna) and Bellevue Creeks to form a large area of relatively gentle land. Forest harvesting is common on the mid and upper slopes. Terraces and gently to moderately sloping land along mid elevations support agriculture and rural residential land use. The lower elevations of the watershed are a mix of urban and rural residential, agriculture, recreational (parks and golf course), and commercial uses.		

Hydrometric Data:

Station	Nat / Reg	Period of record	Drainage area (km²)	Median elev. (m)	Notes
Water Survey of Canada:					
Belgo Creek below Hilda Creek (08NM232)	Reg.	1976-present	70.7	1430	Continuous record 1978-present.
Belgo Creek near Rutland (08NM017)	Reg.	1920-1921	-	-	-
Belgo Creek near the Mouth (08NM225)	Reg.	1976-1982	190	-	Continuous record.
BMID diversion near Kelowna (08NM019)	Reg.	1920-1930	-	-	-
Browne Lake Reservoir above the Dam (08NM216)	Reg.	1973-1977	-	-	-
Daves Creek near Rutland (08NM137)	Nat.	1965-1986	31.1	1290	Continuous record 1967-1986.
Fish Lake at the Outlet (08NM215)	Reg.	1973-1977	-	-	-
Graystoke Lake at the Outlet (08NM230)	Reg.	1977-1998	-	-	Seasonal record.
Hilda Creek near Rutland (08NM018)	Nat.	1920	-	-	Record limited to a single year.
Joe Rich Creek near Rutland (08NM129)	Reg.	1964-1987	44.8	-	Continuous record.
Hydraulic Creek at Outlet of McCulloch Reservoir (08NM011)	Reg.	1919-1986	-	-	Continuous record 1976-80 and 1984-86.
Hydraulic Creek Diversion near Kelowna (08NM039)	Reg.	1919-1968	-	-	-
Hydraulic Creek diversion to SEKID (08NM205)	Reg.	1976-1980	-	-	-
Hydraulic Creek near the Mouth (08NM010)	Reg.	1919-1982	89.6	-	Continuous record 1976-1982.
Hydraulic Creek Southeast Kelowna Diversion (08NM040)	Reg.	1920-1930	-	-	-
Ideal Lake near the Outlet (08NM231)	Reg.	1963-1980	-	-	-
KLO Creek at McCulloch Road (08NM226)	Reg.	1976-1982		-	Continuous record.
KLO Creek near Kelowna (08NM004)	Nat.	1919-1922	-	-	Continuous record.
KLO Diversion near Kelowna (08NM060)	Reg.	1922-1968	-	-	-
Loch Katrine Cr. at the Outlet of Graystoke Lake (08NM229)	Reg.	1977-1998	16.1	-	Continuous record.
Long Meadow Lake Reservoir above the Dam (08NM217)	Reg.	1973-1977	-	-	-
McCulloch Reservoir at McCulloch Dam (08NM213)	Reg.	1973-1986	-	-	-
Mission Creek above Pearson Creek (08NM233)	Reg.	1977-1982	233	-	-
Mission Creek below BMID intake (08NM239)	Reg.	1980	-	-	-
Mission Creek near East Kelowna (08NM116)	Reg.	1949-present	811	1340	Seasonal: 1949-66; Continuous: 1967-present. Real-time.
Mission Creek near Rutland (08NM016)	Reg.	1919-1946	622	-	-
Mission Creek Rutland Diversion (08NM057)	Reg.	1922-1930	-	-	-
Myra Ditch Below KLO Creek (08NM207)	Reg.	1973-1985	-	-	-
Pearson Creek near the Mouth (08NM172)	Nat.	1970-1987	73.6	1560	Continuous record.
Pooley Creek Above Pooley Ditch (08NM210)	Nat.	1973-1979	18.1	-	Seasonal record.
Other:					
Belgo (Ideal) Reservoir at Spillway	Reg.	2007-present	-	-	BMID gauge. Seasonal data.
Benvoulin WUC Diversion Channel	Reg.	2016-present	-	-	Installed in August 2016 and operated by Associated.
Canyon Creek Diversion at Pooley Ditch	Reg.	2004-2014	-	-	SEKID gauge. Installed by Dobson Engineering Ltd. Program cancelled end of 2014.
Fishhawk Reservoir at the Outlet (Spillway)	Reg.	2007-present	-	-	BMID gauge. Installed by Dobson Engineering Ltd. Seasonal data.
Graystoke Reservoir at Spillway	Reg.	2007-present	-	-	BMID gauge. Installed by Dobson Engineering Ltd. Seasonal data.
Hydraulic Creek at SEKID Intake	Reg.	1998-present	-	-	SEKID gauge.
Hydraulic Creek above Sterling Ditch	Reg.	2004-2014	-	-	SEKID gauge. Installed by Dobson Engineering Ltd. Program cancelled end of 2014.
Ideal Reservoir at the Outlet	Reg.	2007	-	-	Installed by Dobson Engineering Ltd.
James Reservoir at Spillway	Reg.	2007-present	-	-	Still operational, open water period.
KLO Creek near the Mouth	Reg.	2016-present	-	-	Installed in August 2016 and operated by Associated.
Loch Long Reservoir at Spillway	Reg.	2007-present	-	-	BMID gauge. Installed by Dobson Engineering Ltd. Seasonal data.
McCulloch Reservoir at McCulloch Dam	Reg.	1995-present	-	-	SEKID gauge.
Mission Creek above 12 km Bridge	Reg.	2016-present	-	-	Installed in March 2016 and operated by ONA as part of the Mission Creek GW/SW Interaction Project.
Mission Creek above BMID Intake	Reg.	2016-present	-	-	Installed in March 2016 and operated by ONA as part of the Mission Creek GW/SW Interaction Project.
Mission Creek below BMID Intake	Reg.	2004-present	-	-	BMID gauge. Installed by Dobson Engineering Ltd. Still operational, seasonal data.
Mission Creek at Casorso Road	Reg.	2016-present	-	-	Installed in March 2016 and operated by ONA as part of the Mission Creek GW/SW Interaction Project.
Mission Creek upstream of East Kelowna Road	Reg.	2007-2009	-	-	MOE Station.
Mission Creek at East Kelowna Road Bridge	Reg.	2016-present	-	-	Installed in August 2016 and operated by Associated.
Mission Creek below Gerstmar Road	Reg.	2016-present	-	-	Installed in March 2016 and operated by ONA as part of the Mission Creek GW/SW Interaction Project.

	Mission Creek upstream of Gordon Drive	Reg.	2006-2007	-	-	MOE Station.
	Mission Creek above Gordon Drive	Reg.	2016-present	-	-	Installed in March 2016 and operated by ONA as part of the Mission Creek GW/SW Interaction Project.
	Mission Creek at Hollywood Road	Reg.	2016-present	-	-	Installed in March 2016 and operated by ONA as part of the Mission Creek GW/SW Interaction Project.
	Mission Creek below KLO Creek	Reg.	2016-present	-	-	Installed in March 2016 and operated by ONA as part of the Mission Creek GW/SW Interaction Project.
	Mission Creek upstream of KLO Road	Reg.	2016-present	-	-	Installed in March 2016 and operated by ONA as part of the Mission Creek GW/SW Interaction Project.
	Mission Creek downstream of KLO Road	Reg.	2016-present	-	-	Installed in August 2016 and operated by Associated.
	Mission Creek WUC Intake	Reg.	2016-present	-	-	Staff plate installation with manual measurements in diversion ditch. Measurements began summer/fall of 2016.
	Mission Creek at Ziprick Road	Reg.	2016-present	-	-	Installed in March 2016 and operated by ONA as part of the Mission Creek GW/SW Interaction Project.
	Myra Ditch below KLO Creek (Old WSC Location)	Reg.	unknown	-	-	-
	Pearson Creek near the Mouth	Nat.	2004-2005, 2007-present	-	-	BMID gauge operated by Gary van Emmerik. Seasonal data. Location of MOE station.
	Pooley Creek Above Pooley (Diversion) Ditch (Old WSC Location)	Nat.	2004-2014	-	-	SEKID gauge. Installed by Dobson Engineering Ltd. Program cancelled end of 2014.
	Priest Creek at the Mouth	Reg.	2016-present	-	-	Installed in August 2016 and operated by Associated.
	Stirling Creek Diversion to McCulloch Reservoir (Old WSC Location)	Reg.	2004-2014	-	-	SEKID gauge. Installed by Dobson Engineering Ltd. Program cancelled end of 2014.

Water suppliers / users:

There are two major water suppliers in the Mission Creek watershed: Black Mountain Irrigation District (BMID) and Southeast Kelowna Irrigation District (SEKID). The RDCO (Falconridge Water Utility), Benvoulin Water Users Community, Mission Creek Water Users Community, Rutland Water Works (groundwater use only, 4 wells in Mission Creek watershed), South Kelowna Water Users Community, and several private water licensees also source water from the Mission Creek watershed (Dobson 2008).

BMID obtains water from two watersheds: Mission Creek and Scotty Creek, a tributary to Mill (Kelowna) Creek. Within the Mission Creek watershed, BMID's intake is located on Mission Creek, just upstream of Daves Creek. This is supported by the following storage reservoirs: Belgo (Ideal) Reservoir, Fish Hawk Reservoir, and Graystoke Reservoir. BMID also operates the Loch Long Reservoir on behalf of the Province of BC for instream flow requirements, particularly during fish migration and spawning periods. In the upper Belgo Creek watershed, BMID diverts Hilda, Diamond Dick, and Mugford Creeks into the Belgo (Ideal) Reservoir. The Mugford diversion is a year-round diversion whereas the other two are operated seasonally when the Belgo (Ideal) Reservoir is below full pool. BMID has no groundwater wells in the Mission Creek watershed, but the RDCO supplies groundwater to the Falconridge Utility from a shallow aquifer.

SEKID sources water from several locations including Hydraulic Creek (main intake is upstream of the confluence with Mission Creek), KLO Creek, Stirling Creek[14], and groundwater wells (3). SEKID operates reservoirs at McCulloch Reservoir, Fish Lake, Browne Lake and Long Meadow Lake. Pooley, Canyon, and Eastern Creeks, tributaries of KLO Creek, are diverted into Hydraulic Creek upstream of McCulloch Reservoir. Hardy Creek, also a tributary to KLO Creek, is diverted into Hydraulic Creek below McCulloch Reservoir. Browne and Long Meadow Reservoirs, in the Grouse Creek drainage, are diverted into Hydraulic Creek below McCulloch Reservoir. This diversion is only used in low runoff years. SEKID has developed three groundwater wells. The primary well is the O'Reilly Road well that is operated year-round. The other two wells are only used to supplement the surface water source during periods of peak demand or periods of elevated turbidity in Hydraulic Creek.

Storage licences / reservoirs:

Reservoir	Water Supplier	Licensed Storage (ML/year)	Actual Storage (ML)
Black Mountain Irrigation District			
Belgo (Ideal) Reservoir	Black Mountain Irrigation District	9,741	6,830
Fish Hawk Reservoir	Black Mountain Irrigation District	1,850	2,276
Graystoke Reservoir	Black Mountain Irrigation District	5,103	5,098
	Total:	**16,694**	**14,204**
South East Kelowna Irrigation District			
McCulloch Reservoir (and Turtle Lake)	South East Kelowna Irrigation District	19,106	18,689
Long Meadow, Browne (Burne), Fish Lakes[15]	South East Kelowna Irrigation District	1,713	928
	Total:	**20,819**	**19,617**
Others			
Belgo (Ideal) Reservoir[16]	BC MFLNRO	752.4	6,830
Loch Long[17]	BC MFLNRO, operated by BMID	925.1	625
	Total:	**1,677.5**	**7,455**

Inter-basin transfers:

Within Mission Creek watershed, there are the following major inter and intra-basin water transfers:

South East Kelowna Irrigation District

1) Stirling Creek (and Affleck Creek), tributaries of the West Kettle River basin, are diverted by SEKID into the McCulloch Reservoir in the Mission Creek watershed during normal and dry years. In wet years (i.e., when McCulloch Reservoir is full), it discharges via its spillway into Idabel Creek, a tributary of the West Kettle River. SEKID has some records of this diversion (to 2014).

2) Pooley, Canyon, and Eastern Creeks, tributaries of KLO Creek, are diverted into Hydraulic Creek upstream of McCulloch Reservoir.

3) Hardy Creek, also a tributary to KLO Creek, is diverted into Hydraulic Creek below McCulloch Reservoir (used only during very dry years).

4) Browne and Long Meadow Reservoirs, in the Grouse Creek drainage, are diverted into Hydraulic Creek below McCulloch Reservoir. This diversion is only used in low runoff years.

Black Mountain Irrigation District

1) Hilda Creek and Diamond Dick Creek diversion into Belgo (Ideal) Lake (seasonally when Belgo (Ideal) Lake is below full pool).

2) Mugford Creek diversion into Belgo (Ideal) Lake (year-round).

City of Kelowna

1) The CoK maintains a diversion channel between Mill (Kelowna) Creek and Mission Creek. Under flood conditions in Mill Creek, water is transferred to Mission Creek to reduce flood volumes throughout the CoK. This occurs usually between April 1 and June 15. Dobson (2008) estimates the normal volume of water diverted at 8,200 ML/yr, whereas Summit (2009b) estimated annual diversions from 1996-2006, and the CoK has actual records of diversion from 2013 to present.

[14] Stirling Creek (and Affleck Creek) are tributary to the West Kettle River basin, and SEKID is licensed to divert water into the Mission Creek watershed during normal and dry years. In wet years, i.e., when McCulloch Reservoir is full, it discharges via its spillway into Idabel Creek, a tributary of the West Kettle River.

[15] Fish Lake has recently been decommissioned.

[16] Water licence includes points of diversion on Belgo, Diamond Dick, Hilda, and Mugford Creeks.

[17] Water licence for Stanley Creek.

Water Use Areas:	Water Use Area ID	Water Supplier	System ID	% of total demand from this source
	49	Future City of Kelowna	2	100
	226	South East Kelowna Irrigation District	2	100
	4	Black Mountain Irrigation District	1	90
	47	Future BMID	1	90
	105	OTHER_Node 22_Mission Creek (mouth)	22	52.4

Groundwater – surface water interaction:	There is likely no net loss / gain of streamflow to or from groundwater across the entire Mission Creek alluvial fan because losses at the top of the fan may be offset by gains along the lower reaches (Summit 2009a). A detailed groundwater / surface water interaction assessment was completed by Lowen and Letvak (1981) for the section of channel below the BMID intake to the mouth, which found multiple reaches that either gained or lost streamflow. Currently, the OBWB is updating the Lowen and Letvak (1981) study. Several hydrometric stations have been established along lower Mission Creek in 2016; however, useful data from these stations are not yet available.
Suggested methodology for weekly streamflow estimation:	**Naturalized Streamflows and LT mad**
	Following discussion with FLNRO staff, the point-of-interest to monitor EFNs on Mission Creek was identified as the location of the long-term hydrometric station Mission Creek near East Kelowna (08NM116). This station has a record of regulated flows since 1949 and is a key reference station for Mission Creek. The location of this station is above the contemporary alluvial fan of Mission Creek, but still overlies a major aquifer system. Thus, there is potential for groundwater / surface water interaction both upstream and downstream of the hydrometric station.
	Weekly naturalized streamflows for the hydrometric station Mission Creek near East Kelowna (08NM116) can be estimated by naturalizing the streamflow record (1996-2010). This involves accounting for upland storage and release patterns, water imports (and diversions), and water extractions upstream of the station. Polar (2008) conducted a detailed review of water use and management information within the Mission Creek watershed, focussing on the period 1996-2006. In summary, weekly estimates of the volume of water extracted above and below the hydrometric station Mission Creek near East Kelowna (08NM116) were developed using records obtained from SEKID, BMID, and the provincial water licence information system. In addition, the influence of reservoir operations was determined by reviewing operational data provided by SEKID and BMID. Lastly, water imported to the watershed from outside the natural contributing area was accounted for. Therefore, the information compiled by Polar (2008) should be updated to include an additional 4 years (to 2010). This will require the compilation of water supplier data from sources such as KJWC (2012) as well as through direct communication with the major water suppliers (BMID and SEKID). Where actual records for water extractions are not available (i.e., privately held licences for extraction), these can be estimated based on the OWDM.
	There is potential that lower Mission Creek gains or loses surface flow to groundwater as it crosses major aquifers near Kelowna. This may affect the accuracy of any naturalized streamflow estimates made downstream of the main point-of-interest (station 08NM116). Until further measurements and studies of GW/SW interaction on lower Mission Creek are completed, there is limited ability to confidently estimate the net gains/losses downstream of hydrometric station Mission Creek near East Kelowna (08NM116).
	As a check of the naturalized time-series, the available records for Pearson Creek near the mouth, both collected by the WSC at hydrometric station 08NM172 (1970-1987) and by the BMID (2004-2005, 2007-present), should be reviewed. Pearson Creek represents the largest unregulated Mission Creek tributary with available streamflow record, and is used as an indicator of Mission Creek natural streamflows within the Mission Creek Water Use Plan (WMC 2010)[18].
	As a secondary check, the final time series should also be compared against previous estimates (see references below) recognizing that different periods of interest can influence results.
	Residual Streamflows Under Current Water Use and Management
	Weekly residual streamflows for Mission Creek under current water use and management can be directly obtained from the regulated streamflow record at Mission Creek near East Kelowna (08NM116).
	Residual Streamflows Assuming Maximum Licence Use
	Weekly residual streamflows for Mission Creek under maximum licensed use should be estimated by summing the naturalized streamflow at Mission Creek near East Kelowna (08NM116) to the following:
	1) Expected weekly net flow (+ or -) associated with upland storage operation (by BMID and SEKID). This information is available from the streamflow naturalization procedure.
	2) Assumed weekly licensed water extraction upstream of the EFN point-of-interest (i.e., station 08NM116).

[18] Pearson Creek streamflow (multiplied by a factor of 6) is a surrogate of Mission Creek naturalized streamflow in the Mission Creek Water Use Plan.

Table A-11 Summary information and recommended approach for developing streamflow datasets for Penticton Creek (from Associated 2017)

Stream:	**Penticton Creek**	**Overall Data Confidence:**	Moderate
Drainage area (km^2):	180.0	**Latitude, Longitude:**	49.50, -119.59
Median elevation (m):	1,282	**Provincial hydrologic zone:**	24
Minimum elevation (m):	342 +/-		
Maximum elevation (m):	2,144		

Watershed description:

Penticton Creek is located on the east side of Okanagan Lake and flows into the south end of the lake at the City of Penticton. The headwaters of the watershed border the headwaters of Bellevue, Chute, Naramata, and Turnbull Creeks. The main tributaries of Penticton Creek include James, Reed, Municipal, Harris, and Steward Creeks. Above about 1300 m, the watershed consists of gently sloping terrain and rounded ridge tops. Below this elevation, Penticton Creek flows through a deep canyon into the surrounding bedrock-dominated mid slopes. Below about 800 m elevation, the creek is incised in a thick outwash terrace comprising sands and gravels. The creek makes a sharp bend to the south and then west around Mount Campbell and onto an alluvial fan. This fan coalesces with the fans of Ellis and Shingle Creeks to form the broad valley bottom on which the City of Penticton is located. The upper portion of the watershed has logging activity and the fan and terraces support residential and agricultural land use.

Hydrometric data:

Station	Nat / Reg	Period of record	Drainage area (km^2)	Median elev. (m)	Notes
Water Survey of Canada:					
Dennis Creek near 1780 metre Contour (08NM242)	Nat.	1985-present	3.73	1893	Continuous record, established for the Upper Penticton Experimental Watershed.
Greyback Lake at the Outlet (08NM169)	Reg.	1970-1987	-	-	-
Nickel Plate Reservoir Outflow (08NM068)	Reg.	1975-1976	-	-	-
Penticton Creek above Dennis Creek (08NM168)	Reg.	1970-1999	35.5	-	Continuous record
Penticton Creek above Diversion (08NM076)	Nat.	1910-1941	-	-	Seasonal record 1936-1941
Penticton Creek below Diversion (08NM031)	Reg.	1919-1921	-	-	-
Penticton Creek below Harris Creek (08NM170)	Reg.	1970-1981	153	-	Continuous record
Penticton Creek Lot 19 Diversion (08NM063)	Reg.	1926-1954	-	-	Seasonal record
Penticton Creek Main Diversion (08NM032)	Reg.	1919-1966	-	-	Seasonal record
Penticton Creek at the Mouth (08NM118)	Reg.	1950-1972	177	-	Seasonal and continuous records
Read Creek near Penticton (08NM069)	Reg.	1911-1930	-	-	-
Two-Forty Creek near Penticton (08NM240)	Nat.	1984-present	4.94	1769	Continuous record, established for the Upper Penticton Experimental Watershed.
Two-Forty-One Creek near Penticton (08NM241)	Nat.	1984-present	4.50	1768	Continuous record, established for the Upper Penticton Experimental Watershed.
Others:					
Penticton Creek at Nanaimo Avenue	Reg.	2004-present	-	-	Owned by City of Penticton, data collected by ONA. Continuous record.
Randolph Creek at Naramata Road (Penticton Creek Diversion)	Reg.	2004-present	-	-	Seasonal record; operated by the City of Penticton.

Water suppliers / users:

The City of Penticton (CoP) is the main water supplier extracting water from the Penticton Creek watershed (Dobson 2008). The CoP has an intake on Penticton Creek approximately 3 km upstream from the mouth (Dobson 2008), which is supported by storage primarily from Greyback Lake (reservoir). The CoP also diverts water from Okanagan Lake, which is treated in a new advanced water treatment plant and from Ellis Creek. The lake intake is a relocated point of diversion for its Penticton Creek water licences. There is one CoP groundwater well located near Warren Avenue, but this well has not been in use since 1996, and is only maintained as an emergency water supply source (Dobson 2008). In addition to the CoP, there are several privately held water licences within the watershed for domestic, irrigation, and livestock watering.

Storage licences / reservoirs:

Reservoir	Water Supplier	Licensed Storage
Howard Lake	City of Penticton	86.0
Penticton Creek (Penticton Cr Lower Diversion Dam)	City of Penticton	61.7
Penticton Creek (Greyback Lake)	City of Penticton	12,581.5[19]
Reed Creek (Reed Lake Dam, non-regulated)	City of Penticton	308.4
	Total:	**13,037.6**

Inter-basin transfers: None

Water Use Areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
30	City of Penticton	4	100
29	City of Penticton	3	8
130	OTHER_Node 46_Penticton Creek (mouth)	46	52.6

Groundwater – surface water interaction:

Summit (2009a) identified that Penticton Creek likely loses water to groundwater and estimated that streamflow is lost to groundwater at a rate of 0.014 m^3/s per km of channel on the alluvial fan.

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Weekly streamflows for Penticton Creek at the apex of the alluvial fan should be based on the records from the following two stations: Vaseux Creek above Solco Creek (08NM171) and Bellevue Creek near Okanagan Mission (08NM035)[20]. The former represents natural streamflow from a higher location within the Vaseux Creek watershed (south of Penticton Creek) and is one of the most complete long-term natural streamflow records in southeast Okanagan. The second hydrometric station, which is considered most representative of streamflow patterns in Penticton Creek, is located just north of Penticton Creek; however, its record runs from 1968 to 1985 (i.e., ending prior to the period of interest). The following steps are required to develop naturalized streamflow estimates:

1) To use the record from Bellevue Creek (08NM035):

a) The record for Bellevue Creek (08NM035) needs to be extended to represent 1996-2010. This can be accomplished by identifying long-term weekly relations between Bellevue Creek (08NM035) and Vaseux Creek (08NM171). Summit (2009a) found a high correlation between the unit discharges of these two streams for the overlapping period of 1971 to 1986. This relation can be used to predict the Bellevue Creek unit discharge for 1996-2010.

b) The predicted unit streamflows for Bellevue Creek (1996-2010) needs to be scaled to represent Penticton Creek at the fan apex (i.e., a larger drainage with a lower median elevation). The adjustment is based on the ratio of predicted normal annual runoffs (from a revised Figure 3-3) between Penticton Creek at the fan apex and Bellevue Creek near Okanagan Mission (08NM035).

2) To use the record from Bellevue Creek, the unit weekly discharge should be scaled according to the ratio of predicted normal annual runoffs (from a revised Figure 3-3) between Bellevue Creek at the fan apex and Penticton Creek at the fan apex.

3) The estimated weekly time series for Penticton Creek at the fan apex would then be reconciled with the LT mad (for 1996-2010) identified by the updated regional runoff relations (i.e., updated version of Figure 3-3) and scaled if necessary.

5) Streamflows at the streamflow point-of-interest (i.e., on the alluvial fan) should then be adjusted according to the expected gain/loss between the fan apex and the EFN point-of-interest. Gains/losses can be assumed uniform throughout the year (unless there is data to the contrary), even though it is likely to vary seasonally with the elevation of groundwater table.

6) As a check, the final time series should be reviewed against the available records for Penticton Creek at Nanaimo Ave (CoP) and reports (e.g., NHC 2001), recognizing that these estimates represent different periods and may be influenced by streamflow regulation. As an additional check, it may be worthwhile to examine the unit discharges for the three currently operating hydrometric stations recording natural streamflows in the high elevations of Penticton Creek watershed (i.e., 08NM240, 08NM241, and 08NM242). Although these hydrometric stations are located at high elevation and were established as part of the Upper Penticton Experimental Watershed (to

[19] Three separate water licenses.

[20] Median elevation of Bellevue Creek at the mouth is 1,384 m.

	examine forestry impacts), by scaling these unit discharges according to updated regional runoff relations, one should arrive at similar values to those obtained by following the above-noted approach.
	Residual Streamflows Under Current Water Use and Management
	Weekly residual streamflows for Penticton Creek under current water use and management should be estimated by summing the naturalized streamflow and the following: 1) Expected weekly net flow (+ or -) associated with upland storage (i.e., primarily Greyback Lake). An assumed fill and release schedule along with the total licensed storage should be used unless information can be obtain from the CoP on historical release patterns. 2) Expected weekly water extraction upstream of the EFN point-of-interest. This information can be based on estimated demands associated with the water use areas identified above using the OWDM.
	Residual Streamflows Assuming Maximum Licence Use
	Weekly residual streamflows for Penticton Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary difference is that estimated demands from the OWDM would be replaced by the estimated total licensed extraction upstream of the EFN point-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.
References:	Useful References to support the Development of Streamflow Datasets Barr, L.J. 1988. Okanagan Region Low Flow Estimates. Memorandum dated May 20, 1988. BC Ministry of Environment and Parks, Water Management Branch. Canada-British Columbia Okanagan Basin Agreement. 1974. Technical Supplement I: Water Quantity in the Okanagan Basin. Office of the Study Director, Penticton, B.C., March 1974. City of Penticton. 2005. Water supply and distribution system information provided to L. Uunila of Summit by Brent Edge, Water Supervisor. Dobson Engineering Ltd. (Dobson). 2008. Water Management and Use Study. Prepared for Okanagan Basin Water Board, December 2008. Grainger and Associates Consulting Ltd. and Streamworks Unlimited. 2010. Penticton Creek Hydrological Risk Assessment. Prepared for BC Ministry of Environment. November 2010. Northwest Hydraulic Consultants Ltd. (NHC). 2001. Hydrology, Water Use, and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, BC. Prepared for BC Fisheries, Fisheries Management Branch, August 2001. Rodgers, R. R., and W. L. Kreuder. 1963. Water Supply and Water Use on Penticton and Ellis Creeks. Canada Department of Agriculture, Prairie Farm Rehabilitation Administration, Engineering Branch. Schnorbus, M. A., R. D. Winkler, and Y. Alila. 2004. Modelling forest harvesting effects on maximum daily peak flow at Upper Penticton Creek. BC Ministry of Forests, Research Branch, Victoria, B.C. Extension Note 67. http://www.for.gov.bc.ca/hfd/pubs/docs Shepherd, B. G. 1993. Letter re: estimates of fisheries flow requirements for Penticton Creek for migration, spawning and incubation in 1993. Ecocat report ID 44475. Summit Environmental Consultants Ltd. (Summit). 2009a. Surface Water Hydrology and Hydrologic Modelling Study – "State of the Basin" Report. Prepared for the OBWB, September 2009. Thyer, M., J. Beckers, D. Spittlehouse, Y. Alila, and R. Winkler. 2004. Diagnosing a distributed hydrologic model for two high-elevation forested catchments based on detailed stand- and basin-scale data. Water Resources Research, Vol. 40, 1-20. Winkler, R., D.L. Spittlehouse, B.A. Heise, T.R. Giles and Y. Alila. 2003. The Upper Penticton Creek Watershed Experiment: A Review at Year 20. Water Stewardship: How Are We Managing? Annual Conference of the Canadian Water Resources Association, Vancouver, BC.

Table A-12 Summary information and recommended approach for developing streamflow datasets for Coldstream Creek (from Associated 2017)

Stream:	**Coldstream Creek**	**Overall data confidence:**	High
Drainage area (km^2):	206.0	**Latitude, Longitude:**	50.22 N, -119.26 E
Median elevation (m):	-	**Provincial hydrologic zone:**	23 (85% est.), 15 (15% est.)
Minimum elevation (m):	391.5 +/-		
Maximum elevation (m):	-		
Watershed description:	Coldstream Creek, a tributary of Vernon Creek, flows south and west from Silver Star Provincial Park, through the District of Coldstream and eventually draining into Kalamalka Lake. The Coldstream Creek watershed is characterised by relatively steep headwaters grading to a broad valley floor near the community of Lavington. Typical land use includes agriculture and urban development in the lower portions of the watershed, and forestry and recreation in the upper portions.		

Hydrometric data:

Station	Nat / Rag	Period of record	Drainage area (km^2)	Median elev. (m)	Notes
Water Survey of Canada:					
Coldstream Creek above Kalavista Diversion (08NM179)	Reg.	1970-1982	207	-	Continuous record
Coldstream Creek near Lavington (08NM124)	Reg.	1910-1979	61.9	-	Continuous record 1969-1979
Coldstream Creek at the Mouth (08NM154)	Reg.	1969-1970	205	-	Continuous record
Coldstream Creek above Municipal Intake (08NM142)	Nat.	1967-present	58.5	1,120	Continuous record 1968-present. Real-time.
Others:					
Coldstream Creek near McClounie Rd.	Reg	2016-present	-	-	EFN Station operated by ONA. Installed in August 2016.
Coldstream Creek at Kirkland Road	Reg.	Unknown	-	-	FLNRO (Dennis Einarson) indicated that site has not been gauged for 5 years. RDNO may be operating station, but it is unknown at this time.

Water suppliers / users: Greater Vernon Water and private licensees.

Storage licences / reservoirs:

Reservoirs	Water Supplier	Licensed Storage (ML/year)
King Edward Lake	Greater Vernon Water (RDNO)	1,356.8
Coldstream Creek	Coldstream Ranch Ltd.	17.3
	Total:	**1,374.1**

Greater Vernon Water (GVW) is the main water supplier in the Coldstream Creek watershed and obtains water from Deer Creek, a tributary to Coldstream Creek (Dobson 2008). The North Okanagan Water Authority Master Water Plan provides information on water use and water storage within the Coldstream Creek watershed (AECOM et al. 2012). Around the year 1900, streamflows within the upper watershed were diverted to supplement irrigation within the Coldstream / Lavington area. This diversion of the upper headwaters from east to west flows along the valley bottom for a few kilometres before joining with the existing creek bed at the junction of Brewer and Craster Creeks (Aqua Resource Management Inc. 2000).

Water Use Areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
102	OTHER_Node 1_Vernon Creek	1	Unknown[21]

Groundwater – surface water interaction: MOE (1982) reported that GW/SW interactions within the Coldstream valley are locally significant to the streamflow and sediment regimes of lower Coldstream Creek. MOE (1982) also reported that there is no surface flow from late summer to early spring on the alluvial fans, which lead into the Coldstream valley from each of the upland basins. However, downstream of these fans, the mainstem of Coldstream Creek is reported to essentially be a groundwater-fed stream during the same period (MOE 1982).

Inter basin water transfer: None

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Weekly naturalized streamflows for Coldstream Creek at the apex of the alluvial fan should be based on the records from the following station: Coldstream Creek above Municipal Intake (08NM142). This record of natural streamflow within the watershed covers over 44 years and is nearly complete. It provides one of the more reliable indicators of natural streamflow patterns in the northeastern portion of the Okanagan. However, to use this record, the following steps are required:

1) The streamflows for Coldstream Creek above Municipal Intake (08NM142) (1996-2010) need to be adjusted to represent a larger drainage[22] with a lower median elevation. The adjustment is based on the ratio of normal annual runoff (from a revised Figure 3-3) between Coldstream Creek above Municipal Intake and at the apex of the alluvial fan (Figure 4-1). Given the lower median elevation, the normal annual runoff (in unit discharge terms) is expected to be slightly less than the runoff above the Municipal Intake.

2) Streamflows at the streamflow point-of-interest (i.e., apex of the alluvial fan) should then be adjusted according to the expected gain/loss between the fan apex and the EFN point-of-interest. This gain/loss may be estimated using the recent streamflow measurements by the ONA at different EFN transect locations on the fan (i.e., a limited record), as well as reviewing available sensitive habitat inventory mapping (SHIM) (i.e., Ecoscape 2009) to identify locations of water diversions on the fan (and/or below WSC 08NM142 to the fan apex). If these records are not deemed reliable, gains/losses on the fan should be assumed zero. Gains/losses can be assumed uniform throughout the year (unless there is data to the contrary), even though it is likely to vary seasonally with the elevation of groundwater table. Following this, weekly naturalized streamflows LT mad can then be calculated at the EFN point-of-interest.

Residual Streamflows Under Current Water Use and Management

Weekly residual streamflows for Coldstream Creek under current water use and management should be estimated by summing the naturalized streamflow and the following:

1) Expected weekly net flow (+ or -) associated with upland storage reservoir operation (i.e., King Edward Lake). GVW should be contacted to identify patterns of reservoir operation and obtain reservoir/water use information (if available); if this information proves difficult to obtain, then an assumed fill and release schedule along with the total licensed storage should be used.

2) Expected weekly water extraction upstream of the streamflow and EFN points-of-interest. This information should be based on the OWDM and the estimated demands associated with the water use areas identified above (i.e., Other_1). Since Coldstream Creek was not specifically modelled in previous runs of the OWDM, effort will be needed to identify the Water Use Areas sourcing water from Coldstream Creek followed by a tally of those Water Use Areas to obtain an aggregate estimate of water extraction along Coldstream Creek (and its tributaries). Model estimates should be corroborated with records of extraction, if available. GVW and Coldstream Ranch should be contacted to obtain such information.

Residual Streamflows Assuming Maximum Licence Use

Weekly residual streamflows for Coldstream Creek under maximum water use should be estimated in a similar way as for the current water use and management. The primary difference is that estimated demands from the OWDM would be replaced by the estimated total licensed extraction and storage upstream of streamflow and EFN points-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.

[21] The OWDM was previously run for the broader drainage area of Vernon Creek at the outlet of Kalamalka Lake. To determine extractions specifically to Coldstream Creek, additional model runs are required.

[22] Unless stated otherwise, all hydrologic estimates are based on unit discharge calculations; therefore, streamflows between two drainages with different areas may be compared.

References:	
	<u>References</u> AECOM, Associated Engineering (B.C.) Ltd. and Kerr Wood Leidal Associates Ltd. 2012. North Okanagan Water Authority Master Water Plan. Prepared for the North Okanagan Water Authority. Agua Resource Management Inc. 2000. Coldstream Creek Restoration Project: Phase I, Summary Report and Recommendations for Future Restoration Efforts in the Coldstream Creek Watershed. Prepared for the North Okanagan Naturalists Club. BC Ministry of Environment (MOE). 1982. Coldstream and Vaseux Creek Watersheds: Analysis of Channel Stability and Sediment Sources. APD Bulletin 27. <u>Useful References to support the Development of Streamflow Datasets</u> Associated Engineering (B.C.) Ltd. 2002. North Okanagan Water Authority Master Water Plan Summary Report. Prepared for the North Okanagan Water Authority, April 2002. BC Ministry of Environment. 2009. Okanagan Stream Trend Monitoring Program – Coldstream Creek Summary Report 2009. Environmental Protection Division. BC Ministry of Environment. 1985. King Edward Lake Reservoir – Plan of Reservoir. Storage Inventory Program. July 1985. BC Ministry of Environment. 1985. King Edward Lake Reservoir – Storage and Basin Data. Storage Inventory Program. July 1985. Canada-British Columbia Okanagan Basin Agreement. 1974. Technical Supplement I: Water Quantity in the Okanagan Basin. Office of the Study Director, Penticton, BC, March 1974. Ecoscape Environmental Consultants Ltd. (Ecoscape). 2009. Coldstream Creek Sensitive Habitat Inventory and Mapping – Inventory Summary Report. Prepared for District of Coldstream, December 2009. Letvak, D.B. 1980. Annual Runoff Estimates for East Side Okanagan Valley. BC Ministry of Environment, Water Management Branch, July 1980. Northwest Hydraulic Consultants Ltd. (NHC). 2001. Hydrology, Water Use, and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, BC. Prepared for BC Fisheries, Fisheries Management Branch, August 2001.

Table A-13 Summary information and recommended approach for developing streamflow datasets for Mill Creek (from Associated 2017)

Stream:	**Mill (Kelowna) Creek**	**Overall data confidence:**	Moderate (Upper Mill Creek), Low (Lower Mill Creek)
Drainage area (km^2):	223.7	**Latitude, Longitude:**	49.88 E, -119.50 N
Median elevation (m):	983	**Provincial hydrologic zone:**	15 (84%), 23 (7%), 24 (9%)
Minimum elevation (m):	342+/-		
Maximum elevation (m):	1,666		
Watershed description:	Mill (Kelowna) Creek is located in the central Okanagan, east of Okanagan Lake near Kelowna. The main tributaries within the sub-basin include Scotty, Whelan, and Dilworth Creeks. The headwaters of the watershed are located on a gently rolling plateau at elevations above about 1,200 m. Between the broad valley bottom and the edge of the plateau, the hillslopes are moderately steep. The creek flows west from the plateau, and then south through the broad low gradient valley bottom of Ellison and Rutland before flowing west through downtown Kelowna and into Okanagan Lake. The lower slopes include residential development, agriculture and industry, an airport and golf courses. Forest harvesting is common on the mid slopes and plateau.		

Hydrometric data:

Station	Nat / Reg	Period of record	Drainage area (km^2)	Median elev. (m)	Notes
Water Survey of Canada:					
Bulman Creek at the Mouth (08NM145)	Reg.	1968-2004	12.7		Continuous record
Scotty Creek near Rutland (08NM036)	Nat.	1911-1964	35	1165	Seasonal record
Kelowna Creek near Kelowna, Lower Station (08NM053)	Reg.	1922-1998	221	1013	Continuous record 1922-1998
Kelowna Creek at Rutland Station (08NM117)	Reg.	1950-1975	162	-	Continuous record 1970-1975
Kelowna Creek near Rutland, Upper Station (08NM026)	Reg.	1911-1922	-	-	-
Kelowna Creek near Rutland (08NM061)	Reg.	1924-1931	77.7	-	-
Moore Lake Reservoir at the Dam (08NM234)	Reg.	1973-1986	-	-	-
Others:					
James Reservoir at Spillway	Reg.	2007-present	-	-	Installed by Dobson Engineering Ltd. for BMID. Seasonal data.
Kelowna Creek Intake	Reg.	2005-present	-	-	GEID gauge. Continuous data.
Mill Creek downstream of GEID Intake	Reg.	2005-2007	-	-	Installed by Dobson Engineering Ltd.
Postill Reservoir Sluiceway	Reg.	2004-present	-	-	GEID gauge. Installed by Dobson Engineering Ltd. Continuous data.
Postill Reservoir Spillway	Reg.	2004-present	-	-	GEID gauge. Installed by Dobson Engineering Ltd. Seasonal data.

Water suppliers / users:

There are three major water suppliers within the Mill Creek watershed: 1) Black Mountain Irrigation District (BMID), 2) Glenmore-Ellison Improvement District (GEID), and 3) Rutland Water Works (RWD) (groundwater source only). The Regional District of Central Okanagan (RDCO) (Sunset Ranch Water Utility) and CoK (lands along lower Mill Creek) also use the watershed for water supply purposes (Dobson 2008). There are also privately held water licences within the Mill Creek watershed. Several golf courses (Sunset Ranch, Kelowna Springs, Shadow Ridge and Okanagan Golf Resorts) and other private holdings are supplied from high capacity wells drawing from the Greater Kelowna aquifer.

BMID obtains water from two watersheds: Mission Creek and Scotty Creek, a tributary to Mill (Kelowna) Creek. Within the Mill Creek watershsed, BMID operates one main storage reservoir, James (Trapper) Lake[23] where spring runoff is captured. After the spring runoff subsides, water is released from the reservoir to Scotty Creek and is captured at a lower elevation intake near the Sunset Ranch Golf Course where it is diverted into a closed pipe distribution system. BMID also has three groundwater wells in the Mill Creek sub-basin: Cornish Road Well, Scotty Creek Well No. 1, and Scotty Creek Well No. 2. These wells have been in use since the late 1970s and are used for irrigation and domestic water supplies. The wells are primarily used from spring to fall and occasionally during winter. The Scotty Creek wells are used as the primary groundwater supply wells, with the Cornish well as an emergency backup.

The primary sources of water for GEID are the Mill (Kelowna) Creek watershed, Okanagan Lake, and groundwater wells. Within the Mill (Kelowna) Creek watershed, GEID's main storage reservoirs include Postill Lake, South Lake, Bulman Lake. Water is captured in the reservoirs during the snowmelt period and released in summer, fall, and winter to supplement natural creek flows. Water from Mill (Kelowna) Creek is diverted to McKinley Reservoir, which is a balancing reservoir with a capacity of 1,170 ML. Water is piped from the McKinley Reservoir into a closed distribution system. Mill (Kelowna) Creek also supplies the Ellison area separately from the McKinley system. The Kelowna Airport has been supplied with water from GEID since 2005. Prior to that time, it was supplied from wells located on the airport property. GEID also operates the following groundwater wells in the watershed: 1) Vector Well No.1 (1984), 2) Ellison Well No. 1 (1985), 3) Airport Well No. 1 (2001), 4) Airport Well No. 2 (2006), and 5) Lochrem Road Well (1996). The wells are used primarily in spring and fall with occasional use during winter.

RWD sources all of its water from groundwater (Greater Kelowna Aquifer). RWD use 12 wells with varying capacities. The wells are located in both the Mission Creek and Mill Creek watersheds, although the Mission Creek wells have the highest flow rates and best water quality so they tend to be used more often.

In addition to the three major water suppliers noted above, the CoK holds a water licence that authorizes the city to divert floodwater from Mill (Kelowna) Creek to Mission Creek. This is not a consumptive licence but rather a diversion license for flood protection using the Mill Creek diversion works on an as-and-when required basis. The BC Ministry of Environment also holds a licence on Mill (Kelowna) Creek for in-stream (conservation) use. This licence stipulates that 0.3 m^3/s is to be maintained within the creek (Dobson 2008).

Storage licences / reservoirs:

Reservoir / Stream	Water Supplier	Licensed Storage (ML/year)	Actual Storage (ML)
Black Mountain Irrigation District			
James (Trapper) Lake	Black Mountain Irrigation District	1,264.3 [24]	1,372[25]
Scotty Creek (Scotty Creek Reservoir)[26]	Black Mountain Irrigation District	561.2	173[29]
	Total:	**1,825.5**	**1,545**
Glenmore-Ellison Improvement District			
Conroy Lakes (Lower and Upper)	Glenmore-Ellison Improvement District	690.7	
Kelowna Creek (Posthill Lake)	Glenmore-Ellison Improvement District	4,933.9 [27]	
Kelowna Creek (Mill Creek Dam, non-regulated)	Glenmore-Ellison Improvement District	1,219.9 [28]	
Moore (Bulman) Lake	Glenmore-Ellison Improvement District	1,233.5 [29]	
Morrison Creek (South Lake)	Glenmore-Ellison Improvement District	493.4 [30]	
	Total:	**8,571.4**	
Others			
Day Pond	Day (Private)	18.5	-
Industry Brook (small reservoir nearby)	Edmond Ranches Ltd. (Private)	49.3	-
Rockface Creek Reservoir (non-regulated)	Algard Estate (Private)	5.2	-
	Sunset Ranch Golf Developments Ltd	7.1	-
Sidede Creek	Edmond Ranches Ltd	24.7	-
Sierra Spring	Airport Sand & Gravel Ltd	6.2	-
Whelan Creek	Duncan (Private)	29.6	-
	Algard Estate (Private)	12.3	-
	Total:	**152.9**	

Inter basin transfers: Under flood conditions (i.e., flows greater than 3.2 m^3/s within Mill [Kelowna] Creek), water from Mill Creek is transferred to Mission Creek by a diversion channel maintained by the CoK (Wildstone Resources 1992; Dobson 2008; Summit 2009b). The purpose of the diversion

[23] Little Trapper Lake (aka Scotty Creek Reservoir) immediately downstream of James (Trapper) Lake was a former reservoir prior to the dam being breached (KJWC 2005).
[24] Includes multiple licences from BMID.
[25] Source: Bob Hrasko, Black Mountain Irrigation District (pers. comm. 2005).
[26] Since a dam breach, this reservoir has not functioned.
[27] Includes multiple licences.
[28] Includes multiple licences.
[29] Includes two licences.
[30] Includes two licences.

channel is to reduce flood volumes throughout the CoK. Average annual diversion volume between 1996-2006 is estimated to be 8,200 ML, typically between April 1 and June 15 (Dobson 2008).

Water use areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
52	Glenmore Ellison Improvement District	1	95
53	Glenmore Ellison Improvement District	2	70
50	Future GEID	1	50
5	Black Mountain Improvement District	2	10
47	Future BMID	1	10
103	OTHER_Node 20_Kelowna (Mill) Creek (mouth)	20	38

Groundwaer – surface water interaction:

Lower Mill Creek flows across a broad low-gradient valley underlain by an extensive aquifer system. NHC (2001) reported that Mill (Kelowna) Creek is likely to gain water from groundwater. In addition, Summit (2009a) reported that there may be no net loss / gain of streamflow to or from groundwater across the entire Mill (Kelowna) Creek alluvial fan because losses at the top of fan are likely offset by gains along the lower reaches. The bottom-line is that there remains considerable uncertainty in quantifying GW/SW interaction along lower Mill Creek.

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Unlike many streams, upon draining the uplands on the east side of the Okanagan Basin, Mill (Kelowna) Creek flows across a broad low gradient valley bottom that is underlain by an extensive aquifer system. To estimate the naturalized streamflow, it is recommended that the upland portion (primary source area) be independently assessed from the lowland (i.e., valley bottom) where groundwater /surface water interactions may be significant.

Primary Source Areas (Upper Mill Creek): The upland portion consists of several west-flowing streams, all of which should have their drainage areas delineated upslope from the point that the stream meets the valley bottom. These drainages, which include the mainstem of Mill (Kelowna) Creek, as well as Whelan and Scotty Creeks and others, should be evaluated with GIS (e.g., to determine drainage area, median elevation) and be accounted for in developing an estimate of total naturalized weekly flow contribution to lower Mill (Kelowna) Creek (i.e., along the valley bottom). Unit discharge of the multiple source areas can be represented by one or more natural surrogate streams of similar physiography and location, which should be examined to determine the most appropriate selection. This includes Clark Creek near Winfield (08NM146), Daves Creek near Rutland (08NM137), and Bellevue Creek near Okanagan Mission (08NM035). In each case, unit discharges from each station should be adjusted based on an updated regional runoff relation (Figure 3-3) to represent the Mill (Kelowna) Creek source area (e.g., median elevation). Since these three WSC hydrometric stations were discontinued prior to the period of interest (1996-2010), it will be necessary to establish relations with these three stations and active long-term natural streamflow stations to extend their records. Relations should be explored with the following to determine the most appropriate means of extending the surrogate station record to 1996-2010: Coldstream Creek above Municipal Intake (08NM142), Whiteman Creek above Bouleau Creek (08NM174), Greata Creek near the mouth (08NM173), Camp Creek at mouth near Thirsk (08NM134), and/or Vaseux Creek above Solco Creek (08NM171). In addition to the three surrogate stations, it is recommended that the unit net inflows to Kalamalka Lake be evaluated as well for 1996-2010, given this drainage is immediately north of Mill (Kelowna) Creek. This is the method used by Summit (2009a) to estimate Mill (Kelowna) Creek naturalized flows, and involves calculating the net inflow to Kalamalka Lake as the difference between the change in lake storage (based on records of Kalamalka Lake at Vernon Pumphouse (08NM143)[31]) and lake outflow as measured at Vernon Creek at outlet of Kalamalka Lake (08NM065). Regardless of which record or combination of records are used as a surrogate, the LT mad should be reconciled with the expected LT mad for the source area of Mill (Kelowna) Creek (i.e., based on an updated Figure 3-3).

Valley Bottom (Lower Mill Creek): There is relatively poor understanding of the GW/SW interaction along the valley bottom of Mill (Kelowna) Creek. Field observations of Mill (Kelowna) Creek indicate that it often loses water on the alluvial fan upstream of the Kelowna International Airport, is frequently dry or has very low flows through the airport, and then begins to pick up flow just downstream (Summit 2007). Given these observations, the lack of streamflow records at the mouth, and limited records of water extraction from the creek (beyond SHIM mapping [Ecoscape 2006]), estimation of natural streamflows along valley bottom is challenging. <u>This will limit the level of confidence in streamflow estimates for points along the valley bottom</u>. To estimate the potential surface water gain/loss along lower Mill Creek, there are a few options available: 1) use the estimates of past and currently on-going GW/SW interaction studies along Mission Creek (immediately to the south) being conducted by the Okanagan Basin Water Board, 2) examine the available period of overlapping regulated records of Kelowna Creek near Kelowna – Lower Station (08NM053) and Kelowna Creek near Rutland, Upper Station (08NM026) to identify if there is any systematic differences as you move downstream along lower Mill Creek and whether there are unique conditions (e.g., baseflows) along Mill (Kelowna) Creek[32], and/or 3) collect multiple point-in-time streamflow measurements along lower Mill (Kelowna) Creek. In the absence of reliable information on GW/SW interaction, gain/losses along lower Mill Creek should be assumed zero.

Residual Streamflows Under Current Water Use and Management

Weekly residual streamflows for Mill (Kelowna) Creek under current water use and management should be estimated independently for both the upper source areas (e.g., Upper Mill Creek and tributaries) and valley bottom (i.e., lower Mill [Kelowna] Creek) by summing the naturalized streamflow in each area to the following:

1) Expected weekly net flow (+ or -) associated with upland storage. An assumed fill and release schedule along with the total licensed storage should be used unless information can be obtain from the BMID and GEID on historical release patterns.

2) Expected weekly water extraction upstream of the streamflow and EFN points-of-interest. This information can be based on estimated demands associated with the water use areas identified above using the OWDM.

3) As a check, it is recommended that estimated residual streamflows be compared with the records at Kelowna Creek near Kelowna, Lower Station (08NM053). Although the streamflows at this station ended in 1998, they provide an indication of the pattern and magnitude of streamflows along Lower Mill (Kelowna) Creek.

Residual Streamflows Assuming Maximum Licence Use

Weekly residual streamflows for Mill (Kelowna) Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary difference is that estimated demands from the OWDM would be replaced by the estimated total licensed extraction upstream of the EFN point-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.

[31] Change in lake volumes require stage-storage tables. This information is available in Summit (2010).

[32] Summit (2009a) suggested that unit baseflows along Mill (Kelowna) Creek were systematically higher than unit net inflows to Kalamalka Lake.

References:	
	References Kelowna Joint Water Committee (KJWC). 2005. Kelowna Joint Water Committee 2005 Strategic Water Servicing Plan. Prepared by Agua Consulting Inc. and Mould Engineering. 2005. Wildstone Resources Ltd. 1992. Okanagan Lake Tributaries Plan, Volume 6 Kelowna Creek Management Place, Includes Overview. Prepared for Planning and Assessment, Southern Interior Region, BC Environment. Useful References to support the Development of Streamflow Datasets Barr, L.J. 1988. Okanagan Region Low Flow Estimates. Memorandum dated May 20, 1988. BC Ministry of Environment and Parks, Water Management Branch. Canada-British Columbia Okanagan Basin Agreement. 1974. Technical Supplement I: Water Quantity in the Okanagan Basin. Office of the Study Director, Penticton, BC, March 1974. Coulson, C.H. 1983. Memorandum re. Kelowna (Mill) Creek Flood Flows. Dobson Engineering Ltd. (Dobson). 2008. Water Management and Use Study: Phase 2 Okanagan Water Supply and Demand Project. Prepared for Okanagan Basin Water Board. March 2008. Dobson Engineering Ltd. 1998a. Interior Watershed Assessment for the Scotty Creek Watershed. Prepared for Riverside Forest Products Limited, August 1999. Dobson Engineering Ltd. 1998b. Interior Watershed Assessment for the Kelowna (Mill) Creek Watershed. Prepared for Riverside Forest Products Limited. December 1998. Ecoscape Environmental Consutlants Ltd. (Ecosape). 2006. Sensitive Habitat Inventory and Mapping (SHIM) – Mill Creek and Bellevue Creek, Kelowna, BC. Prepared for the CoK, February 2006. Johanson, D.A. 1994. Kelowna Creek Sub-Watershed Okanagan Sub-Regional Fisheries and Water Management Plan, January 1994. Northwest Hydraulic Consultants Ltd. (NHC). 2001. Hydrology, Water Use, and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, BC. Prepared for BC Fisheries, Fisheries Management Branch, August 2001. Obedkoff, W. 1990. Okanagan Tributaries Low Flow Studies. Hydrology Section Report, May 1990. Obedkoff, W. 1978. Southeast Kelowna Irrigation District (S.E.K.I.D.) Watershed Hydrology. Memorandum to C.H. Coulson, Water Investigations Branch, March 1, 1978. Polar Geoscience Ltd. (Polar). 2008. Technical memorandum: Preliminary information on streambed losses and gains to groundwater on alluvial fans. Prepared for Okanagan Basin Water Board c/o Brian Guy, Summit Environmental Consultants. November 2008. Reksten, D.E. 1973. Kelowna Creek Water Supply for Glenmore and Ellison Irrigation Districts. Summit Environmental Consultants Inc. (Summit). 2010. Okanagan Water Supply and Demand Project: Phase 2 Summary Report. Prepared for Okanagan Basin Water Board. July 2010. Summit Environmental Consultants Ltd. (Summit). 2009a. Surface Water Hydrology and Hydrologic Modelling Study – “State of the Basin” Report. Prepared for the OBWB, September 2009.

Table A-14 Summary information and recommended approach for developing streamflow datasets for Trout Creek (from Associated 2017)

Stream:	Trout Creek	Overall Data Confidence:	Moderate
Drainage area (km^2):	746.4	Latitude, Longitude:	49.56, -119.62
Median elevation (m):	1,330	Provincial hydrologic zone:	24
Minimum elevation (m):	342 +/-		
Maximum elevation (m):	2,019		

Watershed description:

Trout Creek, located east of the District of Summerland, is the third largest watershed within the Okanagan Basin. It has several tributaries including North Trout, Camp, Bull, Isintok, and Darke Creeks. The watershed consists of plateau with moderately steep slopes with rounded mountains and ridges. Flowing from the forested uplands, Trout Creek drops through a deeply incised canyon before flowing through a section of wider floodplain. Below about 600 m elevation, the creek flows across terraces of thick glacial sediments onto a large alluvial fan near Okanagan Lake. Land use in the watershed includes agriculture, urban development, commercial and recreation in the lower portions of the watershed and range, grazing, and forestry throughout the rest of the watershed.

Hydrometric data:

Station	Nat / Reg	Period of record	Drainage area (km^2)	Median elev. (m)	Notes
Water Survey of Canada:					
Bull Creek near Crump (08NM133)	Nat.	1965-1986	46.9	1530	Continuous record 1969-1986
Camp Creek at Mouth near Thirsk (08NM134)	Nat.	1965-present	34.6	1450	Continuous record. Real-time.
Darke Creek at Meadow Valley (08NM025)	Reg.	1921-1922	-	-	-
Darke Creek northwest fork (08NM023)	Nat.	1921-1922	-	-	Seasonal record
Thirsk Lake near the Outlet (08NM238)	Reg.	1979-1987	-	-	-
Trout Creek near Faulder (08NM054)	Reg.	1921-1954	704	-	Seasonal record
Trout Creek at the Mouth (08NM158)	Reg.	1969-1982	746 +/-	-	Continuous record
Trout Creek near Summerland (08NM042)	Reg.	1920-1928	-	-	-
Trout Creek Summerland Diversion (08NM055)	Reg.	1922-1931	-	-	Seasonal record
Trout Creek below Thirsk Lake (08NM237)	Reg.	1936-1978	-	-	-
Others:					
Trout Creek at Canyon Mouth (Old WSC Location)	Reg.	2004-2009	-	-	MOE station, seasonal with gaps, manual measurements, data quality is uncertain.

Water suppliers / users:

There are two major water suppliers in the area: District of Summerland (DoS) and Meadow Valley Irrigation District (MVID).

The DoS obtains water from Trout Creek, Eneas Creek, Okanagan Lake and groundwater, with the majority (85%) sourced from Trout Creek (Agua 2008). The DoS holds 25 licences (some with multiple points of diversion) (Agua 2008). The DoS primary intake with off-stream settling ponds and a water treatment plant is located on lower Trout Creek approximately 12 km upstream from the mouth. Water demands are supplied by streamflow and from storage in upland reservoirs. The DoS operates nine main reservoirs in the Trout Creek watershed: Crescent, Headwaters 1, 2, 3 and 4, Whitehead, Thirsk, Tsuh and Canyon. Headwater runoff is captured in the Crescent and Headwaters reservoirs. Additional headwater storage is provided in Whitehead Lake and the combined outflow provides the supply to the Thirsk Reservoir. Streamflows downstream of the Thirsk Reservoir are supplemented by streamflow from Camp Creek, Lost Chain Creek, Bearpaw Creek, Bull Creek and Isintok Creek with storage in Tsuh[33] and Canyon Lakes. The DoS operates three wells in the watershed. Two of the wells (TW3 and TW5) are used on an intermittent basis during peak periods. When in use, these wells discharge into the terminal reservoir for the Trout Creek surface water system. The other well is located at the Summerland Rodeo grounds and is used on a minimal basis throughout the year.

MVID operates in the Darke Creek Valley, an important tributary to Trout Creek that includes a considerable amount of irrigated land. Darke Creek has its headwaters at Munro Lake and drains through Darke Lake and on to Trout Creek. Natural streamflows in Darke Creek are not adequate to meet the local irrigation demands, so additional water is diverted into the Darke Creek from Eneas Creek during the freshet period and released from Darke and Munro Lakes to supplement natural streamflows in Darke Creek. Water for irrigation purposes is also pumped by individual landowners from Darke Creek.

In 2005 the DoS, BC Ministry of Environment, and the Fisheries and Oceans Canada collaborated to develop a Water Use Plan for the Trout Creek watershed (WMC 2005). This plan establishes minimum streamflows for fish in the lower main stem. The plan uses the streamflows in Camp Creek as an indicator from which to establish appropriate streamflows downstream of the DoS intake.

Storage licences / reservoirs:

Reservoir / Stream	Water Supplier	Licensed Storage (ML/year)	Actual Storage (ML)
District of Summerland (Source: Agua 2014)			
Thirsk Lake	District of Summerland	5,709	6,490
Headwaters Lake Nos. 1-4	District of Summerland	5,857	4,472
Isintok (Canyon) Lake	District of Summerland	1,665	1,384
Whitehead Lake	District of Summerland	1,442	1,216
Crescent (Paul) Lake	District of Summerland	931	765
Tsuh (Deer) Lake	District of Summerland	370	308
Summerland Balancing Reservoir		0	260
	Total:	**18,884**	**17,255**
Meadow Valley Irrigation District			
Darke Creek [Darke (Fish) Lake]	Meadow Valley Irrigation District	795.6	743 (Letvak 1989)
Munro Lake	Meadow Valley Irrigation District	98.7	-
	Total:	**894.3**	-
Others			
Cerolini Creek (Cerolini Creek Dam, non-regulated)	Pearce (Private)	48.1	-
Chapman Creek (Chapman Lake)	Mount Lehman Fruit Growers Ltd.	161.6[34]	-
Pitin Lake	Mazama Developments Ltd.	123.3	-
	Total:	**333.03**	-

Inter-basin transfers:

Finley Creek (which drains regulated Eneas Lake) and Lapsley Creek, both located in the headwaters of the Eneas Creek watershed, are diverted to Darke Lake in the Trout Creek drainage (Agua 2014; WMC 2005). The Findlay Creek/Lapsey Creek Diversion is licensed to the MVID, which has an intake on Darke Creek.

Water use areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
34	Corp. of the District of Summerland	2	100
82	Meadow Valley Irrigation District	1	75
126	OTHER_Node 42_Trout Creek (mouth)	42	76

Groundwater – surface water interaction:

GW/SW interaction along Trout Creek on the alluvial fan is likely to be significant. Loses to groundwater have been estimated at a rate of 0.04 m^3/s across its alluvial fan (Summit 2009a). These are similar to those estimated for Trout Creek by the WMC (2005). However, there remains considerable uncertainty.

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Weekly streamflows for Trout Creek at the apex of the alluvial fan should be based on the records from the following two stations: Camp Creek at mouth near Thirsk (08NM134) and Bull Creek near Crump (08NM133)[35]. The former represents natural streamflow from a higher location within the Trout Creek watershed. It is also one of the most complete long-term natural streamflow records in west-central Okanagan. The second hydrometric station, which is also natural, is considered even more representative of streamflow patterns in Trout Creek at the fan apex. It is located at slightly lower elevation (relative to Camp Creek) in the southern portion of the Trout Creek watershed.

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[33] Tsuh Reservoir is used as emergency supply (Agua 2008).

[34] Includes two water licences.

[35] The hydrographs of the following WSC hydrometric stations were analyzed and compared with the available (albeit regulated) records on Trout Creek: 1) Shatford Creek near Penticton (08NM037), 2) Camp Creek at mouth near Thirsk (08NM134), 3) Greata Creek near the mouth (08NM173), and 4) Bull Creek near Crump (08NM133). Each of these hydrometric stations are within reasonably proximity to Trout Creek, and have similar watershed physiography and elevations. Despite this, some hydrologic differences were noted for the period of overlapping record, which may reflect small-scale climatic differences, vegetation differences, or different levels of groundwater / surface water interaction. Among the group, unit streamflows in Bull Creek near Crump (08NM133) were most representative of patterns of streamflow in Trout Creek at the fan apex. Peak streamflows were not as high as Camp Creek (08NM134), yet baseflows were comparable to the other hydrometric stations.

However, its record runs only from 1965 to 1986 (i.e., ending prior to the period of interest). The following steps are suggested to develop naturalized streamflows:

1) To use the record from Bull Creek (08NM133):

   a) The record for Bull Creek needs to be extended to represent 1996-2010. This can be accomplished by identifying long-term weekly relations between Bull Creek (08NM13) and Camp Creek (08NM134). Summit (2009a) found a high correlation between the unit discharges of these two streams for the overlapping period of 1965 to 1986. This relation can be used to predict the Bull Creek unit discharge for 1996-2010.

   b) The predicted unit streamflows for Bull Creek (1996-2010) need to be scaled to represent Trout Creek at the fan apex (i.e., a larger drainage with a different median elevation). The adjustment is based on the ratio of predicted normal annual runoffs (from a revised Figure 3-3) between Trout Creek at the fan apex and Bull Creek near Crump (08NM133).

2) The estimated weekly time series for Trout Creek at the fan apex would then be reconciled with the LT mad (for 1996-2010) identified for that location by the updated regional runoff relations (i.e., updated version of Figure 3-3) and scaled if necessary.

3) Streamflows at the streamflow point-of-interest (i.e., on the alluvial fan) should then be adjusted according to the expected gain/loss between the fan apex and the EFN point-of-interest. Gains/losses can be assumed uniform throughout the year (unless there is data to the contrary).

4) As a check, the final time series should be reviewed against the available records for the WSC hydrometric station at Trout Creek at the Mouth (08NM158) and the MOE station at Trout Creek at Canyon Mouth (Old WSC Location), recognizing that these estimates represent different periods and may be influenced by streamflow regulation.

5) As an additional check, reported streamflows from the following reports should also be considered in evaluating the final weekly natural streamflows: Agua (2008; 2014), Associated Engineering (1997), Letvak (1989), NHC (2005), Reksten (1972; 1973), WMC (2003; 2004; 2005a-b), and Weiss (1981).

Residual Streamflows Under Current Water Use and Management

Weekly residual streamflows for Trout Creek under current water use and management should be estimated by summing the naturalized streamflow and the following:

1) Expected weekly net flow (+ or -) associated with upland storage. The DoS should be contacted to obtain current information on storage release schedules and records. One should also refer to Polar (2009a), which provides a detailed analysis of reservoir operations in the Trout Creek watershed, which can be used to define an assumed fill and release schedule.

2) Expected weekly water extraction upstream of the EFN point-of-interest. This information will be based on the OWDM and the estimated demands associated with the water use areas identified above.

Residual Streamflows Assuming Maximum Licence Use

Weekly residual streamflows for Trout Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary difference is that estimated demands from the OWDM would be replaced by the estimated total licensed extraction upstream of the EFN point-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.

References:

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Table A-15 Summary information and recommended approach for developing streamflow datasets for McLean Creek (from Associated 2017)

Stream:	**McLean Creek**	**Overall data confidence:**	Low
Drainage area (km^2):	63.2	**Latitude, Longitude:**	49.38 E, -119.56 N
Median elevation (m):	-	**Provincial hydrologic zone:**	24
Minimum elevation (m):	339		
Maximum elevation (m):	-		
Watershed description:	McLean Creek is approximately 15.0 km long and is located in the southeastern portion of the Okanagan Valley (ONA 2006). The headwaters of McLean Creek originate on a steep valley side neighbouring the Shuttleworth Creek watershed. From its headwaters, McLean Creek flows through an agricultural terrace for approximately 2 km before discharging into Skaha Lake. The alluvial fan of McLean Creek supports residential land use. McLean Creek is the only significant tributary into Skaha Lake (other than the Okanagan River) (Matthews and Bull 2003).		

Hydrometric data:

Station	Nat / Reg	Period of record	Drainage area (km^2)	Median elev. (m)	Notes
Water Survey of Canada:					
McLean Creek near Okanagan Falls (08NM005)	Nat.	1921-1926	20.7	-	Seasonal record
Others:					
There are plans for ONA to install a hydrometric station on this creek in 2017.					

Water suppliers / users: Private licensees only.

Storage licences / reservoirs:

Reservoir / Stream	Water Supplier	Licensed Storage (ML/year)
Derenzy Creek (Lake)	Conroy (Private)	5.6
	Doris Tan Holdings Ltd (Private)	10.5
	Burgers (Private)	3.0
	Golden Hills Strata Plan K268 (Private)[36]	47.5
	Spieldiener (Private)	45.7
Harkin Creek	Spieldiener (Private)	74.0
McLean Creek (McLean Clan Lake, regulated)	The Nature Trust of British Columbia[37]	370.0
Thomas Creek (Thomas Creek Dam, regulated)	The Nature Trust of British Columbia	123.3
	Total:	**679.6**

Inter-basin transfers: None.

Water use areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
-	-	-	-

Note that McLean Creek has not been specifically modelled within the OWDM. Water demands were identified for a larger drainage unit Residual E11. To identify demands from McLean Creek, an additional run of the OWDM will be required following the identification of all land parcels supplied by McLean Creek.

Groundwater – surface water interaction: No information regarding GW/SW interaction is available. A small alluvial fan near the mouth of McLean Creek may be associated with groundwater gains/losses; however, given the size of the alluvial fan and the short length of stream across the fan, zero net change in streamflow is assumed.

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Weekly streamflows for McClean Creek at the apex of the alluvial fan should be based on the record from: Vaseux Creek above Solco Creek (08NM171). This record represents natural streamflow from a slightly higher location within a watershed not far to the south. It also is one of the most complete long-term natural streamflow records in the southeast portion of the Okanagan Basin. The following steps are required to develop naturalized streamflow estimates:

1) Use Vaseux Creek above Solco Creek (08NNM171) as a surrogate for Mclean Creek at the fan apex, given its proximity and watershed characteristics. Recorded unit streamflows in Vaseux Creek (08NM171) should be scaled down to account for the difference in median catchment elevation and thus normal annual runoff. This scaling factor should be identified by using updated regional runoff relations (i.e., Figure 3-3).

2) Weekly time series should then be reconciled with the regionally based normal annual runoff expected for McLean Creek, and if necessary some small scaling may be required.

3) There is potential that McLean Creek gains or loses surface flow to groundwater across its alluvial fan. However, with no specific information available, this gain or loss can be assumed zero.

4) As a check, the relatively short natural record of streamflows at McLean Creek near Okanagan Falls (08NM005) should be reviewed to confirm similarity in hydrograph characteristics to the estimates based on the above approach, recognizing that different periods of interest can influence results[38]. Following this, weekly naturalized streamflows LT mad can then be calculated at the EFN point-of-interest.

Residual Streamflows Under Current Water Use and Management

Weekly residual streamflows for McLean Creek under current water use and management should be estimated by summing the naturalized streamflow and the following:

1) Expected weekly net flow (+ or -) associated with the relatively minor upland storage. An assumed fill and release schedule along with the total licensed storage should be used; and

2) Expected weekly water extraction upstream of the streamflow and EFN points-of-interest. This information should be based on a new model run of the OWDM that accounts for those areas that source water from McLean Creek. Alternatively, archived raw output data from the model can be examined to determine water extractions from McLean Creek. In either case, it is likely that the services of Ron Fretwell (RHF Systems)[39] is required to obtain such data.

Residual Streamflows Assuming Maximum Licence Use

Weekly residual streamflows for McLean Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary difference is that estimated demands from the OWDM would be replaced by the estimated total licensed extraction upstream of the EFN point-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.

References:

Useful References to support the Development of Streamflow Datasets

Barr, L.J. 1988. Okanagan Region Low Flow Estimates. Memorandum dated May 20, 1988. BC Ministry of Environment and Parks, Water Management Branch.

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[36] Includes two licences.

[37] Includes two licences.

[38] To provide context for the McLean Creek record (1921-1926) (i.e., were these dry or wet years?), a review of the records for long-term stations such as Okanagan Lake and River to determine the patterns of net inflows to Okanagan Lake during these years in relation to long-term patterns should be completed. According to Summit (2009), the period 1921-1926 had normal to below normal annual Okanagan Lake net inflows.

[39] Ron Fretwell (RHF Systems) is one of the main computer programmers involved in the development of the OWDM.

Table A-16 Summary information and recommended approach for developing streamflow datasets for Trepanier Creek (from Associated 2017)

Stream:	**Trepanier Creek**	**Overall data confidence:**	High
Drainage area (km^2):	260.0	**Latitude, Longitude:**	49.78, -119.71
Median elevation (m):	1,228	**Provincial hydrologic zone:**	24
Minimum elevation (m):	342 +/-		
Maximum elevation (m):	1,911		

Watershed description:

Trepanier Creek is Community Watershed located on the west side of Okanagan Lake near the Town of Peachland and is located between Powers Creek to the north and Peachland Creek to the south. The watershed drains a gently sloping plateau located to about 1,200 m and includes the tributaries of MacDonald and Lacoma Creeks. Trepanier Creek is deeply entrenched into the plateau and forms a gently sloping, narrow valley bottom from about 800 m elevation down to Okanagan Lake. At about an elevation of 450 m, the creek incises through the benchlands above Peachland and flows across an alluvial fan at Okanagan Lake. The plateau supports forest harvesting and is used extensively for outdoor recreation. The Brenda Mine is located on the uplands, but has not been operational since 1990 and the site has been reclaimed. The Coquihalla Highway - Okanagan Connector (Highway 97) traverses the length of the valley. Residential and agricultural land is located below 600 m elevation.

Hydrometric data:

Station	Nat / Reg	Period of record	Drainage area (km^2)	Median elev. (m)	Notes
Water Survey of Canada:					
Jack Creek at the Mouth (08NM013)	Reg.	1919	40.4	-	-
Trepanier Creek at the Mouth (08NM155)	Reg.	1969-1981	254	-	Continuous record
Trepanier Creek near Peachland (08NM041)	Reg.	1919-1927; 1960-2014	182	1,267	Seasonal 1919-1972. Continuous 1973-1979 and 1983-2014. Vandalized in 2014. May not be re-established.
Others:					
Trepanier Creek at Hwy 97	Reg.	2006-2009	-	-	MOE gauge.
Trepanier Creek downstream of Hwy 97C	Reg.	2006-2007	-	-	MOE gauge.
Trepanier Creek upstream of Hwy 97C	Reg.	2006-2008	-	-	MOE gauge.

Water suppliers / users:

The District of Peachland (DoP) is the main water supplier in the sub-basin. DoP obtains water primarily from Trepanier Creek and Peachland Creek. An emergency system also pumps water from Okanagan Lake. Although DoP has previously used groundwater, those wells are no longer in operation. DoP has one storage reservoir in the Trepanier Creek watershed: Silver Lake, which is used primarily for emergency storage, but is also occasionally used to meet Kokanee salmon streamflow targets as part of an informal Trepanier Creek water use plan (Epp 2009). Another reservoir, Wilson Lake, is located just south within the Peachland Creek watershed; however, the dam maintaining the lake has been breached so there is no storage. Water can also be diverted from the Trepanier Creek watershed to the Peachland Creek sub-basin via the McDonald Creek diversion near the Brenda Mine. The DoP operates an intake on lower Trepanier Creek located off Trepanier Road, downstream of Venner Creek. There are also a considerable number of private water licenses issued within the Trepanier Creek watershed, for domestic and/or irrigation primarily upstream of the DoP boundary.

Storage licences / reservoirs:

Reservoir	Water Supplier	Licensed Storage (ML/year)
Silver Lake*	District of Peachland	562.5[40]
Lacoma Creek (Lacoma Lake, non-regulated)	Thiesmann (Private)	37.0
	Garnett (Private)	11.1
	955759 B.C. Ltd.	62.9[41]
	Fullforce Diamond Drilling Ltd	24.9
	Peterson (Private)	12.1
Law Creek	Klein (Private)	4.9
Hitchner Creek	Quist (Private)	2.3
	Ficke (Private)	5.2[42]
	Total:	**722.9**

Note that Silver Lake is only used for emergency storage.

Inter-basin transfers:

DoP transfers water from the Trepanier Creek watershed into the Peachland Creek watershed via the MacDonald Creek diversion near Brenda Mine. Summit (2009b) provides an estimated average annual diversion volume of 179 ML for the period of 1996-2006, assuming that the diversion occurs between April 1 and September 30. For further details on this diversion and the estimated quantities refer to Summit (2009b).

Water use areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
91	Municipality of Peachland	3	100
14	Bylaw 571 - Dietrich (Star Place)	1	100
113	OTHER_Node 30_Trepanier Creek (mouth)	30	83.6

Groundwater – surface water interaction:

Summit (2009a) identified that Trepanier Creek likely loses water to groundwater, while Obedkoff (1990) provides estimated surface water losses to groundwater for the winter and summer periods.

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Weekly streamflows for Trepanier Creek at the apex of the alluvial fan should be based on the record from: Trepanier Creek near Peachland (08NM041). This is a relatively lengthy and largely complete record of modestly regulated streamflow from a location only slightly higher within the watershed. The following steps are required to develop naturalized streamflows:

1) Minor gaps in the Trepanier Creek record for 1996-2010 can be filled by using weekly relations between Trepanier Creek (08NM041) and Greata Creek near the mouth (08NM173).

2) Naturalize the Trepanier Creek (08NM041) record by totalling all water extractions and any storage regulation[43] upstream of the hydrometric station. Fortunately, the station is just upstream of the major water intake operated by DoP, so that can be excluded. As a result, there are relatively few water users/licensees to account for (i.e., the degree of regulation is modest). The expected weekly water extraction (1996-2010) upstream of the hydrometric station should be based on the OWDM.

3) The naturalized weekly time-series of unit discharge at Trepanier Creek (08NM041) should then be scaled to represent conditions at the fan apex. This should be done using updated the regional runoff relations (i.e., updated Figure 3-3). A small decrease in unit discharge is expected.

4) The scaled weekly time series should then be reconciled with the regionally based normal annual runoff for Trepanier Creek, and if necessary a small additional scaling may be required.

3) There is potential that Trepanier Creek loses surface flow to groundwater across its alluvial fan. There is uncertainty in the rate of loss throughout the year. To estimate this loss, it is recommended that the MOE hydrometric records for Trepanier Creek collected between 2006-2009 be reviewed in concert with estimated water extractions (from the OWDM) between measurement locations. Based on the findings of this review, consider applying streamflow losses (or gains) to the weekly naturalized flow time series at the fan apex to arrive at estimates for the EFN point-of-interest.

4) As a check, the final time series should be reviewed against previous estimates (e.g., Cairns 1992, Hunter 1978, Reksten 1973, Summit 2004, NHC 2003), recognizing that different periods of interest can influence results.

[40] Includes multiple water licences.

[41] Includes three water licences.

[42] Includes two water licences.

[43] Silver Lake is the main regulated storage reservoir, which is principally used for emergency storage; however, it does occasionally get used to meet Kokanee salmon streamflow targets as part of an informal Trepanier Creek water use plan (Epp 2009). The DoP should be contacted to determine lake regulation records (including releases for Kokanee salmon) during 1996-2010.

Suggested methodology for weekly streamflow estimation:	**Residual Streamflows Under Current Water Use and Management** Weekly residual streamflows for Trepanier Creek under current water use and management should be estimated by summing the naturalized streamflow and the following: 1) Expected weekly net flow (+ or -) associated with the relatively minor upland storage. An assumed fill and release schedule along with the total licensed storage should be used unless information from DoP is available on the (emergency) use of Silver Lake; and 2) Expected weekly water extraction upstream of the streamflow and EFN points-of-interest. This information will be based on a combination of actual extractions recorded by DoP and estimated demands associated with the water use areas identified above (based on the OWDM). **Residual Streamflows Assuming Maximum Licence Use** Weekly residual streamflows for Trepanier Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary difference is that estimated demands from the OWDM would be replaced by the estimated total licensed extraction upstream of the EFN point-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.
References:	Useful References to support the Development of Streamflow Datasets Barr, L.J. 1988. Okanagan Region Low Flow Estimates. Memorandum dated May 20, 1988. BC Ministry of Environment and Parks, Water Management Branch. Cairns, R. 1992. Trepanier Creek Investigation Report. BC Ministry of Environment, Lands, and Parks. April, 1992. Dobson Engineering Ltd. (Dobson). 2008. Water Management and Use Study. Prepared for Okanagan Basin Water Board, December 2008. Dobson Engineering Ltd. 2006. Water Availability Analysis. Prepared for the District of Peachland, November 2006. Epp, P. 2009. 2009 Trepanier Creek Flow Monitoring: Water Balance, Fish Habitat and Draft Operating Strategy Implementation. BC Ministry of Environment, Penticton. Annual reports also prepared by P. Epp in 2005, 2006, 2007, and 2008. Epp, P. 2004 - 2007. Flow Monitoring in Trepanier Creek in Microsoft Excel files: Trepanier Creek near Mouth, Trepanier Creek near Hwy 97 Bridge and Trepanier Creek below Hwy 97C. Golder Associates Ltd. 2010. Peachland Creek and Trepanier Creek – Watershed Assessment Report for Drinking Water Source Protection. Prepared for the District of Peachland, May 2010. Hunter, H.I. 1978. Trepanier Creek Water Yield. Hydrology Division, Water Investigations Branch, June 1978. Letvak, D.B. 1980. Annual Runoff Estimates for West Side of Okanagan Valley. BC Ministry of Environment. January 1980. Northwest Hydraulic Consultants Ltd. (NHC). 2003. Trepanier Creek Stream Summary. Prepared for BC Fisheries (Fisheries Management Branch). Note: copy may be filed under Summit Project No. 571-02.01. Northwest Hydraulic Consultants Ltd. (NHC). 2001. Hydrology, Water Use, and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, BC. Prepared for BC Fisheries, Fisheries Management Branch, August 2001. Obedkoff, W. 1990. Okanagan Tributaries Low Flow Studies. Hydrology Section Report, May 1990. Reksten, D.E. 1973. Runoff Estimates for Trepanier Creek Watershed. Summit Environmental Consultants Inc. (Summit). 2009a. Surface Water Hydrology and Hydrologic Modelling Study – “State of the Basin” Report. Prepared for the OBWB, September 2009. Summit Environmental Consultants Ltd. (Summit). 2009b. Assessment of estimates of Okanagan Basin water diversion and imports and sewage return flows provided by Dobson Engineering Ltd. (2008). Internal document, Reference 7200-004.06. Summit Environmental Consultants Ltd. 2004. Trepanier Landscape Unit Water Management Plan. Prepared for Regional District of Central Okanagan and BC Ministry of Sustainable Resource Management, June 2004. Urban Systems Ltd. 2001. Water Supply and Demand Review, District of Peachland. Prepared for the District of Peachland. March 2001.

Table A-17 Summary information and recommended approach for developing streamflow datasets for Powers Creek (from Associated 2017)

Stream:	**Powers Creek**	**Overall Data Confidence:**	Moderate
Drainage area (km^2):	145.3	**Latitude, Longitude:**	49.82, -119.62
Median elevation (m):	1,242	**Provincial hydrologic zone:**	15 (1%), 24 (99%)
Minimum elevation (m):	342 +/-		
Maximum elevation (m):	1,868		

Watershed description:

Powers Creek is a Community Watershed located between Lambly Creek to the north, MacDougall Creek to the east, and Trepanier Creek to the south. The creek drains a small area of plateau above 1,100 m, and then flows through a deeply incised canyon until reaching the benchlands in West Kelowna. Powers Creek has downcut through a terrace of thick glacial sediments near the 600 m elevation to form Glen Canyon. The creek forms a large alluvial fan at Gellatly Road. Forestry activity is common on the plateau portions of the watershed. The benchlands support residential, agricultural, industrial and commercial development.

Hydrometric Data:

Station	Nat / Reg	Period of record	Drainage area (km^2)	Median elev. (m)	Notes
Water Survey of Canada:					
Lambly Lake Diversion to Powers Creek (08NM136)	Reg.	1965-1972	-	-	-
Powers Creek at the Mouth (08NM157)	Reg.	1969-1982	144	-	Continuous record
Powers Creek above Westbank Diversion (08NM033)	Nat.	1920-1974	128	1317	Seasonal record 1965-1974
Powers Creek below Westbank Diversion (08NM059)	Reg.	1912-1987	139	-	Continuous record
Powers Creek Westbank Diversion (08NM034)	Reg.	1919-1931	-	-	Seasonal record 1920-1931
Others:					
Powers Creek at Bear Main	Nat.	2007	-	-	Installed by Dobson Engineering Ltd.
Powers Creek upstream of Jackpine Creek	Nat.	2007	-	-	Installed by Dobson Engineering Ltd. Unknown status.
Powers Creek at Gellatly Rd	Reg.	2004-2006	-	-	Operated by MOE.
Powers Creek upstream from the Lambly Diversion	Nat.	2010-present	-	-	City of West Kelowna. Seasonal records.
Powers Creek downstream from the Lambly Diversion	Reg.	2007-present	-	-	City of West Kelowna. Seasonal records.

Water suppliers / users:

The City of West Kelowna (Westbank System) is the main water supplier within the Powers Creek watershed. They obtain water from two other watersheds in addition to Powers Creek, including Lambly Creek and Alocin Creek (a tributary to the Nicola River). The Westbank System includes several reservoirs for storage (listed below). In addition, Tadpole Lake (in the Lambly Creek drainage) is also used for storage. Water from Tadpole Lake can be diverted into Powers Creek via Alocin Creek (in the Nicola River watershed). In 1945, the Westbank System was granted the right to build a saddle dam on Lambly (Bear) Lake to permanently divert outflow into Powers Creek; as a result, the lake is now within the Powers Creek watershed. The City of West Kelowna operates a water intake and water treatment plant on the lower reaches of watershed (Dobson 2008).

The BC Ministry of Environment holds a water licence on Powers Creek for instream (conservation) use for the maintenance of 0.085 m^3/s within the creek throughout the year (Dobson 2008). In addition, the BC Ministry of Environment placed a *Water Act* Reserve on Powers Creek (and all its tributaries) on June 15, 1989. The *Water Act* Reserve requires that 0.13 m^3/s be maintained within the creek to meet current and projected angling demands for recreational fisheries (Dobson 2008).

Storage licences / reservoirs:

Reservoir	Water Supplier	Licensed Storage	Developed Storage
Bit Creek	City of West Kelowna (Westbank System)	555.066	Unknown
Dobbin Lake	City of West Kelowna (Westbank System)	524.229 [44]	692
Glenrosa Lake	Quist (Private) and Ficke (Private) [45]	7.4935	Unknown
Islaht (Horseshoe) Lake	City of West Kelowna (Westbank System)	15.4185 [46]	995
Lambly (Bear) Lake	City of West Kelowna (Westbank System)	3,490.7484 [47]	3491
Lower Jack Pine (Jackpine) Lake	City of West Kelowna (Westbank System)	951.3215 [48]	1224
Paynter Lake	City of West Kelowna (Westbank System)	431.718	432
Webber Lake	City of West Kelowna (Westbank System)	222.0264 [49]	Unknown
	Total:	**6198.0211**	

Inter-basin transfers:

The City of West Kelowna operates a water diversion from Tadpole Lake in the Lambly Creek watershed to Dobbin Lake in the Powers Creek watershed via Alocin Creek, a tributary of the Nicola River watershed (outside of the Okanagan Basin). Along the diversion there is some local runoff contribution from the Nicola River watershed (Nicola ditch) and the Lambly Creek watershed (Tadpole Lake diversion). Summit (2009b) estimated that the average annual diversion volume into Powers Creek watershed by the Alocin Creek diversion for 1996-2006 was 220 ML. Refer to Summit (2009b) for further details.

Water Use Areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
252	Westbank Irrigation District	1	100
111	OTHER_Node 28_Powers Creek (mouth)	28	46.8

Groundwater – surface water interaction:

Summit (2009a) reports that there is likely no net loss / gain of streamflow to or from groundwater across the entire Powers Creek alluvial fan because losses at the top of fan are likely offset by gains along the lower reaches.

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows and LT mad

Several potential methods to estimate natural streamflows in Powers Creek were identified by Summit (2009a). This included using the natural records from Powers Creek above Westbank Diversion (08NM033); however, the record is seasonal, incomplete and would have required adjusting the data to represent the period of interest. Naturalization of the independently collected streamflow data at Powers Creek at Gelaatly Road was also considered. However, this data could not be obtained and the quality of the data is unknown. The following steps are therefore suggested for the development of naturalized streamflows:

1) Estimate the unit discharge of Powers Creek at the fan apex by averaging the unit discharge (adjusted to represent Powers Creek at the fan apex[50]) from Whiteman Creek above Bouleau Creek (08NM174) and from Trepanier Creek at the fan apex (naturalized) (Table 4-15).

2) Based on this average unit discharge, reconcile the weekly streamflow estimates with the normal annual runoff expected for Powers Creek based on updated regional runoff relations (i.e., Figure 3-3).

3) As indicated above, Powers Creek appears to have no net change in streamflow on the fan, so no adjustment is required to estimate the streamflows at the location of interest.

4) As a check, the final time series should be reviewed against all available streamflow measurements on Powers Creek, recognizing that different periods of interest and regulation can influence results. This should be followed by a review of other reports on Powers Creek including Dobson (2001), Epp (2010), Letvak (1980; 1981), NHC (2001; 2003), and Summit (2004).

Residual Streamflows Under Current Water Use and Management

Weekly residual streamflows for Powers Creek under current water use and management should be estimated by summing the naturalized streamflow and the following:

1) Expected weekly net flow (+ or -) associated with upland storage reservoir operation. The City of West Kelowna should be contacted to identify patterns of reservoir operation and obtain reservoir/water use information (if available); if this information proves difficult to obtain, then an assumed fill and release schedule along with the total licensed storage should be used; and

[44] Includes multiple water licenses.

[45] Three separate water licences.

[46] Multiple water licences; some of which are shared with other reservoirs.

[47] Includes multiple water licences.

[48] Includes four separate water licences.

[49] Includes two water licences.

[50] Such adjustments are to be based on normal annual runoff relations that use median watershed elevation as the independent variable.

	2) Expected weekly water extraction upstream of the point-of-interest. This information will be based on the Okanagan Water Demand Model and the estimated demands associated with the water use areas identified above.
	Residual Streamflows Assuming Maximum Licence Use
	Weekly residual streamflows for Powers Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary difference is that estimated demands from the OWDM would be replaced by the estimated total licensed extraction upstream of the EFN point-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.
References:	Useful References to support the Development of Streamflow Datasets Barr, L.J. 1988. Okanagan Region Low Flow Estimates. Memorandum dated May 20, 1988. BC Ministry of Environment and Parks, Water Management Branch. BC Ministry of Environment. 1990. Okanagan Area Tributaries to Okanagan Lake near Westbank (Peachland, Trepanier, Westbank, Powers, McDougall, Faulkner and Lambly Creeks) Water Quality Assessment and Objectives. August 1990. Canada-British Columbia Okanagan Basin Agreement. 1974. Technical Supplement I: Water Quantity in the Okanagan Basin. Office of the Study Director, Penticton, BC., March 1974. Dobson Engineering Ltd. (Dobson). 2010. Powers Creek Source Assessment Report. Prepared for Westbank Irrigation District. July 2010. Dobson Engineering Ltd. (Dobson). 2008. Water Management and Use Study. Prepared for Okanagan Basin Water Board, December 2008. Dobson Engineering Ltd. (Dobson). 2001. Stream Channel Monitoring Program for the Powers Creek Watershed (2000 Report - Year 1). Prepared for Riverside Forest Products Ltd. Epp, P. 2010. 2009 Flow and Habitat Monitoring: Powers Creek. BC Ministry of Environment, Penticton. March 2010. Annual Powers Creek Flow & Habitat Monitoring reports also prepared by P. Epp for 2005, 2006, 2007 & 2008. Letvak, D. B. 1981. Water Supply Hydrology of the Powers Creek Basin and the Westbank Irrigation District. July 1981. Letvak, D. B. 1980. Annual Runoff Estimates for West Side of Okanagan Valley. BC Ministry of Environment. January 1980. Northwest Hydraulic Consultants Ltd. (NHC). 2003. Stream Summaries: Trepanier, Peachland, Powers, Lambly, and Mission Creeks (draft). Prepared for the BC Ministry of Water, Land and Air Protection, Fisheries Branch. Northwest Hydraulic Consultants Ltd. (NHC). 2001. Hydrology, Water Use, and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, B.C. Prepared for BC Fisheries, Fisheries Management Branch, August 2001. Obedkoff, W. 1990. Okanagan Tributaries Low Flow Studies. Hydrology Section Report, May 1990. Reksten, D. E. 1971. Preliminary Report on Powers Creek Water Yield for Westbank Irrigation District. British Columbia Water Resources Service, Department of Lands, Forests and Water Resources, Victoria, BC. Summit Environmental Consultants Ltd. (Summit). 2009a. Surface Water Hydrology and Hydrologic Modelling Study – “State of the Basin” Report. Prepared for the OBWB, September 2009. Summit Environmental Consultants Ltd. (Summit). 2009b. Assessment of estimates of Okanagan Basin water diversion and imports and sewage return flows provided by Dobson Engineering Ltd. (2008). Internal document, Reference 7200-004.06. Summit Environmental Consultants Ltd. 2004. Trepanier Landscape Unit Water Management Plan. Prepared for Regional District of Central Okanagan and BC Ministry of Sustainable Resource Management, June 2004. Tredger, C.D. 1987. Investigation of Kokanee Enhancement in Okanagan Lake Tributary Streams. BC Ministry of Environment and Parks, Recreational Fisheries Branch, Victoria, BC.

Table A-18 Summary information and recommended approach for developing streamflow datasets for Shingle Creek (from Associated 2017)

Stream:	**Shingle Creek**	**Overall data confidence:**	High
Drainage area (km²):	298.6	**Latitude, Longitude:**	49.48, -119.60
Median elevation (m):	1,273	**Provincial hydrologic zone:**	24
Minimum elevation (m):	339		
Maximum elevation (m):	2,200		
Watershed description:	Shingle Creek is located west of the CoP and flows into Okanagan River between Okanagan and Skaha Lakes. The main tributary to Shingle Creek is Shatford Creek, located in the southern portion of the watershed. The upper part of Shatford Creek is characterized by gentle to moderately steep slopes and a deeply incised valley. Farleigh Creek, which drains Brent and Farleigh Lakes, meets Shatford Creek near an elevation of 680 m. Shingle Creek drains a gently sloping plateau with some locally steep terrain. From the confluence of Shingle and Shatford Creeks to about the 540 m elevation, Shingle Creek is deeply entrenched and has steep valley sides. Below the 540 m elevation, the valley opens up and Shingle Creek crosses a series of kame and outwash terraces then crosses a large alluvial fan west of the CoP. Forestry and agricultural activities take place in the uplands and valleys of the watershed, respectively. Penticton Indian Band (PIB) I.R. No. 1 is located in the eastern portion of the watershed. Land use on PIB I.R. No. 1 includes agriculture, commercial, industrial (wood processing), and rural residential along the valley bottom; however, most of the residential development is located on the fan near Okanagan River.		

Hydrometric data:

Station	Nat / Reg	Period of record	Drainage area (km²)	Median elev. (m)	Notes
Water Survey of Canada:					
Riddle Creek near West Summerland (08NM070)	Nat.	1930-1931	33.4	-	Continuous record
Shatford Creek near Penticton (08NM037)	Reg.[51]	1919-1927; 1964-present	101	1530	Continuous record 1966-present. Real-time.
Shingle Creek above Kaleden Diversion (08NM038)	Nat.	1920-1977	44.8	1537	Seasonal record
Shingle Creek at the Mouth (08NM150)	Reg.	1969-1982	308	1,273	Continuous record 1969-1979
Others:					
Lower Shingle Creek	Reg.	2016-present	-	-	EFN Station operated by ONA. Installed in August 2016.
Upper Shingle Creek	Reg.	2016-present	-	-	EFN Station operated by ONA. Installed in August 2016.

Water suppliers / users: The PIB is the main water supplier in the Shingle Creek watershed, diverting water for domestic and irrigation purposes within their reserve lands. In addition, the PIB extracts water from three wells in or near Shingle Creek (as of 2006, production from these wells was approximately 120 ML). The Farleigh Lake Water Users Community operates a small water treatment system in the Farleigh Creek valley. There are approximately 191 current water licences (including Bobtail Ranch) within the Shingle Creek watershed. Reservoir storage is provided primarily by Brent and Farleigh Lakes. As of September 2014, ONA has operated a sockeye salmon hatchery near Penticton that uses three wells with a total capacity of 2,500 gpm (approximately 0.16 m³/s). Water from these wells is used in the hatchery before being discharged into Shingle Creek (Walker 2014).

Storage licences / reservoirs:

Reservoir / Stream	Water Supplier	Licensed Storage (ML/year)
Brent Lake	Bobtail Ranch Ltd	123.3
	Penticton Indian Band	-[52]
	Farleigh Lake WUC	49.3
Clark Creek	Barrington Ranch Ltd	3.7 [53]
Deschamps Creek (Reservoir, regulated)	Stuart & Company Limited	61.7
Farleigh Lake	Penticton Indian Band	1,233.5
	Farleigh Lake WUC	160.4[54]
Riddle Creek	Stuart & Company Limited	185.0
Shatford Creek	Jmaeff (Private)	74.0
	TBD	37.0
	Lulu Island Winery Ltd	39.5
	Hohmann (Private)	58.0
	Woods (Private)	21.0
	Blossom Winery Ltd.	24.7
	Jmaeff (Private)	515.4
	Leir (Private)	37.0
	Mcfadyen (Private)	31.5
	Manning (Private)	47.4
	Penticton Indian Band	314.5 [55]
	Blair (Private)	9.0
	1071583 B.C. Ltd. (Private)	35.2
	Glover-Raincock (Private)	22.0
	Ackerman (Private)	2.3
Shingle Creek	Bobtail Ranch Ltd	-[56]
	Penticton Indian Band	-[57]
	Farleigh Lake WUC	-[58]
	Farleigh Lake WUC	-[59]
	Total:	**3,085.4**

Inter-basin transfers: None

Water use areas:

Water Use Area ID	Water Supplier	System ID	% of total from this source
217	Penticton Indian Band Reserve 1	3	100
6	Bobtail Ranch	1	100
134	OTHER_Node 51_Shingle Creek (mouth)	51	84.2

Groundwater – surface water interaction: Summit (2009a) identified that Shingle Creek likely loses water to groundwater along its alluvial fan and estimates that streamflow is lost to groundwater at a typical rate of approximately 0.014 m³/s per km of channel. However, this rate likely varies depending on time of year, groundwater table elevation and antecedent conditions.

Suggested methodology for weekly streamflow estimation:

Naturalized Streamflows

Weekly streamflows for Shingle Creek at the apex of the alluvial fan should generally be based on the 1996-2010 record for Shatford Creek near Penticton (08NM037), a station record with relatively minor regulation influence. Given the different drainage areas and elevations, the weekly unit discharge of Shatford Creek should be uniformly scaled down according to the ratio of the normal annual runoff identified for Shatford Creek (median elevation 1,530 m) to Shingle Creek (median elevation 1,273 m). Normal annual runoff estimates should be based on an updated version of the regional runoff relations (Figure 3-3) normalized for the 1996-2010 period. Summit (2009a) identified this ratio as 0.62 for the 1996-2006 period; this means that the unit discharge of Shingle Creek near the mouth is generally about 38% lower than

[51] Assuming all licensees use their allocated volumes of water, water use on average would account for about 0.005 m³/s on an annual basis. This represents about 1% of the estimated normal annual discharge Shatford Creek. Furthermore, a review of the unit discharge records for Shatford Creek near Penticton (08NM037) against the natural Shingle Creek above Kaleden Diversion (08NM038) record (1979-1987) suggests the two streams have nearly identical unit hydrographs, suggesting that the Shatford Creek record reasonably reflects “natural” conditions (Summit 2009a).

[52] Multiple points of diversion under licence. Other points of diversion on Farleigh Lake and Shingle Creek.

[53] Includes three points of diversion on Clark Creek.

[54] Includes two water licenses.

[55] Includes two water licenses.

[56] Multiple points of diversion under licence. Other point of diversion on Brent Lake.

[57] Multiple points of diversion under licence. Other points of diversion on Farleigh Lake and Brent Lake.

[58] Multiple points of diversion under licence. Other points of diversion on Farleigh Lake.

[59] Multiple points of diversion under licence. Other points of diversion on Brent Lake.

	Shatford Creek near Penticton (08NM037). The estimated weekly time series should then be reconciled with the LT mad (for 1996-2010) identified by the updated regional runoff relations (i.e., updated version of Figure 3-3). As a check, the final time series should be reviewed against the records at Shingle Creek at the Mouth (08NM150) and at Upper and Lower Shingle Creek by the ONA, recognizing that these records represent different periods and may be influenced by flow regulation. Streamflows at the streamflow point-of-interest (i.e., on the alluvial fan) should then be discounted according to the expected loss between the fan apex and the EFN point-of-interest. This loss can be assumed uniform throughout the year, even though it is likely to vary seasonally with the elevation of groundwater table.
	Residual Streamflows Under Current Water Use and Management
	Weekly residual streamflows for Shingle Creek under current water use and management should be estimated by summing the naturalized streamflow and the following: 1) Expected weekly net flow (+ or -) associated with upland storage reservoir operation (i.e., Brent and Farleigh Lakes with a total licensed storage of 1,566 ML). The PIB I.R. No. 1 and Farleigh Lake Water Users Community should be contacted to identify patterns of reservoir operation and obtain reservoir/water use information (if available); if this information proves difficult to obtain, then an assumed fill and release schedule along with the total licensed storage will be used. 2) Expected weekly water extraction upstream of the EFN point-of-interest. This information will be based on the OWDM and the estimated demands associated with the water use areas identified above (i.e., PIB I.R. No. 1, Bobtail Ranch, and “Other”).
	Residual Streamflows Assuming Maximum Licence Use
	Weekly residual streamflows for Shingle Creek under maximum licensed use should be estimated in a similar way as for the current water use and management. The primary difference is that estimated demands from the OWDM would be replaced by the estimated total licensed extraction upstream of the EFN point-of-interest. The assumed weekly distribution of water licences would be identified by purpose using the estimated demands from the OWDM.
References	Useful References to support the Development of Streamflow Datasets Dobson Engineering Ltd. (Dobson). 2008. Water Management and Use Study. Prepared for Okanagan Basin Water Board, December 2008. Letvak, D.B. 1988. Runoff in Okanagan Valley 1983-87. Memorandum dated May 3, 1988. BC Ministry of Environment and Parks, Water Management Branch. File S2109, Study 272. Letvak, D.B. 1980. Annual Runoff Estimates for West Side of Okanagan Valley. BC Ministry of Environment. January 1980. Northwest Hydraulic Consultants Ltd. (NHC). 2001. Hydrology, Water Use, and Conservation Flows for Kokanee Salmon and Rainbow Trout in the Okanagan Lake Basin, BC. Prepared for BC Fisheries, Fisheries Management Branch, August 2001. Obedkoff, W. 1980a. Memorandum re. Proposed Irrigation Project for Penticton Indian Band - Storage Requirement. Obedkoff, W. 1980b. A collection of memorandums pertaining to Water Supply for Shingle Creek and Brent Lake. Ecocat Report ID 13061. Summit Environmental Consultants Inc. (Summit). 2009a. Surface Water Hydrology and Hydrologic Modelling Study – “State of the Basin” Report. Prepared for the OBWB, September 2009. Walker, T. 2014. New gravity-fed sockeye hatchery opens in British Columbia. Hatchery International. http://hatcheryinternational.com/Profiles/new-gravity-fed-sockeye-hatchery-opens-in-british-columbia/

Appendix B – Updated Provincial Hydrologic Zone Regional Runoff Relations

Associated Environmental

Date:	July 3, 2018	**File:**	2018-8028.000.002
To:	Okanagan Basin Water Board		
From:	Drew Lejbak, M.Sc., GIT (Associated); Lars Uunila, M.Sc., P.Geo. (Polar Geoscience Ltd.)		
Project:	Okanagan Tennent Method - Streamflow Dataset Development		
Subject:	Development of Updated Regional Runoff Relations		

MEMO

1 INTRODUCTION AND OBJECTIVES

The Okanagan Tennant method is the recommended method for setting initial environmental flow need (EFN) targets for Okanagan streams (Associated 2016)[1]. The Okanagan Tennant method is a desktop assessment that provides initial insight into the risks to aquatic habitat and ecological processes from existing and proposed water allocations relative to natural or naturalized flows. Recommended steps to complete the Okanagan Tennant method are outlined by Associated (2016). There are three steps that require the compilation of specific streamflow data or statistics as follows:

- Step 4 requires the identification of naturalized long-term mean annual discharge (LT mad),
- Step 10 requires the creation of three annual hydrographs (naturalized, residual, and maximum licensed)[2], and
- Step 11 requires the calculation of percentile streamflows for each hydrograph.

To support streamflow dataset development for the application of the Okanagan Tennant method within Okanagan tributaries, the scaling of hydrometric records (i.e., Water Survey of Canada [WSC] or other) from one location within a watershed to another location within the same watershed or to a location within a neighbouring (or regional) watershed is required. Because of this, Associated (2017)[3] identified the need to update provincial regional median elevation runoff relations (i.e., Obedkoff 1998)[4] and/or develop mean annual precipitation versus mean annual volume relations for the 1996-2010 standard period[5].

Following the above, the updating/development of regional runoff relations is a required task prior to streamflow dataset development for the application of the Okanagan Tennant method. Accordingly, the objectives of this memorandum are as follows:

- Update the provincial regional median elevation runoff relations (i.e., Obedkoff 1998; Summit 2009)[6] to the 1996-2010 standard period. Specifically, update the runoff relations for hydrologic zones 14 (Northern Columbia

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[1] Associated Environmental Consultants Inc. (Associated). 2016. Collaborative Development of Methods to Set Environmental Flow Needs in Okanagan Streams, Working Document Version 1, Prepared for Okanagan Basin Water Board, Okanagan Nation Alliance and BC Ministry of Forests, Lands and Natural Resource Operations. May 2016.

[2] A fourth hydrograph is also required when assessing the impacts from a proposed diversion under a new water license application. It is not identified to here, since this hydrograph is to be completed by water authorization officers at a later date when assessing new water licenses.

[3] Associated Environmental Consultants Inc. (Associated). 2017. Recommended methods for the Development of Streamflow Datasets to Support the Application of the Okanagan Tennant Method in Okanagan Streams. Prepared for the Okanagan Basin Water Board, December 2017.

[4] Obedkoff, W. 1998. Streamflow in the Southern Interior Region. BC Ministry of Environment, Lands, and Parks. Water Inventory Section, Resource Inventory Branch, December 1998.

[5] A standard period of 1996-2010 was recommended by Associated (2017) for streamflow datasets development. This period includes the most available WSC information and actual and estimated water demands.

[6] Summit Environmental Consulants Ltd. (Summit). 2009. Surface Water Hydrology and Hydrologic Modelling – State of the Basin Report. Prepared for the Okanagan Basin Water Board, September 2009.

Mountains), 15 (Fraser Plateau), 23 (Okanagan Highlands), and 24 (South Thompson Plateau), which all cover a portion of the Okanagan Basin.

- Develop mean annual precipitation versus mean annual runoff relations for the 1996-2010 standard period using area-weighted mean annual precipitation information (gridded) for the Okanagan Basin obtained from Agriculture and Agri-Foods Canada.

Note that the development of the mean annual precipitation versus mean annual volume relations was a method recommended by the BC Ministry of Forests, Lands, and Natural Resource Operations (after review of Associated [2017]).

2 UPDATED REGIONAL MEDIAN ELEVATION RUNOFF RELATIONS

Regional median elevation runoff relations developed by Obedkoff (1998) and Summit (2009) describe how mean annual runoff varies with elevation and geographic location in the BC Southern Interior (and the Okanagan Basin). The annual runoff predicted by the regional median elevation runoff relations describes the general pattern of runoff and provides a basis for which monthly and weekly runoff can be estimated with knowledge (or estimation) of the distribution of runoff at a point-of-interest. This is particularly useful in ungauged watersheds.

The following sections summarize the methods used to develop updated regional median elevation runoff relations for hydrologic zones “14”, “15”, “23”, and “24”, to the 1996-2010 standard period.

2.1 Hydrometric Station Selection

Obedkoff (1998) and Summit (2009) selected WSC hydrometric stations that were considered representative of regional runoff characteristics for each respective hydrologic zone. Therefore, to update the regional runoff relations to the 1996-2010 standard period, a screening of WSC hydrometric stations located within and surrounding the Okanagan Basin was completed. The hydrometric station screening included the following criteria:

- Recorded natural streamflows, or the level of regulation was deemed insignificant on an annual basis.
- Recorded streamflow throughout the year.
- Overall record of streamflow is generally greater than five years.
- Contained at least some streamflow records during the 1996-2010 standard period.

While the above criteria were desirable, a relatively small number of hydrometric stations within the Okanagan Basin (and surrounding areas) had these characteristics. Therefore, it was necessary to include hydrometric stations lacking some of the desired criteria to provide at least some basic insight to the hydrology of the respective hydrologic zones of interest. In total, 53 hydrometric stations were identified as suitable to support the updating of the regional runoff relations. The 53 hydrometric stations used to update the regional median elevation runoff relations are shown in Figure 2-1 and summarized in Table 2-1.

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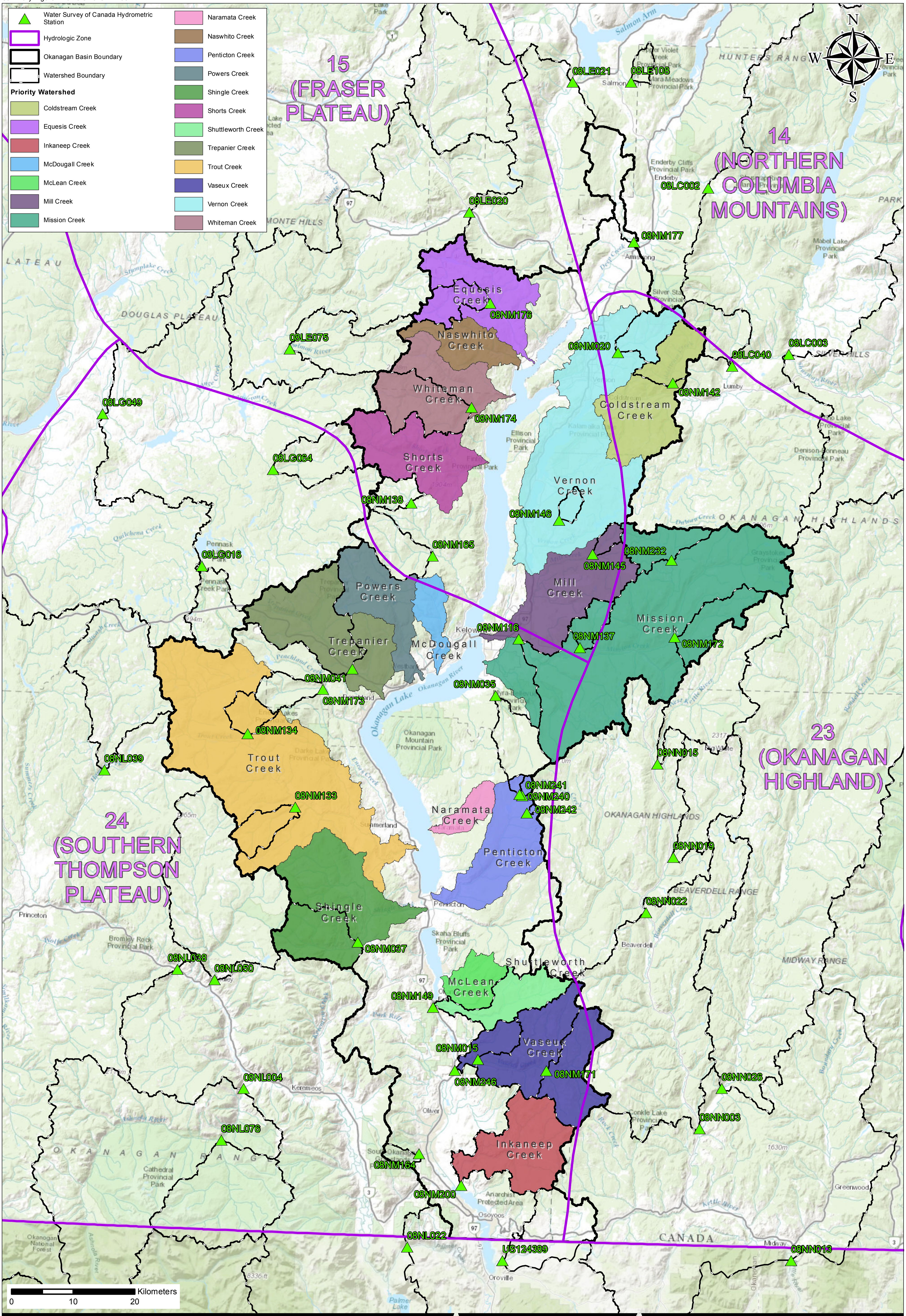

PROJECT NO.: 2018-8028.000.000

DATE: May 2014

DRAWN BY: DA

SUMMARY OF HYDROLOGIC CHARACTERISTICS AND WATER SURVEY OF CANADA HYDROMETRIC STATIONS USED TO UPDATE REGIONAL RUNOFF RELATIONS

Okanagan Basin Water Board

Okanagan Tennant Method – Streamflow Dataset Development

Associated Environmental

Table 2-1 List of Water Survey of Canada hydrometric stations used to develop updated regional median elevation runoff relations

Hydrologic Zone	WSC Station No.	WSC Station Name[1,2]	Natural / Regulated	Years of Record	Drainage Area (km^2)	Median Elevation (m)	Normal Annual Runoff[3] (mm)	Mean Annual Precipitation[4] (mm)	Runoff : Precipitation Ratio
14	08LE077	**Corning Creek near Squilax**	Nat	1996-present	28.0	1322	404	776	0.52
14	08LE108	**East Canoe Creek above Dam**	Nat	1983-present	16.4	1067	206	795	0.26
14	08LC002	**Shuswap River near Enderby***	Reg	1911-present	4725	1281	593	933	0.64
14	08LC003	**Shuswap River near Lumby**	Reg	1913-present	2006	1419	803	995	0.81
14	08LC040	**Vance Creek below Deafies Creek**	Nat	1970-present	68.2	1050	227	720	0.32
15	08LE112	**Chase Creek above the Mouth**	Reg	1996-present	293.2	1249	173	623	0.28
15	08NM146	Clark Creek near Winfield	Nat	1968-1982, 2013-present	14.7	1366	156	712	0.22
15	08NM137	Daves Creek near Rutland	Nat	1965-1986	31.6	1316	107	672	0.16
15	08NM177	Deep Creek at Young Road	Nat	1970-1975	79.7	689	51	587	0.09
15	08NM176	Ewer Creek near the Mouth	Nat	1971-1986	51.5	1453	202	760	0.27
15	08NM165	Lambly Creek above Terrace Creek	Reg	1970-1998	77.2	1397	222	793	0.28
15	08LE075	**Salmon River above Salmon Lake**	Nat	1965-2002	140.6	1375	156	762	0.20
15	08LE020	**Salmon River at Falkland**	Reg	1911-present	1050	1189	92	595	0.15
15	08LE021	**Salmon River near Salmon Arm**	Reg	1911-present	1559	1128	105	592	0.18
15	08NM138	Terrace Creek near Kelowna	Reg	1965-1992	32.2	1473	268	841	0.32
15	08NM174	Whiteman Creek above Bouleau Creek*	Nat	1971-present	107.3	1434	184	805	0.23
23	08NM232	Belgo Creek Below Hilda Creek	Reg	1976-present	64.1	1405	256	810	0.32
23	08NM145	Bulman Creek at the Mouth	Reg	1968-2004	13.9	1398	142	788	0.18
23	08NM020	BX Creek above Vernon Intake	Reg	1921-1999	53.5	1166	169	755	0.22
23	08NM142	Coldstream Creek above Municipal Intake*	Nat	1967-present	61.8	1132	126	705	0.18
23	08NN013	**Kettle River near Ferry***	Nat	1928-present	5684	1317	248	-	-
23	08NN026	**Kettle River near Westbridge**	Reg	1975-present	2146	1447	402	760	0.53
23	08NM116	Mission Creek near East Kelowna	Reg	1949-present	785.9	1393	243	739	0.33
23	08NM172	Pearson Creek near the Mouth	Nat	1970-1987	73.2	1572	377	879	0.43
23	08NN019	Trapping Creek near the Mouth*	Nat	1965-present	147.7	1361	299	653	0.46
23	08NN003	**West Kettle River at Westbridge**	Reg	1914-present	1898	1348	211	639	0.33
23	08NN022	**West Kettle River below Carmi Creek**	Nat	1973-1996	1186	1393	258	683	0.38
23	08NN015	**West Kettle River near McCulloch***	Nat	1949-present	231	1628	467	854	0.55
24	08NL004	**Ashnola River near Keremeos***	Nat	1914-present	1054	1881	206	-	-
24	08LG064	**Beak Creek at the Mouth**	Nat	1982-2001	89.9	1460	155	777	0.20
24	08NM035	Bellevue Creek near Okanagan Mission	Nat	1911-1986	72.7	1541	155	653	0.24
24	08NM133	Bull Creek near Crump	Nat	1965-1986	45.9	1547	87	554	0.16
24	08NM134	Camp Creek at the Mouth near Thirsk*	Nat	1965-present	34.7	1456	127	684	0.19
24	08NM242	Dennis Creek near 1780 m Contour	Nat	1985-present	1.50	1902	1173	834	1.41
24	08NL076	**Ewart Creek near Cathedral Park**	Nat	1998-present	251.3	1955	222	-	-
24	08NM173	Greata Creek near the Mouth*	Nat	1971-present	43.9	1305	55	644	0.09
24	08NL050	**Hedley Creek near the Mouth**	Nat	1973-present	390.3	1677	184	586	0.31
24	08NM200	Inkaneep Creek near the Mouth	Reg	1973; 2006-present	178.8	1299	65	494	0.13
24	08LG049	**Nicola River above Nicola Lake**	Reg	1915-present	1415	1324	92	615	0.15
24	USGS 12438900	**Ninemile Creek near Oroville, WA**	Reg	2006-present	121	1153	14	-	-

Hydrologic Zone	WSC Station No.	WSC Station Name[1,2]	Natural / Regulated	Years of Record	Drainage Area (km^2)	Median Elevation (m)	Normal Annual Runoff[3] (mm)	Mean Annual Precipitation[4] (mm)	Runoff : Precipitation Ratio
24	08LG016	**Pennask Creek near Quilchena**	Nat	1920-present	85.3	1672	255	756	0.34
24	08NM037	Shatford Creek near Penticton	Reg	1919-1927; 1964-present	100.9	1526	111	528	0.21
24	08NM149	Shuttleworth Creek at the Mouth	Reg	1969-2010	90.0	1541	68	628	0.11
24	08NL038	**Similkameen River near Hedley***	Nat	1965-present	5574	1421	260	-	-
24	08NL022	**Similkameen River near Nighthawk**	Reg	1928-present	9141	1476	225	-	-
24	08NL039	**Siwash Creek near Princeton**	Reg	1967-present	253.9	1468	158	664	0.24
24	08NM164	Testalinden Creek in Canyon	Nat	1969-1986	12.8	1257	65	536	0.12
24	08NM041	Trepanier Creek near Peachland	Reg	1919-2012	184.1	1365	155	660	0.23
24	08NM240	Two-forty Creek near Penticton	Nat	1984-present	4.97	1752	403	772	0.52
24	08NM241	Two-forty-one Creek near Penticton	Nat	1984-present	5.19	1724	360	770	0.47
24	08NM015	Vaseux Creek above Dutton Creek	Nat	1919-1982	254.8	1600	162	665	0.24
24	08NM171	Vaseux Creek above Solco Creek*	Nat	1970-present	117.5	1694	239	683	0.35
24	08NM246	Vaseux Creek near the Mouth	Reg	2006-2010	294.1	1569	88	649	0.14

Note:

1. WSC station names that are bolded are located outside of the Okanagan Basin.
2. An '*' represents a WSC hydrometric station used to normalize streamflow records to the 1996-2010 standard period.
3. Mean annual runoff for the 1996-2010 standard period.
4. Area-weighted mean total annual precipitation for the 1996-2010 standard period. Missing values are due to climate datasets not available from Agriculture and Agri-Foods Canada south of the Canada-United States international border.

2.2 Regional Median Elevation Runoff Relations

For each of the selected hydrometric stations (Section 2.1), mean annual discharge (in units of m3/s) for each year of record were compiled and converted to mean annual unit discharge (i.e., runoff, in units of mm). To make comparisons for the 1996-2010 standard period, mean annual runoff data was normalized. While there are different approaches to adjust data of different periods so that they reflect a standard period, a relatively straightforward approach was adopted for this task. It involved scaling the mean annual runoff for the available period of record at each hydrometric station by a factor that reflected how much runoff over the specific period compared to the 1996-2010 period. This factor was based on averaging the patterns of runoff from 11 hydrometric stations listed in Table 2-1 that operated between 1996 and 2010 and have records of natural streamflows. Although the patterns of mean annual runoff vary slightly between the 11 hydrometric stations, the overall average pattern was considered reasonably consistent in the region. The normalized runoff for each of the 53 hydrometric stations is presented in Table 2-1.

Following the approach applied by Obedkoff (1998), all normalized runoff data was first stratified by hydrologic zone (Figure 2-1) and then plotted against median elevation of the drainage area[7] on semi-log graph paper (Figure 2-2). The best-fit relations for the four hydrologic zones of interest were then fitted by eye using professional judgement since not all hydrometric stations are given equal weighting. This is necessary since some of the hydrometric stations have regulated streamflow, some have relatively short records, and some maybe influenced by groundwater-surface water interactions on alluvial fans.

A suite of parallel lines on semi-log graph paper (curvilinear or arithmetric paper) reflect the general pattern of increasing runoff with elevation and increasing runoff from the south to the north as one moves from hydrologic zones “24” to “15” to “23” to “14”.

[7] The drainage area for each of the 53 hydrometric stations was calculated using Geographic Information System (GIS) techniques and elevation information obtained from GeoBC. As a result, drainage areas may differ than those reported by the WSC and Obedkoff (2009). In addition, corresponding median elevations for each respective drainage area were calculated using GIS techniques and are updated from Obedkoff (1998).

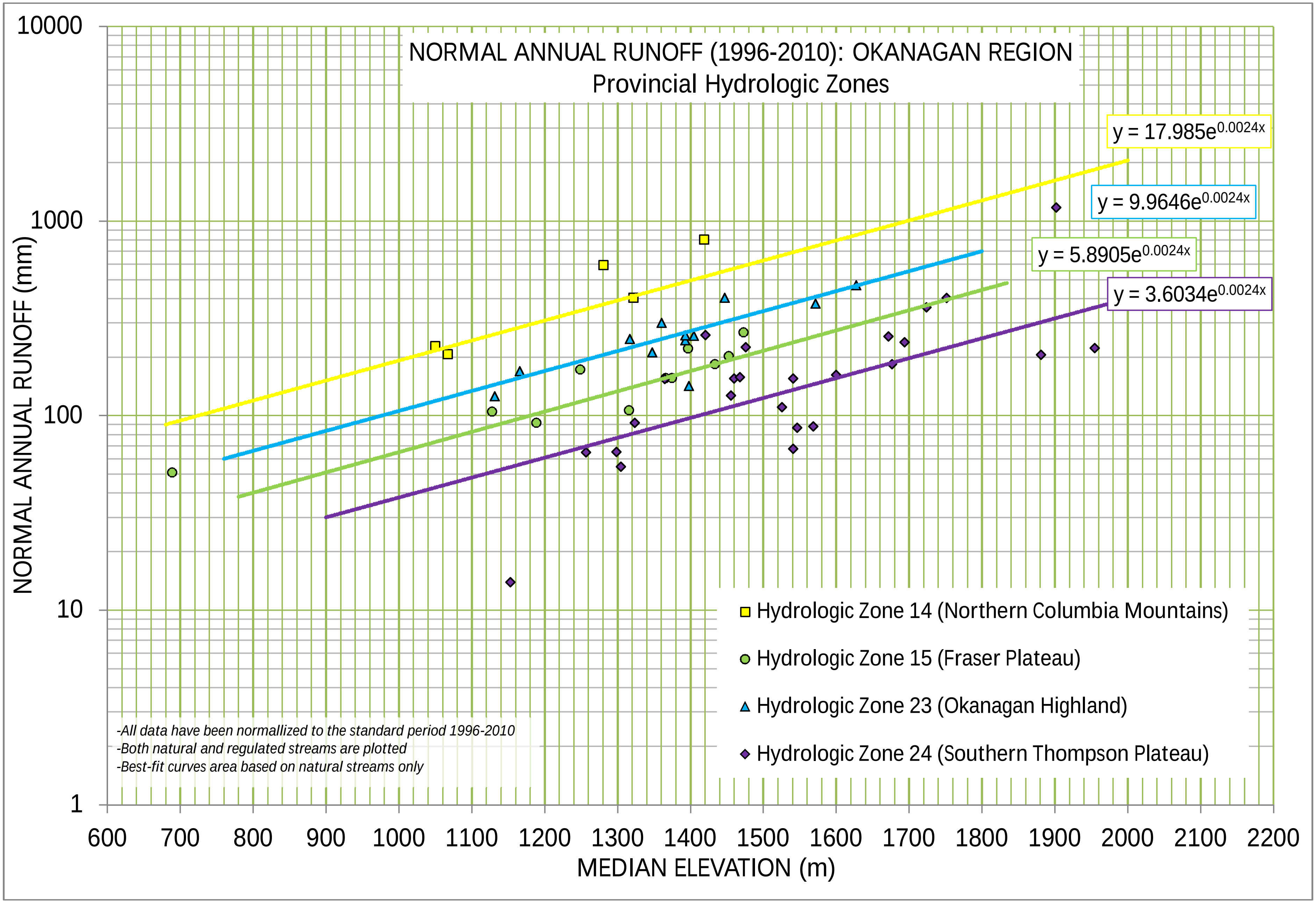

Figure 2-2 **Updated normal annual runoff (1996-2010) relations for provincial hydrologic zones 14 (Northern Columbia Mountains), 15 (Fraser Plateau), 23 (Okanagan Highlands), and 24 (South Thompson Plateau)**

3 REGIONAL PRECIPITATION RUNOFF RELATIONS

In addition to the regional median elevation runoff relations (Section 2.2), precipitation runoff relations can be used to support scaling of runoff within or between watersheds (Bovee 1982)[8]. Following this, gridded precipitation information was obtained from Agriculture and Agri-Foods Canada for the spatial extent of the regional WSC hydrometric station watersheds included within Table 2-1. The gridded precipitation information was available at a 500 m by 500 m cell size and included the mean total annual precipitation for each cell for each year of the standard period (1996-2010).

For each of the regional WSC hydrometric station watersheds, an area-weighted precipitation value was calculated and the mean annual precipitation for the 1996-2010 standard period is included in Table 2-1. Following Bovee (1982), the mean annual precipitation was plotted against mean annual runoff for each respective WSC hydrometric station for each hydrologic zone (Section 2.2). The results found that there were no significant relationships between mean annual precipitation and runoff within respective hydrologic zones, which can be observed by the variability in runoff:precipitation ratios reported in Table 2.1. As a result, no specific precipitation runoff relations were developed to support the scaling of hydrometric records within or between watersheds. Instead, the runoff:precipitation ratios (Table 2.1) can be used to generally review/confirm scaling factors obtained from the updated regional median elevation runoff relations (i.e., Figure 2-2).

[8] Bovee, K. 1982. A Guide to Stream Habitat Analysis Using the Instream Flow Incremental Methodology. Instream Flow Information Paper No. 12. Western Energy and Land Use Team.

Appendix C – Temporal Period Streamflow Adjustment Factor

Associated Environmental

Date:	August 3, 2018 **File:** 2018-8028.000
To:	Nelson Jatel, Okanagan Basin Water Board
From:	Drew Lejbak
Project:	Development of Streamflow Datasets to Support the Application of the Okanagan Tennant Method within Okanagan Streams
Subject:	Temporal Period Streamflow Adjustment Factor

MEMO

1 INTRODUCTION

Associated (2017) outlines a general approach and specific steps for the development of streamflow datasets within the Okanagan Basin tributaries to support the setting of environmental flow needs (EFNs) using the Okanagan Tennant method. Specifically, Associated (2017) provides methods for the development of the following weekly streamflow datasets:

- naturalized long-term mean annual discharge (LT mad);
- representative time-series of naturalized (or natural) streamflow (i.e., streamflow in the absence of any regulation);
- representative time-series of streamflow under current water use and management (i.e., residual streamflow); and
- representative time-series of streamflow assuming maximization of licensed storage and withdrawals (i.e., maximum licensed residual streamflow).

For establishing EFNs using the Okanagan Tennant method, long-term streamflow datasets are required to sufficiently capture climate variability while also representing "current" (and presumed near future) water management within respective watersheds. Thus, streamflow statistics are required that are both long enough to gain statistical confidence and include wet and dry periods. Associated (2017) recommended that for the purposes of streamflow dataset development to support the Okanagan Tennant method, the 1996-2010 (n = 15 year) period be adopted. This period was recommended because of the lack of information on water management within the Okanagan Basin specifically pertaining to upland reservoir operations prior to 1996. In addition, Agriculture and Agri-Foods Canada noted that the Agricultural Land Use Inventory (ALUI) (that the Okanagan Water Demand Model [OWDM] uses to support water demand estimates) is insufficient to reflect land use conditions within the Okanagan Basin prior to the mid-1990's.

Accordingly, the 1996-2010 period was adopted for application of streamflow dataset development to support the application of the Okanagan Tennant method. However, following review of draft streamflow datasets for some Okanagan Basin tributaries, the Okanagan Nation Alliance (ONA) expressed concern over the summer streamflow estimates based on the 1996-2010 period (McGrath, pers. comm., 2018). Specifically, the ONA noted that based on historic knowledge, the initial estimates of naturalized streamflows for the summer period (August to September) were suspected to generally underestimate the streamflows experienced in recent historical times that are known to support fish population needs (McGrath, pers. comm., 2018). If this suspicion were true, then the initial streamflow datasets would introduce undesirable bias into the EFN-setting process.

To address ONA's concern, this memorandum re-examines the 1996-2010 period in relation to other long-term periods. Furthermore, this memorandum reviews patterns of natural/human influenced climate variability and provides a recommendation to adjust streamflow datasets to make them more representative of streamflow conditions supporting historic fish populations needs. This memorandum is provided to representatives of the Okanagan Basin Water Board, ONA, BC Ministry of Forests, Lands, Natural Resource Operations, and Rural Development, and BC Ministry of Environment for review, comment, and approval for moving forward.

2 STREAMFLOW VARIABILITY IN THE OKANAGAN BASIN

2.1 Background

It is known that the climate of the Okanagan Basin is changing, and this has led to several water supply and demand studies to investigate current and future water availability (e.g., Summit 2010; Polar 2012). The longest available records in the Okanagan Basin date from about 1900 and show increased air temperatures in the years leading up to 2013 and reduced snow as a proportion of total precipitation (Summit 2009; MOE 2016). Future climate projections indicate that winter, summer, and mean annual air temperatures will increase over the next 80-100 years, and there will be a seasonal shift in precipitation with more falling in the winter and less in the summer (Cohen et al. 2001 and 2004; MOE 2016). Summit (2009) notes that the hydrologic implications include a thinner snowpack, earlier snowmelt, and lower streamflows in the late summer, and increased agricultural water demand because of drier and hotter summers and a longer growing season.

The predicted future hydrologic trends for the Okanagan Basin are generally consistent with the results of other investigations completed on historic streamflow records in Canada. Both Whitfield and Cannon (2000) and Zhang et al. (2001) reviewed historic streamflow records and found that for available periods of record (i.e., 10-year to 50-year periods), locations within the interior of BC generally were found to have declining summer streamflows and increasing winter streamflows. These changes in streamflow patterns were attributed to interdecadal variations in hydroclimatic variables only, since the assessment of long-term tendencies was limited by dataset availability.

2.2 Summer and Winter Streamflows – Okanagan Basin

Understanding that climate and hydrologic patterns have deviated from long-term conditions within the interior of BC, a preliminary step to assessing whether the 1996-2010 period is reflective of long-term conditions is to review available natural streamflow record trends within the Okanagan Basin.

In the Okanagan Basin only the following four active Water Survey of Canada (WSC) hydrometric stations have a lengthy (i.e., >40 years) record of natural streamflows[1]:

- Camp Creek at the Mouth near Thirsk (WSC Station No. 08NM134; Period of Record = 1965-present; 34.6 km^2);
- Vaseux Creek above Solco Creek (WSC Station No. 08NM171; Period of Record = 1970-present; 117 km^2);
- Coldstream Creek above Municipal Intake (WSC Station No. 08NM142; Period of record = 1967-present; 60.6 km^2); and
- Whiteman Creek above Bouleau Creek (WSC Station No. 08NM174; Period of Record = 1971-present; 107 km^2).

[1] The WSC hydrometric station Great Creek near the Mouth (WSC Station No. 08NM173) is noted by the WSC as measuring natural streamflows. However, upon further discussions with the WSC (Hutchinson, pers. comm., 2018), it appears that the hydrometric station may have been classified incorrectly due to the presence of Glen Lake dam upstream, which historically regulated streamflows downstream for a portion of the year. Thus, this hydrometric station was not considered further to support this review/analysis.

Using a consistent period of record for all hydrometric stations (i.e., 1971-2014; n = 44 years)[2], late summer (August to September) and winter (December to March) runoff was calculated (in units of mm)[3]. Figures 2-1 and 2-2 present annual summaries of late summer and winter runoff, respectively, for these four WSC hydrometric stations. The results suggest that on average, total late summer runoff has generally been declining[4], while no observable change in total winter runoff has occurred over the available period of record. However, when comparing the long-term results of each WSC hydrometric station to the 1996-2010 period, individual differences are noted. These differences are summarized in Table 2-1.

The data presented in Table 2-1 show that for the available WSC hydrometric stations, late summer runoff for the 1996-2010 period is consistently lower than for the 1971-2014 period. However, for winter runoff, there is no consistent difference between the 1996-2010 and 1971-2014 periods. The summer runoff results agree with expected/predicted hydrologic regime changes for the Okanagan Basin, while the winter runoff results do not identify any noticeable changes.

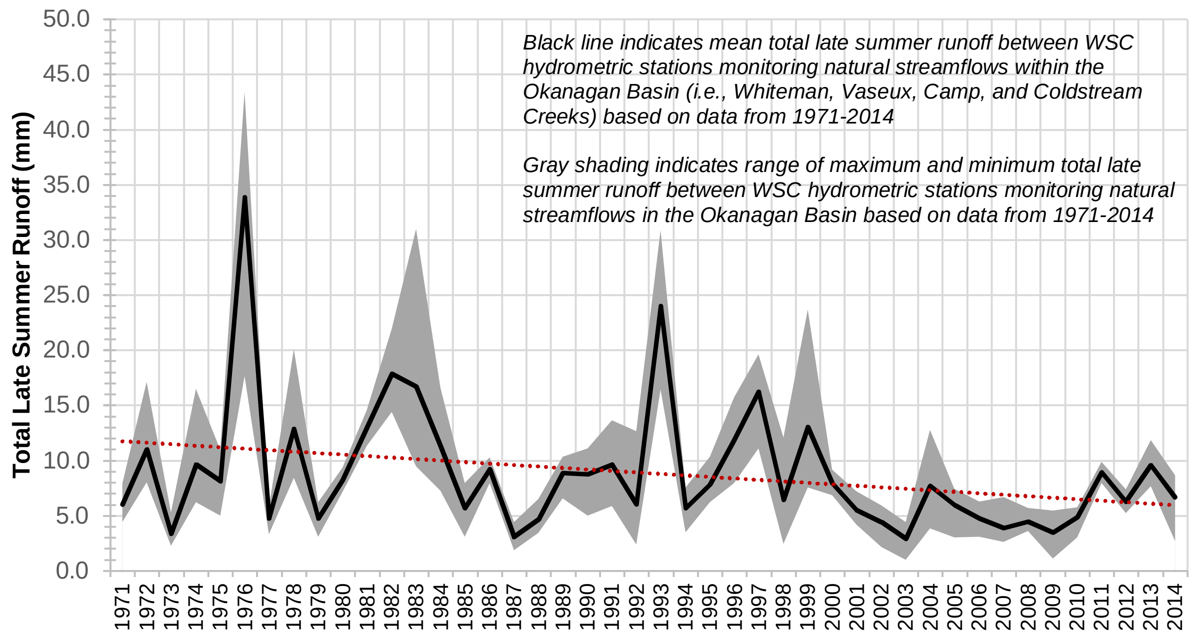

Figure 2-1 Summary of total late summer (August to September) runoff variability between four WSC hydrometric stations monitoring natural streamflows within the Okanagan Basin, 1971-2014

[2] The WSC reports that each hydrometric station is active (i.e., recording streamflows to-date); however, streamflow records are only published (available) consistently to 2014.

[3] Late summer and winter runoff were selected for analysis purposes, since these periods represent low streamflow windows that are important for maintaining aquatic habitat and meeting fish periodicity needs.

[4] Total late summer runoff at each WSC hydrometric station was observed to be declining in a similar manner at each monitoring location.

Memo To: Nelson Jatel, Okanagan Basin Water Board
August 03, 2018

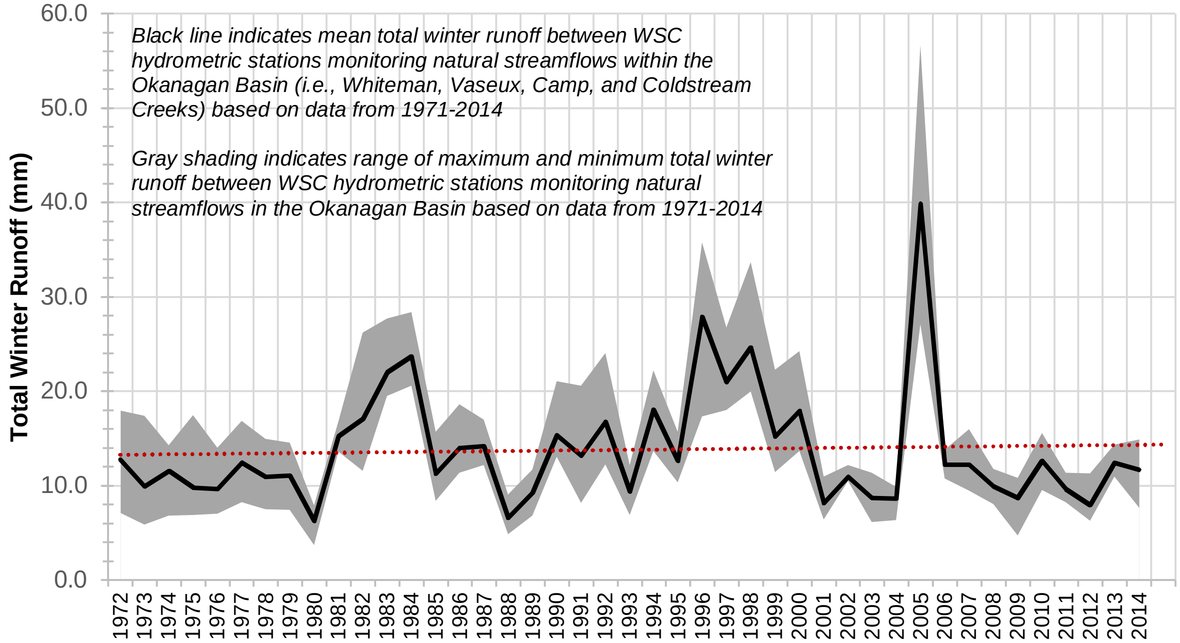

Figure 2-2 Summary of total winter (December to March) runoff variability between four WSC hydrometric stations monitoring natural streamflows within the Okanagan Basin, 1971-2014

Table 2-1 Summary of runoff variability between four WSC hydrometric stations monitoring natural streamflows within the Okanagan Basin

WSC Hydrometric Station	Total Late Summer (August to September) Runoff (mm)						Total Winter (December to March) Runoff (mm)					
	1971-2014		1996-2010		1996-2010 period in comparison to the 1971-2014 period		1971-2014		1996-2010		1996-2010 period in comparison to the 1971-2014 period	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Whiteman Creek above Bouleau Creek (08NM174)	6.59	4.99	4.34	3.11	Lower	Lower	12.69	11.21	15.07	11.23	Higher	No Change
Vaseux Creek above Solco Creek (08NM171)	11.02	8.59	8.88	5.94	Lower	Lower	13.06	12.03	14.90	12.18	Higher	No Change
Camp Creek at the Mouth near Thirsk (08NM134)	9.34	7.83	7.23	6.28	Lower	Lower	15.33	14.52	15.41	13.25	No Change	Lower
Coldstream Creek above Municipal Intake (08NM142)	8.50	7.17	7.14	5.17	Lower	Lower	14.09	11.29	18.21	11.41	Higher	No Change

3 LONG-TERM PERIOD REVIEW

Upon review of the 1996-2010 period in comparison to the available long-term period, ONA's concern that the 1996-2010 period summer runoff represents a drier period in comparison to long-term conditions is confirmed. The potential for a long-term declining trend in late summer runoff was not specifically addressed in the 2016 Okanagan EFN-setting methods document (Associated 2016). In that document, the authors recommend selection of a naturalized LT Mad value and naturalized streamflow datasets that are "representative" of current climate and water management conditions, and where the human influence on streamflow has been removed; but do not specifically address methods to investigate or account for long-term trends in climate.

The Okanagan Tennant method relies on the selection of an LT Mad value within the initial EFN-setting methods steps (i.e., Step #4 of the Okanagan Tennant method), while within-year and between-year seasonal variability is not reviewed/assessed until later steps (i.e., Steps #10 and #11 of the Okanagan Tennant method). This presents a challenge since the selection of a more recent temporal period may consistently result in streamflow conditions that are drier or wetter than historic conditions. This is currently the situation with declining summer runoff observed for >40-years in the Okanagan Basin (see Section 2). Therefore, <u>for applying the Okanagan EFN-setting methods, the selection of a temporal period (moving forward) for LT Mad and for seasonal/fish periodicity applications needs to balance the periods of available information, natural climate variability (i.e., El Nino – Southern Oscillation [ENSO] and Pacific Decadal Oscillation [PDO] cycle), and climate change influences to-date. This suggests that the Okanagan Tennant method (as described by Associated [2016]) may need to be revised to add an additional step to review climate variability/change or historic knowledge of fish presence and streamflows prior to selection of an LT Mad (i.e., Step #4).</u>

Nevertheless, in the current application of the Okanagan Tennant method, as noted within Section 1, the 1996-2010 period was recommended for Okanagan EFN-setting applications because it was felt to adequately consider climate variability and encompass the period with the most available water management information. However, the 1996-2010 period does not appear to provide a temporal window that matches well with historic conditions of streamflow and fish presence that have been observed by ONA staff. Subsequent sections provide a recommendation for a representative long-term period for EFN-setting that balances available information, natural climate variability, and climate change influences to-date in more detail and considers ONA's knowledge of historic streamflows and fish presence within the Okanagan Basin.

3.1 Available Streamflow and Water Use Information

As outlined by Associated (2017), the 1996-2010 period was recommended for the Okanagan EFN-setting application because of limitations on water management information prior to this period, and because existing ALUI datasets were deemed insufficient to reflect land use conditions if/when applying the OWDM for periods prior to the mid-1990s. The 1996-2006 period is generally consistent with that used by the Okanagan Water Supply and Demand Project (i.e., 1996-2006), which was also selected since it was identified to have the most information available on actual water use and reservoir management for the investigation (Summit 2010).

Since knowledge of naturalized and residual streamflows is required to apply the Okanagan Tennant method, capturing/incorporating actual water use and reservoir management is critical for the creation of representative and defendable streamflow datasets. However, as outlined within Section 2.2, WSC hydrometric stations with longer term periods of record are available within the Okanagan Basin. Similarly, numerous nearby regional WSC hydrometric stations are also available; however, there are only two recording natural streamflows with continuous periods of records longer than those available within the Okanagan Basin:

- Similkameen River near Princeton (WSC Station No. 08NL007; Period of Record = 1945-present; 1,810 km^2); and
- Kettle River near Laurier (WSC Station No. 08NN012; Period of Record = 1930-present; 9,930 km^2).

Therefore, based on within and outside Okanagan Basin data availability, and with the reliance on the existing active Okanagan Basin WSC hydrometric stations for scaling purposes (i.e., Associated 2017), it appears that the period of 1971-2014 would provide the longest period for EFN-setting purposes. As outlined within Section 2.2, this is the consistent period of record between all natural WSC hydrometric stations within the Okanagan Basin. The 1971-2014 period also appears to capture natural climate variability and climate change influences to-date, and the period likely represents streamflow ranges that Okanagan Basin watersheds will experience in the near future (i.e., 10-20 years). The selection of this period also removes the subjective identification of a period deemed to represent more appropriate streamflow conditions for EFN-setting that are difficult to quantify (i.e., pre-settlement within the Okanagan Basin, pre-human influenced climate change). The following section summarizes the 1971-2014 period further.

3.2 Long-Term Period Climate and Streamflow Variability

With the 1996-2010 period summer runoff identified to represent a drier period relative to recorded long-term conditions, the climate and streamflow variability of the 1971-2014 period was investigated further to compare to the 1996-2010 period. Specifically, total annual precipitation measured within Lake Country (at Environment Canada climate stations – Winfield [1128958] and Okanagan Centre [1125700])[5] and Penticton (at Penticton A [1126150]) was summarized to review the range of wet and dry years included within the 1971-2017 period (Figure 3-1)[6].

Figure 3-1 identifies alternating periods of wet and dry years throughout the 1971-2014 period, while the 1996-2010 period largely includes years with below normal total annual precipitation. Similarly, streamflow variability over the 1971-2014 period indicates trends of wet and dry periods. Cumulative departure from mean monthly runoff (following the approach applied by Kresch [1994]) was calculated for each of the four active WSC hydrometric stations monitoring natural streamflows within the Okanagan Basin (Figure 3-2). The cumulative departures are generally consistent between each WSC hydrometric station and show a slight correlation with the wet and dry period precipitation trends illustrated in Figure 3-1. Also, the cumulative departure results between WSC hydrometric stations are similar, suggesting that the climate variability captured between 1971-2014 within the Okanagan Basin is generally consistent regionally.

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[5] Due to an incomplete dataset for the Winfield climate station for the 1971-2014 period, available data from the Okanagan Centre climate station was used to fill data gaps due to its proximity to the Winfield monitoring site. However, for some years (i.e., 1982, 1983, 1986, and 2009-2011) no data or very limited data was available at both sites, so those years were not included.

[6] The Environment Canada climate stations used to create Figure 3-1 represent the climate stations with the most continuous total precipitation records available for 1971-2014.

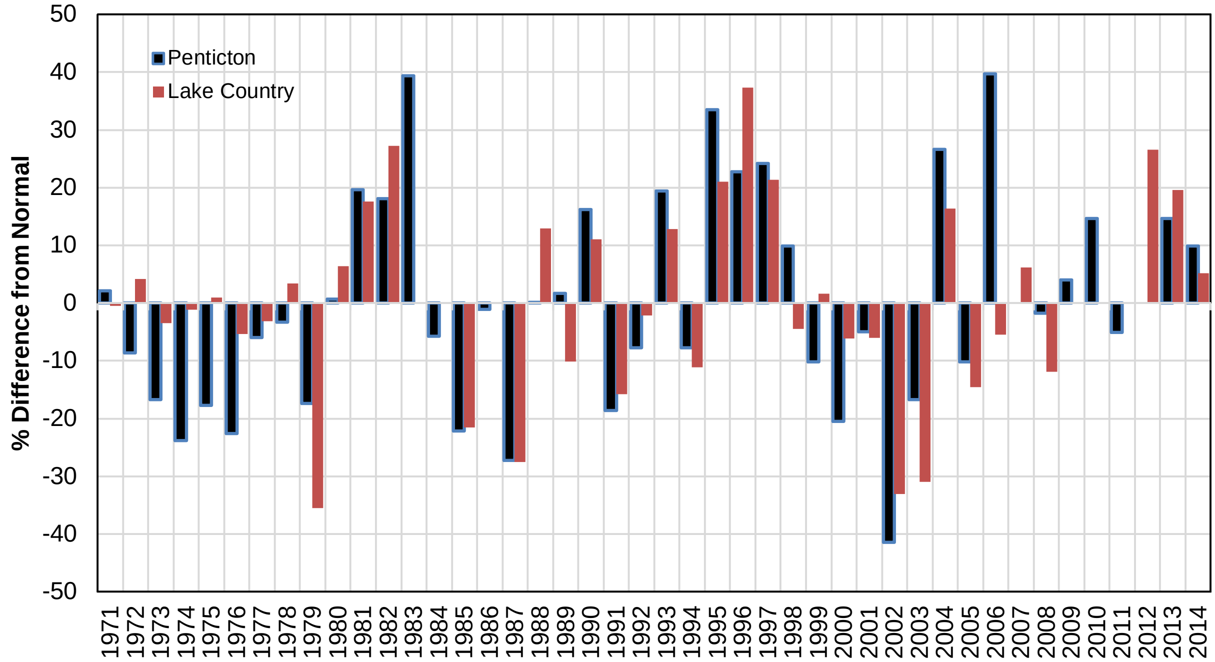

Figure 3-1 Total annual precipitation for Lake Country and Penticton, BC, plotted as the difference in percentage from the long-term (1971-2014) normal

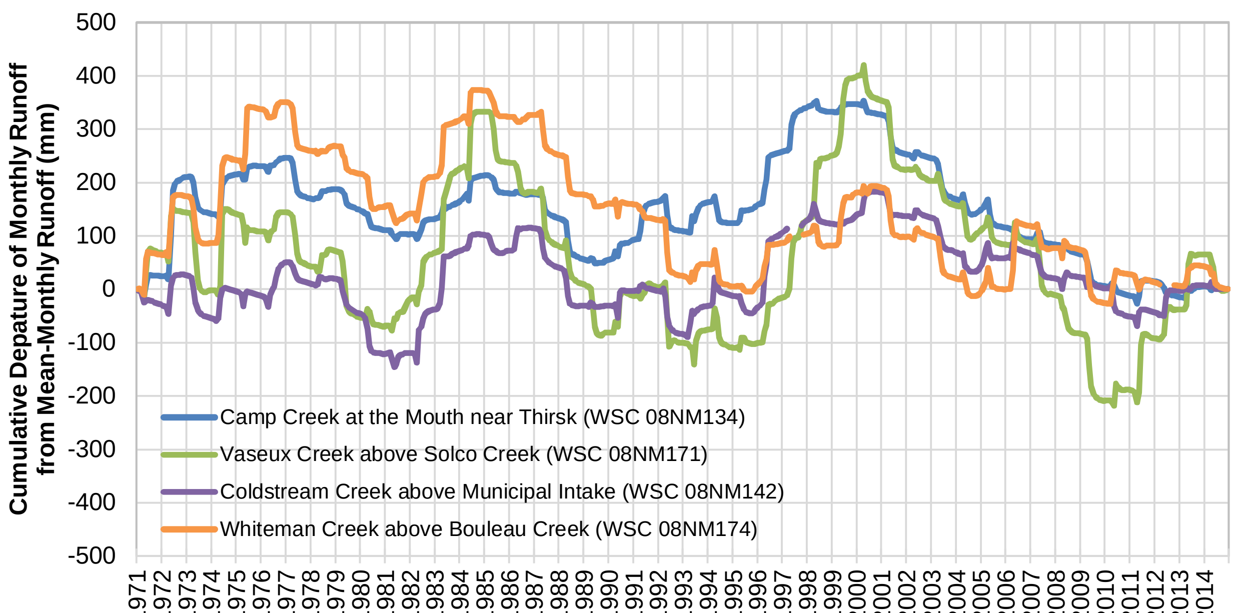

Figure 3-2 Cumulative departure of monthly mean runoff from mean-monthly runoff for four natural streamflow WSC hydrometric stations within the Okanagan Basin, 1971-2014

In addition, the mean cumulative departure from mean monthly runoff for the WSC hydrometric stations was compared to the nearby long-term regional WSC hydrometric stations (i.e., Kettle River at Laurier and Similkameen River near Princeton). The 1971-2014 period was compared specifically to available periods of long-term records (i.e., 1950-2014) available at the regional WSC hydrometric stations (Figure 3-3). Figure 3-3 indicates the 1971-2014 period has trends of increasing (i.e., wet) and decreasing (i.e., dry) departures recorded consistently between all WSC hydrometric stations, while post-1960 at the regional WSC hydrometric stations there appears to be a larger overall trend toward drier conditions. The results also suggest that the Okanagan Basin WSC hydrometric stations are better represented by the streamflows recorded by the Kettle River than the Similkameen River. This is likely related to the headwaters of the Similkameen River located within the Cascade Mountains, which experiences a more coastal precipitation pattern and larger snowfall/rainfall than that within the BC interior. Thus, annual unit runoff and freshet volumes of the Similkameen River are higher than that of the Kettle River and Okanagan Basin.

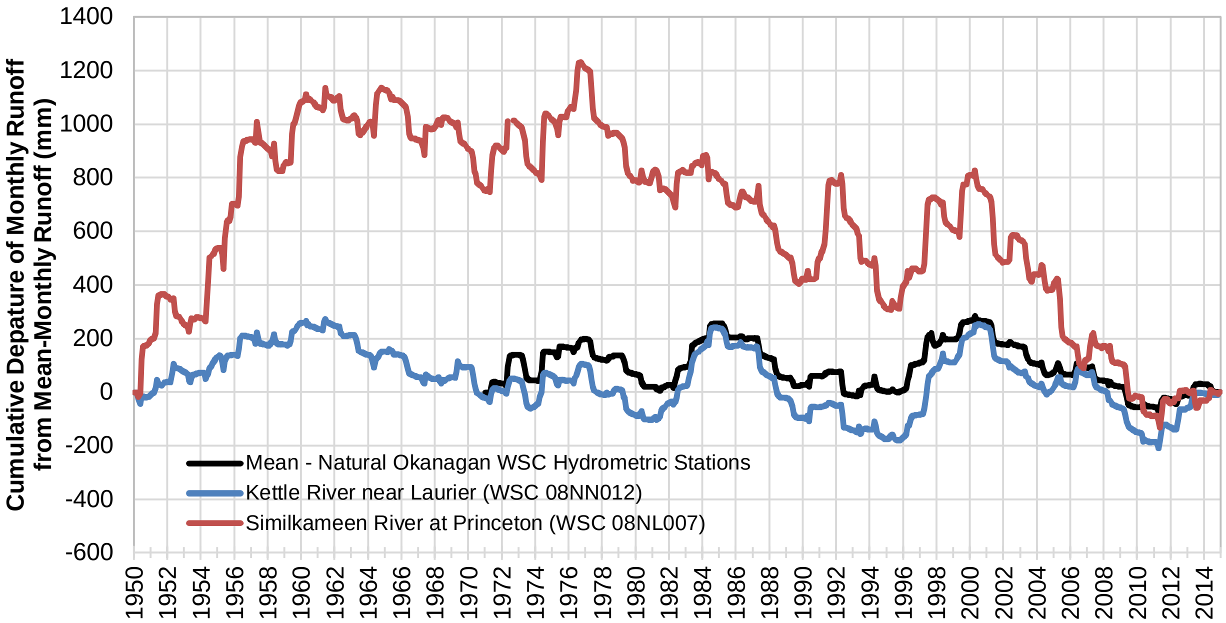

Figure 3-3 Cumulative departure of monthly mean runoff from mean-monthly runoff for Okanagan Basin and regional WSC hydrometric stations, 1950-2014

The 1971-2014 period was also reviewed in context of the El Niño / Southern Oscillation (ENSO) cycle to identify the range of warm and cold climatic periods within the Northern Hemisphere. Figure 3-4 summarizes the Oceanic Niño Index (ONI) for 1971-2014 with red periods representing warm conditions and blue periods representing cold conditions (NWS 2018). The ONI is a measure of the departure of oceanic sea surface water temperatures within the equatorial Pacific Ocean and is one measure of the ENSO cycle. Although not a direct indicator of climate variability within the Okanagan Basin, upon review of Figure 3-4, the ONI varies between warm and cold periods, suggesting that the 1971-2014 period captures a range of natural (or climate change enhanced) climatic variability and no specific bias (i.e., overly warm or cold) at the hemisphere level is noticeable.

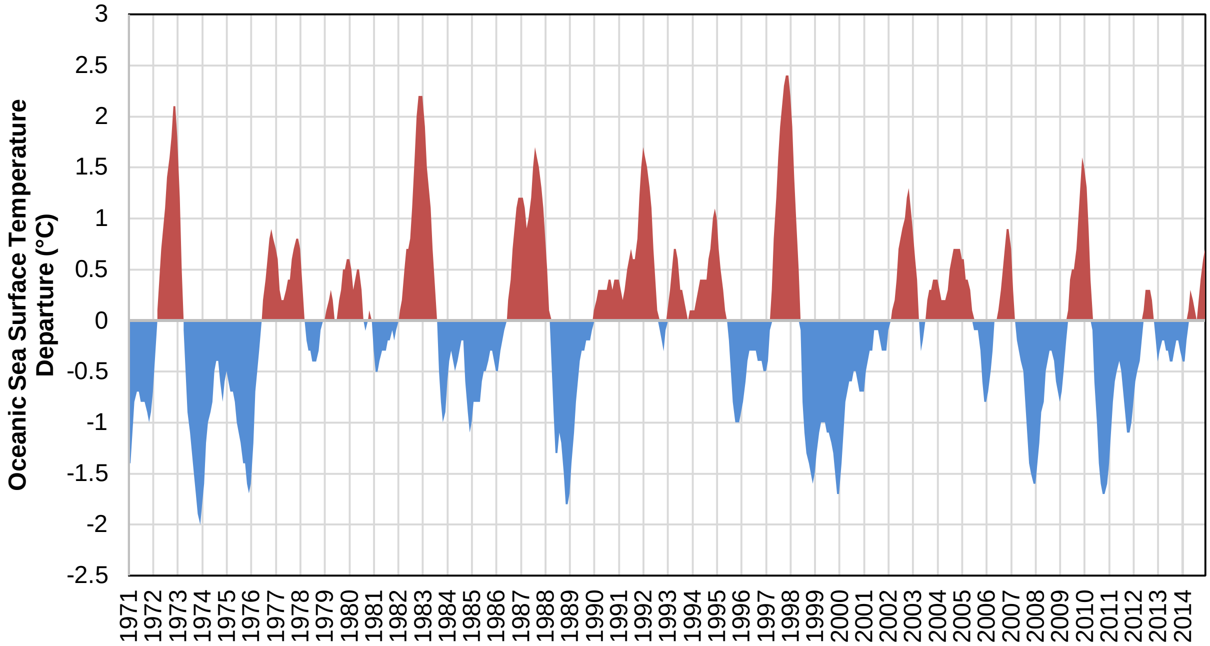

Figure 3-4 Oceanic Niño Index (from NWS 2018)

Similarly, the 1971-2014 period was also reviewed in context of the Pacific Decadal Oscillation (PDO) cycle. Figure 3-5 summarizes the PDO Index for 1971-2014 with red periods representing warm conditions and blue periods representing cold conditions (NOAA 2018). The PDO Index is a measure of the departure of oceanic sea surface water temperatures within the North Pacific Ocean. Although not a direct indicator of climate variability within the Okanagan Basin, upon review of Figure 3-5, the PDO Index captures a range of natural (or climate change enhanced) climatic variability and it appears that colder conditions have been prevalent in the North Pacific Ocean region within more recent times (i.e., post year 2000).

Based on the results of the above comparisons/reviews, the 1971-2014 period appears to provide an unbiased period of dry and wet climatic and streamflow conditions. Second, the Similkameen River may not represent the runoff regime of the Okanagan Basin appropriately enough for the present purposes. Third, although the Kettle River runoff regime appears to reflect that of the Okanagan Basin, the drainage area (i.e., 9,930 km^2) is an order (or orders) of magnitude larger than the Okanagan watersheds-of- interest for EFN-setting. Thus, some of the unique runoff characteristics of smaller watersheds may not be captured within the Kettle River streamflow records. Therefore, the 1971-2014 period is deemed the most appropriate period for EFN-setting, since the period is supported by actual WSC hydrometric station records from watersheds within the Okanagan Basin that capture any unique regional and smaller watershed characteristics that may exist.

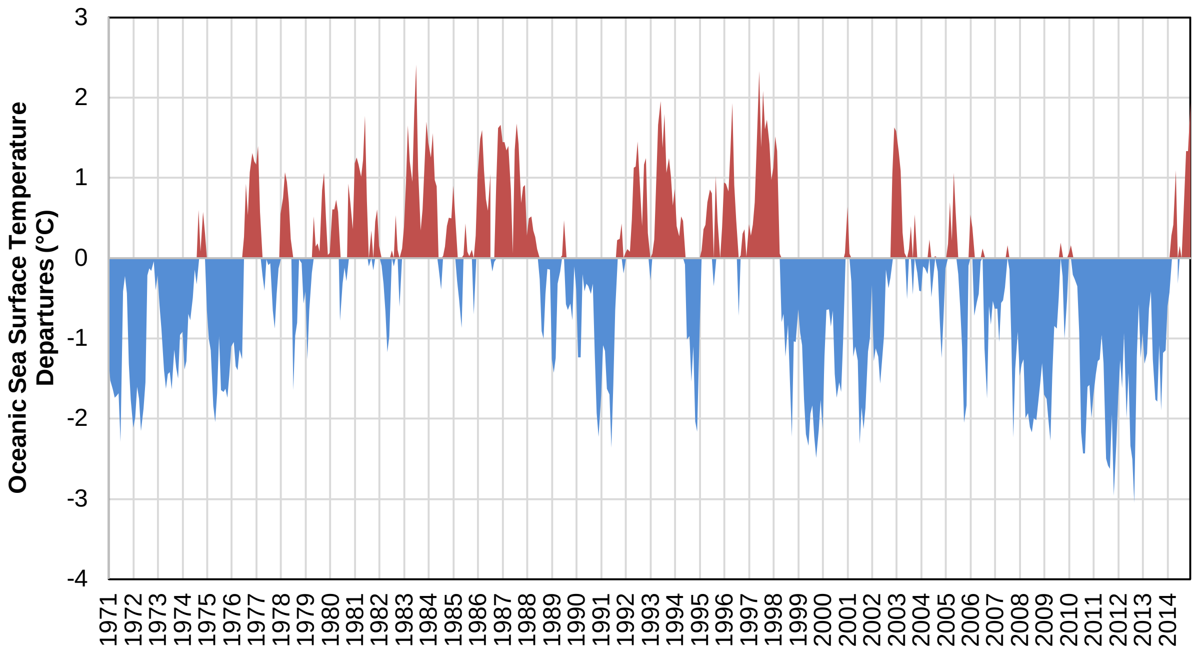

Figure 3-5 Pacific Decadal Oscillation Index (from NOAA 2018)

4 STREAMFLOW DATASET ADJUSTMENT FACTORS

Following review of the available long-term data within the Okanagan Basin, to address ONA's concern over low summer streamflow estimates, it is recommended to amend the development of streamflow datasets to support the application of the Okanagan Tennant method (as outlined by Associated [2017]) to reflect the 1971-2014 period. However, since Associated (2017) has outlined specific methods to develop weekly streamflows for the 1996-2010 period, it is recommended that dataset development still proceeds using those methods, but the resultant streamflow datasets be adjusted to 1971-2014 conditions using weekly ratios – because actual water use information and land use spatial coverages are not generally available prior to the mid-1990s.

The range of mean weekly ratios between the 1971-2014 and 1996-2010 periods for the four natural streamflow WSC hydrometric stations is presented in Figure 4-1. The results indicate that for early season streamflows (i.e., January to early June), the 1971-2014 period represents lower streamflows than the 1996-2010 period, while early summer to late fall streamflows are higher. Although the application of this adjustment method may result in reduced streamflows during the early season, higher streamflows will be calculated for the summer and fall periods which are of immediate concern to ONA for EFN-setting purposes.

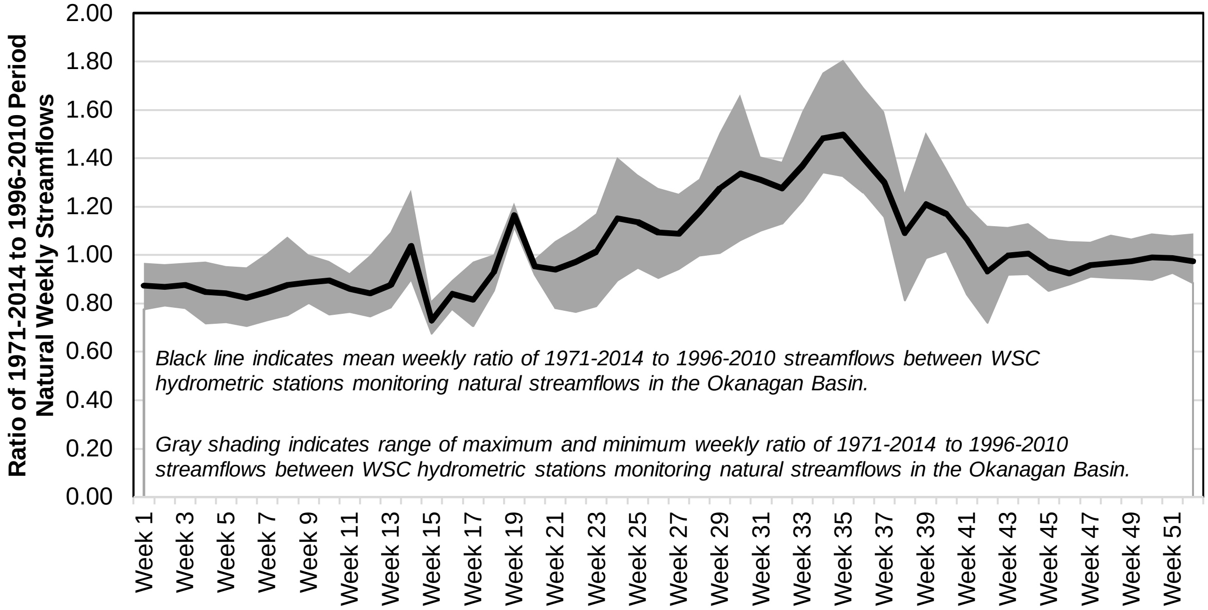

Figure 4-1 Summary of mean weekly streamflow ratios between 1971-2014 and 1996-2010 for four natural streamflow WSC hydrometric stations within the Okanagan Basin

For application purposes, it is suggested that the most appropriate weekly ratios from individual WSC hydrometric stations be applied on a watershed-by-watershed basis (i.e., Whiteman Creek weekly ratios used to adjust streamflow datasets for Whiteman Creek and other watersheds where appropriate [i.e., Naswhito Creek, Equesis Creek]), or the average weekly ratio for watersheds that are not necessarily represented well individually by one of the four natural streamflow WSC hydrometric stations (i.e., McDougall Creek). This approach leaves the selection and application of adjustment factors to professional judgment to incorporate knowledge of the Okanagan Basin, watershed(s) of interest, and/or required dataset development methods (i.e., Associated 2017). In addition, to support application purposes, the weekly ratios between the 1971-2014 and 1996-2010 periods for the four natural streamflow WSC hydrometric stations and the mean of all WSC hydrometric stations were smoothed using the LOESS function to remove some of the spikiness that occurs between weeks (an artefact of the calculation procedure). Figure 4-2 presents the smoothed weekly ratios (i.e., adjustment factors) to be used for streamflow adjustment purposes, and a tabular summary of the values is provided in Appendix A.

The streamflow dataset adjustment factors are to be applied to naturalized streamflow datasets (i.e., LT Mad and mean weekly streamflows) developed following Associated (2017), while the adjustment is carried through for the development of the residual and maximum licensed streamflow datasets. Thus, 15 years (i.e., 1996-2010) of streamflows will still be created following Associated (2017), but the resultant streamflow values will be adjusted to represent the long-term conditions discussed in Section 3. This adjustment assumes that individual year climate datasets used within the OWDM (to estimate actual water use) are still applicable for dataset development – it is only that the naturalized streamflow available is adjusted to represent long-term values.

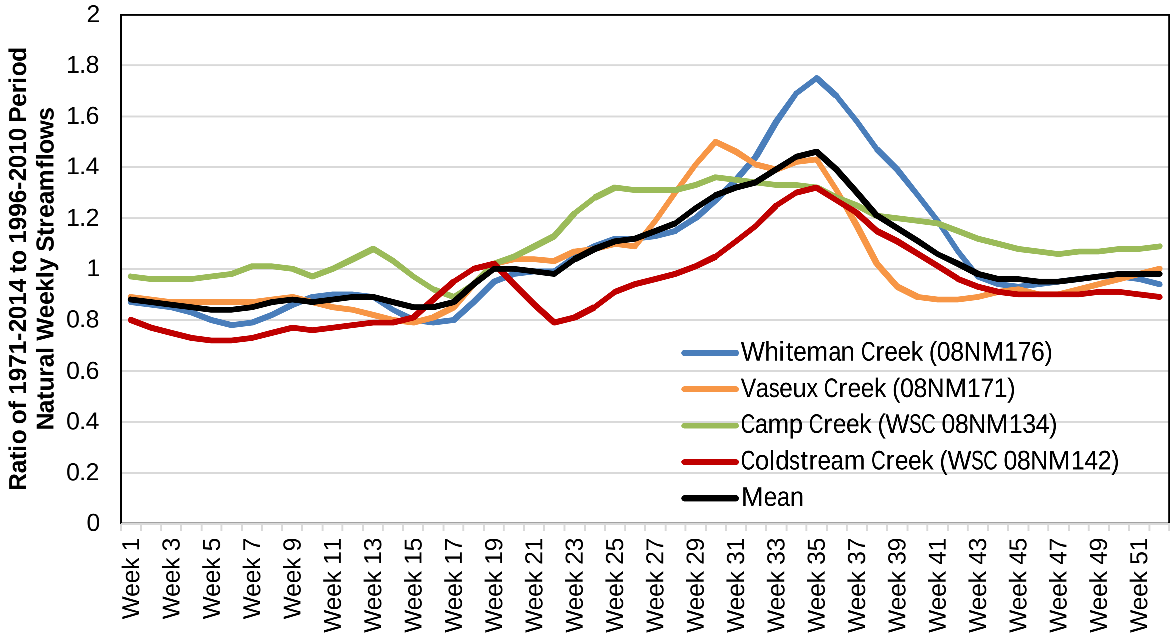

Figure 4-2 **Smoothed mean weekly streamflow ratios between 1971-2014 and 1996-2010 for four natural streamflow WSC hydrometric stations within the Okanagan Basin**

4.1 Example Application of the Streamflow Dataset Adjustment Factors

Table 4-1 summarizes an example application of the streamflow dataset adjustment to showcase the difference between resultant LT Mad and selected fish periodicity streamflow windows for Whiteman Creek (at the streamflow point-of-interest – apex of alluvial fan) for the two temporal periods. Note that the 1996-2010 period values were developed following Associated (2017), while the 1971-2014 period values represent the adjusted 1996-2010 period values using the weekly ratio adjustment calculated for Whiteman Creek (WSC Station No. 08NM174).

Table 4-1 Comparison of Whiteman Creek streamflows at the streamflow point-of-interest between 1996-2010 and 1971-2014 (adjusted) periods

Fish Periodicity	Applicable Time Period	Whiteman Creek Streamflow[1] (m^3/s)	
		1971-2014 (Adjusted)	1996-2010 (following Associated 2017)
LT Mad	-	1.09	1.12
Fry / Smolt Emigration	Apr 1 - Apr 30	1.74 (1.83)	2.17 (2.29)
Flushing Flows	Apr 15 - June 30	4.05 (3.62)	4.20 (3.78)
Migration / Spawning – Kokanee Salmon	Aug 22 - Oct 21	0.184 (0.167)	0.129 (0.118)
Rearing – Rainbow Trout	July 1 - Oct 31	0.522 (0.400)	0.423 (0.338)
Freshet Rampdown	June 15 - July 7	1.60 (1.47)	1.42 (1.31)
Migration / Spawning - Large Rainbow Trout	May 1 - June 30	4.37 (3.75)	4.41 (3.78)
Incubation	Oct 15 - March 31	0.204 (0.176)	0.225 (0.195)

Note:
1. Values colored black reflect mean streamflow values and red reflect median streamflow values for the noted fish periodicity (n = 15 years).

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APPENDIX A – WEEKLY STREAMFLOW ADJUSTMENT FACTORS

Table A-1 Summary of mean weekly streamflow ratios (by WSC hydrometric station and overall mean) to adjust 1996-2010 period streamflow datasets to the long-term conditions

Week ID	Temporal Period Weekly Streamflow Adjustment Factors				
	Whiteman Creek above Bouleau Creek (08NM174)	Vaseux Creek above Solco Creek (08NM171)	Camp Creek at the Mouth near Thirsk (08NM134)	Coldstream Creek above Municipal Intake (08NM142)	Mean (all WSC Hydrometric Stations)
Week 1	0.87	0.89	0.97	0.80	0.88
Week 2	0.86	0.88	0.96	0.77	0.87
Week 3	0.85	0.87	0.96	0.75	0.86
Week 4	0.83	0.87	0.96	0.73	0.85
Week 5	0.80	0.87	0.97	0.72	0.84
Week 6	0.78	0.87	0.98	0.72	0.84
Week 7	0.79	0.87	1.01	0.73	0.85
Week 8	0.82	0.88	1.01	0.75	0.87
Week 9	0.86	0.89	1.00	0.77	0.88
Week 10	0.89	0.87	0.97	0.76	0.87
Week 11	0.90	0.85	1.00	0.77	0.88
Week 12	0.90	0.84	1.04	0.78	0.89
Week 13	0.89	0.82	1.08	0.79	0.89
Week 14	0.84	0.80	1.03	0.79	0.87
Week 15	0.80	0.79	0.97	0.81	0.85
Week 16	0.79	0.81	0.92	0.88	0.85
Week 17	0.80	0.85	0.89	0.95	0.87
Week 18	0.87	0.94	0.94	1.00	0.94
Week 19	0.95	1.02	1.02	1.02	1.00
Week 20	0.98	1.04	1.05	0.94	1.00
Week 21	0.99	1.04	1.09	0.86	0.99
Week 22	0.99	1.03	1.13	0.79	0.98
Week 23	1.05	1.07	1.22	0.81	1.04
Week 24	1.09	1.08	1.28	0.85	1.08
Week 25	1.12	1.10	1.32	0.91	1.11
Week 26	1.12	1.09	1.31	0.94	1.12
Week 27	1.13	1.19	1.31	0.96	1.15
Week 28	1.15	1.30	1.31	0.98	1.18
Week 29	1.20	1.41	1.33	1.01	1.24
Week 30	1.27	1.50	1.36	1.05	1.29
Week 31	1.35	1.46	1.35	1.11	1.32
Week 32	1.44	1.41	1.34	1.17	1.34
Week 33	1.58	1.39	1.33	1.25	1.39
Week 34	1.69	1.42	1.33	1.30	1.44
Week 35	1.75	1.43	1.32	1.32	1.46
Week 36	1.68	1.31	1.28	1.27	1.39
Week 37	1.58	1.17	1.25	1.22	1.30
Week 38	1.47	1.02	1.21	1.15	1.21

Week ID	Temporal Period Weekly Streamflow Adjustment Factors				
	Whiteman Creek above Bouleau Creek (08NM174)	Vaseux Creek above Solco Creek (08NM171)	Camp Creek at the Mouth near Thirsk (08NM134)	Coldstream Creek above Municipal Intake (08NM142)	Mean (all WSC Hydrometric Stations)
Week 39	1.39	0.93	1.20	1.11	1.16
Week 40	1.29	0.89	1.19	1.06	1.11
Week 41	1.19	0.88	1.18	1.01	1.06
Week 42	1.07	0.88	1.15	0.96	1.02
Week 43	0.97	0.89	1.12	0.93	0.98
Week 44	0.94	0.91	1.10	0.91	0.96
Week 45	0.93	0.92	1.08	0.90	0.96
Week 46	0.94	0.90	1.07	0.90	0.95
Week 47	0.95	0.90	1.06	0.90	0.95
Week 48	0.96	0.92	1.07	0.90	0.96
Week 49	0.97	0.94	1.07	0.91	0.97
Week 50	0.97	0.96	1.08	0.91	0.98
Week 51	0.96	0.98	1.08	0.90	0.98
Week 52	0.94	1.00	1.09	0.89	0.98

Appendix D – Equesis Creek Watershed Streamflow Datasets (Digital)

Appendix E – Naswhito Creek Watershed Streamflow Datasets (Digital)

Appendix F – Vaseux Creek Watershed Streamflow Datasets (Digital)

Appendix G – Whiteman Creek Watershed Streamflow Datasets (Digital)

Appendix H – Shorts Creek Watershed Streamflow Datasets (Digital)

Appendix I – Inkaneep Creek Watershed Streamflow Datasets (Digital)

Appendix J – Shuttleworth Creek Watershed Streamflow Datasets (Digital)

Appendix K – McDougall Creek Watershed Streamflow Datasets (Digital)

Appendix L – Naramata Creek Watershed Streamflow Datasets (Digital)

Appendix M – Mission Creek Watershed Streamflow Datasets (Digital)

Appendix N – Penticton Creek Watershed Streamflow Datasets (Digital)

Appendix O – Coldstream Creek Watershed Streamflow Datasets (Digital)

Appendix P – Mill Creek Watershed Streamflow Datasets (Digital)

Appendix Q – Trout Creek Watershed Streamflow Datasets (Digital)

Appendix R – McLean Creek Watershed Streamflow Datasets (Digital)

Appendix S – Trepanier Creek Watershed Streamflow Datasets (Digital)

Appendix T – Powers Creek Watershed Streamflow Datasets (Digital)

Appendix U – Shingle Creek Watershed Streamflow Datasets (Digital)