Effectiveness Monitoring Plan

Trestle Channel Habitat Enhancement Project

Prepared for the Pacific Salmon Foundation
and
Fraser Valley Watersheds Coalition

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Pearson Ecological
Consulting for Conservation

PACIFIC SALMON FOUNDATION

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Acknowledgments

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We are grateful for the opportunity to work with all of you!

Photo Credits:
Pearson Ecological Inc.

Project Biologist:
Mike Pearson, PhD, RPBio, QEP
2840 Lougheed Highway
Agassiz BC
V0M 1A1
604 785-7246
mike@pearsonecological.com

1 Introduction

In 2017 Pacific Salmon Foundation (PSF) initiated a pilot project to develop standard methods for routine effectiveness monitoring (REM) of their projects. Five recently completed, PSF funded project sites in the Fraser Valley were selected for inclusion. One of these is the Trestle Channel Project, the most recent phase of restoration of the Browne Creek Wetlands in south Chilliwack. The project was led by the Fraser Valley Watersheds Coalition (FVWC) with design and construction supervision provided by the local Resource Restoration Unit of Fisheries and Oceans Canada. Work was completed in March 2016. It received support, including funding and in-kind contributions from a broad range of local institutions and organizations (FVWC 2015).

REM is envisioned as collaboration between the group(s) that led project construction, local First Nations and professional biologists. The intent is to collect high quality data for evaluation of project success, to increase awareness of habitat issues, and help build technical capacity within First Nations and the stewardship groups. In this case, participants from Soowahlie First Nation, The WaterWealth Project, Fraser Valley Watersheds Coalition and the broader community are working with Pearson Ecological to collect the data.

This report describes the effectiveness monitoring plan and methodology of the Trestle Channel project and reference sites. It is based on the projects goals and objectives, as articulated in the original funding application from FVWC to the PSF Community Salmon Program and on the project monitoring plan workshop held on October 5, 2017.

2 Watershed Context

The Trestle Channel Project site lies within the traditional territory of the Soowahlie First Nation on the Vedder River floodplain, approximately 11 km upstream from the Fraser River, near Yarrow. Approximately 6 km upstream of the site, at the Vedder Bridge, the Vedder River becomes the Chilliwack River, which originates in North Cascades National Park (Washington) and drains a watershed of over 1200 km^2. Most of it is forested, including significant areas of valley-bottom old-growth conifer forest upstream of Chilliwack Lake (Figure 1: Project Location in the Watershed). Timber harvesting and recreational activities are significant land uses in the watershed. Urban development and agriculture are the predominant land uses along the Vedder River. It is flanked on both banks by dikes, and walking trails and is heavily used for recreation.

The River's name changes at the Vedder Bridge because it did not originally flow westward from that point, as it does now. Prior to 1875 it flowed north for 8.5 km, splitting into the multiple braiding channels of an extensive delta, before emptying into the Fraser River. In the early 1870s settlers blocked off the entrance to delta's sloughs in an attempt to reduce flooding in Chilliwack. The river deposited debris and eroded soil against the logs, eventually diverting the entire flow through the previously small Vedder Creek (Woods 2001), which emptied into Sumas Lake at or very near the current location of Trestle Channel. Sumas Lake in turn was drained in the 1920's (Figure 2 Project Location and Configuration of Surrounding Waterbodies). Around that time the Vedder River floodplain was also diked for flood control (Rafter 2001; Woods 2001). Hopedale Slough and Trestle Channel were active side channels of the Vedder River until a secondary dike at the bank of the Vedder River was constructed in the 1960's, restricting flows and fish access into these floodplain channels.

Figure 1: Location of Project Sites, at Chilliwack

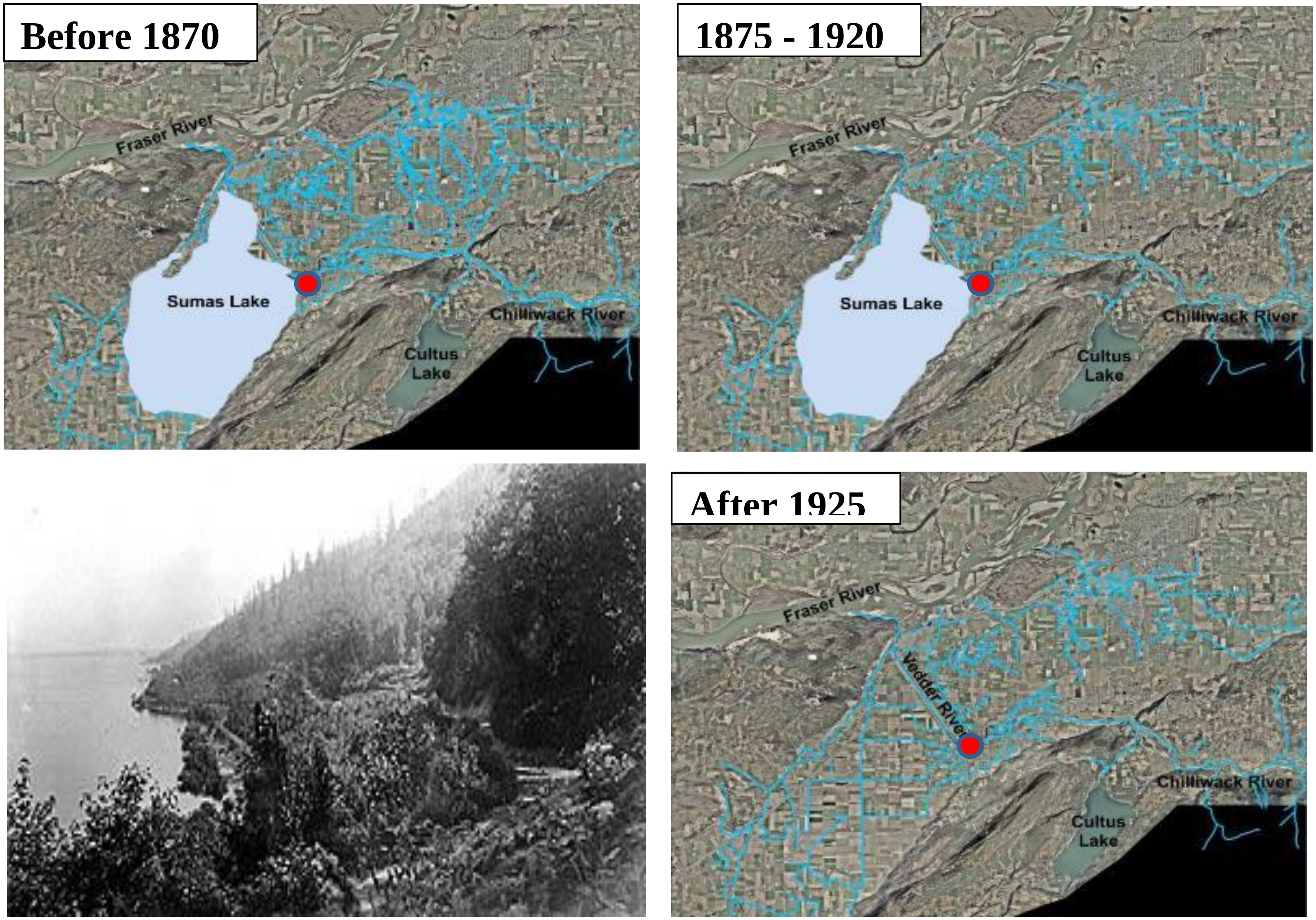

Figure 2: Project Location (red dot) and Configurations of Surrounding Waterways Prior to the 1870s. Photograph is of Sumas Lake at Sumas Mountain.

3 The Project Site

The Project Site, Trestle West Channel, (UTM 10U 569795 E 5437758 N) is located in mature second growth deciduous forest on the floodplain of the south bank of the Vedder River (Figure 3: Project Site). It is bounded to the north by the Vedder Rotary Trail and the Vedder River, a railway track to the east, and Vedder South Dyke Trail to the south.

The Project works consisted of restoring flows to a channel isolated by construction of a secondary dike in the 1960s and re-connecting it to the Vedder River. Trestle Channel was also enlarged and complexed with woody debris. The riparian understory was cleared of extensive Himalayan blackberry growth and was planted with native trees and shrubs to improve the adjacent fish habitat. It is approximately 800 m in length.

Figure 3: Trestle Channel Enhancement Site(Top), confluence with the Vedder River (Left), and with large woody debris across the channel (Right), 2017

4 Objectives

Species focused objectives for habitat enhancement in the Trestle Channel were not clearly stated, but were inferred from the application as:

1. Increase spawning capacity for Chum Salmon.
2. Increase spawning capacity for Coho Salmon
3. Increase rearing capacity for juvenile Coho Salmon.
4. Increase productive capacity for resident Cutthroat and Rainbow Trout
5. Provide breeding habitat for native amphibians, particularly Red-legged Frog.

5 Monitoring Study Design

5.1 Baseline Conditions

Construction of the secondary dike at the bank of the Vedder River in the 1960s disconnected Trestle Channel from the Vedder River and deprived it of flow. Its pools and spawning gravels were infilled with sediment and organic debris. Although quantitative baseline data on fish use and habitat conditions prior to project construction were not collected in Trestle Channel. It can be assumed that its use by salmonids for the previous 50 years has been extremely limited or absent.

5.2 Reference Sites

Two reference sites are used for comparisons with the Trestle Channel Project Site. Both are older habitat restoration projects. One of them, Peach Creek (Figure 6) is located on the same river within 2 km of Trestle Channel, and the other in the Coquitlam River watershed, 60 km to the west (Figure 5: Or Creek Habitat Complex); Reasons for their selection and objectives for which they are appropriate references are provided in Table 1: Reference Sites.

Table 1: Reference Sites for Montitoring Effectiveness of Trestle Channel.

Site	Reference Type	Information Provided
Or Creek Habitat Complex	Regional Restoration	Conditions in similarly designed 30+ yr. old habitat creation site in ‘pristine’ setting
Peach Creek	Regional Restoration	Conditions in similarly designed 30+ yr. old habitat restoration site in the same watershed with significant historical monitoring data.

5.2.1 Or Creek Habitat Complex

The Or Creek off channel complex (UTM 10U 516790 E 5465009 N) is the second reference site (Figure 4: Or Creek). It enters the Coquitlam River a short distance downstream of the Coquitlam Water Supply Reservoir. In 1993 Fisheries and Oceans Canada completed a major off channel habitat creation project within the portion of the watershed managed for drinking water supply. It is closed to the public, forested and subject to very little human disturbance. It is similar to Trestle Channel in that it is a side channel with a regulated flow intake (culvert) from a moderate sized river that originates in a largely forested, mountainous watershed. It also has similar water quality, types of habitat present and salmonid species present. It functions as a regional reference site, representative of regional conditions with minimal ongoing human influence.

Figure 4: Or Creek Habitat Complex in the Coquitlam River Watershed.

5.2.2 Peach Creek

Peach Creek (UTM 10U 571869 E 5439027 N), a tributary of Vedder River is a reference site, for Trestle Channel (Figure 5: Peach Creek). It is located in the floodplain of the Vedder River and consists of a mix of riffle-pool channel form and off channel ponds (Figure 5: Peach Creek). It was restored by DFO in the 1990's and is considered one of the most productive groundwater-fed side channels in the Vedder system.

According to local signage, prior to enhancement, the channel lacked pool habitat deeper than 10 cm under most flow conditions and natural development of deeper pools was prevented by the substrate which is predominantly gravel. The City of Chilliwack in partnership with Fisheries and Oceans Canada, PSF, and FVRD extended salmon spawning habitat along Peach Creek. In August 2017, City of Chilliwack and DFO deepened and extended this channel further upstream of the sampled sections to further increase available habitat.

No suitable, natural, un-impacted floodplain channels exist in the Vedder/Chilliwack system to use in this capacity due to the history of habitat alterations described in Section 2. It is a watershed scale reference site; close enough to be affected by the same local influences (fish community, flood events etc.) but far enough away not to be affected by the restoration work at Trestle Channel. Peach Creek enters the Vedder River less than 2 km away. It contains upstream ponds and downstream riffle habitats. Mean and maximum flows are greater, but minimum flows less than in Trestle Channel. The western (downstream) half of it runs dry during drought conditions, including those of summer/fall 2017.

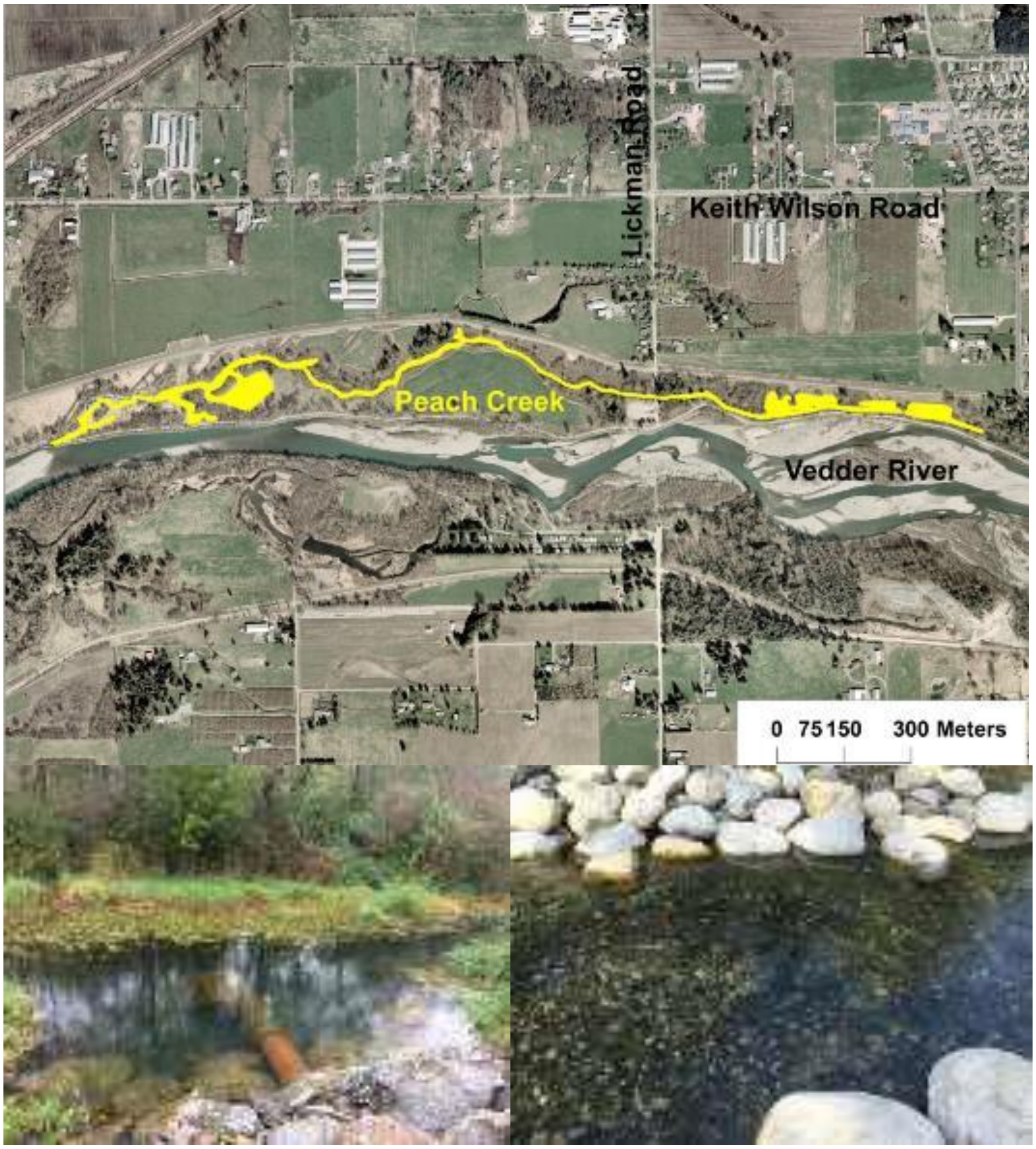

Figure 5: Peach Creek Reference Site South of Chilliwack.

5.3 Monitoring Duration

Current funding for this pilot project is limited to two years; however, the monitoring program is designed to include 6 monitoring years spread over a decade (Figure 7). Within each of the six monitoring years the sampling is completed according to the seasonal schedule detailed in Section 7.

By not monitoring every year, costs are greatly reduced over a 10 year post-project monitoring period. This gives the project site more time to recover or mature, and is likely to provide a better picture of its long term trajectory. Two year pulses are recommended to prevent the excessive influence of an unusual year (Pearson et al. 2005)

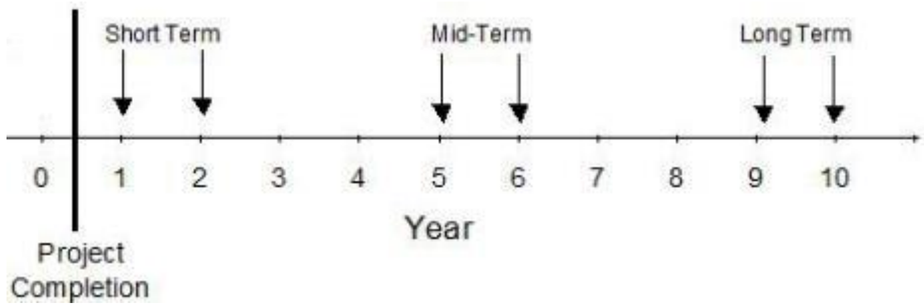

Figure 7: Sampling Will be Completed in Pulses, with the Short Term Period beginning in Fall 2017 (Details in Section 7: Sampling Schedule).

5.4 Monitoring Questions and Indicators

Well-designed monitoring programs are designed to answer specific questions that relate directly to project objectives. This ensures that monitoring obtains the data needed to evaluate whether objectives are achieved, partially achieved or not achieved and that time and money is not wasted on monitoring things that do not relate to the project objectives.

In this plan, indicators of success for each project objective are identified, questions regarding the indicator's status are written and sampling methods capable of answering each question are listed (Table 2: Questions, Indicators and Sampling Methods). This table is the heart of the monitoring plan.

Table 2: Questions, Indicators and Sampling Methods Associated with Monitoring Objectives.

Objective	Indicator	Question	Sampling Method	Effort: Frequency	Effort: Replicates
1. Increase spawning capacity for Chum/Coho Salmon	Spawner density	Is density of salmon spawners per 100 m spawning habitat higher or lower at Trestle Channel than in the reference sites?	Spawner Survey	3 surveys Oct-Dec	Census
	Access	Are spawners present in all sections of the project and reference sites?	Spawner Survey	3 surveys Oct-Dec	Census
		Do beaver dams or other obstructions appear to be blocking access to spawning habitat in project or reference sites?	Survey for obstructions	3 surveys Oct-Dec	Census
	Substrate size	Is the size distribution of the gravel within similar to reference sites and within range of published values?	Pebble Counts	annual Aug-April	100 particles
	Substrate embeddedness	Is the proportion of substrate <2mm in size higher or lower than at reference sites?	Digital image analysis	Annual Aug-Apr	4 transects per site 4 photos/transect
		What is the average level of embeddedness of particles?	Esimated Percent embedded*	Annual Aug-April	10 particles
	Cover for Spawners	Are the number of instream cover objects, length of undercut banks, and area of pool depth > 40 cm per 100 m of channel higher or lower than in the reference sites?	Longitudinal channel survey	Annual Aug-April	2 Reach of 12 channel widths
2. Increase rearing capacity for juvenile Coho Salmon. 3. Increase productive capacity for resident trout.	Catch per unit effort	Is the average number of coho/cutthroat/rainbow trout per trap/seine higher or lower than in the reference sites?	Feddes traps Gee traps Pole seine* Beach seine*	Apr & Nov Apr & Nov Apr only Apr only	>18/site >18/site >3/site >3/site
	Average Length/Weight	Is the average length/weight of Coho higher or lower than in	Fish board and balance	Apr & Nov	>30 preferred
	Average condition factor	Is the condition factor (weight/ length^{3}x10000) of coho/cutthroat/rainbow trout higher or lower than in the reference sites?	Fish board and balance	Apr & Nov	>30 preferred
	CPUE of Predatory fish	Is the average number of predatory fish >15 cm per trap higher or lower than in reference sites?	Fish board	Apr & Nov	NA
	Proportion of catch composed by salmonid/native/introduced species	Is the proportion of total fish caught that are salmonid/native/introduced higher or lower than in reference sites?	Feddes traps Gee traps Pole seine* Beach seine*	Apr & Nov Apr & Nov Apr only Apr only	>18/site >18/site >3/site >3/site
	Invertebrate food availability	Is the biomass of available invertebrates available to fish higher or lower than in the reference sites?	Surber sampler, Hess sampler, and/or D-net	Sept	3 per site
	Periphyton	Is periphyton coverage higher or lower than in the reference sites?	EPA 50 Dot Method	Aug-Sept	12 (3 per x-sectional transect)
		Is periphyton thickness higher or lower than in the reference sites?	Scrape Test	Aug-Sept	10 Rocks

4. Provide breeding habitat for native amphibians, particularly Red-legged Frog.	Egg mass density	Is the density of red-legged frog/other amphibian egg masses higher or lower than in the references sites?	Egg mass surveys	1 survey March-April	NA
		Is the average number of adult/tadpoles Red-legged frog, Northwestern salamander/introduced amphibian species per trap higher or lower than in the reference sites?	Feddes traps Gee traps Pole seine* Beach seine*	Apr & Nov Apr & Nov Apr only Apr only	>6/reach >6/reach >3/reach >3 reach
All	Canopy Cover	Is average percent canopy coverage at midline of channel higher or lower than in the reference sites?	Digital analysis of canopy photographs	Jun-Sep	20 per site
			Spherical densiometer	Jun-Sep	20 per site
			Visual Estimates*	Jun-Sep	6 per site
		What proportion of riparian area is under canopy of tree and shrub layers?	Point transects	Jun-Oct	5+ transects 20+ points per
	Plant Survivorship in Restored Plots	What is ratio of live plants in restored plots to number of each species planted?	Census	June-Oct	All planted areas
	Plant Growth in Restored Plots	What is average growth (cm/year) of riparian plants in restored plots?	Surveyors rod Photographs	Jun-Oct	>10 / species
	Plant Species Composition in Established Riparian Areas	What is the proportion of each species present in monitoring plots?	Census	Jun-Oct	All planted areas
	Plant Size in Established Riparian Areas	What is average diameter at breast height of trees within each of 5 monitoring plots? What is average height of shrubs within each of 5 monitoring plots?	Diameter Tape Surveyors Rod	Jun-Oct	All Trees 30 shrubs
	Water Quality	Is the temperature/dissolved oxygen/pH within tolerance limits of salmonids at all times?	Various Meters Temp. Loggers	Apr/Sept/Nov Hourly	Each trap/site Min. 1 per site
		What is water quality/site health rating using macroinvertebrate indices from the Streamkeepers Manual and from CABIN analysis?	Surber sampler, Hess sampler, and/or D-net	Sept	3 per Site CABIN = 3 min travelling kick
	In Stream Habitat Complexity	Is the density of cover objects/length of undercut bank/area of pool depth >40 cm per 100 m of channel higher or lower than in the reference sites?	Longitudinal survey Pond transects	Annual Aug-Apr	3 sections of 100 m channel 3 transects
	Site Photographs	How has site changed over monitoring period as seen from standard viewpoints?	Photographs	Spring/Summer/ Fall	>5 viewpoints
	Stability of banks and habitat structures	Are banks and habitat structures stable and functional?	Visual Inspection Photographs	Jun-Oct	All
		Is scour or sediment deposition altering channel or pond profiles?	Pond Transects Channel cross sections	Annual Aug-Apr	4 per site

6 Field Methods

As this monitoring project is part of a larger pilot project, intended to develop standard methods and protocols, the methods described below may be modified, added to, or even dropped during the course of the study. In the case of fish sampling, riparian surveys, and amphibian surveys, methods are already fairly well developed and unlikely to change much. In contrast, those for water quality, macroinvertebrates spawner surveys, and habitat complexity may well change significantly with field experience. In these cases, we will try to ensure that data is comparable before and after changes through cross calibration.

6.1 Spawner Surveys

Three spawner surveys will be conducted between mid-October and mid-December, separated by a minimum of 2 weeks. Project Site and Reference Sites will be surveyed by foot. Counts of live fish, dead fish and redds will be made in the sections (reaches) of the Project and Reference sites shown in Figure 6: Reaches Surveyed.

Dead fish will be opened to confirm gender and determine what proportion of eggs remain in females. Although our typical survey protocol includes cutting dead fish in half to avoid recounts in subsequent surveys, this will not be done at Peach Creek to avoid confounding surveys conducted by DFO staff. When possible, spawning surveys will be conducted jointly with the DFO crew.

6.2 Fish Passage

During surveys the location of potential migration obstructions, particularly beaver dams, will be recorded by GPS and photographed. Presence or absence of spawners above each of the dams will also be recorded.

6.3 Fish and Amphibian Sampling

Fish will be sampled in April and November of each year. Spring sampling is intended to document Chum and Coho Salmon fry, non-natal Chinook Salmon use and use by resident Cutthroat and Coho Salmon. Fall sampling is intended to document overwintering habitat use and salmon spawning activity.

Feddes Traps and Gee traps will be set in pairs overnight and baited with dried cat food and commercially processed salmon roe. Gee traps are double-ended funnel traps measuring 16 ½” x 9”. Feddes traps are similarly shaped but larger: 32” x 16” and are able to capture larger fish, providing a more complete inventory of the fish community. A beach seine and pole seine will be used in the April sampling in suitable habitats, but not in November to avoid damaging salmon redds.

Fish and amphibians captured will be identified to species and counted. Fork lengths of salmonids will be measured after light anesthesia in MS-222 (70 mg/L) or clove oil [1](40mg/L).

[1] [1] Anesthetic solution is 1 part clove oil to 9 parts ethanol. Use 2 ml solution in 5 Litres water

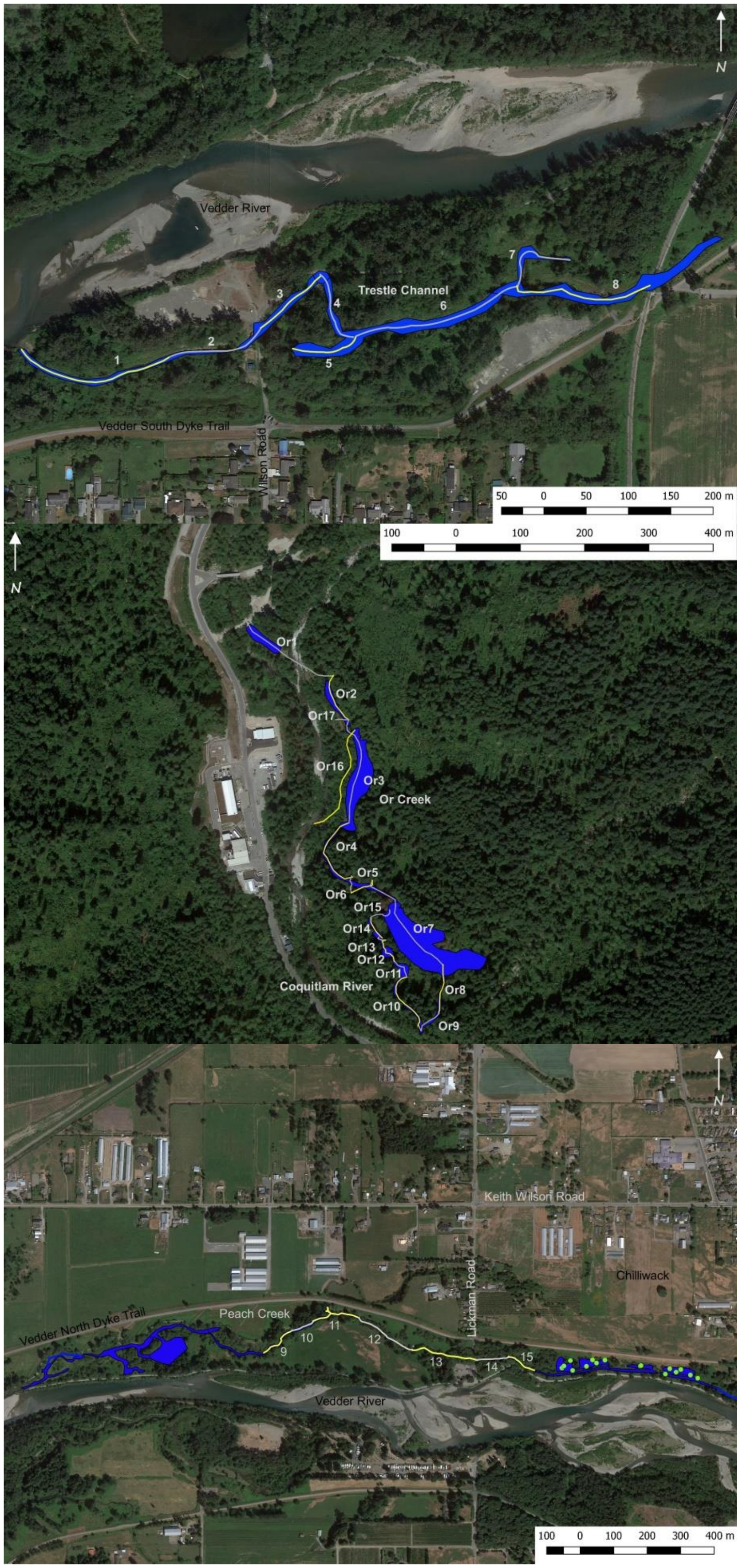

Figure 6: Reaches Surveyed for Salmonid Spawners and Redds in Trestle Channel (Top), Or Creek (Middle) and Peach Creek (Bottom.

At least one representative photograph will be taken of each species captured. All fish and amphibians will be promptly released at their point of capture.

Mean length and Fulton's condition factor[2] of salmonids will be compared between project and reference sites using Welsh's t-test for samples of unequal size and variance. Catch per unit effort (mean number of fish per trap) will be reported for each species.

6.4 Amphibian Egg Mass Survey

The entire wetted areas of the Project and Reference sites will be surveyed for amphibian egg masses in March or early April of each monitoring year using the same sections as for spawner surveys (Figure 6). Egg masses will be identified to species and total numbers recorded for each section. Representative photographs of each species of egg mass will be taken.

6.5 Macroinvertebrate Sampling

Macroinvertebrate sampling has two distinct purposes: a) to assess water quality/site health, and b) to assess the amount of invertebrate food that is available to fish. Both the existing Streamkeepers method and the more detailed standard protocol of the Canadian Aquatic Biomonitoring Network (CABIN) are designed to assess water quality and site health. They do not distinguish between invertebrates that are available for fish to eat and those that are buried in substrate and not available. Nor do they assess how much biomass (food) the invertebrates represent, as the focus is on what types of invertebrates are present, not on their size.

To assess **water quality and site health**, we will use the standard Streamkeeper Methodology and compare results to a full CABIN analysis (2018 only) of Project and Reference Sites. For the Streamkeeper assessment, three replicate Surber samples will be obtained from riffle habitats (if present) in September of each monitoring year. If no riffles are present, samples will be obtained with an invertebrate kick net or a Hess sampler (Bain & Stevenson 1999). Invertebrates will be live sorted and classified using standard references (Merritt & Cummings 1996; Voshell 2002) Site assessment metrics described in the Streamkeepers Handbook (Taccogma et al. 1995) will be used to characterize the site. These include an index of the prevalence of pollution tolerant and intolerant taxa, the number of EPT taxa, proportion of sample comprised of EPT taxa, and the proportion of the sample comprised by the most abundant taxon.

The Streamkeeper method identifies some of the more important groups at the level of Order rather than Family (e.g. mayfly rather than prong-gilled mayfly). We will identify EPT taxa (mayfly, stonefly and caddisfly) to Family level using a microscope and classify their pollution tolerance following Voshell (2002). Reference samples of taxa from each site will be preserved in ethanol labelled vials. The entire sample of invertebrates from each replicate Surber sample will also be preserved.

CABIN sampling will be completed by a qualified biologist with the assistance of Project Partners in fall 2018. Only sites with erosional habitat types (riffles, runs, cascades) can be included in CABIN sampling. Taxonomic identifications will be done by Cordillera Labs, Summerland. Sites will be compared with appropriate local CABIN reference sites selected by

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[2] $C = W/L^3 * 10{,}000$, where W= weight in grams, and L = fork length in millimetres (Murphy & Willis 1996)

an algorhythm on the basis of habitat data. Results will be plotted using Reference Condition Assessment, the standard CABIN analysis.

Invertebrate abundance as fish prey will be assessed on the samples collected for the Streamkeepers site health assessment. Each of the taxonomic groups, except burrowing taxa (Planarians and Oligochaetes) and mollusks, will be sorted into 3 to 5 size categories if notable size variation is present. The mass of each size category of each group will be estimated using the mean length and length-dry mass regressions from Smock (1980), Meyer (1992) and Benke (1999). The ‘available’ invertebrates from each sample will be preserved in ethanol for independent laboratory measurements (UBC) of ash free dry weight to facilitate evaluation of the method.

6.6 Periphyton

Periphyton is a mixture of algae, bacteria, other microbes and detritus that is attached to submerged surfaces. It is an important food source for macroinvertebrates and fish and its abundance is an excellent indicator of stream productivity. Abundance will be assessed using two methods: the standard CABIN sampling method (Environment Canada 2012), and the US Environmental Protection Agency rapid survey method (Stevenson & Bahls 1999).

The Streamkeepers and CABIN methods consists of scraping rocks from erosional habitats with a metal ruler and estimating the thickness of periphyton in mm (Environnement Canada 2012). We will sample 10 rocks from erosional areas during macroinvertebrate sampling using this method.

The EPA Method employs a clear bottomed bucket marked with a grid of 50 dots. The number of dots that occur over macroalgae in each of the thickness categories used in the CABIN method is recorded at 3 equally spaced stations across the cross sectional transects in erosional habitats (see Section 7.9.2).

6.7 Water Quality

Streamkeepers methods and proposed comparative methods are listed in Table 4. Basic water quality measurements include water temperature, dissolved oxygen, pH, specific conductivity and turbidity. These will be compared for accuracy and precision (variance) with standard professional methods and for cost and ease of use by non-professionals. Some candidate methods may be discontinued after the first year of monitoring, if they are clearly inferior to alternatives.

Table 3: Methods to be compared in measuring water quality attributes.

Attribute	Methods
Water temperature	*Hand thermometer Electronic meters (ECTestr35; YSI DO Pro) Temperature logger (Onset V2 Logger)
Dissolved oxygen	*HACH kit (Model OX-2P) DO meter (YSI DO Pro) DO Logger (Onset Hobo U26-001)
Specific conductivity	Conductivity meter (ECTestr35)
pH	*pH meter (ECTestr35) *Test strips (Hydrion pH 1.0-12.0)

	*Colorimetric test kit (Lamotte Precision pH 3.0-10.5)
Turbidity	Turbidity meter (Lamotte 2020 we Turbidimeter) *Turbidity Test Kit (Lamotte, 0-200 JTU) 120 cm turbidity tube (Dynamic Aqua Supply)

* Existing Streamkeepers method

Water quality will be measured at each trap location with meters only. Comparison of all methods will be made at least once annually with multiple participants making the same measurements at the same location to provide comparable data.

Analyses will include:

- Comparison of measured values to Canadian standards for aquatic life (CCREM 2015)
- Calculation and graphing of mean and 95 % confidence limits of all data
- Comparison of precision of alternative methods of measuring each variable
- Comparison of data and conclusions that could be drawn from spot measurements and logging of temperature and dissolved oxygen
- Temperature duration curves from water temperature loggers.
- Mapping of spatial variations in temperature and dissolved oxygen within project and control sites in mid-summer
- Assessing the frequency of instrument calibration necessary to obtain accurate results
- Measuring time to stabilization of readings for all meters.

6.8 Riparian Vegetation

Most of the riparian zone around the Project Site consists of mature second-growth forest. These riparian areas will be assessed for species composition and plant size. Areas planted with native species during the project will be assessed for plant survivorship, canopy development and growth. Percent canopy coverage over the channel of Project and Reference sites will also be assessed.

As riparian planting areas extensive at Trestle Channel, 4 monitoring plots will be established at the site totaling a minimum of 1000 m^2. Plot locations were established by using a random number generator (https://www.random.org/integers/). to identify a distance in metres upstream from the outlet to the Vedder River, with even numbers indicating a left bank location and odd numbers indicating a right bank location (Table 4: Random Locations). UTM Coordinates for a point on at the top of bank were generated by measuring the distance on high resolution satellite photographs on a GIS system (ArcMap 10.2). In the field the plot corner will be the closest point at the top of bank to the GPS Location. From this point the plot will extend inland, perpendicular to the channel, to the limit of the project planting area or 15 metres whichever is less. It will extend upstream the distance required to form a plot area of approximately 250 m^2. The corners will be marked with capped metal stakes.

In Year 1 (summer 2018), a census of each plot will be completed with all native trees and shrubs identified to species and counted. Diameter at breast height of trees larger than 10 cm diameter will be measured using a diameter tape (5 m, Forestry Suppliers Inc.). Shrub height will be measured using a 5 m surveyor's rod. Where density is high every 2^{nd} or 3^{rd} tree will be measured to produce a sample size of at least 30 per plot. In subsequent years, counts will allow annual percent survivorship to be calculated. Representative specimens of each species encountered will be photographed. Each plot will be photographed from its downstream corner at the channel. Average, standard deviation and range of height measurements for each area will also be reported.

Canopy development will be assessed using band transects. Transect centre lines extend inland from the metal stake corresponding to the UTM coordinates in Table 4. Each will be 12 x 4 m in size, with 25 evenly spaced sampling points located in the field using a tape measure (along the centerline) and a surveyors rod, laid across it with 2 m extending each side of the tape. Observation points are located at the 0, 1, 2, 3 and 4 m marks on the surveyors rod when it is laid across the tape at 0, 3, 6, 9, and 12 m marks.

Plants with canopy overlying an observation point will be identified to species. Species are categorized as trees, shrubs, native wetland plant, or grass/herbaceous, Woody debris, rock and bare soil are also noted for each observation point. Proportion of observations corresponding to each category will be calculated.

Canopy coverage over the channel will be assessed from measurements made at bank full elevation at the channel centre, every 10 m along all of the Aquatic Survey Reaches and the length of each riparian monitoring plot using three methods:

- A spherical densitometer, in which percent coverage of sections of sky are visually estimated using reflections in a grid etched on a convex mirror (Robert E. Lemmon Forest Densiometers, Model A).
- Vertical photographs using an iPad mini and analyzed using the image analysis program Image-J (Ecological Forester 2011)
- The CABIN method; a visual estimate using increments of 25 % coverage (Environnement Canada 2012)

Table 4: Random Locations Selected for Riparian Plots and Transects and Aquatic Habitat Surveys.

Location	Plot/Transect	Start Point	Random Distance	UTM E 10U	UTM N 10U
Trestle Channel	Riparian Plot/Transect 1	Vedder River	24	569541	5437740
	Riparian Plot/Transect 2	Vedder River	499	569796	5437777
	Riparian Plot/Transect 3	Vedder River	710	569979	5437827
	Riparian Plot/Transect 4	Vedder River	888	569998	5437881
	Aquatic Survey Channel	Vedder River	225	569594	5437752
	Aquatic Survey Pond	Vedder River	556	569850	5437781
Peach Creek	Riparian Plot/Transect 1	Lickman Road	529	573017	5438993
	Riparian Plot/Transect 2	Lickman Road	649	573116	5438970
	Riparian Plot/Transect 3	Lickman Road	754	573237	5438939
	Riparian Plot/Transect 4	Lickman Road	825	573299	5438899
	Aquatic Survey Channel	Lickman Road	248	572722	5438973
	Aquatic Survey Pond	Lickman Road	616	573087	5438983
Or Creek	Riparian Plot/Transect 1	Coquitlam River	119	516792	5464984
	Riparian Plot/Transect 2	Coquitlam River	180	516751	5465017
	Riparian Plot/Transect 3	Coquitlam River	731	516702	5465251

	Riparian Plot/Transect 4	Coquitlam River	910	516663	5465413
	Aquatic Survey Channel	Coquitlam River	143	516773	5464990
	Aquatic Survey Pond	Coquitlam River	371	516763	5465053

Figure 7: Randomly Selected Locations of Riparian Monitoring Plots/Transects and Aquatic Habitat Survey Reaches in the Trestle Channel (Top), Peach Creek, (Middle), and Or Creek (Bottom).

6.9 Aquatic Habitat Surveys

For flowing stream channels the length of the survey reach will be 12 bankfull channel widths (Wb). For larger ponds reach length can be doubled to 24 x Wb to improve coverage, and may extend downstream of the start point if the end of the pond is reached in the upstream direction in less than 24 x Wb. Note that Cross Sectional Transects are the only aquatic survey method that will be applied to pond Reaches.

6.9.1 Selecting the Survey Reaches

The downstream limit of the aquatic habitat survey reaches were randomly selected as described for riparian monitoring plots and transects in Section 6.8 (Table 4). One reach in flowing channel habitat and one in pond habitat were selected for each Project and Control site.

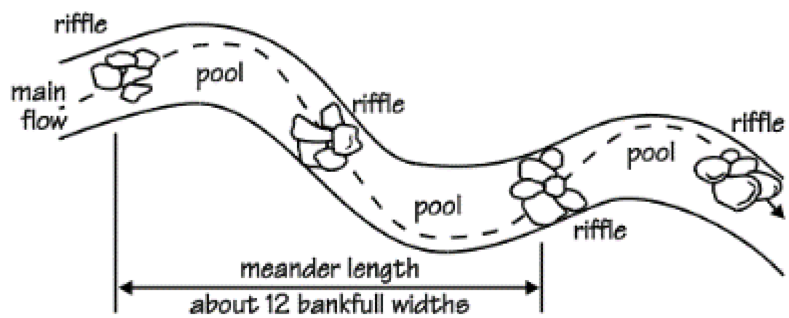

Figure 8: Meander Pattern of a Typical Natural Channel (from Taccogna & Munro 1995)

6.9.2 Channel Cross Sectional Surveys

The first cross sectional transect will be established at the downstream end of the survey reach (point in Table 4). It will be oriented perpendicular to the channel and extend 5 m inland from the top of bank with endpoints permanently marked with capped metal stakes. Its coordinates will be recorded using a GPS. Four additional transects will be established at equal intervals along the length of the Reach (Figure 9: Cross-sectional Transects), each tagged with the transect number (ascending order in an upstream direction).

Elevations along transects will be measured relative to 2 benchmarks; either ground level at the end point marker stakes or other stable features. Elevation measurements will be made with a surveyor's transit or laser level such that a minimum of 15 measurements are taken along the transect. Measurement locations will include the top of bank, toe of bank, and at least 3 additional, equally spaced locations on the channel bed. Minimum measurement intervals for channels of different widths are prescribed in Table 5.

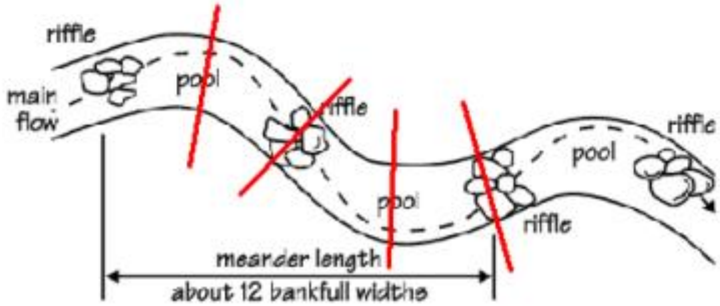

Figure 9: Locations of Cross-sectional Transects Within Aquatic Survey Reach of a Channel (adapted from Taccogna & Munro 1995)

Table 5: Maximum intervals for elevation measurements on the channel bed for streams of different width.

Bankfull Channel Width (Wb)	Maximum Interval On Channel Bed (m)
< 5 m	5 equally spaced measurements
5-20 m	1
20-40 m	1.5
>40 m	2

Reported data will include:

- Measurement of bankfull width
- Location of centre of main flow path (thalweg)
- Mean, maximum and standard deviation of bankfull depth
- Counts of cover objects that intersect the transect (wood greater than 10 cm diameter and 100 cm length, boulder > 25 cm diameter, other similar objects)
- Metres of transect crossing beds of submerged plants (macrophytes)
- Where turbidity levels permit, the length of each transect will be filmed using a GoPro or other underwater video camera.
- Photographs facing upstream and downstream from the midpoint of the transect
- Underwater video of full transect unless prevented by high turbidity

6.9.3 Longitudinal Survey

The longitudinal survey is used to characterize conditions and to map habitat units within the aquatic habitat survey reach. Distance is measured with a hip-chain zeroed on the downstream end of the aquatic habitat survey reach.

The **longitudinal profile** is measured using a surveyor's transit or laser level following the main flow path or the deepest part of the channel if no flow is visible. Elevations are recorded at each change in slope along the length, paying particular attention to record the highest points (e.g. riffle crest) and lowest points (maximum depth in pool). **Channel slop**e is measured as the difference between water level at the upstream and downstream limits of the survey reach.

Residual pool depth is the difference between the deepest point in a pool and the highest invert elevation downstream of it (e.g. low point in riffle crest).

Lengths of habitat units, including pools, riffles, runs, lateral pools, off-channel ponds are recorded from the hip-chain and the percent of reach length occupied by each type is calculated. There is sometimes overlap in habitat units. For example, a shallow pool in a gravel bar may be located beside a riffle. This may cause the sum of percent reach length for all habitat units to exceed 100.

Bank condition is assessed by measurement of the length of each bank that is:

- Non-erodible due to the presence of natural rock too large to be moved by streamflow.
- Non-erodible material associated with artificial stabilization (rip-rap, concrete etc.)
- Visibly eroding or sloughing
- Undercut

Percentage of reach length for each is reported.

Cover is assessed by counting cover objects within the channel. These include logs and stumps more than 10 cm in diameter and 100 cm in length, boulders more than 25 cm in diameter, and other similarly sized objects that could provide hiding areas for fish. The number of objects per 10 m of channel length is reported and per channel area (reach length x bankfull width) is reported.

6.9.4 Substrate Composition

Substrate composition in erosional habitats (riffles, runs or cascades) is assessed using 'Wolman pebble counts' (Bain 1999). The intermediate axes (2nd longest dimension) of 100 substrate particles are measured using calipers when possible, and a folding ruler when the particle is too large for calipers.

Particles are collected from erosional habitats only (riffles, runs, cascades), along a **zig-zag transect.** The transect starts at the base of whichever bank is on the outside of the meander bend where it intersects with the most downstream cross-sectional transect. It extends diagonally across the channel and upstream to the base of the far bank at the midpoint between the first and second cross-sectional transects, then turns to re-cross the channel to the 2nd transect (Figure 10). This pattern is continued for the length of the habitat survey reach.

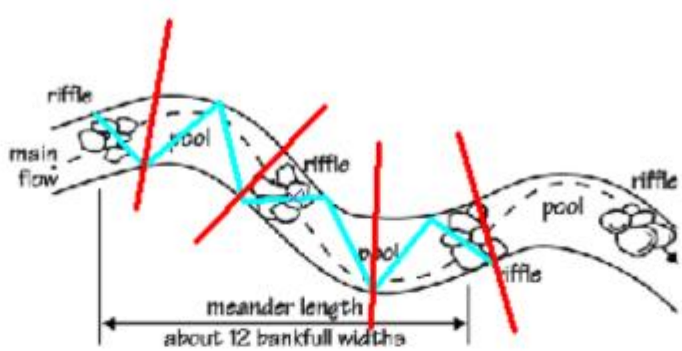

Figure 10: The Zig-Zag Transect Used for Assessing Substrate Size. Only Riffles and Other Erosional Habitats in its Path are Sampled (adapted from Taccogna & Munro 1995).

One step is taken into the erosional habitat along the transect without observing where the foot will fall, and the particle touching the centre of the toe of the boot is selected for measurement. This is repeated until 100 particles have been selected. The length of step is adjusted according to the length of erosional habitat available in the survey to maximize the portion of it that is sampled.

Mean, median and standard deviation of particle size are calculated and reported and a cumulative frequency line is plotted (Figure 10: Example cumulative particle size distribution plot). Particle size data are sorted, smallest to largest. The rank (1 = smallest, 100= largest) is plotted on the y-axis and the b-axis length in mm is plotted on the (log-scale) x-axis. The higher the line is on the left side of the plot, the higher the proportion of fine particles. In Figure 11, the dashed line represents a site where over 25 % of particles were 2 mm in diameter or less. The solid line represents a site where only or 2 % of particles were that small.

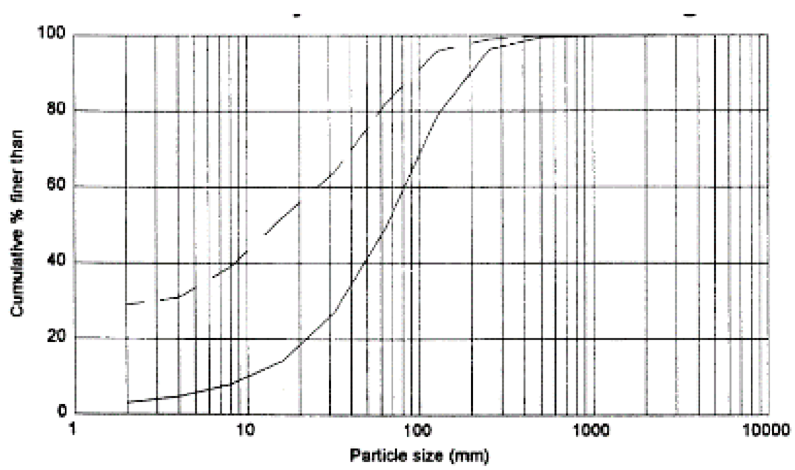

Figure 11: Example of Cumulative Particle Size Plot from a Wolman Pebble Count. The Dashed Line Indicates a Site with a Much Higher Proportion of Fine Particles (Sediment) Than the Solid Line (adapted from Bevenger & King 1995).

6.9.5 Substrate Embeddedness

Fine sediment infills the spaces between larger substrate particles in stream channels that are occupied by benthic invertebrates and fish, significantly reducing stream productivity. Two methods will be used to estimate embeddedness: the standard Streamkeepers/CABIN method and a new protocol using digital photography.

The Streamkeepers protocol consists of visually estimating the percent of each 10th particle selected in the Wolman Pebble Count (see above) that was buried in fine sediment using a relatively coarse scale (25, 50, 75 100 %).

A rapid method using digital photographs was recently published (Turley et al. 2016), which has the advantage of providing a permanent record, allowing cross checking between observers and visual comparison of the same areas before and after construction. A high resolution (16+ megapixel) waterproof camera with short (macro) focal capabilities will be used to photograph the stream bed along each of the cross sectional transects (see 6.10.2 Cross Sectional Transects) at ¼, ½ and ¾ of the channel width. The camera is held under water and its height above the substrate measured. The field of view is calibrated in advance by photographing a metre stick at height increments of 1 cm starting at 2 cm. Imaging software is used to resize photos to actual size and areas with particles less than 2 mm diameter are estimated by overlaying a 10x10 grid (i.e. one square = 1 % fines). The result is 12 photographs per site). Experienced operators can reportedly process a photograph in less than 5 min (Turley et al. 2016).

6.9.6 Photo-Monitoring

Photo monitoring points at precisely identifiable locations or markers with flagged metal stakes and a permanent label are listed in Table 6 and shown on Figure 12.

Table 6: Locations of Photo Monitoring Points for Trestle Channel, Peach Creek and Or Creek Sites. Locations are shown on Figure 12.

Watershed	Name	Easting	Northing	Description
Trestle Channel	TRP1	569397	5437772	At Vedder River
	TRP2	569484	5437722	Standing on stump
	TRP3	569573	5437746	Access road
	TRP4	569685	5437785	Wilson Road culvert
	TRP5	569751	5437849	From Beaver Box
	TRP6	569775	5437789	Upstream/downstream of spanning log
	TRP7	569722	5437761	End of south arm
	TRP8	569774	5437771	From Point
	TRP9	570000	5437823	Middle arm confluence
	TRP10	569980	5437889	Corner of side channel
	TRP11	570082	5437829	Trail crossing near RR
Peach Creek	PC1	572490	5439001	From Lickman Road
	PC2	572763	5438977	Pond 4 from dyke
	PC3	572791	5439017	Pond 4
	PC4	572808	5439022	Pond 3 taken from west end
	PC5	572848	5438979	Pond 3 from dike
	PC6	573034	5439007	Pond 2 from east end
	PC7	573052	5438983	Peach footbridge between ponds
	PC8	573052	5438998	Pond 1 from west end
	PC9	573283	5438913	Peach footbridge end of Webster Rd
Or Creek	ORP1	516536	5465499	Upper pond
	ORP2	516673	5465430	Culvert outlet
	ORP3	516704	5465357	From point
	ORP4	516702	5465216	Culvert crossing
	ORP5	516691	5465124	From spanning log
	ORP6	516768	5465091	Downstream from maple on mound
	ORP7	516732	5465060	Twin spanning logs

	ORP8	516736	5465030	From point
	ORP9	516769	5465009	Big pond from twin cedars
	ORP10	516786	5465022	Small pond across from twin cedars
	ORP11	516847	5464981	Big pond south outlet
	ORP12	516820	5464877	Outlet from upstream side

Figure 12: Locations of Photo-monitoring Points at Trestle Channel, Peach Creek and Or Creek. Coordinates and descriptions are provided in Table 6.

7 Sampling Schedule

Table 7: Appropriate Timing for Sampling

Sampling Periods	J		F		M		A		M		J		J		A		S		O		N		D	
Fish Sampling																								
Water Quality																								
Macroinvertebrates																								
Riparian Habitat																								
Amphibian Survey																								
Aquatic Habitat Quality																								
Periphyton																								
Photo-monitoring																								

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