2020

Mission Creek Restoration Initiative Effectiveness Monitoring, 2016-2019

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Executive Summary

The Mission Creek Restoration Initiative (MCRI) is a multi-stakeholder partnership formed in 2008 to address declining fish stocks and restore natural function to the lower reaches of Mission Creek, located in Kelowna, BC.

Phase I restoration began in 2015-2016 in a stretch of Mission Creek downstream of Casorso Road, where 540 m of the southern dike trail was setback. This setback resulted in 18,000 m^2 floodplain re-engagement and side channel reconnection. In addition, habitat features were installed and four notch pools were excavated in left bank to re-meander the stream. Adaptive management occurred in to improve side channel flow patterns and remove accumulated sediment. In 2019, boulder clusters in two different formations were installed to direct flow into meander notch 2 and to increase habitat complexity.

Post-construction monitoring of fish habitat and site use has been conducted annually since 2016 to document effectiveness and inform adaptive management. Key findings are summarized in the table below.

Performance indictors		**Key findings post works**
Stream substrate	Median substrate size	Coarsening of stream bed materials (D_{50}).
Fish habitat quality and diversity	In-stream habitat type area	Increased diversity in habitat types; the site has been dynamic with annual changes.
	Gravel bar length and area	Increase in gravel bars.
	Instream cover refugia	Several installed log features lost following 2017 and 2018 freshets; boulders installed in 2019.
	Invasive macrophytes	No macrophyte colonization pre or post works.
Fish population, densities and composition	Fish holding and rearing (Rainbow Trout[1] and Kokanee[2])	Diversity of fish species using new pool-notches, but fish use and diversity decreased after pool infilling.
	Redd counts and spawner distribution (Kokanee)	In all years the water depth, velocity, and substrate (D_{50}) were within the preferred ranges for kokanee spawners.
Riparian habitat quality	Riparian plant species composition and cover	Re-colonization present but low, due to plants lost from scouring from freshet.
	Native planting survival	Low planting and stake survival but natural colonization occurring.
	Shoreline stability	The majority of restored banks are unstable.
	Plant community classification	Not yet completed.
Amphibian population	Species composition and relative abundance	Low relative abundance and diversity of amphibians but site still an important habitat in the landscape.

[1] *Oncorhynchus mykiss*
[2] *Oncorhynchus nerka*

The restoration site endured two significant freshets and a variety of discharges post construction. Restoration effects may not be significantly obvious for 5 – 20 years after construction, and therefore, on-going monitoring for adaptive management is highly recommended to document;

- annual changes in gravel bed sizes,
- bank stability,
- kəkniʔ (*Kokanee*) spawning use, and
- floodplain re-growth.

The Okanagan Nation Alliance (ONA) looks forward to continuing to document the successes and challenges of these projects as part of the larger vision of Okanagan Nation Elders in healing the watershed and kł cp̓əlk̓ stim̓ - 'cause to come back'.

Acknowledgements

A project on the scale of MCRI requires coordination, collaboration and collective commitment from a diversity of agencies (from technical expertise, knowledge, funding and support). Acknowledgement of the following participants, supporters and funders include the;

- Mission Creek Restoration Initiative (MCRI) Steering Committee,
- City of Kelowna,
- Westbank First Nation,
- Regional District of Central Okanagan,
- British Columbia Ministry of Forests, Lands and Natural Resource Operations (FLNRORD),
- Okanagan Nation Alliance,
- Fresh Outlook Foundation,
- Fisheries and Oceans Canada (DFO),
- Freshwater Fisheries Society of BC,
- Habitat Conservation Trust Foundation,
- BC Conservation Foundation,
- Sncəwips Heritage Museum,
- Kelowna and District Fish and Game Club,
- Oceaola Fish and Game Club,
- Okanagan Basin Water Board (OBWB),
- Peachland Sportmen's Association,
- Recreational Fisheries Conservation Partnership Program,
- Trout Unlimited Canada (Okanagan Branch),
- Copper Sky Productions,
- Dobson Engineering,
- Ecoscape Environmental Consultants Ltd.,
- Golder and Associates,
- Interior Land Reclamation,
- Okanagan College,
- UBC Okanagan, and
- The En'owkin Centre.

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List of Acronyms and Okanagan Place Names

Acronym	Organizations and Programs
MCRI	Mission Creek Restoration Initiative
ONA	Okanagan Nation Alliance
FLNRORD	Ministry of Forests, Lands, Natural Resource Operations and Rural Development (Province of BC Ministry, formerly known as FLNRO and MOE)
DFO	Fisheries and Oceans Canada
WSC	Water Survey of Canada
OBWB	Okanagan Basin Water Board
Acronyms and/or Abbreviations	**Terminology**
KO	Kokanee
RBT	Rainbow Trout
EFN	Environmental Flow Needs
XS	Cross section
SC	Side channel
WL	Water level
US	Upstream
DS	Downstream
FP	Floodplain
LB	Left bank
RB	Right bank
GB	Gravel bar
RR	Riprap
LWD	Large wood debris
SWD	Small wood debris
R	Riffle
RE	Run end
M	Margin
DR	Deep riffle
DY	Dike
G	Glide

nsyilxcn Place Names*ł	Location
nx̌ʷaqʷaʔstn	Mission Creek area
kłusxənitkʷ	Okanagan Lake
q̓awsitkʷ	Okanagan River
nsyilxcn Species Names*	**Aquatic Species**
kəkṅi or kəkniʔ	Kokanee
qixʷəlx	Sucker spp.

* Indigenous Peoples of the Okanagan are the exclusive owners of their cultural and intellectual properties[3]
ł Translations courtesy of Richard Armstrong and First Voices

[3] As referenced through the United Nations Declaration on the Rights of Indigenous Peoples (2007).

1.0 Introduction

The Mission Creek Restoration Initiative (MCRI) is a multi-stakeholder collaboration formed in 2002 to address the need for restoration in the lower 12 km of the nx̌ʷaqʷaʔstn (*Mission Creek area*). Mission Creek provides almost one-third of flows into the kɬusxənitkʷ (*Okanagan Lake*) and habitat for multiple important aquatic and terrestrial species, notably stream spawning populations of kəkniʔ (*kokanee)*[4][5] of the upper Okanagan Basin.

Extensive channelization since the 1950s on Mission Creek has resulted in the following reductions in ecological value (Urban Systems 2015);

- 60% of total channel length,
- 80% of spawning and rearing habitat for fish, and
- 75% of wetland and riparian habitat.

Phase I restoration was a 540-m dike setback on the south side of the creek between Casorso Road and Gordon Drive. Construction occurred in the fall 2015 and summer 2016 (Dobson Engineering Ltd. 2015). Objectives of this phase included;

- restored floodplain,
- re-connected side channel habitat for seasonal salmonid rearing,
- installed instream habitat features (large woody debris (LWD)/boulder structures), and
- increased river sinuosity and bed diversity (installed 4 meander notches/ pools[6]).

In 2018, adaptive management works included (Dobson Engineering Ltd. 2018);

- regrading and removal of accumulated sediment within the side channel and at its inflow to restore flow patterns, and
- delivery of boulders on site for future restoration use.

In 2019, boulders were installed in two different configurations for the purposes of flow re-direction and habitat complexing (Dobson Engineering Ltd. 2019; Lukey and Alex 2019). The configurations include;

- boulders arranged into six rows of “hockey sticks” to direct more flow into notch 2, and
- two clusters consisting of 4 boulders each to provide refuge for juveniles.

Restoration effectiveness monitoring was initiated in 2016 to document baseline responses to the restoration works (Alex et al. 2016) and continued annually until 2019. The current report summarizes results from years 1 to 4 post-construction monitoring.

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[4] *Oncorhynchus nerka*

[5] Throughout the written body of this document, kəkniʔ will be used. Throughout the tables and figures of this document, Kokanee and/or the abbreviated KO will be used.

[6] Notches were excavated laterally into the banks to increase meander, and pools were created by excavating downward at theses notches.

1.1 Monitoring objectives

The overall objective of monitoring was to document the effectiveness of the restoration at MCRI Phase I and its impacts on indigenous species. Specific objectives, measured performance indicators, and the desired outcomes are outlined in **Table 1**. Performance indicators were designed to both answer questions about long-term effectiveness and short-term adaptive management.

Table 1. Monitoring objectives in relation to the performance indicators measured, associated ecosystem processes and benefits, and expected response.

Performance Indictors		**Objective**	**Expected outcomes**
Stream bed substrate composition	Median substrate size	Spawning sized gravels remain after restoration and fines are reduced	Gravel sizes remain within the range used by kokanee (KO) and Rainbow Trout[7] (RBT)
Fish habitat quality and diversity	Instream habitat type area[8]	Increase diversity of wetted habitat types	Increase in pool habitat
	Instream cover refugia	Increase instream salmonid cover features	Increase in LWD (including root wads), and boulders
	Invasive macrophytes	Monitor changes in macrophyte communities	No introduction of invasive macrophytes
Fish population, densities and composition	Fish holding and rearing (RBT and KO)	Document use and location in time and by feature	Increase reach use by KO and RBT
	Redd counts and spawner distribution (KO)	Document use, and depth and velocity at redds	Continued use by KO spawners at the variety of fall flows
Riparian habitat quality	Riparian plant species composition and cover	Re-establish riparian buffer, shade and nutrient sources	Increased diversity and abundance of native vegetation; increased canopy and ground cover
	Native planting survival		Survival of native plantings (80 % survival target rate)
	Shoreline stability	Reduce erosion	Increased ground cover over time; stable river banks
	Plant community classification (not covered in report)	Re-establish target cottonwood ecosystem	Site classified as native cottonwood ecosystem variant
Amphibian population	Species composition and abundance	Document use by location and time	Increased/stable amphibian presence over time

[7] *Oncorhynchus mykiss*

[8] Meander notches were counted as pool habitat.

1.2 Study area and project works

The study area is located on Mission Creek, between Casorso Road and Gordon Drive (**Figure 1**), along the southern edges of Kelowna, British Columbia. Mission Creek flows westward entering into the central basin of kɬusxənitkʷ (*Okanagan Lake*).

Figure 1. Location and project site area for Phase 1 of Mission Creek Restoration Initiative (MCRI). The yellow star on the top map indicates location of Water Survey of Canada (WSC) real-time hydrometric station #08NM116.

1.3 Timeline to detect the effectiveness of restoration

Table 2 outlines the recommended timeline for measuring monitoring parameters post-treatment and assumptions for pre-treatment comparison data. Restoration effects may not be significantly obvious for 5 – 20 years after construction (Schuett-Hames and Pleus 1996) and ongoing monitoring is highly recommended.

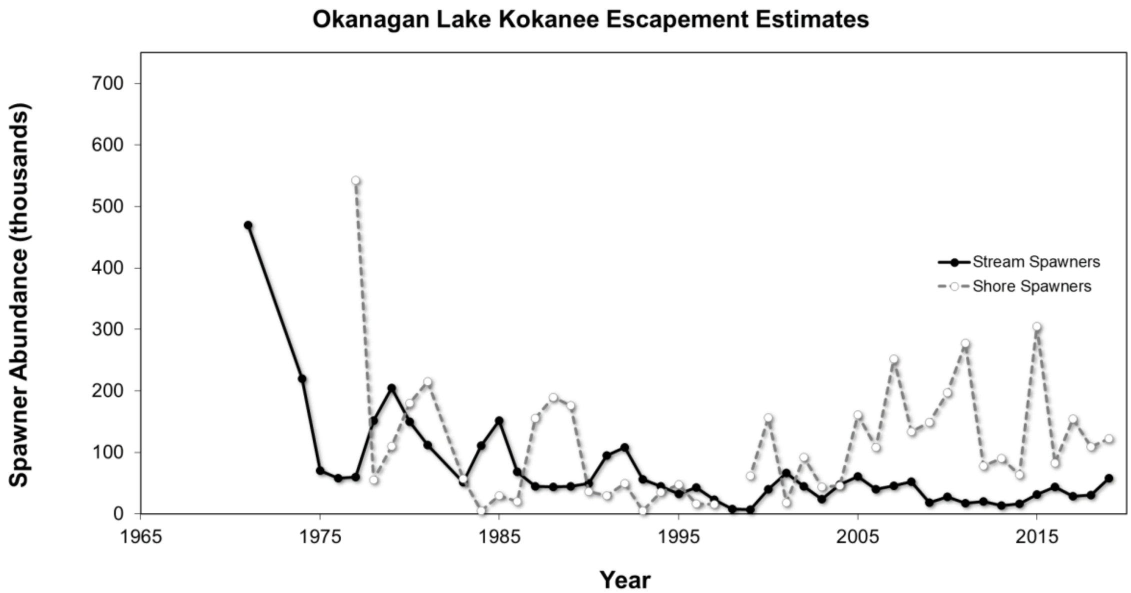
Table 2. Timeline for effectiveness monitoring.

				Post treatment				
Performance Indictors		**Season**	**Pre-treatment**	**2016**	**2017**	**2018**	**2019**	**2020**
Substrate composition	Median substrate size	Summer	Assume collections in Sept 2016 are pre-treatment	✓	✓	✓	✓	x
Habitat quality and diversity	Instream habitat type area	Late summer	Assume no features previously except for gravel bars	✓	✓	✓	✓	x
	Instream cover area		Assume no cover except for dike vegetation	✓	✓	✓	✓	x
	Invasive macrophytes		Assume collections in Sept 2016 are pre-treatment	✓	✓			x
Fish population densities and composition	Fish holding and rearing (RBT and KO)	Spring, summer, fall	Assume 0 to little fish holding before restoration	✓	✓	✓		x
	Redd counts and spawner distribution (KO)	Fall	Refer to Webster data on pre-treatment Kokanee use	✓	✓	✓	✓	x
Riparian habitat quality	Species composition and cover	Spring, late summer	Use 2016 data as management baseline	✓	✓	✓		x
	Native planting survival	Fall		✓	✓			x
	Shoreline stability	Fall		✓	✓	✓		x
	Plant community classification	Spring, late summer	Ecoscape (2015)					x
Amphibian population	Species composition and abundance	Spring, summer	Ecoscape (2015)			✓		

✓= completed
x = planned

2.0 Aquatic response

Mission Creek is an important contributor of Okanagan Lake kəkniʔ, producing a significant proportion of the run compared to other Okanagan Lake streams (**Figure 2**). Escapement of kəkniʔ in Mission Creek has steadily decreased since the 1970's. Therefore, fish habitat restoration in Mission Creek should be a priority for the recovery of kəkniʔ in Okanagan Lake.



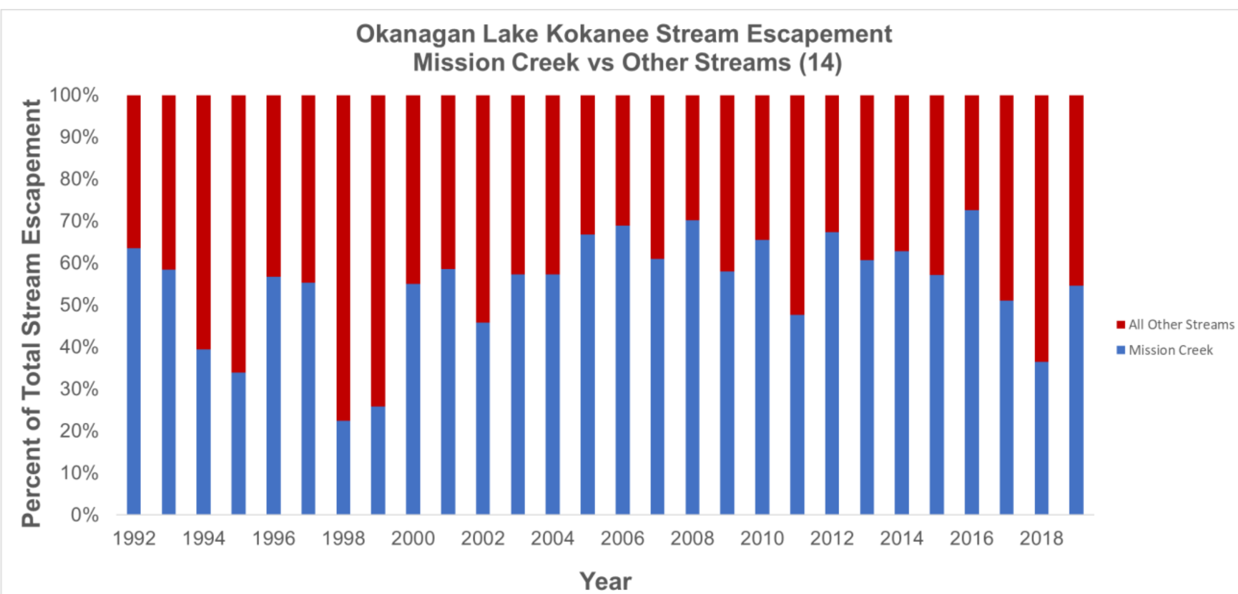


Figure 2. Okanagan Lake escapement estimates for stream spawners and shore spawners (top) and the proportion of total stream escapement contributed by Mission Creek vs. 14 other streams (bottom; Figures provided by Eric Hegerat, FLNRORD, 2019).

2.1 Discharge across the monitoring period

Annual flows and flows on survey dates are shown in **Figure 3** and **Table 3**. Discharge comparisons are important to determine whether differences between survey results across years may be influenced by flow differences. Discharge data was obtained from Water Survey of Canada Station #08MN116, located approximately 6 km upstream of the project site (**Figure 1**).

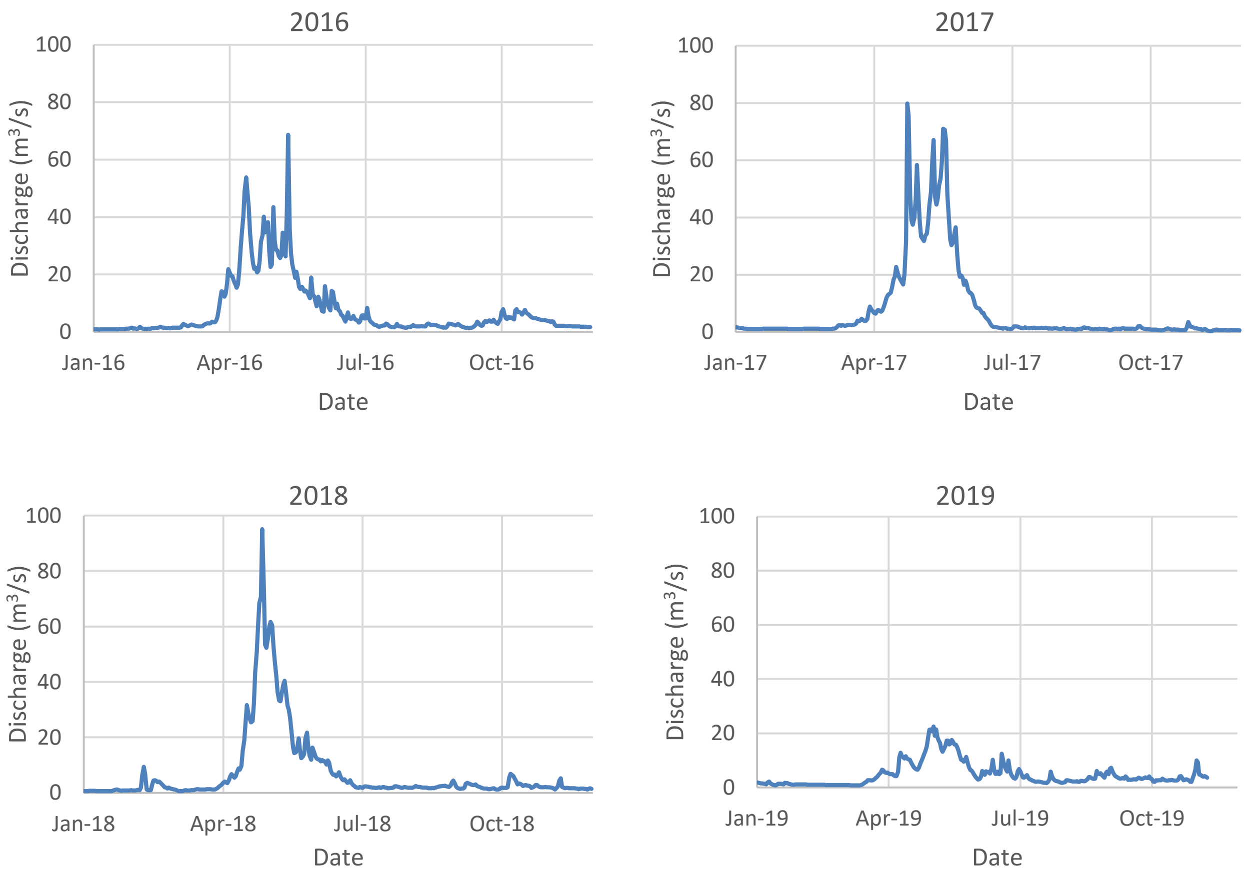


Figure 3. Discharge measured at WSC Station # 08MN116 from 2016-2019.

Table 3. Daily average discharge during data collection in 2016-2019 (WSC Station # 08MN116).

Survey	Year	Average Discharge (m^3/s)
Snorkel/visual surveys	2016	1.41-2.72
	2017	0.80-1.41
	2018	1.89-3.35
	2019	n/a
Cross-sections	2016	2.72
	2017	0.94-1.14
	2018	n/a
	2019	n/a
Habitat types	2016	2.72
	2017	1.08
	2018	3.35
	2019	3.27
Instream cover	2016	2.72
	2017	1.19
	2018	1.91
	2019	3.00
Redd survey	2016	2.03
	2017	0.80
	2018	2.08
	2019	3.00
Macrophytes	2016	2.03
	2017	1.08
	2018	n/a
	2019	n/a
Gravel bars	2016	2.72
	2017	0.94
	2018	1.91
	2019	3.00
Substrate Composition	2016	2.72
	2017	0.94
	2018	3.35
	2019	3.27

2.2 Sampling methods

Table 4 outlines the general methods and seasonal timing for sampling. Details of the sampling methods are found in Appendix A. Description of sampling sites and location are found in **Figure 4** and described in **Table 5**.

Table 4. Methods of monitoring the parameters.

Performance Indictors		Timeline	Method	Details in Appendix
Stream substrate composition	Median substrate size	Summer	Modified Wolman substrate procedures to determine the D_{50} and D_{84}[9]	A1
Habitat quality and diversity	Instream habitat type area	Late summer	Visual surveys; the area of pools, riffles and glides within the study area; the number, type and dimension of each salmonid habitat feature are determined; measurement of cross-sections	A2 – morphometry A3 – features A4 – cross-section
	Instream cover area		Watershed Restoration Program procedures Johnston and Slaney 1995. Cover % by type	A5
	Invasive macrophytes		Visual surveys; Macrophytes species are identified and coverage density is recorded	A6
Fish population, densities and composition	Fish holding and rearing (RBT and KO)	Summer	Snorkel surveys identifying species and age classes. Focus on notch/ pool habitat	A7
		All Year	Biosampling for length, weight and scale (age). For any fish caught during sampling	none caught to date
	Redd counts and spawner distribution (KO)	Fall	Individual redds and redd patches located, recorded and mapped; spawning density, water depth, velocity, and substrate size at redds measured. A visual count of spawning, holding, and dead kəkniʔ is conducted	A8 – redd survey A9 – velocity/ water depth A10 – spawner count

[9] D_{50} = median grain size; D_{84} = grain size at which 84% of the sample is smaller

Figure 4. Location of MCRI aquatic monitoring XS's, pools/notches, and reaches (in relation to reach breaks and landmarks).

Table 5. Locations and descriptions of cross sections (XS).

XS #	Reach	Location Descriptions
XS1	US	Most upstream XS, above project works, about 153m down from Casorso Bridge. In line with an OBWB groundwater gauge
XS2	P1	Reach with 1st Notch. XS across side channel outlet on the LB (or top of re-connected floodplain), about 55m from XS1
XS3	P2	Reach with 2nd Notch (Back Watered), encompassing area of floodplain along fence line south (or inside corner of new dike and re-connected floodplain). XS about 120m down from XS2, in line with an instream EFN WL logger
XS4	P3	Reach with 3rd Notch. XS directly through the center of Notch 3 (with a 1.5m center depth and 0.5m side depths). XS at high point near dike, about 72m from XS3. Reach spanning across from most of the projects works Floodplain
XS5	P4	Reach with 4th Notch. XS at Western Boundary of floodplain works (i.e. floodplain freshet-inlet) in line with instream EFN WL logger about 90m down from XS4
XS6	DS	Most downstream XS, below project works, about 108m from XS5 at the "1km" trail marker (on north dike pathway). In line with OBWB groundwater gauge

2.3 Data and discussions

The summary of the results for aquatic monitoring parameters are found in **Table 6**, detailed data are found in appendices.

Table 6. Aquatic monitoring results summary.

Performance Indictors		Result					Key Findings	Appendix
		Pre-works (2016)	2016	2017	2018	2019		
Stream substrate composition	Median substrate size	Assume same sizes as 2016 post works	46.5 ± 4.0 mm	49.5 ± 4.2 mm	55.7 ± 11.6mm	54.0 ± 4.5mm	Coarsening of bed materials.	B1
Habitat quality and diversity	Instream habitat type area	Riffle (R): 12,324 Pool (P): 0 Glide (G): 3,960	R: 12,324 P: 688 G: 3,960	R: 11,070 P: 520 G: 4,128	R: 5,460 P: 410 G: 8,845	R: 8,942 P: 730 G: 5,708	Sharp decline in riffles after 2018 freshet; increased diversity in habitat types; the site is dynamic with annual changes.	B2
	Gravel bar length (L) and area (A)	Assume same sizes as 2016 post works	L: 170 m A: unknown	L: 457 m A: 901 m^2	L: 405 m A: 1,720 m^2	L: 333 m A: 1,440 m^2	Increase in gravel bars.	B2
	Instream cover area	LWD (m^2): 0.15 RW (m^2/#): 0/0 Boulders (#): 10	LWD (m^2): 35 RW (m^2/#): 6/12 Boulders (#): 37	LWD (m^2): 32 RW (m^2/#): 11/15 Boulders (#): 31	LWD (m^2): 26 RW (m^2/#): 2/2 Boulders (#): 4	LWD (m^2): 26 RW (m^2/#): 0/0 Boulders (#): 74	Overall increase since pre-works; losses occurred during 2018 freshet; boulders increased after 2019 adaptive management.	B3
	Invasive macrophytes	0	0	0	0	0	No macrophyte colonization.	B4
Fish population, densities and composition	Fish holding and rearing (RBT and KO)	unknown	95 spawners in notch pools 426 all fish spp.	28 spawners in notch pools 2404 all fish spp.	3 spawners in notch pools 1059 all fish spp.	N/A	Diversity of fish species using new pool-notches, but fish use and diversity decreased after pool infilling.	B5
	Redd counts and spawner distribution (KO)	unknown	Depth: 25 cm Velocity: 0.44 m/s D_{50}: 27 mm 18 % of area used	Depth: 20 cm Velocity: 0.25 m/s D_{50}: 22 mm 7 % of area used	Depth: 28 cm Velocity: 0.47 m/s D_{50}: 29 mm 3 % of area used	Depth: 21 cm Velocity: 0.42 m/s D_{50}: 27 mm 3 % of area used	All years within preferred depth, velocity, and D_{50} range for kokanee.	B6

2.3.1 Substrate composition

Key findings for substrate composition at cross-sections in the study area include:

- Substrate size coarsened over the four years. Median size (D_{50}) was 46.5mm in 2016, 49.5 mm in 2017, 55.7 mm in 2018, and 54.0 mm in 2019 (
- **Figure** 5, Appendix B1).
- Coarsening is more apparent in the upper size ranges, while the composition of mid to smaller substrate remained similar across the years. D_{84} values increased from 67.0 mm to 92.5 mm (
- **Figure** 5).
- In 2018, patches of sand within a matrix of cobble substrate were observed in reaches P2, P3, and P4 (**Figure 6**). This is a novel observation and could have resulted from deposition from the 2018 freshet. Sandy substrate was observed in 2019, but in a much smaller area compared to 2018.

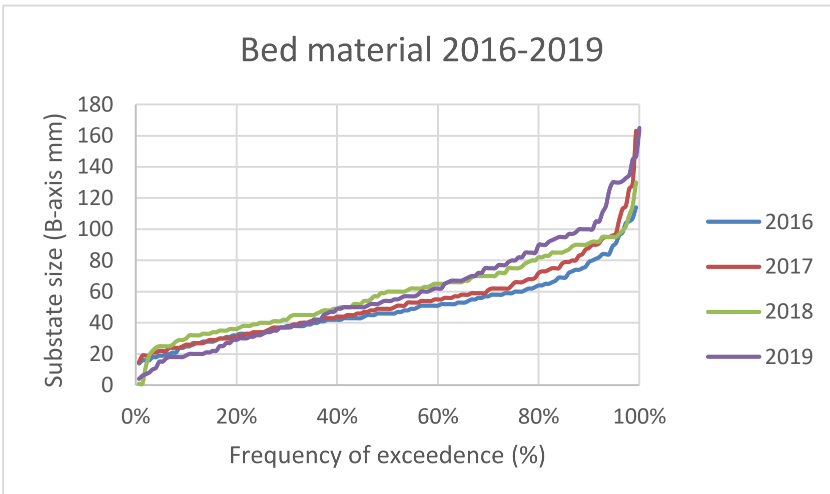


Figure 5. Exceedance frequency of bed material among years.

Figure 6. Sandy substrate within matrix of cobbles at P2, P3, and P4 in 2018.

2.3.2 Fish habitat quality and diversity

Key findings for changes in fish habitat types and gravel bars within the study area include:

- There was an overall increase in pool area from pre-restoration conditions due to creation of pools at the meander notches. Infilling of two of these notches resulted in a loss of pool habitat from 2016 to 2018 (688 to 410 m^2; **Table 7**; Appendix B2). In 2019, little geomorphic changes occurred due to a small freshet.
- In 2017, notch 1 completely filled in with gravel, and the pools at notches 2 and 3 experienced some sediment deposition. By 2018, the pool at notch 3 completely filled in, and the pools at notches 2 and 4 experienced continued sediment deposition. Notch 4 no longer has flow due to sediment deposition at the upstream end (**Figure 7**).
- There is an overall decrease in riffle and increase in glides over the past four years, although the site remains dynamic and shifts each year. Differences in flows on survey dates could be a contributing factor to these changes as riffles start to look more like glides at higher flows.
- The total length of gravel bars increased from 155 m pre-restoration to 457 m in 2017 (**Table 7**, Appendix B2). Gravel bar length decreased in 2018 from 457 m to 405 m, but gravel bar area almost doubled due to increased gravel bar widths encroaching into the main channel. This is consistent with widespread deposition and channel changes observed following the extreme freshet in 2018. Gravel bars remained largely unchanged in 2019 with the exception of one small bar in the upstream reach which was covered by the flows observed during the survey date.
- There was a decreasing trend in total wetted habitat area due to gravel bar encroachment into the main channel (**Table 7**).

Table 7. Habitat types and gravel bar development over the years of study.

Habitat Type	Pre-restoration	2016	2017	2018	2019
Riffle area (m^2)	12,324	12,324	11,070	5,460	8,942
Pool area (m^2)	0	688	520	410	730
Glide area (m^2)	3,960	3,960	4,128	8,845	5,708
Gravel bar area (m^2)	unk	unk	901	1,720	1,440
Gravel bar length (m)	155	155	457	405	333
Total wetted area (m^2)	16,284	16,972	15,718	14,715	15,380
Total area (m^2)	16,284	16,972	16,619	16,435	16,820

Figure 7. Post-construction pool and subsequent infilling.

Key findings of instream cover within the study area include:

- Of the 41 m^2 of LWD cover (including root wads), only 26 m^2 remained in 2019. Losses of LWD were largely due to infilling of pools at the meander notches (**Figure 7)** although a small proportion was washed away by the freshet. Despite this, there remains a net increase of 26 m^2 LWD since pre-construction conditions in 2016 (**Table 8**, **Figure 8**, Appendix B3). New downed cottonwood trees were found during monitoring, though they were few and generally washed away by freshet. It is recommended that cottonwood regrowth be continuously monitored as they can be important contributions of instream LWD.
- The installed root wads were observed as the most utilized cover with fish in the snorkel surveys in 2016 and 2017 monitoring years. By 2019, the root wads were lost in the freshets and LWD became the most utilized cover during snorkel surveys.
- Of the 37 boulders placed, 4 remained in 2018 surveys. The loss of boulders was due to infilling of pools at the notches and burial from freshet. In 2019, 67 boulders were installed during adaptive management works, increasing instream cover features.

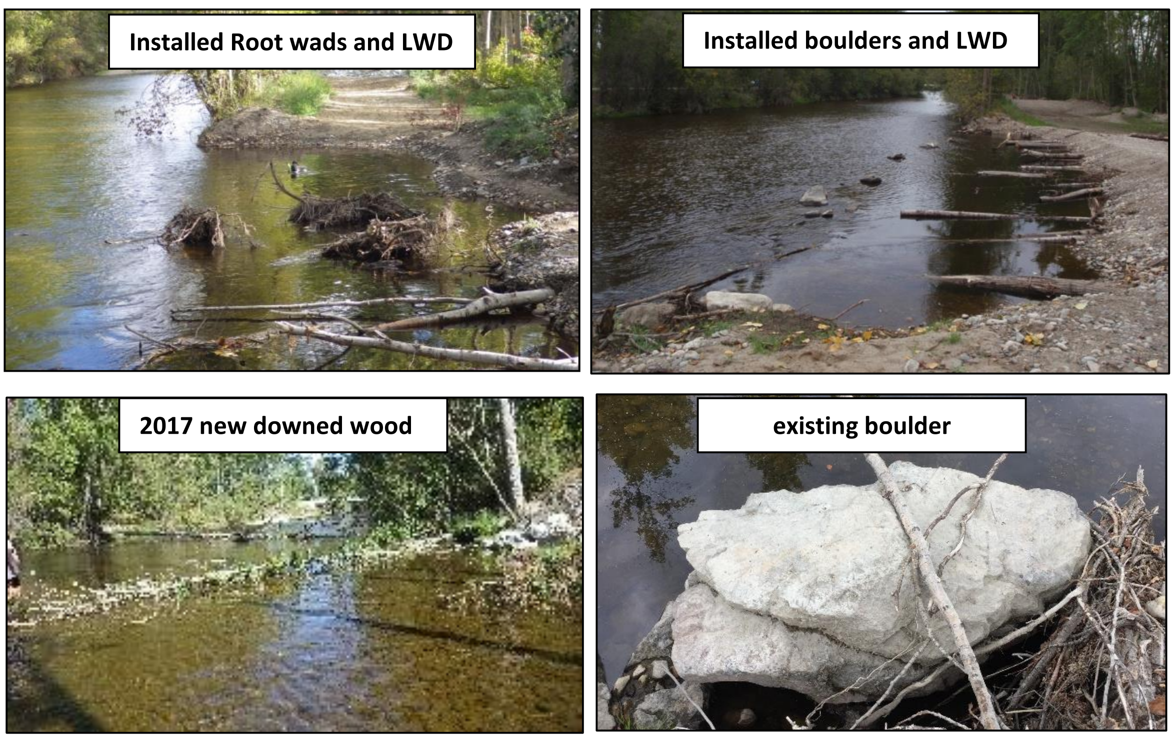


Figure 8. Examples of habitat features at the site.

Table 8. Cover feature measurements by reach from 2016 to 2019.

	Total			
Year	**2016**	**2017**	**2018**	**2019**
Large woody debris, excluding rootwads (m^2)	35	32	26	26
Rootwads (m^2)	6	11	2	0
Rootwads (#)	12	15	2	0
Boulders (#)	37	31	4	74

Invasive macrophytes were identified as a potential concern as they are often quick to colonize slower velocity, sandy bottomed areas such as the newly constructed pools. Fortunately, no macrophytes were observed throughout the restoration site from 2016 to 2019 (Appendix B4).

Comparisons of cross-sections in 2016 and 2017 post-works are depicted in **Figure 9** with details in Appendix B1. Note that discharge was lower in 2017 than 2016 (**Table 3**, section 2.1). Significant sediment deposition was noted at;

- notch 1, which completely infilled,
- notch 2, which partially infilled,
- notch 3, which partially infilled (by 2018 it completely infilled), and
- notch 4, which experienced deposition at the location of the old bank.

There was no bank erosion issue on the north dike. Cross-sectional surveys were not completed in 2018 and 2019.

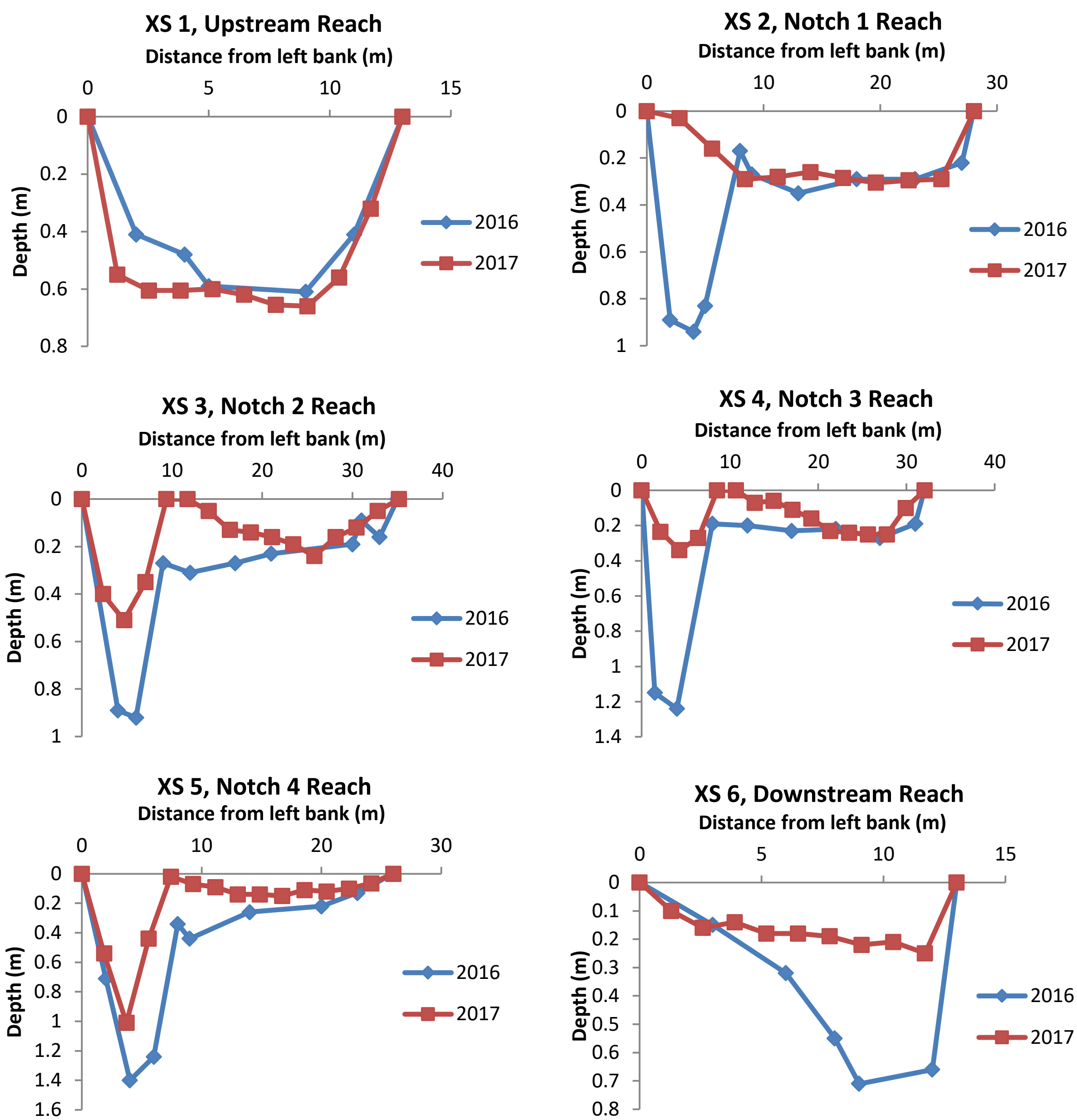


Figure 9. Cross section profiles in 2016 and 2017.

2.3.3 Fish population, density, and composition

Visual counts were conducted from the banks of the entire study area to count spawning, holding, and dead adult kəkniʔ. Visual counts were not conducted in 2019. Key findings are detailed in **Table 9** and Appendix B5.

Table 9. Visual survey count of kəkniʔ in 2016, 2017, and 2018.

Year	2016	2017	2018
Spawning	177	100	2
Holding	12	79	66
Dead	Not counted	926	356

Snorkel surveys were completed in the pool-notches only and targeted all fish species. Snorkel surveys were not conducted in 2019. Key findings of snorkel and visual survey counts are detailed in **Table 10** and Appendix B5, and include:

- In 2016, notch 1 had the most kəkniʔ spawners while notch 3 and 4 were used by large numbers of Redside Shiners (*Richardsonius balteatus*).
- In 2017, notch 4 had the highest number of spawners while notches 2 and 3 were used by large numbers of Redside Shiners and Longnose Dace (*Rhinichthys cataractae*). The pool at notch 1 was infilled by the time of the fall surveys. The highest species diversity was observed in 2017 at 4 species.
- In 2018, only 3 kəkniʔ spawners were observed, all in notch 2. Notch 4 was used by large numbers of Redside Shiners. Since 2017, the pool at notch 3 has also infilled and the pool at notch 4 has become a semi-stagnant backwater pond.

Table 10. Snorkel survey count summary in 2016, 2017, and 2018.

Notch	Notch 1			Notch 2			Notch 3			Notch 4			Total by species		
Year	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
kəkniʔ spawners	62	N/A	N/A	25	2	3	2	0	N/A	6	26	0	95	28	3
Rainbow Trout	0	N/A	N/A	0	1	0	0	1	N/A	0	1	0	0	3	0
qixʷəlx (Sucker)[10]	0	N/A	N/A	1	0	0	0	0	N/A	0	0	0	1	0	0
Redside Shiner	27	N/A	N/A	0	899	50	180	510	N/A	123	369	1006	330	1778	1056
Longnose Dace	0	N/A	N/A	0	159	0	0	431	N/A	0	3	0	0	593	0
Other (unknown)	0	N/A	N/A	0	2	0	0	0	N/A	0	0	0	0	2	0
Total per pool	89	N/A	N/A	26	1063	53	182	942	N/A	129	399	1006	426	2404	1059

Selection of spawning areas by salmon are a function of availability and preference. For reference when discussing habitat targets and outcomes for kəkniʔ habitat at MCRI, the following values are referred to for optimal target ranges;

- water depth (at fall spawning flows): > 0.06 m (Ford et al. 1995),
- water velocity (at fall spawning flows): 0.15 m/s – 0.85 m/s (Ford et al. 1995), and
- spawning gravel size: D_{50} of 30 mm (Long 2002).

[10] *Catostomus* spp.

The study area was surveyed for kəkniʔ redds where water depth, velocity, D_{50}, and habitat type was recorded. Key findings for redd surveys include:

- Water depths and velocities at redds were within the preferred range for kəkniʔ (**Table 11**) and occurred at the difference discharges among years.
- Kəkniʔ were selecting for mean gravel sizes (D_{50}) of 22 to 29 mm (**Table 11**), even though the available substrate throughout the site was on average much larger (D_{50} of 47 to 56 mm; **Figure 5**). Substrate coarsening is a concern because suitable gravel sizes may become limited when fish returns are higher, and the site is no longer underutilized by kəkniʔ.
- In 2016 and 2017, redds were primarily located at riffles (**Table 12**). In 2018 and 2019, spawning mostly occurred in deep riffles. The shift in spawning habitat type could be due to smaller gravel accumulating in deep riffle areas. A follow-up assessment would be required to confirm this.
- Overall spawning area utilized decreased from 17.7% to 3.4% of the restoration area. This coincides with decreasing spawner numbers observed with each subsequent year; therefore, the total area is underutilized for these population densities. It is recommended to survey at larger kəkniʔ returns to assess the total utilization of the reach.

Table 11. Redd measurements for 2016 to 2019.

	depth (cm)				velocity (m/s)				D50 (mm)			
	2016	**2016**	**2016**	**2019**	**2016**	**2017**	**2018**	**2019**	**2016**	**2017**	**2018**	**2019**
mean	**25**	**0.44**	**0.44**	**0.44**	**0.44**	**0.25**	**0.47**	**0.42**	**27**	**22**	**29**	**27**
min	20	0.05	0.05	0.05	0.05	0.15	0.12	0.17	10	20	20	20
max	36	0.62	0.62	0.62	0.62	0.36	1	0.78	40	30	45	30

Table 12. Spawning habitat types for 2016 to 2019.

	Riffle	Run end	Margin	Deep riffle	Gravel bar end	Total Redd	TOTAL % used
2016 area (m^2)	2763	138	12	97.5	0	3011	17.7
2017 area (m^2)	1123	109	0	9	0.5	1242	7.3
2018 area (m^2)	20	91	0	333	68	511	3.1
2019 area (m^2)	134	101	54	273	10	571	3.4

3.0 Riparian vegetation response

Vegetation monitoring occurred within the floodplain (referred to as the Stage 1 site), and along the shoreline of the Mission Creek mainstem (referred to as the Stage 2 site).

Pre-works, the Stage 2 site was described as (Ecoscape 2015):

- Dominated by multi storied black cottonwood forest with occasional trembling aspen, mountain alder, Douglas-fir and paper birch.
- This forest likely originated after the original Mission Creek dike construction and represents a young to maturing forest with the average stand age being in the range of 75 to 80 years, with occasional veteran trees.
- The shrub layer in these areas was typically a well-developed snowberry-rose community. Weeds and invasive species were common throughout.
- Surrounded by urban/rural/agriculture areas punctuated by wetland features (e.g. Stage 1 dike setback area).

For a full site description, including surrounding habitat and land use, refer to Ecoscape (2015).

Documenting changes in vegetation composition is important in monitoring the effects of the project, and tracking bank stabilization and riparian habitat quality and quantity post-disturbance.

3.1 Sampling methods

Native plant survival surveys were conducted at the Stage 1 floodplain site (FP) in summer 2016 and 2017. Observers walked the floodplain and noted the survival of all visible plantings and stakes placed in winter 2016 following Stage 1 construction (dike setback).

Vegetation surveys were conducted within the Stage 2 construction footprint in 2017 and 2018 to serve as a baseline for on-going post-works monitoring and adaptive management. The Stage 2 footprint was divided into "notch" and "other" locations. Notch locations included the meander notch and notch bank slopes. Other locations included the areas between the notches, which generally were lower sloped and not anticipated to experience consistent flows across seasons. Surveying included a basic standard method of stratified random transects and plots. General methods are found in **Table 13** with specific monitoring methods found in Appendix A11. Data was summarized accordingly as notch and other.

Table 13. Methods and timeline for monitoring riparian vegetation response.

Performance indicators		Timeline	Methods	Appendix
Riparian habitat quality	Species composition and cover	Spring, late summer	Random stratified transect/plot sampling method; % ground cover and species, % canopy cover recorded.	A11
	Native plant survival	Fall	Record survival of previous plantings (Stage 1 floodplain, Stage 2 footprint).	A11
	Shoreline stability	Fall	Random stratified transect/plot sampling method; % soil type, substrate embeddedness, shoreline stability rank (Henshaw and Booth 2000).	A11

3.2 Data and discussions

The summary of the results for vegetation monitoring parameters and shoreline stability are found in **Table 14**. Detailed data are found in Appendix B7 and B8.

Table 14. Riparian monitoring results summary.

Performance Indictors		Result				Key Findings
		Pre-works (2016)	2016	2017	2018	
Riparian habitat quality	Species composition and cover	unk	18 spp total; 33% are invasive	Assessed summer 2017, reported in 2018 results	16 spp total; 38% are invasive	Re-colonization present but low, due to scouring from freshet
	Native planting survival	unk	< 1 % healthy and 33 % stressed plantings; 19 % live stake survival	10 % healthy and 6 % stressed plantings; 0 live stake survival	Not assessed in 2018	Low planting and stake survival but natural colonization occurring
	Shoreline stability	unk (previous dike channel)	97 % notch banks slightly unstable to completely unstable; low embeddedness and ground cover	Not assessed in 2017	87 % notch banks slightly unstable to completely unstable; low embeddedness and ground cover	The majority of sections are unstable; slight increase in stability due to riprap installed

3.2.1 Stage 1 floodplain plantings survival

Key findings from floodplain plantings survival monitoring include:

- Salvaged plant condition improved slightly in 2017 compared to 2016, though condition and survival are generally low (**Table 15**). As of 2017, 35 % of the originally salvaged plants were observed, of which 29 % were healthy and 18 % stressed. Eighty-nine of the original 400 live stakes were observed (22%), 0 of which displayed above-ground growth.

- In both years, the floodplain retained water longer than anticipated (pers. comm. MCRI Steering Committee), contributing to the oversaturation of many of the salvaged species. Significant sedimentation in the floodplain also occurred, burying many of the plantings and stakes.

- Visual observation indicates natural succession in the floodplain is occurring (**Figure 10**). Following 2016-17 monitoring observations and recommendations the Steering Committee decided to forego further planted plant survival monitoring and follow-up planting and allow the floodplain to continue to success naturally; therefore, floodplain planting survival was not assessed in 2018.

- 2018 visual observations indicate significant sediment deposition occurs annually within the floodplain burying plants established in previous years; however, Black Cottonwood and willow colonization continues to occur naturally and annually on newly deposited fine sediment in the floodplain. Sediment dynamics are likely contributing to the colonization success of the cottonwood and willow, though long-term survival is unknown.

Table 15. Survival and condition of the 300 native plantings conducted in the floodplain.

		Condition			Total individuals
	Year	Healthy	Stressed	Dead	
Total observed (N)	2016	1	99	11	111
	2017	29	18	59	106
Proportion of total planted (%)	2016	0.3	33	4	n/a
	2017	10	6	20	n/a

Figure 10. Floodplain condition over time.

3.2.2 Stage 2 new creek bank vegetation and stability

Key findings from bank vegetation and stability monitoring are shown in **Table 16** and depicted in **Figure 11**:

- The Stage 2 shape along the notches/mainstem left bank and side channel changed significantly during freshets 2017 and 2018; however, overall instability values are similar across years (**Table 16**). One exception is increased stability in localized sections following riprap installation in fall 2017. However, all of Notch 4 and large portions of Notch 3 still lack any bank stabilization. Overall, the majority of sections are classified slightly to completely unstable.

- Sand, silt, and gravel make up the majority of the Stage 2 construction substrate.

- Percent ground cover is very low overall but higher in the flatter "other" areas (likely due to the lesser degree of disturbance during Stage 2 construction/adaptive management, and easier conditions for vegetation to establish).

- Vegetation colonization is present but low, with 2018 having less vegetation than 2016. This is likely due to the scouring from 2018 freshet flows combined with survey timing. 2016 vegetation surveys were conducted in late summer/fall, while 2018 surveys conducted in early summer, with comparatively less time for plants to re-establish post-freshet.

- Although re-vegetation is required in all sections of the banks, efforts are recommended to be focused on the slopes, with attention paid to the anticipated freshet elevation and shear stress dictating the type of planting/stabilization and species put in the sloped areas.

- Overall native vegetation diversity is low within the Stage 2 disturbed area. There is also low incidence of BC Weed Act listed species within the Stage 2 disturbed area (Canada thistle) (Appendix B7 contains full list of species and management priorities).

Figure 11. Example of exposed, unstable banks, installed riprap, and naturally colonized cottonwood/willow seedlings in 2016 through 2018.

Table 16. Summary of results for stability of riparian vegetation.

		Notches		Other	
		2016	2018	2016	2018
Average soil composition (%)	fines	27	18	40	39
	sand	31	26	20	31
	gravel	28	42	18	24
	cobble	12	5	8	5
	boulder	1	*9	5	0
	other (live roots)	2	0	6	0
Substrate embeddedness (%)	0-25 % embedded	39	47	14	39
	25-75 % embedded	56	53	45	33
	> 75 % embedded	22	0	41	28
Stability category (%)	armored banks	0	9	4	11
	stable	4	5	7	0
	slightly unstable	17	5	18	7
	moderately unstable	42	18	64	29
	completely unstable	38	64	7	54
	Comment	notch bank 2:1 slope			
Average ground cover (%)		3	3	18	28
Average canopy cover (%)		21	17	27	26
Vegetation colonization	Total # species	11	12	18	16
	Total # introduced species	3	3	6	6
	Comment	1 noxious weed present		1 noxious weed present	

*2017 addition of riprap along some notch banks.

4.0 Amphibian relative abundance

Multiple amphibian species were observed within the general MCRI area prior to the restoration works (**Table 17**). The MCRI site contains a diversity of wetted habitat post-restoration, and therefore holds potential breeding habitat for a variety of amphibians. Amphibian surveys were conducted in spring – summer 2018 at the MCRI site.

Table 17. Species observed or with potential to occur at the MCRI site.

Nsyilxcən	Common name (scientific name)	Provincial status	SARA status	COSEWIC status	*Observed or Potential
p'əs ʷaqs	Great Basin Spadefoot (*Spea intermontana*)	Blue	Threatened	Threatened	Ecoscape (2015)
	Western toad (*Anaxyrus boreas*)	Yellow	Special Concern	Special Concern	Potential
	Columbia Spotted Frog (*Rana luteiventris*)	Yellow	Not listed	Not At risk	Ecoscape (2015), Lukey (2016)
	Pacific Chorus Frog (*Pseudacris regilla*)	Yellow	Not listed	Not listed	Ecoscape (2015)
	Long-toed Salamander (*Ambystoma mavortium macrodactylum*)	Yellow	Not listed	Not At risk	Ecoscape (2015)

4.1 Sampling methods

Three types of surveys were conducted for amphibians, in accordance with or slightly modified from BC RIC Standards and Ecoscape baseline methods (**Table 18**, **Figure 12**, Appendix A12; Ecoscape 2015).

Table 18. Amphibian survey effort summary.

Search type	Survey dates 2018	Brief description
Active search	26 April 23 May 6 June 28 June	Perimeter of each wetted area surveyed for all life stages of all species; included random dip netting.
Auditory surveys	27 April 23 May 6 June	Three listening stations at upstream, middle, and downstream sections of site. Observers listen for calling adult males for 5 minutes per station.
Minnow (Gee) traps	6/7 June 27/28 June	Minnow traps randomly set overnight in each wetted area (incl. notches but not mainstem); checked after approximately 12 hours.

Figure 12. Examples of areas minnow (Gee) trapped for amphibians.

4.2 Data and discussion

The summary of the results for amphibian monitoring are found in **Table 19**. Detailed data are found in Appendix B9.

Table 19. Amphibian monitoring results summary.

Performance Indictors		Result				Key Findings
		Pre-works (2016)	2016	2017	2018	
Amphibian monitoring	Species composition and abundance	unknown	Not assessed in 2016	Not assessed in 2017	Columbia Spotted Frog and Pacific Chorus Frog detected	Low relative abundance and diversity of amphibians but site still an important habitat in the landscape.

Two amphibian species, Columbia Spotted Frog and Pacific Chorus Frog, were detected at the restoration site between April 26 – June 28th, 2018 (**Table 20**, **Figure 13**, Appendix B9). One adult male Pacific Chorus Frog was detected within the floodplain, and 4 Columbia Spotted Frogs (3 adults, 1 juvenile) observed scattered throughout the site. No eggs or larvae of any species were detected. A site reconnaissance on July 25th indicated no suitable wetted areas off the mainstem were available to survey.

Table 20. Amphibian detections.

Survey type	Species	Lifestage	Sex	# individs.	Location notes
Auditory	Pacific Chorus Frog (*Pseudacris regilla*)	Adult	Male	1	floodplain
	Columbia Spotted Frog (*Rana luteiventris*)	Adult	Male	1	wetted ditch on north side setback dike, at WFN IR corner
Active search	Columbia Spotted Frog (*Rana luteiventris*)	Adult	Unk	1	floodplain
Trap	Columbia Spotted Frog (*Rana luteiventris*)	Adult	Female	1	floodplain in flowing water near upstream widened area/side channel
	Columbia Spotted Frog (*Rana luteiventris*)	Juvenile	Unk	1	isolated notch pool

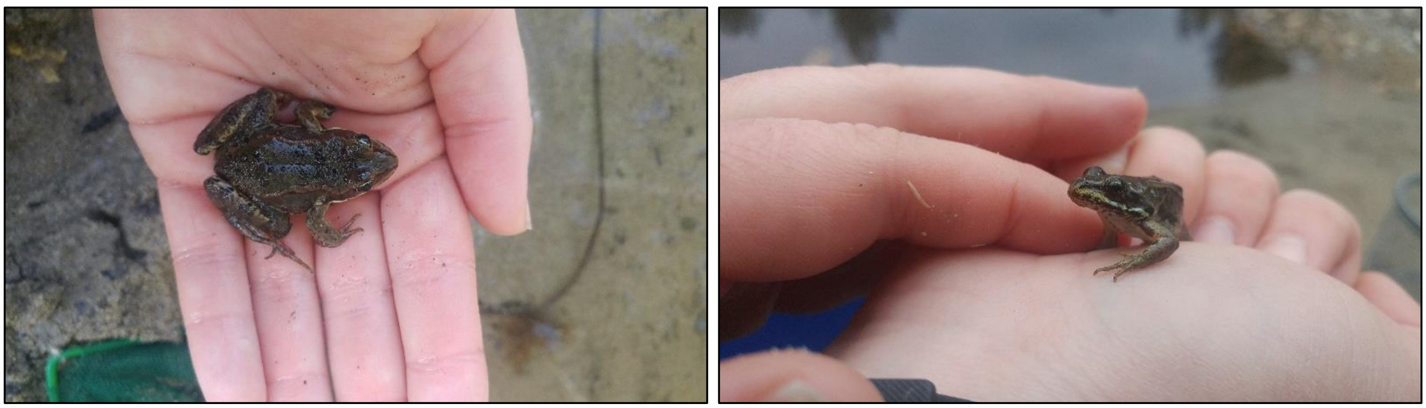


Figure 13. Columbia Spotted Frog adult (left) and juvenile (right) detected during surveys.

Overall relative abundance and diversity of amphibians was low at the MCRI Phase I site. A number of reasons may apply:

- Water temperature may be too cold and/or fluctuate too frequently. The flow-through of water in the floodplain water may not allow time for stagnation and surface water warming. Fluctuating levels may deter egg-laying when more stable habitat may be available nearby, such as farmland ponds or Michaelbrook Marsh. Pacific Chorus Frogs were heard in higher abundance in adjacent farmland and across the mainstem.
- A high amount of noise and light pollution from neighboring athletic field and roads was observed which may deter breeding activity.
- Great Basin Spadefoots prefer very shallow, warm, stagnant, fish-free ponds (COSEWIC 2007, NRCS 2006, SIRART 2008). The site experienced deep inundation with velocity for the duration of freshet, with access of fish, during the 2 post-restoration freshets.
- Presence of fish may deter amphibian breeding in general within the restoration site.
- Hydroperiod may be unsuitable (pooled areas mostly dry by June 6, completely dry before July 25; **Figure 14**).
- The site occurs within a highly developed area; surrounding source amphibian populations may be low in general and require time to reach the MCRI site at detectable levels.

Although relative abundance and diversity was low within the site, this site still represents important amphibian habitat within the Kelowna landscape. The floodplain represents migration corridor habitat and rare low-elevation floodplain and off-channel habitat. Additionally, the floodplain site is a likely contributor of insect prey for amphibians and other insectivorous fish and wildlife.

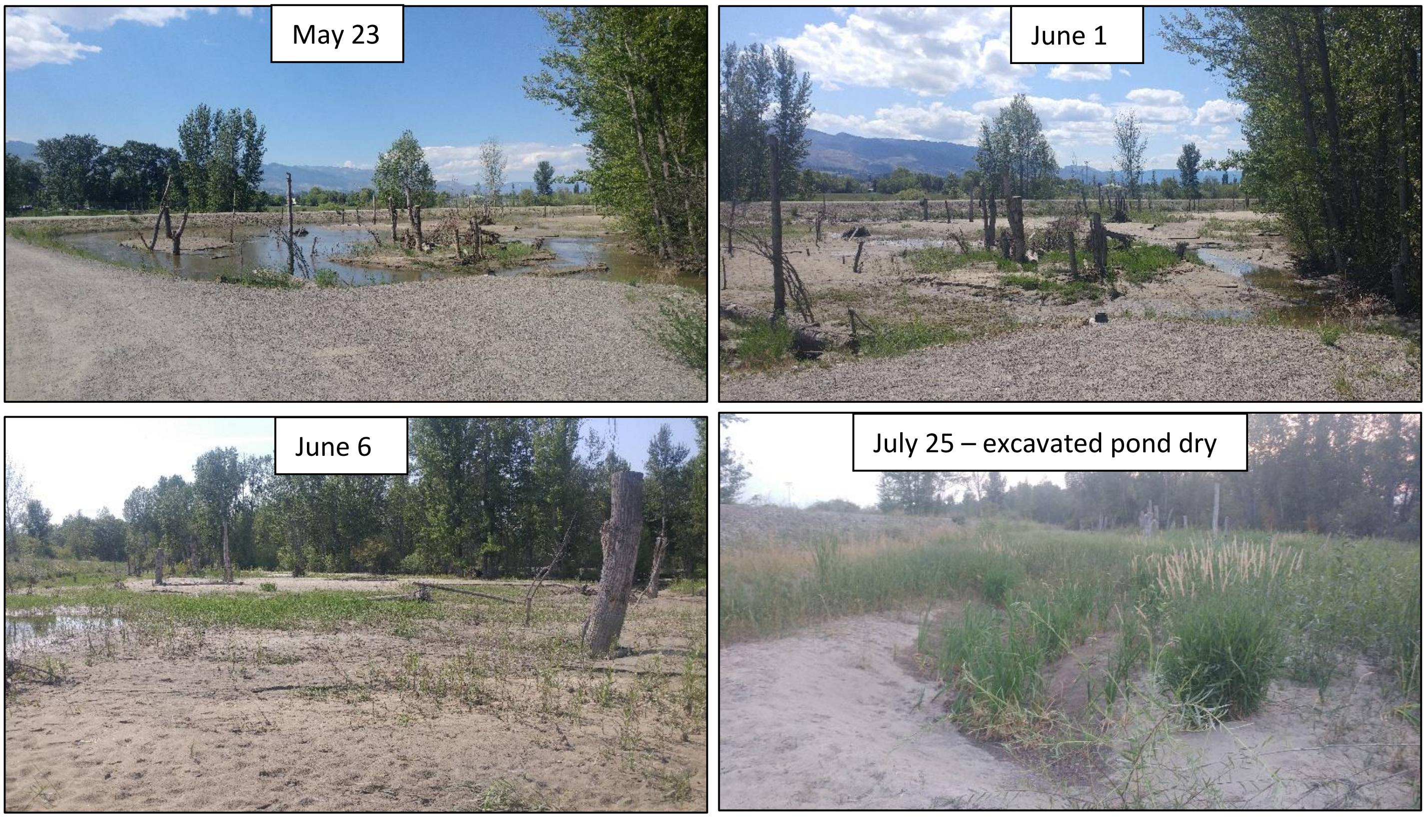


Figure 14. Floodplain surface water conditions during survey period.

5.0 Fish entrapment and incidental wildlife observations

Non-target fish and wildlife were observed at the site during the aquatic, vegetation, and amphibian monitoring sessions. The following two sections elaborate on these incidental observations.

5.1 Fish entrapment

5.1.1 Background and survey methods

A site reconnaissance on June 1st indicated that receding water levels were leaving isolated, pooled areas throughout the site which had potential for stranding native fish. Minnow (Gee) traps were opportunistically deployed during amphibian surveys, targeted at fish, after consulting Tara White (FLNRORD) and Steve Mathews (MCRI Coordinator). Minnow (Gee) traps were set June 6th/7th and June 27th/28th.

5.1.2 Data and discussion

Fish were detected in all wetted areas off of the mainstem, including the main floodplain area, side channel, and Stage 2 footprint when surface water elevations were lower following freshet (**Table 21**, **Figure 15**, Appendix B9).

- June 6 surveys, all wetted areas had connection to mainstem (i.e. no entrapment at time of surveys); 5 species observed using the floodplain and side channel.
- June 27th/28th surveys: 0 fish trapped or observed in the isolated pools, though pools were largely dried up for an unknown period of time (**Figure 14**).

Fish use the floodplain, though mortality was not detected during these surveys. However, these surveys were opportunistic, and missed the exact time period when the water receded and resulted in isolated pools. Based on temperature and oxygen requirements of native riverine fish the period for morality to occur was likely missed during these surveys, and therefore a true mortality estimate unavailable.

Floodplains connected to mainstems benefit fish population health (Ericksen et al. 2009, Sellheim 2015), and flooding is an important part of salmonid life history (Brown 2002). A certain level of fish entrapment in floodplains is natural (Brown 2002), and likely contributes to nutrient cycling within river ecosystems (Nagrodski et al. 2012). However, fisheries managers may want to avoid entrapment of depressed fish populations. We recommend the MCRI Steering Committee discuss the costs and benefits of potential entrapment at the MCRI Phase I site, and whether action or mitigation is required.

Table 21. Fish minnow (Gee) trapped during 2018 surveys.

Species	Size	# individuals
Rainbow Trout	< 10 cm	7
Longnose Dace	< 10 cm	3
unknown minnow	< 10 cm	16
Redside Shiner	< 10 cm	19
Sculpin	< 10 cm	2
Total individuals		**47**

Figure 15. Examples of fish detected and isolated pools from 2018 minnow (Gee) trap surveys.

5.2 Incidental wildlife observations

Non-target species observations were recorded during amphibian and vegetation surveys. Multiple non-target wildlife species were observed directly or via signs (**Table 22**, **Figure 16**).

Table 22. Incidental non-target species observations during 2018 surveys.

Common name (scientific name)	BC Listing	# individuals	Life stage	Observation notes
American Black Bear (*Ursus americanus*)	Yellow	2	juvenile; adult	footprint; floodplain and stage 2
Raccoon (*Procyon lotor*)	Yellow	1	adult	footprint; floodplain and stage 2
Eastern Grey Squirrel (*Sciurus carolinensis*)	Exotic	1	adult	stage 2 trees
Deer (*Odocoileus* spp.)	Yellow	unk	adult	tracks, scat
Great Blue Heron (*Ardea herodias*)	Blue	1	adult	foraging at notches
Common Merganser (*Mergus merganser*)	Yellow	2	adult	mainstem
Mallard (*Anas platyrhynchos*)	Yellow	10	adult (1); ducklings (9)	floodplain
Swallow (*Tachycineta* spp.)	Yellow	unk	adult	floodplain
Northern Flicker (*Colaptes auratus*)	Yellow	1	adult	floodplain and stage 2
Bald Eagle (*Haliaeetus leucocephalus*)	Yellow	1	adult	stage 2 trees
Common Nighthawk (*Chordeiles minor*)	Yellow	5	adult	flyover
Canada Goose (*Branta canadensis*)	Yellow	7	adult (2); gosling (5)	stage 2 gravel bar; floodplain
Killdeer (*Charadrius vociferus*)	Yellow	1	adult	floodplain

Figure 16. Examples of the diversity of wildlife prints on site, and Great Blue Heron foraging at notch (bottom right).

6.0 Recommendations and next steps

It has been a valuable opportunity to record post-treatment conditions and observe the outcome of enhanced areas for the Mission Creek restoration work. Over the past four years of monitoring, Mission Creek has experienced two consecutive extreme freshets in 2017, and 2018, which has caused widespread geomorphic changes to the restoration site. Despite these changes, the project resulted in increases in habitat complexity, instream cover, floodplain/riparian function, and flood capacity. Monitoring has been valuable in directing adaptive management works in 2018 and 2019, which aimed to improve flow patterns and restore instream cover features lost after the initial restoration. Future adaptive management works should maintain/restore other fish habitat features lost since restoration works, such as root wads, along with bank stabilization. Monitoring should continue long-term in order to better understand sediment dynamics at the site, monitor fish and amphibian use, monitor vegetation succession and invasive species, and determine the long-term success of the restoration works.

Detailed recommendations include:

- For future restoration of woody debris, focus on root wads and LWD with high complexity (branches/roots), and place low enough so that they are functional at all flows.
- Continue to monitor habitat types and gravel bars to see if restoration works will influence re-organization and/or continued movement.
- Continue to monitor substrate composition in relation to the preferred range for kəkniʔ spawning, conducting modelling where necessary to understand changes in tractive force.
- Continue to monitor percent cover particularly after adaptive management works.
- Continue snorkel and visual surveys during the fall spawning run, comparing kəkniʔ use by reach.
- Complete invertebrate survey of the site to assess ecosystem health due to restoration.
- Continue monitoring vegetation establishment with focus on meander banks and other exposed slopes. Conduct planting/seeding to increase rate of colonization and stabilization. Bio-engineering for stabilization is recommended over riprap and other hard engineered options.
- Monitor the hockey stick boulder clusters for long-term pool habitat maintenance and pool 4 adaptive management possibly.
- Allow the floodplain to continue colonizing naturally while monitoring succession and introduced invasive vegetation.
- Continue to allow sedimentation/disturbance in the floodplain but monitor the rate of sedimentation; some sedimentation is critical in facilitating establishment of riverine cottonwood-associated plant communities.
- Continue monitoring amphibian presence and abundance, particularly in years varying in freshet level/duration, and following recent adaptive management applications (e.g. floodplain outlet modification).
- Restorations of this nature require time for regeneration of vegetation. Vegetation monitoring should occur over at least 10 years to ensure stability, vegetation colonization are occurring, and habitat benefits are maximized. Monitoring sessions can occur every 3-5 years.
- Repeat baseline studies until 2020 (5 years post-restoration) to monitor site succession and whether progress is consistent with restoration goals.

Next steps:

- Steering committee discuss how to approach potential fish entrapment mortality (costs/ benefits, monitoring, etc.).
- Apply for additional funds to complete the monitoring plan in full.
- Compile data from complementary studies of the creek and study area to give a full picture of the system and the impacts of restoration works.
- Adaptively manage the design into additional restoration areas.

The ONA looks forward to continuing to document the successes and challenges of these projects as part of the larger vision of Okanagan Nation Elders in healing the watershed and "bringing it back" *kt cp'əlk' stim'*.

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Appendix A: Sampling procedures

Appendix A1: Modified Wolman pebble count

Sampling Equipment: **Sampling Equipment**:

- Callipers
- Data sheets
- Waders and safety equipment

Study Site Locations:

- XS1
- XS2
- XS3
- XS4
- XS5
- XS6

Sampling Methods:
(From Kondolf 1997; Wolman 1954)

1. Step-toe procedure along cross-sections (perpendicular to flow).
2. Sample streambed from one bank to the other (targeting areas of relatively homogeneous particle-size distributions (i.e. spawning habitat types).
3. With eyes averted, safely reach down to the tip of the boot and select the first particle. Don't count bedrock, garbage, construction debris, or organic materials. Otherwise, measure whatever the tip of the boot first touches, be it silt, gravel, cobble or boulder.
4. If you hit fine sediment that covers a rock completely (not sporadically), count the fines, not the rock.
5. If you've hit fine sediment, you don't need to pick it up. Just call out "fines," and the recorder will enter a tally in the "<4 mm" row.
6. Measure the diameter of the sample along its intermediate axis (to find this, first find the longest axis; then find the smallest axis (that is perpendicular to the longest axis). There is now one more axis that is perpendicular to both the longest and shortest axes—that is the intermediate axis, or b-axis.
7. If you can't easily remove the rock from the bed, excavate around it and measure it in place. (You may have to "let the dust clear" for a few seconds.) The intermediate axis will be the smaller of the two exposed axes.
8. Record sampled particle size.
9. Repeat this procedure, crossing back and forth across the streambed (counts should be done all in one day with a minimum of 100 counts).

In this case, 25 counts were done per cross-section, with a total of 150 counts calculated for the entire project area. The pebble count method is modified to target low flow (wetted width of stream) since monitoring interest is in substrate conditions during spawning periods (i.e. low flows).

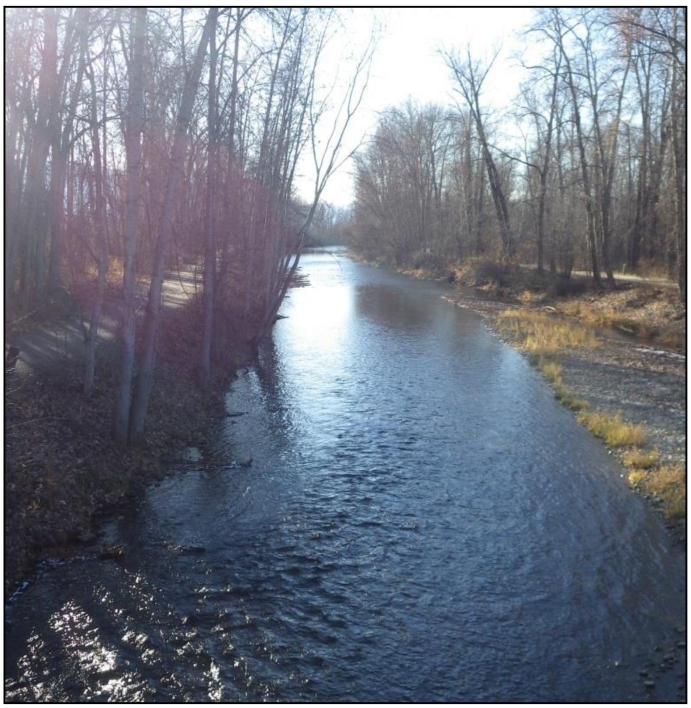
Appendix A2: Channel morphometry measurements

Sampling Equipment:

- 100’ tape, or range finder
- camera, photo log
- Safety equipment

Study site locations:

- Reach 1
- Reach 2
- Reach 3
- Reach 4
- Reach 5
- Reach 6



Sampling Methods:

1. Sketching the reach as laid out in Newbury and Gaboury (1993).
2. Beginning at the Casorso Bridge, the reach is walked while recording the length and width of habitat types such as Notches, riffles and glides.
3. The surface area of each feature is then calculated in meters.
4. Photographs of each habitat type are taken.

Appendix A3: Fish habitat feature measurements

Sampling Equipment:
- 100’ tape or range finder
- Camera
- River safety equipment

Notch 2

Study Site Locations:
- Reach 1
- Reach 2
- Reach 3
- Reach 4
- Reach 5
- Reach 6

Sampling Methods:

For each LWD

1. Tally on the data sheet the number of pieces by category and zone of **lowest** intrusion. The zones are defined as:
    a. the **wetted channel** (the wet part of the stream) on the day you are monitoring,
    b. the **bankfull channel**.
2. If it is noticeable that some of the LWD has been installed as part of a restoration project, rather than having been recruited naturally, make tallies in 2 separate sub-columns: “natural” and “artificial.”
3. After tallying, write out and circle the total number in each box. Remember to write zeroes if none is observed.
4. If there are any pieces that don’t meet the criteria of 10cm diameter and 1 m length but nevertheless seem to be serving channel-forming or habitat-creating functions, note them on the data sheet.
5. Take photos of the features such as LWD pieces.

For SWD
1. Note the length of the bank covered in SWD
2. Measure the depth of protrusion in the river of the SWD

Boulders
1. Count the total number of boulders

Gravel bars
1. Note the length of the bank covered of gravel bar
2. Measure the depth of protrusion in the river of the bar based on bankfull width

Appendix A4: Cross section sampling procedures for depth measurements

Sampling Equipment:

- Measuring Tape
- Measuring Rod
- Camera
- River safety equipment

Study Site Locations:

- XS1
- XS2
- XS3
- XS4
- XS5
- XS6

Sampling Methods:

Based on the discharge measurement section (4.2.5) of the Manual of Standard Operating Procedures for Hydrometric Surveys in British Columbia (RISC 2009).

1. Locate and verify monuments. Describe monuments (or landmarks) and or any changes to the site.
2. Place a tagline across the watercourse at (pre-selected) cross sections (refer to guidelines in "Locating the Metering Section" in subsection 4.2.5.1).
3. Anchor the tagline with the zero referenced to the initial point. The initial point is a permanently marked point at the start of a cross section, normally located above the high water mark.
4. Wade across the watercourse, stringing the tagline at a right angle to the direction of the current.
5. Secure the tagline on either shore and determine the overall width of the metering section.
6. Spacing of (preferably at least 10) verticals along the tagline (follow guidelines in "Locating the Metering Section" in subsection 4.2.5.1).
7. Record the tagline distance for the edge of water (if there is a steep drop at the edge of the stream, the first "vertical" depth observation should be taken close to the edge).
8. Traverse along the cross-section to the next vertical(s). Record (vertical) distance(s) on the tagline. Observe and record the depth (standing downstream from the measuring rod so as not to influence the measurement).

Appendix A5: Instream cover area

Cover is a structural element in the wetted channel or within 1 metre of the water surface that serves to visually isolate fish and/or to provide suitable microhabitats where fish can hide, rest or feed (Johnston and Slaney 1995).

Sampling Equipment:

- Range Finder
- Measuring tape

Study Site Locations:

- Reach 1
- Reach 2
- Reach 3
- Reach 4
- Reach 5
- Reach 6

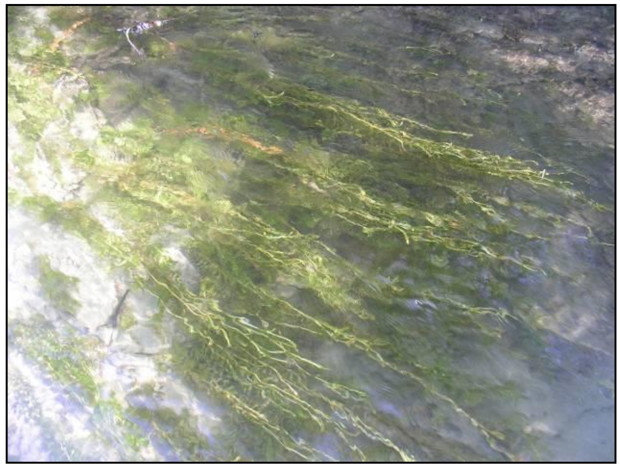
Sampling Methods:

Estimate the total surface area in each reach that is covered by the following cover types:

- SWD = small woody debris
- LWD = large woody debris
- B = Boulders
- C = undercut banks
- DP = deep pool (i.e. the portion of a pool with a depth >1m)
- OV = overhanging vegetation within 1 metre of the water surface
- IV = instream vegetation.

Record the dimensions of each cover feature to create an area.

Appendix A6: Macrophytes sampling



Sampling Equipment:

- GPS
- Measuring tape
- Data sheets
- Camera
- Plastic bags and waterproof labels
- Snorkel equipment
- Safety equipment

Study Site Locations:

- Reach 1
- Reach 2
- Reach 3
- Reach 4
- Reach 5
- Reach 6

Methods for the Mainstem Channel Survey:

1. Divide the mainstem in 2 portions: Right side and Left side (data collection is recorded per reach).
2. Walk (or snorkel, pending on visibility and depth) in along the right portion of the mainstem and record information on each herbarium (area covered by Macrophytes):
    - Note the shape of the herbarium: rectangle or triangle.
    - Take the measurements of the herbarium with the measuring tape or the range finder depending on the size of the herbarium: length (m), width (m).
    - Take the GPS coordinates of the middle of the herbarium. For herbarium that are 10m or more in length, take a GPS point at each extremity of the herbarium.
    - Note the density of the herbarium (i.e. the percentage of coverage by Macrophytes): 1%, 5%, 10%, 25%, 50%, 75%, and 100%.
    - Note each species present in the herbarium and it relative abundance (i.e. the percentage of the herbarium covered by each species).
    - Take pictures and note other observations.
3. Walk (or snorkel, pending on visibly) in along the left portion of the mainstem and record the same information on each herbarium.

Appendix A7: Snorkeling procedures

Sampling Equipment:

- Snorkel equipment and wetsuit
- GPS
- Data sheets
- Camera
- Safety equipment

List of reaches:

- Reach 1
- Reach 2
- Reach 3
- Reach 4
- Reach 5
- Reach 6

Survey Methods:

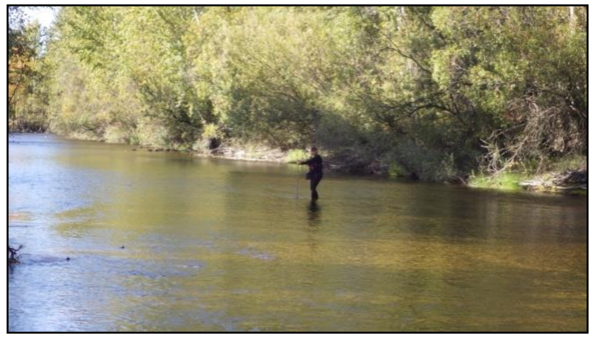
1. Snorkeling surveys are conducted to identify, enumerate and classify salmonids and non-salmonids into length categories. Data collection is recorded per reach and includes the start and end times, species (for salmonids), family (for non-salmonids), the number of fish of each species or family, and the length category (<10 cm, 10 – 20 cm, 20 – 30 cm, 30 – 40 cm, or > 40cm).

Description of the biological measurements collected.

Measurement	General Description	Units
Fish species	Salmonids and non-salmonids are identified to species where possible.	Species or family
Number of fish	The number of fish, of each species and family, are counted.	Number
Length category	Counted fish are measured and classified into one of three fish length groups (<10cm, 10-30cm, or >30cm).	cm

2. The underwater visual distance, average wetted width, stream temperature and environmental conditions at the time of the survey are also recorded. The number of crew members needed for the snorkel survey is dependent upon the underwater visual distance. Five snorkelers are required for this project due to average wetted width of 25m
3. Each snorkeler floats downstream in a straight line across the wetted width of the stream and spaced in intervals determined by the underwater visual distance.

Appendix A8: Redd distribution assessments



Sampling Equipment:

- GPS
- Measuring Rod
- Velocity meter
- Range finder
- Waders and safety equipment

List of reaches:

- Reach 1
- Reach 2
- Reach 3
- Reach 4
- Reach 5
- Reach 6

Survey Methods:

All patches of redds are mapped and measured and the spawner density within each redd patch is estimated to the nearest 25%. The highest observed redd densities are taken to represent 100% density with medium low and very low observed redd densities representing 75%, 50% and 25%, respectively. Single redds are not included as redd patches. In addition to clearly defined single redds, any patches smaller than 3 m^2 are assumed to be single redds based on ONA's experience observing kəkniʔ redds in the q̓awsitkʷ (*Okanagan River*).

Patterns in spawning habitat location within the channel are also identified, namely the distribution of individual measured redds (i.e. those near transects) and redd patches by spawning habitat type. The six spawning habitat types are:

1. Deep riffle: deep turbulent flow found throughout the site length, with depths greater than 0.3m;
2. Run-end: shallow to deep runs found immediately upstream of islands or mid-channel bars;
3. Riffle: shallow turbulent flow found throughout the site length, with depths less than 0.3m;
4. Margin: found along the steep sides of islands, bars, and banks especially on the downstream side of inside bends;
5. Side-channel: characterized as having much shallower water than the main channel but not including areas where the main channel split into nearly equal halves; and
6. Bar-end: a sub-class of margin habitat found on the low gradient downstream tails of bars.

In each redd patch, water depth and water velocity are measured using a velocity meter. Descriptive statistics (mean, range, standard deviation) are calculated for each of the habitat variables using data from all of the redd patches measured.

Appendix A9: Velocity measurements

Sampling Equipment:

- Pygmy velocity meter
- Range Finder
- Stop watch
- Calculator

Study Site Locations:

- kəkniʔ spawning bed(s) within in each reach (1-6)

Sampling Methods:

1. Locate spawning beds and describe locations (and or reaches).
2. Situate velocity meter for best representation of flow measurements (around spawning beds).
3. Position the velocity meter, whereby the operator:
   a. stands downstream from (and to the side of) the meter.
   b. holds the meter's wading rod vertically (if the axis of the meter is not kept vertical, the meter will under-register)
   c. aligns the metering wheels parallel to the direction of flow
4. Set the meter to the correct depth (60% of the water depth measured from the water surface) to begin measurement.
5. Count and record the number of revolutions the bucket wheels make for the duration of 40 seconds.

Along the spawning beds, water depth is documented at the same point where average velocities are recorded. The average velocity of the water depth profile is taken at 60% of the water depth measuring from the water surface using a velocity meter that recorded averages over 40 seconds. Velocity meters need to be calibrated and tested periodically during the study.

Appendix A10: Kokanee spawning enumeration survey

Sampling Equipment:

- Personal safety gear
- Tally counters
- Thermometer
- Polarized glasses for crew
- Brimmed hats for crew

List of reaches:

- Reach 1
- Reach 2
- Reach 3
- Reach 4
- Reach 5
- Reach 6

Survey Methods:

1. The study area surveyed by instream snorkeler from upstream reach downstream through all remaining reaches from late September for a total of 3 daily surveys.
2. Visual counts at Mission Creek are conducted by a one-person crew floating downstream through thalweg.
3. Observers count live (holding and spawning) and dead fish within the channel.

Appendix A11: Vegetation and shoreline stability surveys

Sampling Equipment:

- 100’ tape or range finder
- camera
- Magnifying glass (for grasses)
- Paper bags for samples if needed
- Clinometers (for tree height)
- Plant identification guides
- 1 x 1 m plot

Study site locations:

- Notches and Other (sections between Notches) on left bank of main creek stem

Sampling Methods:

Vegetation surveys using a random stratified transect/plot method:

1. Using a random number table mark out transect lines and plot points
    a) Using a monument as a marker, count steps (or use a measuring tape) to mark out the first transect line start point along the upstream section
    b) Go back to the monument
    c) Select a new random number. Using the same technique as before (steps or measuring tape) mark the second transect line start point
    d) Repeat steps 1 and 2 until you have start points for:
        i. transects at the upstream section
        ii. transects along targeted areas of concern (i.e. Notches in this case)
        iii. transects at the downstream section
    e) Map out transect lines in each section, directing the transect line perpendicular to the bank
    f) Travel along each transect line, sampling 2 x 2 m plots:
        i. Use the random number table to determine how far along each transect to place plots:
            1. 1 plot per transect at the upstream and downstream sections
            2. 2 plots per transect at the pond section
    g) Identify vegetation species found in each plot (recording priority levels, high = listed on provincial weed act and noxious, medium = not listed as noxious, regionally or weed act, but invasive, low = introduced, invasive, with minimal known detrimental ecological impacts, or easier to manage)
    h) Measure: % ground cover, % canopy cover, % native species cover, % soil composition by substrate, substrate embeddedness, shoreline stability classification ("very unstable" to "very stable", based on slope, substrate, and vegetation establishment (from Henshaw and Booth 2000).

Appendix A12: Amphibian monitoring

Active larval searches

Sampling Equipment:

- Data sheets
- Calipers
- Thermometer
- Relative Humidity meter
- Site –appropriate personal safety gear (i.e. reflective wear for night surveys, gators if walking through potential rattlesnake habitat, etc.)
- Headlamp
- Flashlight
- Buckets
- Dip net
- Camera
- Stopwatch (i.e. time-keeping device)
- Field gear sterilization protocol, spray bottle, bleach, and scrub brushes
- Amphibian reference call samples (http://www.env.gov.bc.ca/wld/frogwatch/whoswho/calls/)
- Amphibian identification guides

Survey Methods (see MELP 1998):

1. Survey site on calm, high-visibility days during daylight (wind less than Beaufort scale 3).
2. "shoreline" is defined as the intersection of water and land; "shallow water" is defined as water up to 1 m in depth; and "shore" is defined as the area along the bank within 3 m of the shoreline (MELP 1998).
3. Fill out known information on data sheets.
4. Walk perimeter of all wetted areas (i.e. floodplain, side channel, pools) and visually survey shoreline, shallow water, and shore for eggs, larvae, and mature individuals.
5. As you travel perimeter, conduct repetitive dip-net searches. Scoop the dip-net into the water and along the bottom 2-3 cm, in a 1 m breadth. The direction of scooping and dragging should run parallel to the shoreline. Search the dip-net for eggs and larvae captured.
6. Record remaining data fields.
7. Sterilize field gear between surveys and locations according to MOE (2008) and Advisory Practice #5-Didymo (APB).

Auditory surveys

Sampling Equipment:

- Data Sheet
- Time Keeper

Survey Methods (adapted from MELP 1998):

1. Surveys conducted on calm evenings, 1 hour after sunset wind less than Beaufort scale 3.

2. Arrive at site and listening station; wait 1 minute to allow wildlife to resume activities following disturbance of your arrival.

3. Listen for calling amphibians for 5 minutes per listening station (Pierce and Gutzwiller 2004).

4. Record the calling intensity level and number of individuals calling. Fill in remaining data fields before leaving site.
5. Clean all field gear according to the hygiene protocol for amphibian field researchers (MOE 2008) and Advisory Practice #5- Didymo (APB) to prevent cross-site contamination.

Minnow (Gee) trapping

Sampling Equipment:

- Camera
- Minnow (G) traps (number dependant on wetted areas)
- Clips for traps
- Cat food for bait
- Rope/stake to attach trap to shore
- Bucket for processing samples caught
- Calipers
- Data sheets
- Thermometer
- Relative Humidity meter
- Site –appropriate personal safety gear (i.e. reflective wear for night surveys, gators if walking through potential rattlesnake habitat, etc.)
- Headlamp
- Flashlight
- Dip net
- Camera
- Stopwatch (i.e. time-keeping device)
- Field gear sterilization protocol, spray bottle, bleach, and scrub brushes
- Amphibian reference call samples (http://www.env.gov.bc.ca/wld/frogwatch/whoswho/calls/)
- Amphibian identification guides

Sampling Methods (adapted from MELP 1998):

1. If using bait, put bait in each trap with a tea-infuser ball.
2. Set traps randomly and stratified along the perimeter of the wetland, notches, side channel (i.e. all wetted areas except mainstem).
3. Tie rope to each trap, and anchor traps to stakes on shore or secure tree stumps, fences, etc. Lost traps are a source of mortality for any animals trapped inside.
4. Ensure all traps are left one-third above water to allow trapped animals access to oxygen.
5. Check traps every day within maximum 12 hour intervals to minimize trap mortality and ensuring traps are not set in the heat of day. Record individual data and release immediately upon processing into the same area individuals were captured from.
6. Sterilize all gear according to MOE (2008) and Advisory Practice #5- Didymo (APB).

Appendix B: Monitoring data

Data available upon request, at the discretion of the Mission Creek Restoration Initiative Steering Committee.