Photo source: NHC, November 2021

French Creek Enhancements at French Creek Valley Farm

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EXECUTIVE SUMMARY

French Creek Valley Farm (FCVF) retained Northwest Hydraulic Consultants Ltd. (NHC) to provide hydrotechnical engineering services to develop designs to mitigate bank erosion and enhance aquatic fish habitat along French Creek. Erosion along the right (south) bank is resulting in loss of land to the floodplain currently used for agricultural purposes. The 200 m length is vertically incised in the soft floodplain soils at an outside bend that lacks vegetation with substantive root mass capable of fortifying the bank. Without enhancement, erosion along the bank is anticipated to continue to cause further loss of arable land.

French Creek is an ungauged stream with no recorded water level or discharge data available. To estimate flows along the creek, NHC conducted Regional Flood Frequency Analysis using the nearby Dove Creek watershed as a proxy. From the analysis, the 50-year peak instantaneous discharge, selected as the suitable return period interval for design purposes, was estimated to 208 m^3/s. This includes a 20% consideration for climate change.

An uncalibrated HEC-RAS 2D hydraulic model was developed to estimate the hydraulic conditions along the creek. Model geometry used LiDAR data collected in 2019 publicly available for download from the Government of British Columbia's website. The model results for 50-year discharge indicate the average velocity along the reach is estimated to 2.8 m/s with flow depths upwards of 2.6 m.

Large Woody Debris (LWD) complexes capable of withstanding the hydraulic conditions were designed to provide protection to the eroding bank and enhance habitat along the reach. Issued for Permitting drawings (Appendix A) present the proposed locations and configurations of the LWD complex features. Each complex is comprised of 3 pieces of LWD cabled to ballast rock. In total, 51 LWD pieces will be placed in crossed configurations forming 17 complexes.

Cost to construct the complexes are approximated to be on the order of $177,000 (in 2021 dollars). This includes a 25% contingency.

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1 INTRODUCTION

In 2021, French Creek Valley Farm (FCVF) retained Northwest Hydraulic Consultants Ltd. (NHC) to provide hydrotechnical engineering services to develop designs to mitigate erosion and enhance fish habitat along a 200 m length of French Creek's right bank that is actively eroding and resulting in loss of land to the south bank floodplain. This report provides details on the analyses conducted to develop the designs and is comprised of the following sections:

- Site description (overview, site visit, and geophysical setting);
- Hydrological analysis (watershed characteristics, flood frequency analysis, and climate change considerations);
- Hydraulic analysis (model description, results, and limitations);
- Hydrotechnical analysis (scour estimates and stable rock size);
- Design (guides, standards, and codes, quantities, costs, and construction access); and
- Recommendations and next steps.

Plans, details and specifications are provided in the enclosed drawings set (Appendix A). These drawings and the details in this report are intended to support the subsequent phases of the project which include permitting, funding, contractor vetting, and finally, construction implementation.

1.1 Project Objective

The objective of the project is to protect the actively eroding bank adopting a "soft-engineering" approach that aligns with the FCVF owners' goal of enhancing fish habitat and avoids use of hard measures such as a conventional riprap revetment.

2 SITE DESCRIPTION

A site field review was conducted on October 26, 2021 by Aaron Blezy, P.Eng. (NHC) and the owners of FCVF, Claudia and Dean Bruyckere. The project site is located along French Creek on FCVF [1420 Hodges Road in Parksville, BC], approximately 2.7 km upstream of the creek's mouth to the Strait of Georgia. Erosion along the right bank is resulting in loss of the south bank floodplain along a 200 m (approx.) length that is used for agricultural purposes. The length is at an outside bend in the stream (Figure 2.1) that lacks vegetation with substantive root mass capable of fortifying the bank and is causing the bank to become vertically incised up to 2.5 m (approx.) in the soft floodplain soils. The channel slope along the reach is relatively low (0.5%) and the average bed material particle size was estimated to 25 mm. Anecdotally, the bank has retreated upwards of 5 m over the past 2 years. (pers. comm. (C. and D. Bruyckere). Figure 2.2 to Figure 2.5 highlight erosion along the bank length.

The subject reach is entrenched in the Nanaimo Lowlands physiographic region on Vancouver Island. This region is characterized by unconsolidated soils deposited during the last two glaciation events

(Bednarski, 2015). Surficial bed materials along the reach are comprised of alluvial silt, sand, and gravel intermixed with cobble. The creek is entrenched in a 250 m wide valley near elevation El. 20 m; the lateral plateaus to valley are between elevation El. 50 m and El. 60 m. The flood channel is aligned along the toe of the north plateau escarpment. On average, the flood channel is 19 m wide. Erosion at a bend is causing the channel to widen, currently estimated to between 30 m and 40 m wide.

Relic channels through the floodplain reveal historical flow courses and highlight the dynamic nature of the channel through the reach. Floodplains by nature are typically low gradient, depositional zones with reduced capacity to transport sediment. Bed accretion occurs and channel avulsions have the tendency to occur creating new flow courses. An example of a relic channel is outlined in Figure 2.1.

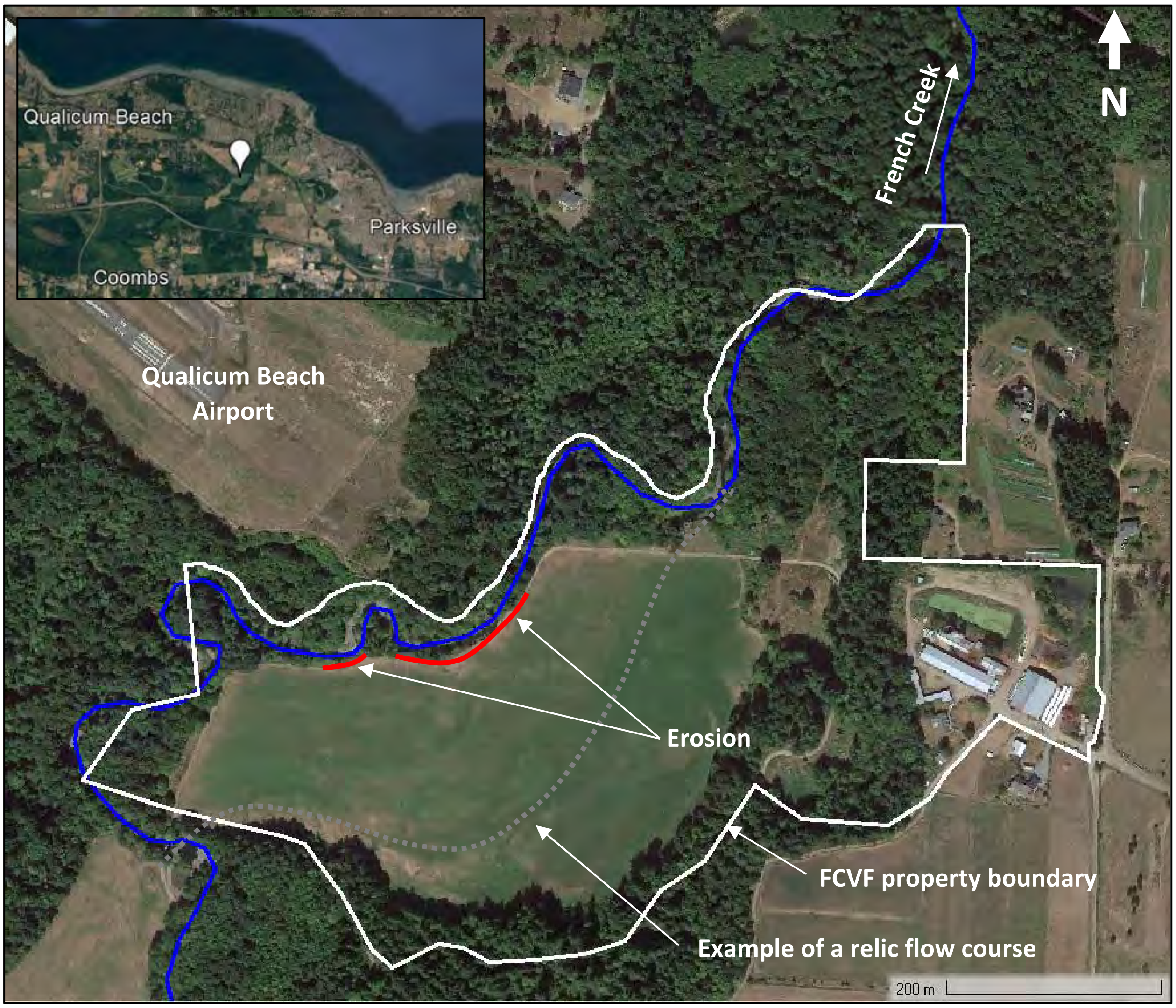


Figure 2.1 Project location at French Creek Valley Farm (Google earth imagery; cadastral data from iMapBC).

Figure 2.2 Gravel deposit and vegetation in the channel, upstream end of property.

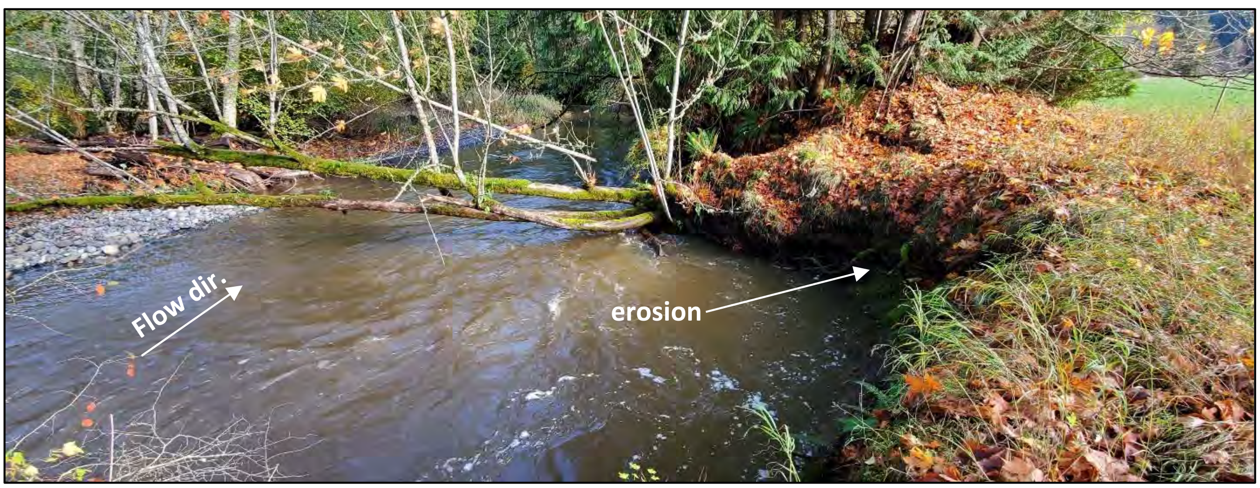


Figure 2.3 Significant erosion resulting in fallen trees and high-cut bank, upstream of project site.

Figure 2.4 Evidence of erosion during high flows, and aggraded gravel bar. Located just upstream of project site, before extreme river bend.

Figure 2.5 Erosion on right channel bank; location of project site.

3 HYDROLOGICAL ANALYSIS

3.1 Watershed Characteristics

French Creek is approximately 25 km long with headwaters in the steep, forested Beaufort Mountains at 1080 m mean sea level and flows east into the Strait of Georgia between Parksville and Qualicum Beach, BC. From the mountain range, French Creek drains through lowlands used for farming, rural residential, commercial, and urban residential development. The largest body of water in the watershed is the Hamilton Marsh, which drains into French Creek downstream of the Alberni Highway (Highway 4) (MWLAP, 2002). Mount Arrowsmith causes a rain shadow effect, which influences the stream hydrology; moving upstream towards the headwaters the watershed becomes more cool and wet. Approximately 80% of the annual precipitation is received between October and May. Floods occur between October and March and are generated by heavy rainstorms combined with snowmelt from higher elevations in the watershed.

The weather station at Qualicum Beach Airport reports an annual total rainfall of 1695 mm. According to NHC (2021a), the mean annual precipitation (MAP) for the adjacent Englishman River watershed (southeast) is 2013 mm, and the adjacent Qualicum River watershed to the west has a MAP of 1982 mm. Therefore, it is likely that the MAP for the French Creek watershed is around 2000 mm.

The Fresh Water Atlas (FWA) states a total watershed area of 69.7 km^2 (Figure 3.1). The watershed area at the project site is approximately 68 km^2. French Creek is an ungauged watershed and therefore, direct runoff measurements are not available. To determine anticipated flood flows for given return periods, a number of gauged watersheds operated by Water Survey of Canada (WSC) were investigated to determine suitable proxy gauges to regionalize flows for French Creek. The *Hydrological Analysis Technical Memorandum* (NHC, 2021c) provided in Appendix C provides further details on proxy gauge analysis, flood frequency analysis (FFA), quality assurance, and climate change considerations.

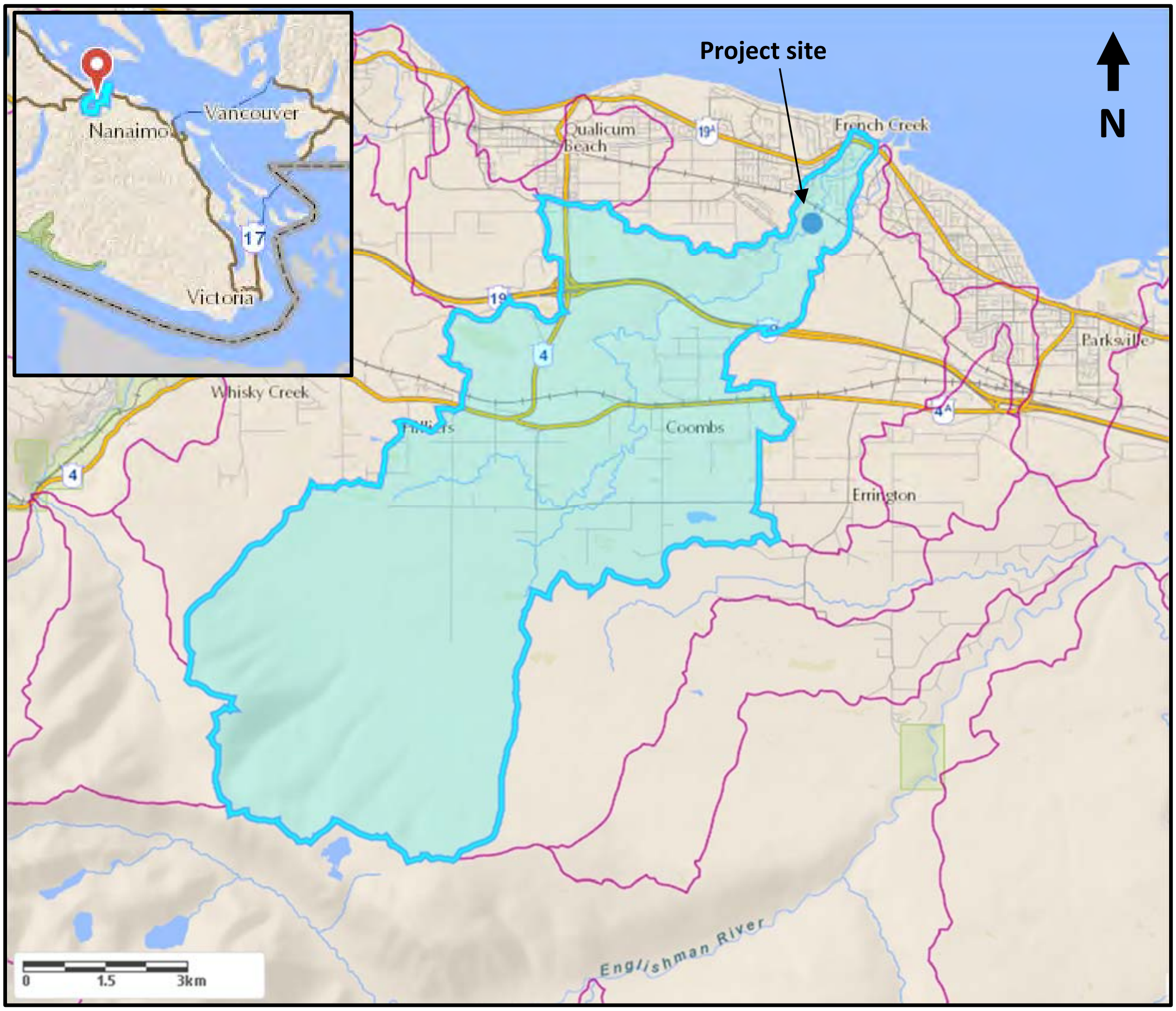


Figure 3.1 French Creek Watershed area and project site location (source: FWA and iMapBC).

3.2 Design Discharge

Several streams on the west coast of southern Vancouver Island were considered for regionalizing discharge to the French Creek watershed. Characteristics considered to determine the most appropriate gauged rivers were watershed area, gauge elevation, median basin elevation, MAP, and whether the watershed was regulated. Of the 11 streams reviewed, Dove Creek (WSC gauge ID 08HB075) was determined to be an appropriate proxy watershed and was adopted for regional FFA analysis. Results of the analysis are presented in Table 3.1.

Table 3.1 Dove Creek and French Creek peak instantaneous discharge (QPI) for given return period.

Return Period	Annual Probability of Occurrence	Dove Creek QPI (LN) (m^3/s)	French Creek QPI (LN) (m^3/s)
200	0.005	142	217
100	0.01	127	195
50	0.02	113	173
20	0.05	95	145
10	0.1	81	124
5	0.2	67	102
2	0.5	46	71

3.3 Climate Change

A detailed climate change flood assessment was outside the scope of the present study. Instead, a simplified approach was adopted based on the Engineers and Geoscientists of British Columbia (EGBC) guideline Legislated Flood Assessments in a Changing Climate in BC (2018). The guideline recommends adding 20% to design discharges to account for the potential future effects of climate change if an increasing trend is detected. If no trend is detected, only a 10% increase is recommended. Four rivers were used to determine if any trends existed in the region. A statistically significant increasing trend was detected for Dove Creek and therefore, a climate change increase of 20% was applied. Table 3.2 provides the climate change adjusted return period flood flows for French Creek regionalized to the project site.

Table 3.2 Peak instantaneous discharge adjusted for climate change for given return period on French Creek.

Return Period	French Creek QPI + 20% CC (m^3/s)
200	261
100	234
50	208
20	174
10	148
5	122
2	85

4 HYDRAULIC ANALYSIS

Flood levels and extents at the subject site on French Creek were evaluated using an uncalibrated 2D HEC-RAS (RAS2D) model. RAS2D is suitable for hydraulic modeling in rivers, manmade channels and other hydraulic structures. The modeling technique of combining a large cell with underlying terrain features by RAS2D allowed for detailed simulation of the interaction of overland flow with topographic controls and features on the floodplain. NHC's *Hydraulic Modeling Analysis Technical Memorandum* (NHC, 2021b) in Appendix D provides further details on the numerical model and analysis limitations.

4.1 Numerical Model

Model geometry was derived using 2018 and 2019 LiDAR data from the Ministry of Forests, Lands, Natural Resource Operations, and Rural Development (FLNRORD), GeoBC.

Since there was no recorded discharge data available for French Creek, there was no means to calibrate the model. As such, the initial roughness estimates (Table 4.1) were used in design model runs to determine velocity estimates. The variation in roughness values is generally representative of changes in channel morphology, slope, and bed material.

Table 4.1 Roughness values used in hydraulic modelling

Land-use	Manning's Roughness Coefficient
Forest	0.10
Low brush	0.07
Agriculture/grassland	0.036
Mixed urban and forest	0.08
French Creek	0.04

4.2 Model Scenarios

Designs will be developed based on 50-year return period, selected as a suitable return period interval for design purposes and will account for climate change. Figure 4.1 illustrates the spatial distribution of velocity and the approximate extent of flooding. The 50-year discharge including climate change is estimated to 208 m^3/s; the estimated maximum velocity, average velocity and depth along the subject reach where erosion is actively occurring were estimated to 3.4 m/s, 2.8 m/s, and 2.5 m, respectively.

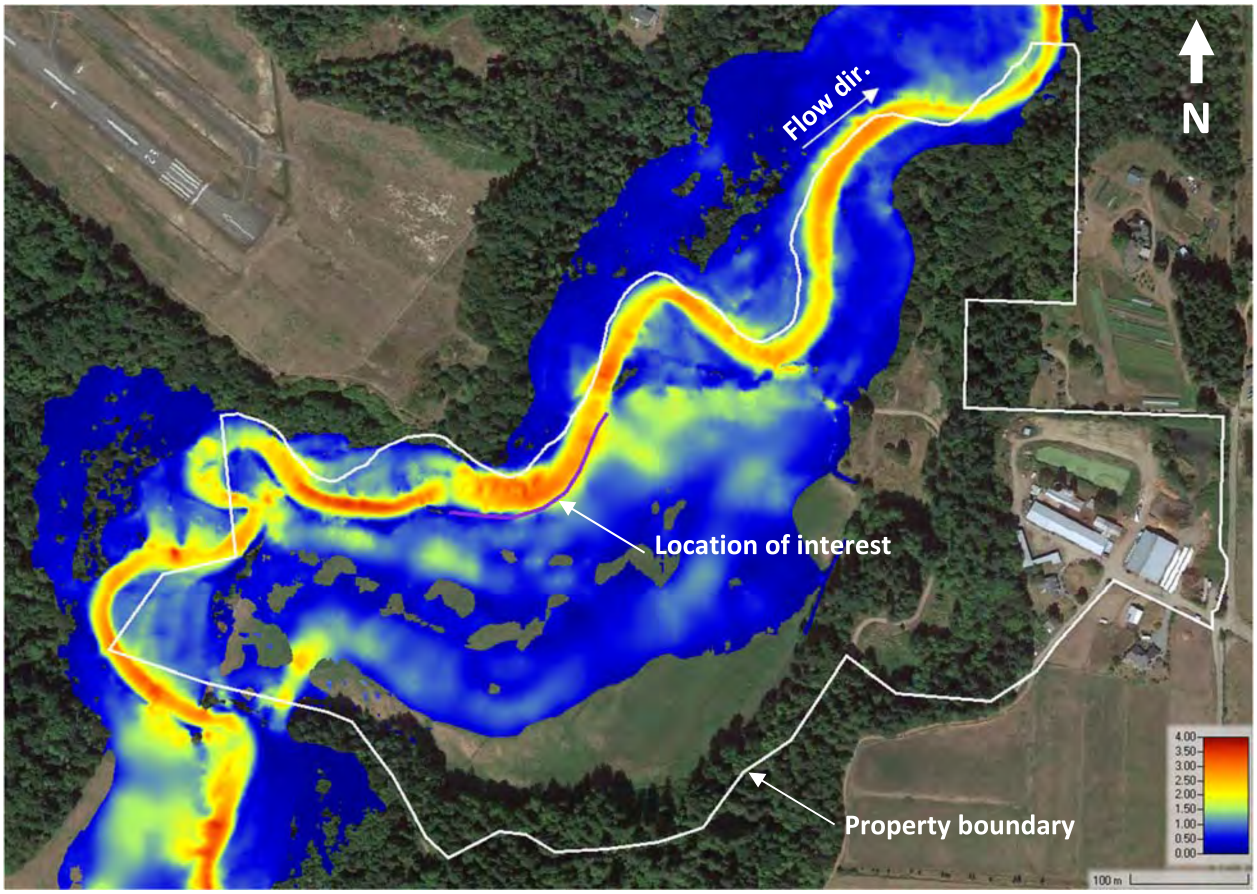


Figure 4.1 Modelled French Creek velocity during 50-year discharge from estimated climate change conditions.

4.3 Analysis Limitations

The following summarizes the key limitations of the hydraulic analysis:

- The model geometry at the project site is based on 2018 and 2019 LiDAR without bathymetric data. There is uncertainty in the model results due to lack of detail within the modelled channel.
- The flows used in the model are estimated based on proxy gauges and professional expertise. Model results are therefore a best estimate based upon these estimated flows.
- The model has not been calibrated or validated using measured water levels or velocities at the project site. As such, model results should be considered a rough estimate.

5 HYDROTECHNICAL DESIGN

The right bank of French Creek at the subject reach location lacks complexity and cover for fish refuge and is actively eroding. Without enhancement, erosion along the bank is anticipated to continue to cause further loss of arable land. Large Woody Debris (LWD) complexes are proposed to enhance habitat value and add complexity and roughness to the bank to mitigate bank erosion.

The critical rock size and scour depth for a 50-year return period event have been estimated to help inform the design. These are discussed in the sections below.

5.1 Stable Bed Material Size

The modified Shields equation was used to estimate the stable rock size in French Creek for the 50-year design flow. The stable rock size (D_{30}) was calculated to 180 mm[1]. Table 5.1 provides the channel characteristics used to estimate the critical rock size.

Table 5.1 French Creek characteristics used to approximate stable rock size (D_{30}).

Parameter	Value	Units
Flow (50-year + climate change)	208	m^3/s
Manning's roughness	0.04	-
Bed slope	0.5	%
Maximum depth	2.6	m
Top width	40	m
Maximum velocity	3.4	m/s
Average velocity	2.8	m/s
Shear velocity	0.36	m/s
Initiation of sediment transport	0.045	N/m^2
Density of rock	2650	Kg/m^3
Rock D_{30} from Shields	180	mm

5.2 Scour Estimates

Based on the channel characteristics and design flood flows, anticipated natural scour depths typically associated with bends in streams were estimated to between 0.2 m and 0.6 m for the 50-year design flow below the existing bed level using methodology developed by Blench (1975); considering the wood load along the banks and within the stream, local scour and contraction scour could conceivably be deeper than 0.6 m. Due to French Creek's high sediment load, scour in the bed is anticipated to quickly infill.

[1] The D_{30} value is the diameter of rock for which 30% of the gradation sample passes through a sieve opening.

Figure 5.1 Proposed location for LWD complexing at French Creek Valley Farm.

5.3 Standards and Guidelines

Design guides, standard methods, and approaches used in the design include:

1. U.S. Department of the Interior Bureau of Reclamation (2015). Reclamation Managing Water in the West. Bank Stabilization Guidelines Report No. SRH-2015-25.
2. D'Aoust & Millar (1999) Large Woody Debris Fish Habitat Structure Performance and Ballasting Requirements, Watershed Restoration Management Report No. 8.

5.4 Configuration of Large Woody Debris Complexes

LWD complexes are to be positioned on the outside bend along the right bank. Each element in the complex has been designed to be capable of withstanding the hydrodynamic forces along the reach, detailed in the previous sections. Each complex is comprised of 3 pieces of LWD cabled to ballast rock. LWD pieces will be partially embedded into the stream bed and bank and protrude between 2.0 m and 2.5 m instream from the toe of the right bank. On average, the complexes will be spaced 8 to 10 m, or roughly 3 to 4 times the instream protrusion length. In total, 51 LWD pieces will be placed in crossed configurations forming 17 complexes. Issued for Permitting drawings (Appendix A) present the locations and configurations of the proposed LWD complexes.

Hydraulic variations are anticipated near the proposed LWD complexes resulting in localized increases in velocity, turbulence, and scour. Estimating these variations requires rigorous computational effort. Therefore, the design was completed using the average velocity along the reach with a factor of safety applied. It should be recognized the complexes do not mitigate from other hazards such as long-term geomorphological trends, landslides, flooding, upstream avulsion, or sediment input and are limited to protecting the susceptible bank section where erosion is anticipated to continue to advance south if left untreated.

Anchoring will be required to ballast the complexes to counteract the buoyant and drag forces generated from the flow. Ballast for the complexes were sized based on conditions corresponding to the 50-year return period flood and the following assumptions:

- Full submergence of LWD's
- Velocity = 2.8 m/s
- Length of LWDs = 8 m
- Log diameter = 0.6 m
- root wads are 2.5 m wide with a wad length of 1.0 m
- Buoyancy factor of safety of 1.2 to counteract the buoyancy force
- Drag factor of safety of 1.2 to counteract the drag force
- LWD elements are approximately 45 and 135 degrees to flow

Ballast requirements to anchor the LWD to the channel bank are presented in Table 5.2.

Table 5.2 LWD ballasting parameters.

	No. of Ballast Rocks (with Rootwad)			No. of Ballast Rocks (without Rootwad)		
	2	3	4	2	3	4
Diameter of boulder	1.45 m	1.27 m	1.15 m	1.14 m	1.00 m	0.92 m
Mass per boulder	4,275 kg	2,850 kg	2,138 kg	2,050 kg	1,400 kg	1,070 kg

Each LWD piece is to be ballasted individually and not cabled to adjacent logs. This is to reduce the likelihood of multiple LWD's being transported downstream as a single unit in the event of failure. Using cedar logs, the design life is anticipated to be as high as 20 to 30 years.

5.5 Quantity Estimate

Table 5.3 details the estimated conceptual design quantities.

Table 5.3 Quantity estimates for construction.

Item	No. Units	Unit	Note
LWD	51	piece	8 m X 0.6 m (L X D) with 2.5 m diameter root wads
Ballast boulders	102	boulders	1.4 m diameter with a total mass of 8,600 kg per complex (two boulders)
Steel cable	505	m	16 mm cable; 2.5 m X 2 cables per ballast boulder X 102 boulders

5.6 Cost Estimate

Construction cost to implement the enhancements is estimated at $177,000. This includes a 25% contingency. This total does not include Professional costs (e.g. engineer, biologist, environmental monitor, etc.). Assumptions include:

- Labour, equipment, and materials are based on typical contractors and suppliers costs;
- LWD supply costs are $700 per stem with attached rootwad;
- Mobilization and demobilization time is 10 hours;
- Spoil generated from excavations will be retained on-site and re-used in construction of overbank areas, fill to seed void spaces, and general site grading; and
- Enhancements (including access and replanting) will require 5 days to complete.

A summary of the cost estimate is presented in Table 5.4; detailed breakdown is provided in Appendix B.

Table 5.4 Cost Estimate Summary

Item	Cost
Mobilization/demobilization	$7,700
Overhead	$8,700
Site Prep.	$6,700
LWD complex installations (supply and install)	$118,600
Unfactored construction costs	$141,600
Total Cost (with 25% contingency)	**$177,000**

5.7 Access, Staging and Laydown

French Creek Valley Farm is accessed via Hodges Road. Once on the property, primary access to the project site will be along the existing gravel road. It is envisioned the field south of the bend will be utilized for equipment staging and material laydown; the structures can be constructed directly from the right stream bank with minimal disturbance to surrounding land, vegetation, and channel.

6 CONCLUSIONS & NEXT STEPS

This project provides designs for LWD complexes on French Creek at French Creek Valley Farm. The purpose is to enhance habitat and mitigate bank erosion. Specific locations for the structures at the site may be adjusted with the approval of the project engineer during construction. In addition to the measures presented, incorporating a 10 m to 15 m wide riparian zone planted with cedar, fir, alder and sword fern could provide additional complexity and cover along the bank line and serve to stabilize the loose floodplain soils through plant root growth.

Work should be carried out based on best management practices and within all terms and conditions of the governing laws, bylaws, guidelines, and permits.

Rivers and creeks are dynamic in nature; gravel bar formation, shifting of materials, accumulation of additional wood debris, streambed scour, and other changes may occur at the site. Therefore, periodic inspections and maintenance may be required. Inspections should occur if notable changes in the bank or movement in the complexes are observed. Examples of maintenance are: repairing or replacing mechanical connections, replacing degraded logs (expected lifespan is greater than 30 years), replacing frayed cable, and/or removing excessive rafted debris, etc. Inspections and maintenance should be recorded for future reference. Further details of maintenance and inspections can be provided post-construction.

6.1 Permitting

Prior to constructing the LWD complexes, it is recommended that discussion be held with DFO and MFLNRO to confirm permitting requirements and authorize the works (i.e., MFLNRO WSA Section 11, DFO S. 35 Authorization). Obtaining the appropriate permits and permissions are the responsibility of French Creek Valley Farm. NHC can support acquisition or recommend an Environmental Professional.

6.2 Contract

Once funding is confirmed, NHC can finalize the design, help develop a contract to implement the enhancements and assist with the contractor vetting and selection process. The contract will be directly awarded between FCVF and the contractor with NHC able to support construction as the project consultant.

6.3 Construction Window

Construction is to be complete within the 2022 fish window, typically between August 1st and September 15th for the south coast region. Representatives from NHC can help guide construction. It is envisioned a field engineer will review construction material suitability and guide construction for the initial placement as well as oversee any key design milestones or changes to design.

7 CLOSURE

We appreciate this opportunity to work with French Creek Valley Farm and hope this document meets your current needs. Please feel free to contact myself or Aaron Blezy by telephone (250-754-6425) or email (kknox@nhcweb.com | ablezy@nhcweb.com) to discuss further.

8 REFERENCES

Aguirre-Pe, J., Olivero, M. L., and Moncada, A. T. (2003). Particle densimetric Froude number for estimating sediment transport. Journal of Hydraulic Engineering, 129(6), 428–437.

Eaton, B., Church, M., and Ham, D. (2002). Scaling and regionalization of flood flows in British Columbia, Canada. Hydrological Processes, 16(16), 3245–3263. doi:10.1002/hyp.1100.

J. M. Bednarski, (2015). Surficial Geology and Pleistocene stratigraphy from Deep Bay to Nanoose Harbour, Vancouver Island, British Columbia. Geological Survey of Canada Open File 7681.

Joyce, S., and Chantler, A. (2001). A Method for the Analysis of Scour Potential and Protective Works Design at Pipeline Crossings of Mobile-Bed Rivers. Pipelines 2001 (pp. 1–12). American Society of Civil Engineers.

MWLAP (2002). French Creek Watershed Study. Ministry of Water, Land and Air Protection and Ministry of Sustainable Resource Management.

NHC (2021). British Columbia Extreme Flood Project - Regional Flood Frequency Analysis - Technical development report and manual to complete a regional flood frequency analysis (Bulletin 2020-1-RFFA, NHC PN3004476). Report prepared by Northwest Hydraulic Consultants Ltd. (NHC) for the British Columbia Ministry of Forests, Lands, Natural Resource Operations, and Rural Development.

Northwest Hydraulic Consultants Ltd. (2010). French Creek bank erosion protection measures, Miller Road Community Park (Report No. 3-5199). Prepared for the Regional District of Nanaimo.

Shields, A. (1936). Application of Similarity Principles and Turbulence Research to Bed-Load Movement. California Institute of Technology, Pasadena

Squire, M. (2021). Water Resources - Managing your water. Available from: https://ehq-production-canada.s3.ca-central-1.amazonaws.com/02f8c51f4f13f1eda7176290e39b0b24db1fd2eb/original/1616693846/e8f4342171793d94453fd646428d0a0e_Environmental_Stewardship.pdf (Accessed 25 November 2021)

T. Blench and Associates Ltd. (1975). Design of Pipeline Crossings at Braided Rivers. Prepared for Northern Engineering Services Limited and Canadian Arctic Gas Study Limited.

US Department of the Interior (2015). Reclamation Managing Water In the West. Bank Stabilization Design Guidelines. Report No. SRH-2015-25

APPENDIX A
ISSUED FOR PERMITTING DRAWINGS

NOTES:

1. HYDRAULIC DESIGN DATA:

HYDRAULIC DESIGN DATA	
DISCHARGE, Q (50-YR)	208 m^3/s
WATER VELOCITY	2.8 m/s
DEPTH	2.6 m

2. WORK LIMITS

2.1. ALL WORK AREAS WILL BE CLEARLY FLAGGED, SNOW-FENCED OR OTHERWISE MARKED IN THE FIELD PRIOR TO CONSTRUCTION ACTIVITIES BY THE CONTRACTOR. THERE WILL NOT BE DISTURBANCES TO VEGETATION OTHER THAN AS DEFINED ON THE CONSTRUCTION DRAWINGS.

2.2. MATURE TREES ARE NOT TO BE DISTURBED UNLESS DIRECTED BY THE CONSULTANT OR CONSULTANT-DESIGNATED REPRESENTATIVE.

2.3. ADDITIONAL RESTORATION WORKS AT CONTRACTOR'S EXPENSE MAY BE REQUIRED FOR DISTURBANCES BEYOND DESIGNATED ZONES, AS DETERMINED BY THE CONSULTANT OR CONSULTANT-DESIGNATED REPRESENTATIVE.

2.4. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE REPAIR OF DAMAGE CAUSED BY HIS OPERATIONS TO ROAD SIDE SLOPES, FILL SLOPES, DITCH BOTTOMS AND BACK SLOPES. SUCH REPAIR SHALL INCLUDE FILLING OF HOLES, REMOVAL OF DEBRIS, REGARDING AND CONTOURING, CLEAN-OUT OF DITCHES, RE-PLACEMENT OF ROAD CRUSH, RE-SODDING, OR ANY OTHER WORK AS DIRECTED BY THE CONSULTANT OR CONSULTANT-DESIGNATED REPRESENTATIVE LEAVING THE WORK SITE IN AN ACCEPTABLE CONDITION .

2.5. THE CONTRACTOR IS RESPONSIBLE FOR SITE AND TRAFFIC CONTROL.

2.6. ACCESS AREAS, TRAILS AND TOTE ROADS MUST BE RESTORED PRIOR TO DEMOBILIZATION.

2.7. THE CONTRACTOR SHALL TAKE ALL CONSIDERATIONS TO LIMIT AND/OR REDUCE THE FOOTPRINT OF THE WORK SITE.

2.8. WORK IS TO BE PERFORMED IN STRICT ACCORDANCE WITH WORKERS COMPENSATION BOARD OCCUPATIONAL HEALTH AND SAFETY REGULATIONS AND GUIDELINES AS ESTABLISHED IN THE *WORKERS COMPENSATION ACT.*

3. DIMENSIONS

3.1. ALL DIMENSIONS ARE EXPRESSED IN METRES.

3.2. HORIZONTAL COORDINATES TO UTM NAD 83 ZONE 10

3.3. VERTICAL DATUM TO CGVD2013.

4. LARGE WOODY DEBRIS (LWD)

4.1. PREFERRED LWD SPECIES IS CONIFEROUS RED OR YELLOW CEDAR. DOUGLAS FIR SITKA SPRUCE OR WESTERN HEMLOCK MAY BE ACCEPTED.

4.2. PLACEMENT AND ARRANGEMENT OF LWD COMPLEXES MAY VARY FROM DRAWINGS WITH DIRECTION FROM THE CONSULTANT.

4.3. USE REDHEAD C-6 EPOXY OR APPROVED EQUIVALENT.

4.4. METHODS FOR SECURING CABLE TO ANCHOR ROCKS AND LWD:

a. DRILL 250 MM DEEP HOLES THROUGH BOULDER. 4 HOLES PER ANCHOR BOULDER; 2 CABLES PER END (4 TOTAL PER LWD)
b. FLUSH HOLES WITH WATER A MINIMUM 3 TIMES OR UNTIL WATER CLEAR FREE OF DUST.
c. DRILL HOLES THROUGH LWD. MAINTAIN 75% CORE WIDTH
d. RUN CABLE THROUGH DRILL HOLES TO "HORSESHOE" CABLE AROUND THE LWD.
e. ENSURE CABLE IS APPROPRIATE LENGTH SO ROCK AND LWD SIT SNUG WITH ONE ANOTHER AND SLACK IS MINIMAL.
f. FILL DRILL HOLES WITH EPOXY AS RECOMMENDED BY THE MANUFACTURER.
g. PLACE ENDS OF CABLE IN EPOXIED HOLES.
h. LET DRY AND TEST BOND BY LIFTING THE LWD AND ROCK ASSEMBLY WITH THE EXCAVATOR.
i. IF CABLE PULLS OUT, RE-TRY.

4.7. RECOMMENDED LWD DIMENSIONS:

ROOTWAD WIDTH = 2.5 m;
STEM DIAMETER = 0.6 m;
LENGTH = 8 m.

SUPPLIED LWD'S DIMENSIONS MAY VARY. BALLAST DIMENSIONS SHALL BE IN ACCORDANCE WITH SCHEDULE 'A' ON SHEET 004 (DIMENSIONS IN METRES).

4.8. THE CONTRACTOR IS ADVISED LWD SECURING WILL BE COMPLETED BY THIRD-PARTY.

5. BALLAST ROCK

5.1. ROCK IS TO BE ROUGHLY EQUI-DIMENSIONAL; WITH LENGTH NOT MORE THAN 2.4 TIMES THE WIDTH OR THICKNESS AS MEASURED AT THE MIDDLE OF THE STONE.

5.2. ROCK IS TO BE HARD, DURABLE, AND ABRASIVE RESISTANT QUARRY OR TALIS STONE, FREE FROM SEAMS, CRACKS, CLEAVAGE PLANES, LAMINATIONS, ORGANICS, AND DEBRIS. GRANITE, QUARTZITE PREFERRED, BASALT, LIMESTONE, AND DOLOMITE MAY BE ACCEPTABLE UPON ENGINEERS APPROVAL.

5.3. ROCK SOURCE IS TO BE APPROVED BY THE QUALIFIED PROFESSIONAL.

5.4. SPECIFIC GRAVITY IS TO BE GREATER OR EQUAL TO 2.65.

5.5. IF ROCK IS FROM A QUARRY, TESTING OF THE MATERIAL SHALL BE IN ACCORDANCE WITH CSA A23.2-15A “PETROGRAPHIC EXAMINATION OF AGGREGATES”.

6. BED AND BANK CONTOURING

6.1. BED SUBSTRATE EXCAVATED FROM THE BED SHALL REMAIN IN THE CREEK AND BE USED AT AREAS DESIGNATED FOR FILL PLACEMENT AS SHOWN IN THE DRAWINGS. IMPORT FILL IS NOT REQUIRED. UNDER NO CIRCUMSTANCES ARE IN-SITU MATERIALS TO BE REMOVED FROM SITE.

nhc northwest hydraulic consultants

REVISIONS		
0	2021-12-13	ISSUED FOR PERMITTING AND FUNDING PURPOSES

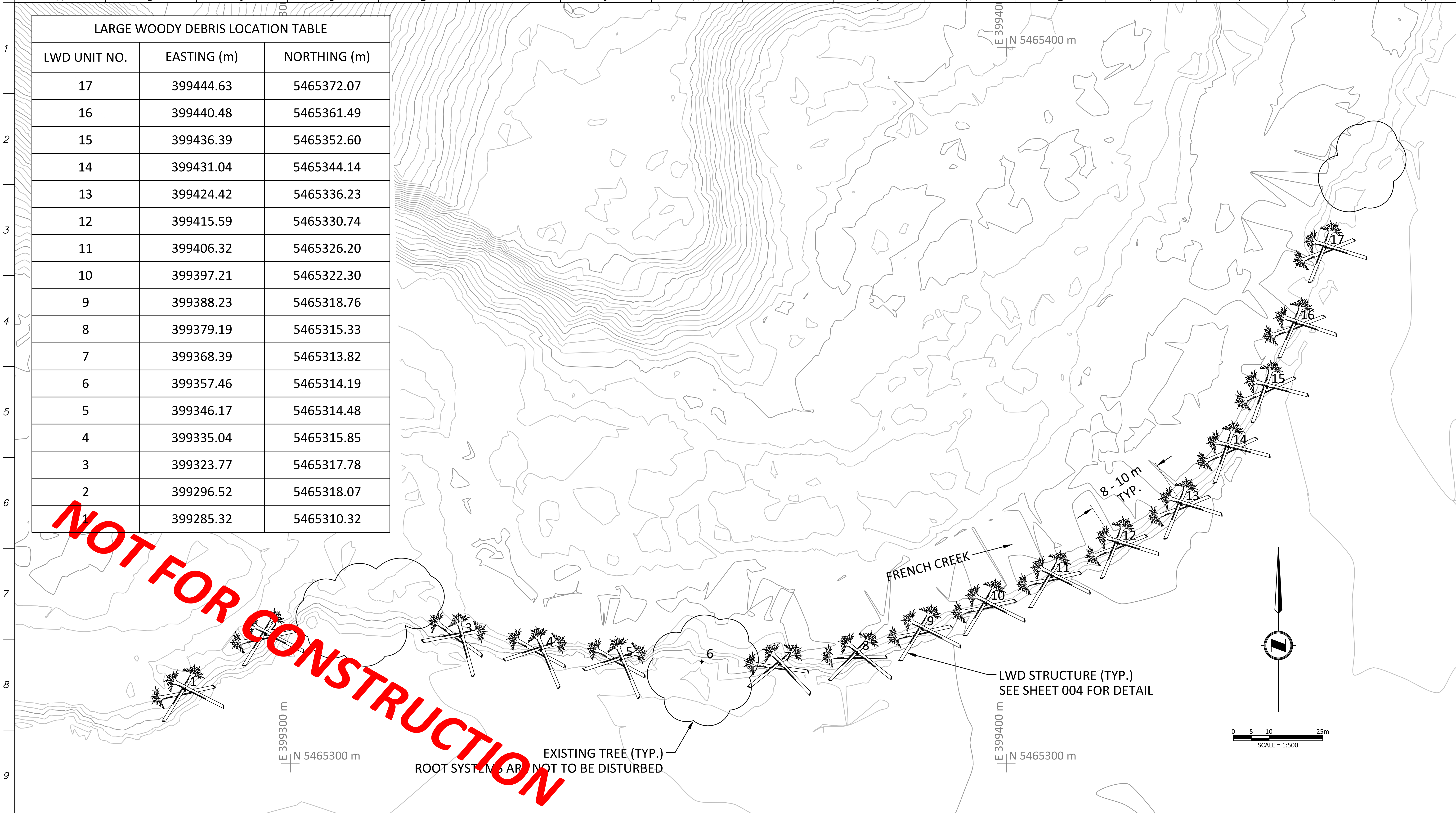
DRAWING INFORMATION	
DATE	8 Dec 2021
DESIGNED BY	K. KNOX
DRAWN BY	A. BLEZY
CHECKED BY	A. BLEZY
SHEET SIZE	B (11" x 17")

FRENCH CREEK VALLEY FARM

STREAM STABILIZATION AND HABITAT ENHANCEMENTS
SITE LAYOUT
PLAN

PROJECT NUMBER	3006096
DRAWING NUMBER	002
SHEET NUMBER	002
REVISION	0

LARGE WOODY DEBRIS LOCATION TABLE		
LWD UNIT NO.	EASTING (m)	NORTHING (m)
17	399444.63	5465372.07
16	399440.48	5465361.49
15	399436.39	5465352.60
14	399431.04	5465344.14
13	399424.42	5465336.23
12	399415.59	5465330.74
11	399406.32	5465326.20
10	399397.21	5465322.30
9	399388.23	5465318.76
8	399379.19	5465315.33
7	399368.39	5465313.82
6	399357.46	5465314.19
5	399346.17	5465314.48
4	399335.04	5465315.85
3	399323.77	5465317.78
2	399296.52	5465318.07
1	399285.32	5465310.32



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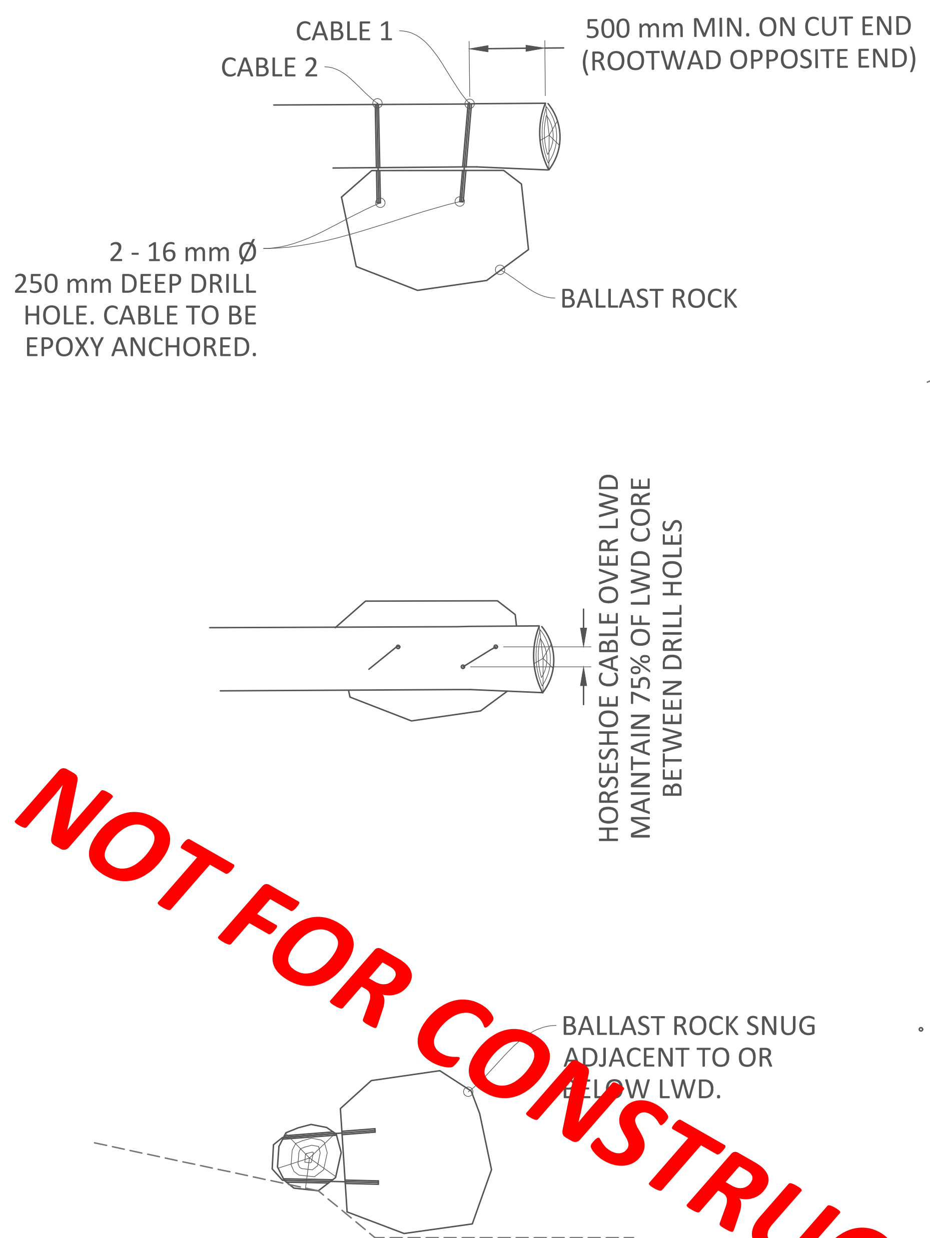
REVISIONS		
0	2021-12-13	ISSUED FOR PERMITTING AND FUNDING PURPOSES

DRAWING INFORMATION	
DATE	8 Dec 2021
DESIGNED BY	K. KNOX
DRAWN BY	A. BLEZY
CHECKED BY	A. BLEZY
SHEET SIZE	B (11" x 17")

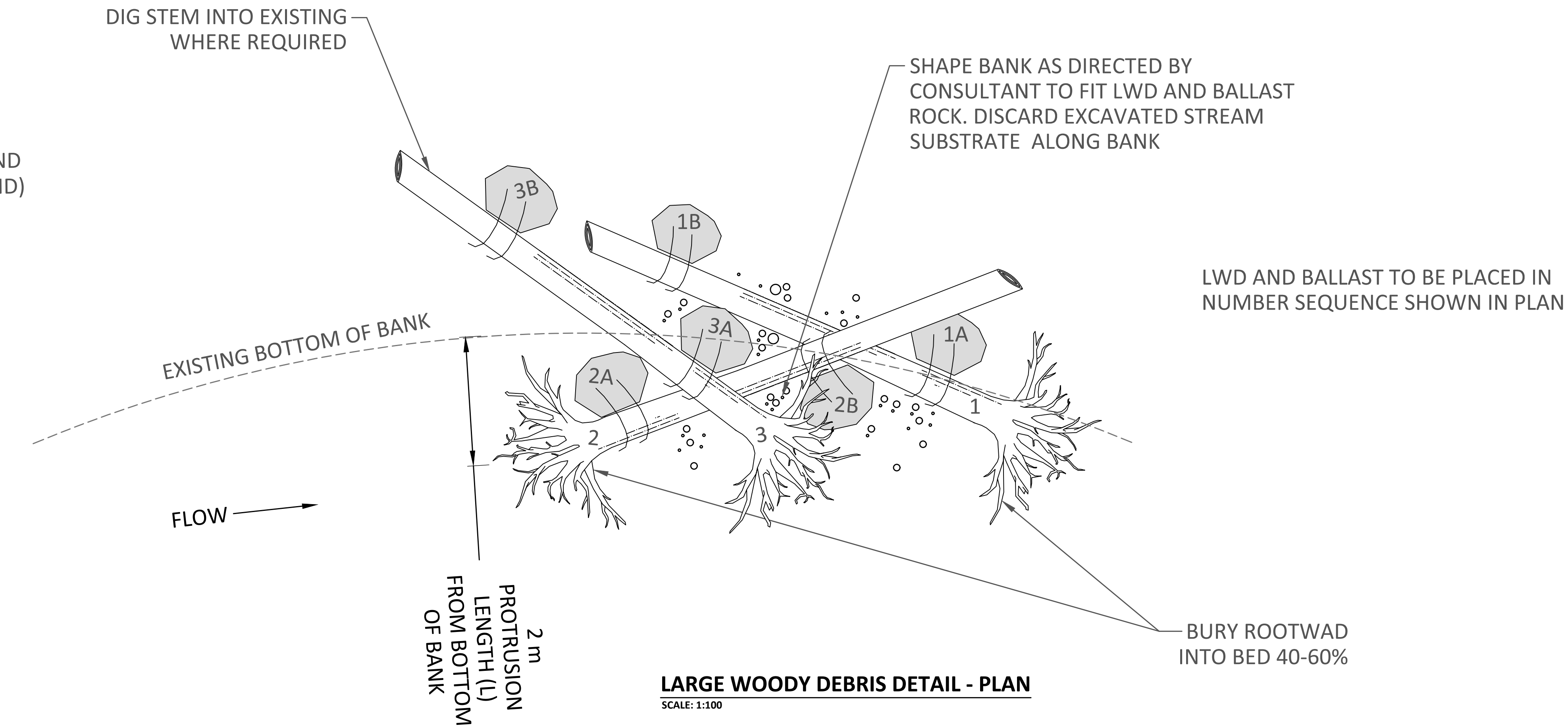
FRENCH CREEK VALLEY FARM

STREAM STABILIZATION AND HABITAT ENHANCEMENTS
LARGE WOODY DEBRIS LAYOUT
PLAN

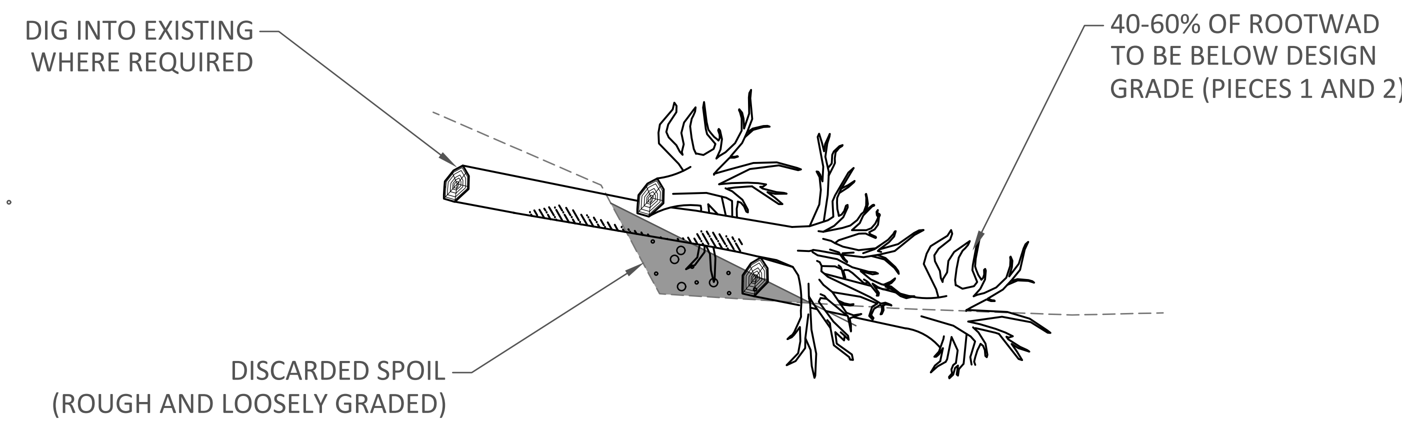
PROJECT NUMBER	3006096
DRAWING NUMBER	003
SHEET NUMBER	003
REVISION	0



BALLAST DETAIL
SCALE: 1:50



LARGE WOODY DEBRIS DETAIL - PLAN
SCALE: 1:100



LARGE WOODY DEBRIS DETAIL - SECTION
SCALE: 1:100

SCHEDULE A - 8.0 m LWD

NO. OF BALLAST BOULDERS	BOULDER DIA. (W/ ROOTWAD)	BOULDER DIA. (W/O ROOTWAD)
2	1.45	1.14
3	1.27	1.00
4	1.15	0.92

nhc northwest hydraulic consultants

REVISIONS		
0	2021-12-13	ISSUED FOR PERMITTING AND FUNDING PURPOSES

DRAWING INFORMATION	
DATE	8 Dec 2021
DESIGNED BY	K. KNOX
DRAWN BY	A. BLEZY
CHECKED BY	A. BLEZY
SHEET SIZE	B (11" x 17")

FRENCH CREEK VALLEY FARM

STREAM STABILIZATION AND HABITAT ENHANCEMENTS DETAILS

PROJECT NUMBER 3006096
DRAWING NUMBER 004
SHEET NUMBER 004
REVISION 0

APPENDIX B

DETAILED COST ESTIMATE BREAKDOWN

Table 1 French Creek Valley Farms Construction Cost Estimate.

Item	Description of Item	Qty	Units	Unit Rate	Component Total	25% Contingency by item	Total
MOBILIZATION / DEMOBILIZATION							**$7,700**
Contractor Mob/demob							
Construction Supervisor / Foreman w/ Truck	1	10	hr	$90	$900	$1,125	
Labourers	1	10	hr	$60	$600	$750	
Excavator	2	10	hr	$260	$5,200	$6,500	
Storage Trailer	1	1	mo	$500	$500	$625	
Low Boy	2	1	hr	$250	$250	$313	
Chipper	1	1	hr	$100	$100	$125	
Grader	1	1	hr	$110	$110	$138	
OVERHEAD							**$8,700**
Support Costs							
LOA or Travel	2 - operators, 1 - foreman, 1 - labourer	10	d	$250	$2,500	$3,125	
OT	2 h / d for 10 d @ $40 / h (x4)	20	h	$40	$3,200	$4,000	
Environmental Monitor		10	d	$300	$3,000	$3,750	
SITE PREPARATION							**$6,700**
Traffic Control / Fencing / Safety Signage Set-up		4	h	$150	$600	$750	

Item	Description of Item	Qty	Units	Unit Rate	Component Total	25% Contingency by item	Total
Clearing & Chipping		10	h	$510	$5,100	$6,375	
Misc. Equip. and Materials		1	LS	$1,000	$1,000	$1,250	
LWD COMPLEXING							**$118,600**
Complexes							
LWD Supply	8 m X 0.6 m log with 2.5 m root wad (assume 3.5 cubes per wad)	51	logs	$700	$35,700	$44,625	
LWD Transport	Source within 2-hour round trip (80 yd demo bin), 4 complexes per trip	26	h	$150	$3,825	$4,781	
Stainless Steel Cable	5/8" dia. 6x19 Wire Core Stainless Steel Wire	505	m	$25	$12,625	$15,781	
Ballasting Rock Supply	Dia. = 1.4 m	388	T	$35	$13,580	$16,975	
Ballasting Rock Transport	10 T Tandem Axle	39	h	$110	$4,268	$5,335	
Construction Time	Estimate 0.75 complexes constructed per hour	68	h	$670	$45,560	$56,950	
Misc. Equip.(Drills, Epoxy, crosby clamps)		1	LS	$3,000	$3,000	$3,750	
CONSTRUCTION COSTS (including 25% contingency)							**$177,000**
Project Costs							$141,600
Contingency cost (25%)							$35,400

APPENDIX C
HYDROLOGICAL ANALYSIS TECHNICAL MEMORANDUM

northwest hydraulic consultants

December 14, 2021

NHC Reference 3006096

French Creek Valley Farm
1420 Hodges Road
Parksville, BC V9P 2B5

Attention: **Dean Bruyckere and Claudia Bruyckere**

Via email: dbruyckere@shaw.ca; cbruyckere@shaw.ca

Re: **French Creek Enhancements at French Creek Valley Farm**
Hydrological Analysis Technical Memorandum Final, Rev. 0

Northwest Hydraulic Consultants (NHC), under contract to French Creek Valley Farm (FCVF), completed a hydrologic assessment for French Creek. This Technical Memorandum has been prepared to determine anticipated flood flows on French Creek at the FCVF near Parksville, BC. This letter provides information on methods and results of the hydrology analysis and has been prepared for a technical audience.

1 Watershed Characteristics

French Creek is approximately 25 km long with headwaters in the steep, forested Beaufort Mountains at 1080 m mean sea level, that flows into the Strait of Georgia with mouth situated between Parksville and Qualicum Beach, BC. From the mountain range, French Creek drains through lowlands used for farming, rural residential, commercial, and urban residential development. The largest body of water in the watershed is the Hamilton Marsh, which drains into French Creek downstream of the Alberni Highway (highway 4) (MWLAP, 2002). Mount Arrowsmith causes a rain shadow effect, which influences the stream hydrology; moving upstream towards the headwaters the watershed becomes more cool and wet. MWLAP (2002) states that during the winter the climate is controlled by moist maritime air masses associated with cyclonic storms and easterly onshore winds. Approximately 80% of the annual precipitation is received between October and May. Floods occur between October and March and are generated by heavy rainstorms combined with snowmelt from higher elevations in the watershed.

The weather station at Qualicum Beach Airport reports an annual total rainfall of 1695 mm. According to NHC (2021), the mean annual precipitation (MAP) for the adjacent Englishman River watershed (southeast) is 2013 mm, and the adjacent Qualicum River watershed to the west has a MAP of 1982 mm. Therefore, it is likely that the MAP for the French Creek watershed is around 2000 mm.

The Fresh Water Atlas (FWA) states a total watershed area of 69.7 km^2 (Figure 1.1). The watershed area at the project site is approximately 68 km^2. French creek is an ungauged watershed and therefore, direct runoff measurements are not available. To determine anticipated flood flows for given return periods, a number of gauged watersheds were investigated to determine suitable proxy gauges to regionalize flows for French Creek. The gauges are owned and operated by Water Survey of Canada (WSC).

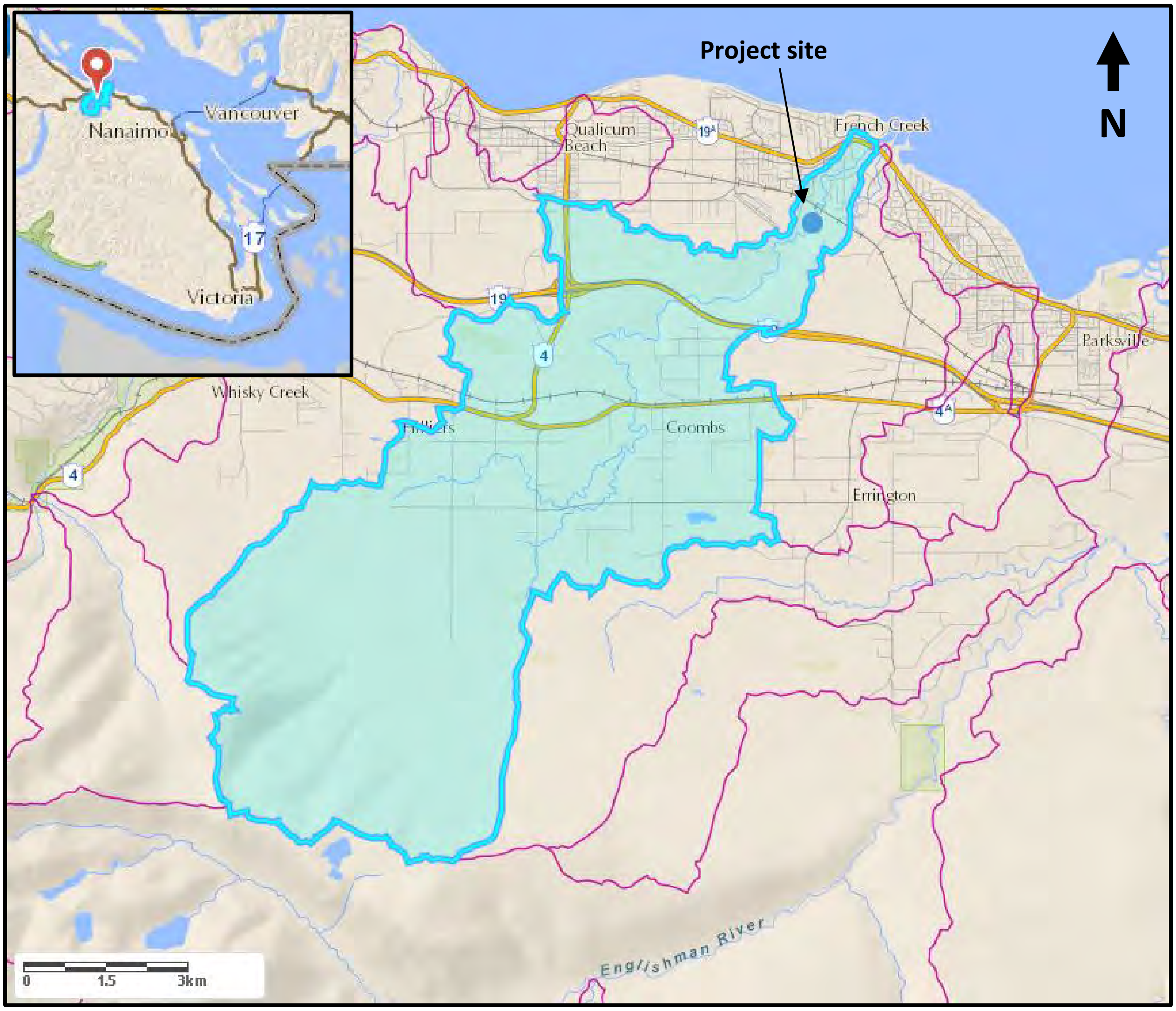


Figure 1.1 French Creek Watershed area and project site location (source: FWA and iMapBC).

2 Streams for Estimating French Creek Discharge

2.1 Gauged Rivers Considered

A number of rivers on the west coast of southern Vancouver Island were considered for regionalizing discharge to the French Creek watershed. Characteristics considered to determine the most appropriate gauged rivers were watershed area, gauge elevation, median basin elevation, MAP, and whether the watershed was regulated (Table 2.1).

Table 2.1 Gauged streams considered for use in regionalizing flows for French Creek.

WSC Gauge	Stream	Watershed Area (km^2)	Gauge Elev. (m)	Median Basin Elev. (m)	Mean Annual Precip. (mm)	WSC Regulation
08HA016	Bings Creek	20.1	31	147	1445	Unregulated
08HB074	Cruickshank River	213.0	157	987	2927	Unregulated
08HB075	Dove Creek	44.2	63	315	1980	Unregulated
08HB025	Browns River	87.9	62	947	2673	Unregulated
08HB022	Nile Creek	18.9	21	221	1762	Regulated
08HB001	Qualicum River	147.0	10	374	1982	Regulated
08HB024	Tsable River	107.0	2	741	2634	Unregulated
08HB032	Millstone River	97.0	62	247	1537	Unregulated
08HB002	Englishman River	319.0	6	543	2013	Regulated
08HB029	Little Qualicum River	237	10		1982	Regulated
08HB041	Jump Creek	62.2	280	500	3021	Regulated
N/A	French Creek	68	20	< 300	2000	Unregulated

Data sourced from NHC (2021). Jump Creek median basin elevation determined from reviewing Google Earth terrain, and Jump Creek MAP provided by Squire (2021). French Creek watershed area from FWA, gauge elevation determined from Google Earth terrain at project site, median basin elevation from MWLAP (2002).

Of the above streams, Nile Creek, Dove Creek, Englishman River, and Little Qualicum River were determined to be most appropriate for regionalization. The MAP for both Bings Creek and Millstone River watersheds was too low, Cruickshank River and Jump Creek watersheds were too high in elevation and the MAP was too high, the MAP for both Browns River and Tsable River watersheds was also too high. Qualicum River was not used due to discharge records ending in 1974.

2.2 Peak Instantaneous and Maximum Annual Daily Discharge Records

The annual peak instantaneous discharge (QPI) was required from the flow records to determine the maximum anticipated flows. If a QPI value was not recorded, it may still be able to be estimated. For every year that an annual maximum daily discharge (QPD) and a QPI are recorded for the same storm, a QPI:QPD ratio (peaking ratio) can be calculated. Any missing QPI records may be estimated for a given year from the average of all peaking ratio values, provided the year had a recorded QPD.

Englishman River

QPD records have been continuously recorded on the Englishman River since 1979, with two additional records in 1915 and 1916. QPI records began in 1986, providing many years of overlap with QPD in which to calculate a more accurate average peaking ratio for estimating missing QPI records. The average peaking ratio for the Englishman River was 1.55.

Little Qualicum River

On the Little Qualicum River, QPD records were recorded from 1962-1986, then from 2013 onwards; a QPD is also available for 1960. QPI records are available from 1962-1986, and sporadically from 2013. An acceptable number of years of overlap of QPI and QPD records are available to calculate an appropriate average peaking ratio to estimate missing QPI records. The average peaking ratio for the Little Qualicum River was 1.45.

Nile Creek

The QPD has been recorded on Nile Creek since 1960; QPI measurements began in 2011. Only six QPI records aligned with the date on which the QPD was recorded. If the QPI and QPI dates do not align, they cannot be used to estimate the peaking ratio. This is because the recorded QPI was not associated with the recorded QPD. The average peaking ratio was determined and used to estimate the missing QPI from over the record length. The range in peaking ratios over the six years was 1.28 to 2.28, which indicates that this small watershed is highly sensitive to precipitation input. Due to the wide range in peaking ratios, the lack of data available to determine an accurate average peaking ratio, and the majority of the QPI values being estimated from this average ratio, Nile Creek was determined to be unsuitable for regionalizing flows on French Creek.

Dove Creek

Both the QPI and QPD have been recorded on Dove Creek sing 1985; the QPI is only missing for 1990. The average peaking ratio for Dove Creek was 1.69 and was used to estimate a QPI value for 1990.

The QPI values for each year of record for each of the four streams were used in a flood frequency analysis (FFA).

3 Flood Frequency Analysis

A FFA was completed for each of the four streams considered for regionalization: Englishman River, Little Qualicum River, Nile Creek, and Dove Creek. The recorded and estimated QPI at each gauge was used in the analysis to determine the maximum anticipated flow for a given return period flood event. Once the FFA results for each of the four streams were complete, they were regionalized to the ungauged French Creek using the following equation, results are provided in Table 3.1:

$$Q_{ungauged} = Q_{gauged} \cdot \left(\frac{Area_{ungauged}}{Area_{gauged}}\right)^{b}$$

Where Q_{gauged} is a flow (of a particular return period) of a gauged site, and $Area_{gauged}$ and $Area_{ungauged}$ are watershed areas for gauged and ungauged basins. The scaling exponent, b, is used as it is assumed that peak flows scale according to a power law form (Eaton et al., 2002). Since French Creek is in Ecoprovince 13.1, as defined in NHC (2021), the scaling factor is 1.0.

Log Pearson III (LP III) distribution provided the best fit to discharge data in the FFA for both Englishman River and Little Qualicum River. In the FFA for Nile Creek, the Gumbel (Gum) distribution appeared to fit data best. Log Normal (LN) distribution provided the best fit to data for the Dove Creek FFA where discharge was on an increasing trend at greater return periods (Figure 3.1). French Creek flow estimates resulting from Nile Creek were too large. For the 200-year return period they were more than 100 m^3/s greater than the next highest estimate. Results from Little Qualicum River were too low. For a conservative approach, results using this gauge were not considered. Flood flow estimates from Englishman River were lower than estimates from Dove Creek, which could be due to the river flows being regulated. For a conservative approach FFA results from Dove Creek were used to estimate flood flows on French Creek (Table 3.2). Additionally, since French Creek, like Dove Creek, is not regulated, it was anticipated that Dove Creek would provide a better representation of the French Creek watershed. Dove Creek discharge data used in the FFA was from 1985-2018.

Table 3.1 French Creek QPI for given return period regionalized from the noted gauged streams.

	French Creek Regionalize flows from			
Return Period	**Englishman River QPI (LP III) (m^3/s)**	**Little Qualicum River QPI (LP III) (m^3/s)**	**Nile Creek QPI (Gum) (m^3/s)**	**Dove Creek QPI (LN) (m^3/s)**
200	144	83	349	217
100	136	78	314	195
50	128	73	278	173
20	115	65	230	145
10	104	57	193	124
5	91	49	155	102
2	68	33	97	71

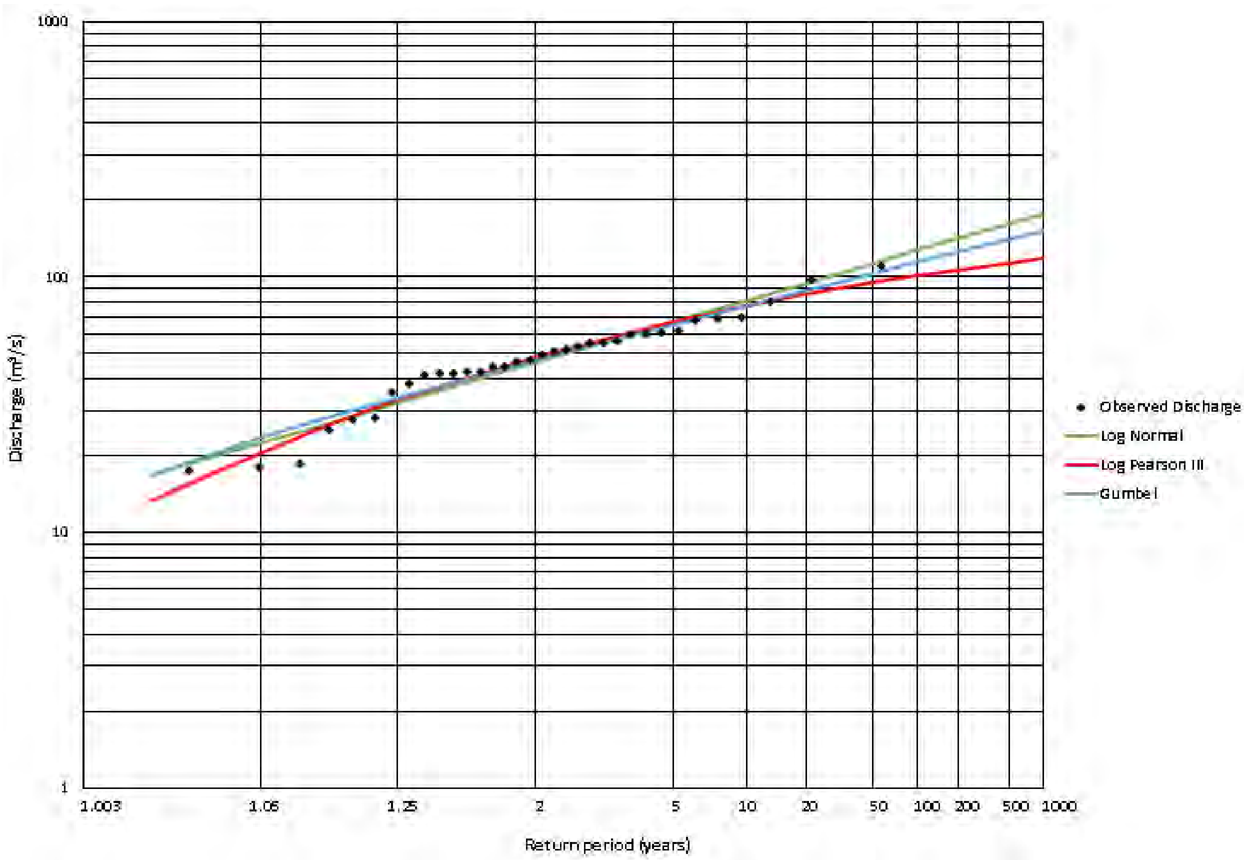


Figure 3.1 Flood Frequency Analysis for Dove Creek (WSC gauge 08HB075). Log Normal distribution provides most conservative estimate while Log Pearson III appears to underestimate flows at greater return periods.

Table 3.2 Dove Creek and French Creek QPI for given return period.

Return Period	Dove Creek QPI (LN) (m^3/s)	French Creek QPI (LN) (m^3/s)
200	142	217
100	127	195
50	113	173
20	95	145
10	81	124
5	67	102
2	46	71

4 Quality Assurance

Nine streams (Table 4.1) were used to determine the relationship of watershed area to 200-year flood flow on the southeast coast of Vancouver Island. The 200-year discharge estimate for French Creek was compared to this relationship to check that results aligned (Figure 4.1). Using Dove Creek as a proxy, flow results for regionalized French Creek were in keeping with the overall correlation. Additionally, two reports provided estimates for the 100-year and 200-year discharge on French Creek (Table 4.2), which match fairly well to the results of this analysis.

Table 4.1 Gauged rivers on the southeast coast of Vancouver Island used to determine correlation in watershed area versus 200-year discharge.

WSC Gauge ID	River	Watershed Area (Km^2)	200-year QPI (m^3/s)
80HA003	Koksilah River	209	501
08HA016	Bings Creek	20.1	27
08HB002	Englishman River	319	677
08HB029	Little Qualicum River	237	289
08HB011	Tsolum River	251	320
08HD011	Oyster River	302	501
08HB032	Millstone River	86.2	67
08HB022	Nile Creek	18.9	128
08HB07	Dove Creek	44.2	107
N/A	Regionalized French Creek	67.7	217

Note: watershed area from NHC (2021); French Creek Watershed area from Fresh Water Atlas and scaled to site location.

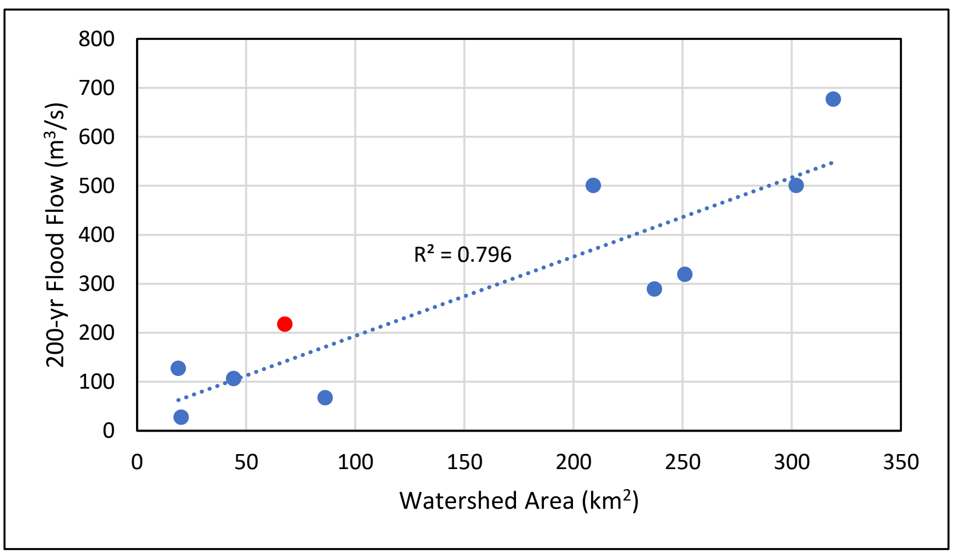


Figure 4.1 Trend in gauged rivers on the southeast coast of Vancouver Island used to ensure results for regionalized French Creek (red) aligned with the trend.

Table 4.2 Comparison of 100-year and 200-year estimated flood flows from various studies.

Source	100-year QPI (m^3/s)	200-year QPI (m^3/s)
NHC (2010)	150	-
(MWLAP, 2002)	-	210
Current study	195	217

5 Climate Change

A detailed climate change flood assessment was outside the scope of the present study. Instead, a simplified approach was adopted based on the Engineers and Geoscientists of British Columbia (EGBC) guideline Legislated Flood Assessments in a Changing Climate in BC (2018). The guideline recommends the following approach for determining the potential impacts of climate change on design flood discharges when specific climate modelling and analysis is not available:

1. For a waterbody of interest, complete a temporal trend analysis of available historical peak discharge data. In the absence of such data, regional streamflow data may be utilized. In the absence of regional streamflow data, precipitation data may be utilized;
2. If an increasing trend is detected in any of the analyses, it is recommended that design discharges be increased by 20% to account for the potential future effects of climate change;
3. If no increasing trend is detected, it is recommended that design discharges be increased by 10% to account for the potential future effects of climate change.

A non-parametric Mann-Kendall Trend analysis was completed to determine if there was any statistically significant trend (significance α=0.05) in discharge on the four rivers considered to be appropriate proxy gagues: Englishman River, Little Qualicum River, Nile Creek, and Dove Creek. The analysis results are presented in Table 5.1. A statistically significant increasing trend was detected for Dove Creek, which was used to regionalize flows for French Creek. No statistically significant trend was detected for the other three streams. Since a trend was detected for Dove Creek, and by extension French Creek, a climate change increase of 20% was applied. Table 5.2 provides the climate change adjusted return period flood flows for French Creek.

Table 5.1 Trend analysis results for regional WSC gauges.

WSC Gauge	Record	Years of Record	Mann-Kendall p-value	Statistical Significance
08HB002 Englishman River Near Parksville	1915 - 1916, 1979 - 2020	44	0.591	Non-significant
08HB029 Little Qualicum River Near Qualicum Beach	1960 - 1986, 2013 - 2020	34	0.150	Non-significant
08HB022 Nile Creek Near Bowser	1960 - 2021	62	0.942	Non-significant
08HB075 Dove Creek Near the Mouth	1985 - 2018	34	0.016	Significant

Table 5.2 Peak instantaneous discharge adjusted for climate change for given return period on French Creek.

Return Period	French Creek QPI + 20% CC (m^3/s)
200	261
100	234
50	208
20	174
10	148
5	122
2	85

6 Closure

We hope this document meets your current needs. Please feel free to contact either Kylie Knox or Aaron Blezy by telephone (250.754.6425) or email (kknox@nhcweb.com | ablezy@nhcweb.com) to discuss further.

Sincerely,

Northwest Hydraulic Consultants Ltd.
Permit to Practice Number: 1003221

Report prepared by:

Kylie Knox, EIT
Hydrotechnical Engineer

Report reviewed by:

Aaron Blezy, P.Eng.
Hydrotechnical Engineer | Associate

DISCLAIMER

This report has been prepared by **Northwest Hydraulic Consultants Ltd.** for the benefit of **French Creek Valley Farm** for specific application to the **French Creek Enhancements at French Creek Valley Farm.** The information and data contained herein represent **Northwest Hydraulic Consultants Ltd.** best professional judgment in light of the knowledge and information available to **Northwest Hydraulic Consultants Ltd.** at the time of preparation and was prepared in accordance with generally accepted engineering and geoscience practices.

Except as required by law, this report and the information and data contained herein are to be treated as confidential and may be used and relied upon only by **French Creek Valley Farm**, its officers and employees. **Northwest Hydraulic Consultants Ltd.** denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents.

7 References

Eaton, B., Church, M., and Ham, D. (2002). Scaling and regionalization of flood flows in British Columbia, Canada. *Hydrological Processes*, 16(16), 3245–3263. doi:10.1002/hyp.1100.

MWLAP (2002). *French Creek Watershed Study*. Ministry of Water, Land and Air Protection and Ministry of Sustainable Resource Management.

NHC (2021). *British Columbia Extreme Flood Project - Regional Flood Frequency Analysis - Technical development report and manual to complete a regional flood frequency analysis* (Bulletin 2020-1-RFFA, NHC PN3004476). Report prepared by Northwest Hydraulic Consultants Ltd. (NHC) for the British Columbia Ministry of Forests, Lands, Natural Resource Operations, and Rural Development.

Northwest Hydraulic Consultants Ltd. (2010). *French Creek bank erosion protection measures, Miller Road Community Park* (Report No. 3-5199). Prepared for the Regional District of Nanaimo.

Squire, M. (2021). *Water Resources - Managing your water*.

APPENDIX D

HYDRAULIC MODELLING ANALYSIS TECHNICAL MEMORANDUM

northwest hydraulic consultants

December 14, 2021

NHC Reference 3006096

French Creek Valley Farm
1420 Hodges Road
Parksville, BC V9P 2B5

Attention: Dean Bruyckere and Claudia Bruyckere

Via email: dbruyckere@shaw.ca; cbruyckere@shaw.ca

Re: French Creek Enhancements at French Creek Valley Farm
Hydraulic Modeling Analysis Technical Memorandum Final, Rev. 0

Northwest Hydraulic Consultants (NHC), under contract to French Creek Valley Farm (FCVF), completed a hydrologic assessment for French Creek. Flood levels and extents at the subject site on French Creek were evaluated using an uncalibrated 2D HEC-RAS (RAS2D) model. RAS2D is suitable for hydraulic modeling in rivers, manmade channels and other hydraulic structures, including applications in flood mapping and dam breach analysis. The modeling technique of combining a large cell with underlying terrain features by RAS2D allowed for detailed simulation of the interaction of overland flow with topographic controls and features on the floodplain. The objectives of the hydraulic modeling analysis were to:

- Estimate water levels and inundation extents at the site on French Creek for estimated future floods.
- Estimate velocities at the site to inform erosion protection/habitat enhancement designs for proposed conditions under the climate change conditions for 50-year discharge.

This letter provides information on methods and results of the hydraulic modeling analysis and has been prepared for a technical audience.

1 Numerical Model

The RAS2D model domain (Figure 1.1) included approximately 3,200 m of French Creek, extending approximately 1300 m upstream and 360 m downstream of the property, respectively. The Digital Elevation Model (DEM) forms the main building block of a 2D model. It is a representation of the channel bathymetry and floodplain topography. Typically, the DEM combines LiDAR data to represent the overbank terrain and bathymetric surveys to characterize the rivers bottom elevations. Since LiDAR was obtained during lower flows on French Creek, detail was determined to be acceptable without completing a bathymetric survey. The DEM had a 1.0 m cell size; the model elevations were derived using 2018 and 2019 LiDAR from the Ministry of Forests, Lands, Natural Resource Operations, and Rural Development (FLNRORD), GeoBC.

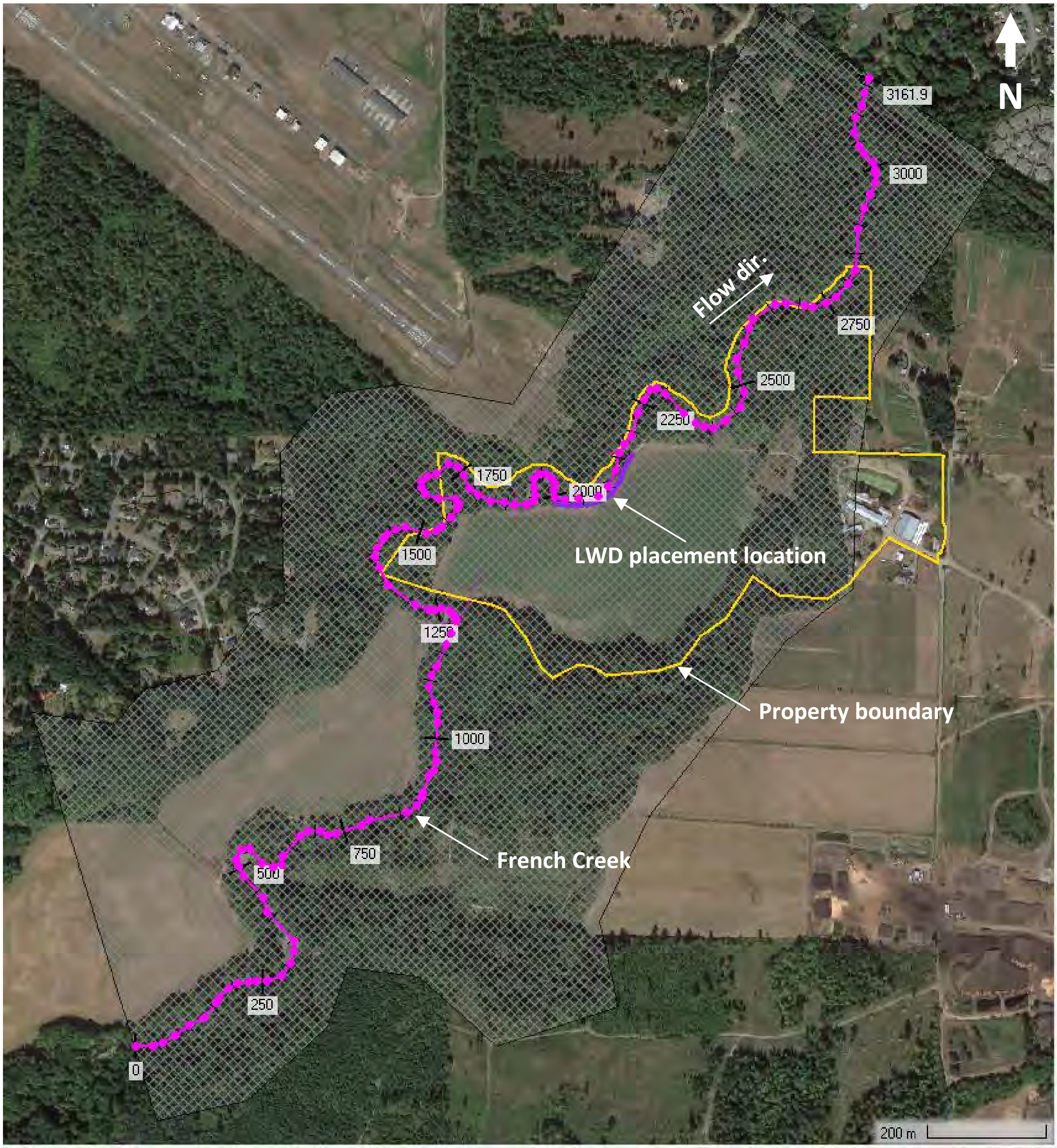


Figure 1.1 RAS2D model domain (black hatching) at French Creek Valley Farm (yellow) on French Creek (pink, stationed with 0.0 m at the upstream end) (cadastral data from iMapBC, December 2021).

The 2D mesh was generated in the RAS Mapper module of HEC-RAS using variable cell resolutions. Cell sizes were selected to optimize model result accuracy and computational times based on NHC's experience with similar models elsewhere. Breaklines were used to capture the effects of natural high ground as a means of flow obstruction, and to provide better detail in channel and overland flow paths.

Typically, initial roughness coefficients based on river characteristics, land use and ground cover are assigned and then refined during the calibration process. The roughness, represented by Manning's n values, is the primary parameter used for calibration of a 2D model. Since there was no recorded discharge data available for French Creek, there was no means to calibrate the model. As such, the initial roughness estimates (Table 1.1) were used in design model runs to determine velocity estimates. The variation in roughness values is generally representative of changes in channel morphology, slope, and bed material.

Table 1.1 Roughness values used in hydraulic modeling

Land-use	Manning's Roughness Coefficient
Forest	0.10
Low brush	0.07
Agriculture/grassland	0.036
Mixed urban and forest	0.08
French Creek	0.04

2 Model Scenarios

The LWD designs were developed based on 50-year flood conditions and account for climate change. Figure 2.1 illustrates the spatial distribution of velocity and the approximate extent of flooding. The river discharge was 208 m^3/s with maximum velocity of approximately 3.4 m/s in the area of interest for erosion protection; the average velocity in this vicinity was 2.8 m/s.

3 Analysis Limitations

The following summarizes the key limitations of the hydraulic analysis:

- The model geometry at the project site is based on 2018 and 2019 LiDAR without bathymetric data. There is uncertainty in the model results due to lack of detail within the modelled channel. We recommend that bathymetric surveys be carried out if this model is to be used for future studies.
- The flows used in the model are estimated based on proxy gauges and professional expertise. Model results are therefore a best estimate based upon these estimated flows.
- The model has not been calibrated or validated using measured water levels or velocities at the project site. As such, model results should be considered a rough estimate. We recommend that water levels and velocities be measured over a range of river flow conditions and that the model be calibrated and validated if it is to be used for future detailed analysis.

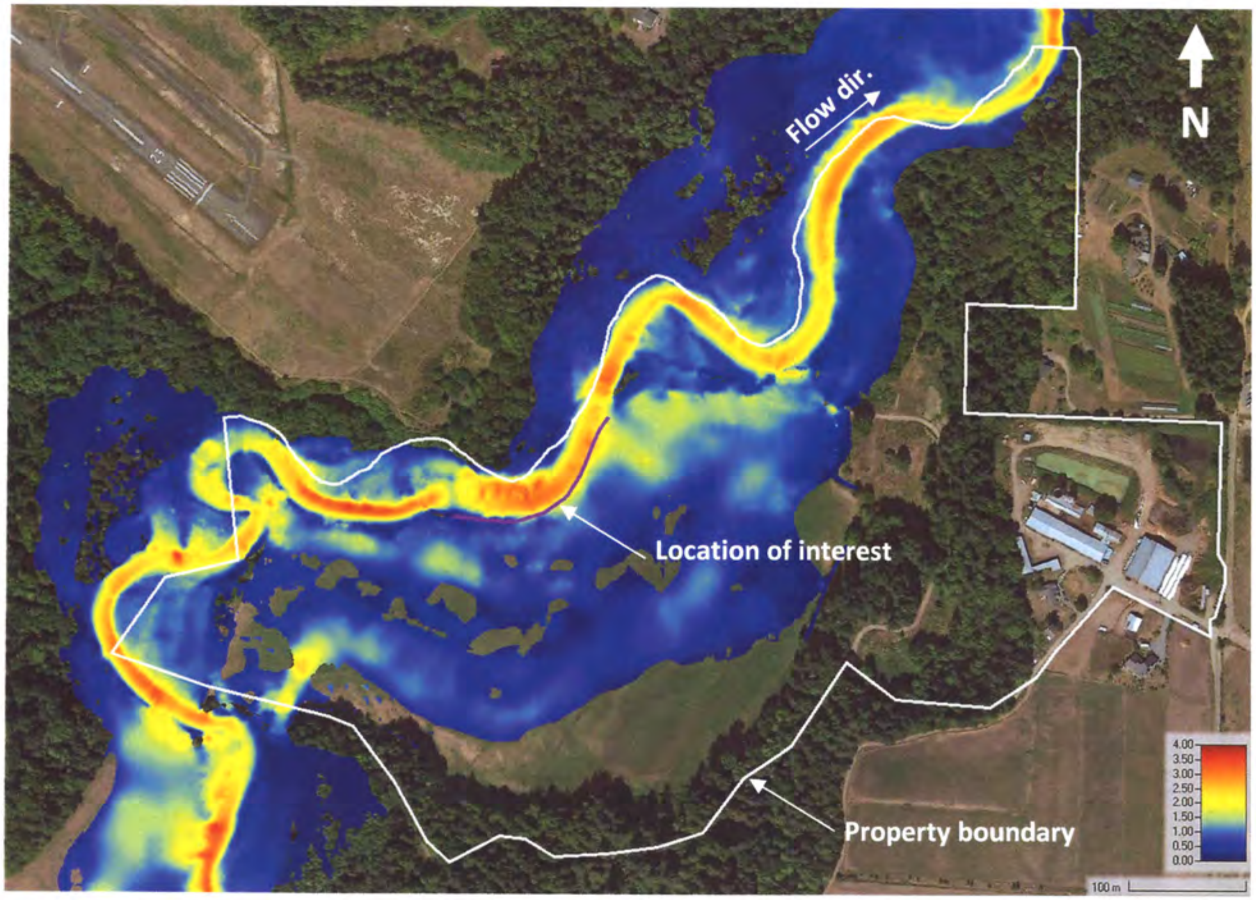


Figure 2.1 Modelled French Creek velocity during 50-year discharge from estimated climate change conditions.

4 Closure

We hope this document meets your current needs. Please feel free to contact either Kylie Knox or Aaron Blezy by telephone (250.754.6425) or email (kknox@nhcweb.com | ablezy@nhcweb.com) to discuss further.

Sincerely,

Northwest Hydraulic Consultants Ltd.
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DISCLAIMER

5 References

Eaton, B., Church, M., and Ham, D. (2002). Scaling and regionalization of flood flows in British Columbia, Canada. *Hydrological Processes*, 16(16), 3245–3263. doi:10.1002/hyp.1100.

MWLAP (2002). *French Creek Watershed Study*. Ministry of Water, Land and Air Protection and Ministry of Sustainable Resource Management.

NHC (2021). *British Columbia Extreme Flood Project - Regional Flood Frequency Analysis - Technical development report and manual to complete a regional flood frequency analysis* (Bulletin 2020-1-RFFA, NHC PN3004476). Report prepared by Northwest Hydraulic Consultants Ltd. (NHC) for the British Columbia Ministry of Forests, Lands, Natural Resource Operations, and Rural Development.

Northwest Hydraulic Consultants Ltd. (2010). *French Creek bank erosion protection measures, Miller Road Community Park* (Report No. 3-5199). Prepared for the Regional District of Nanaimo.

Squire, M. (2021). *Water Resources - Managing your water*.