Designing Resource Road Stream Crossings Considering Climate Change: Two Case Studies from Coastal BC

FPInnovations Climate Change Webinar Series – January 14, 2021

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Outline

Design Flood Hydrology Overview

Legislative and Professional Guidance Context

Parson Creek, Belize Inlet

Ehthlateese Village Creek, Uchucklesaht Inlet

- Setting
- Regional and Rational Method DFH
- Climate change considerations
- Design considerations

Summary of DFH, Climate Change and Resiliency Considerations

Introduction to Design Flood Hydrology

"Hydrology is not an exact science…"

-C.H. Coulson

Introduction to Design Flood Hydrology

"Forest hydrology is a good-natured guess"

- G. Glen Beaton

DFH in the Resource Industry – Context

Legislative Requirements:

Forest and Range Practices Act

Forest Planning and Practices Regulation Sec. 74(1) Peak Flows:

> A bridge or culvert must be designed to pass the highest peak flow that can reasonably be expected within the return periods specified for the length of time it will remain on site

DFH in the Resource Industry – Context

Legislative Requirements, FPPR Sec. 74(1):

Anticipated period the bridge or culvert will remain on the site	Peak flow return period
For a bridge or culvert that will remain on site for up to 3 years	10 years
For a bridge that will remain on site from 3 to 15 years	50 years
For a bridge that will remain on site for over 15 years	100 years
For a culvert that will remain on site for over 3 years	100 years
For a bridge or culvert within a community watershed that will remain on site for over 3 years	100 years

DFH in the Resource Industry – Context

MFLNRORD Guidance:

Forest Service Bridge Design and Construction Manual (1999)
Sec. 3.11 Hydrology and Hydraulics:

- Bridges shall be designed to accommodate the design flood including any floating debris without resulting in damage to the structure, approaches and abutments, downstream resources or environmental values.
- Bridges subject to potential debris torrents and debris flows shall be designed to accommodate the debris torrents and debris flows without the above damage unless otherwise directed by the ministry. – **Not always practical given debris flows can be orders of magnitude greater than "clear water" peak flows!**

DFH in the Resource Industry – Context

Guidelines for Professional Services in the Forest Sector – Crossings V.2, (APEGBC/ ABCFP, 2014):

Sec 4.3.3 - Hydrology, Hydraulics and Morphology

- An appropriate design peak flow must be determined
- This usually involves applying several different analytical methods and the *Professional of Record (POR)* should compare the results using professional judgment and local experience to select an appropriate design value
- Check analytical results against actual site observations

DFH in the Resource Industry – Context

Guidelines for Professional Services in the Forest Sector – Crossings V.2, (APEGBC/ ABCFP, 2014):

Sec 4.3.3 - Hydrology, Hydraulics and Morphology

- The *POR* must translate the design peak flow into the hydraulic impacts on the proposed crossing
- Hydraulic analysis is necessary to determine the required waterway opening and configuration, as well as scour/ erosion protection
- Consideration should be given to the conveyance of debris, ice jams or other factors

DFH in the Resource Industry – References

- *Manual of Operational Hydrology in BC* (Coulson, 1991)
- *British Columbia Streamflow Inventory* (Coulson, Obedkoff, 1998)
- Publicly available Climate Tools
- *Handbook of Steel Drainage and Highway Construction Projects* (American Iron and Steel Institute)
- *Rainfall Frequency Atlas for Canada* (Environment Canada, 1985)
- Intensity-Duration-Frequency (IDF) curves
- *Water Survey of Canada* Hydrometric Data
- *CulvertBC* website
- *Legislated Flood Assessments in a Changing Climate in BC* (EGBC, 2018)
- *Developing Climate Change Resistant Designs for Highway Infrastructure in BC* (EGBC, 2020)

DFH in the Resource Industry – Common Analytical Methods

Common Methods for Determining Design Peak Flows:

- Rational Method
- Regional Method
- Statistical Frequency Analysis
- SCS Runoff Curve Method
- Proprietary methods
- Field observations used to check other methods
- "California Method" (3x bank full/ HW area) for minor culverts <2,000mm

DFH Analytical Methods

Manual of Operational Hydrology in BC, Sec 7.2, Table 1: Methods for Estimating Extreme Peak Flows

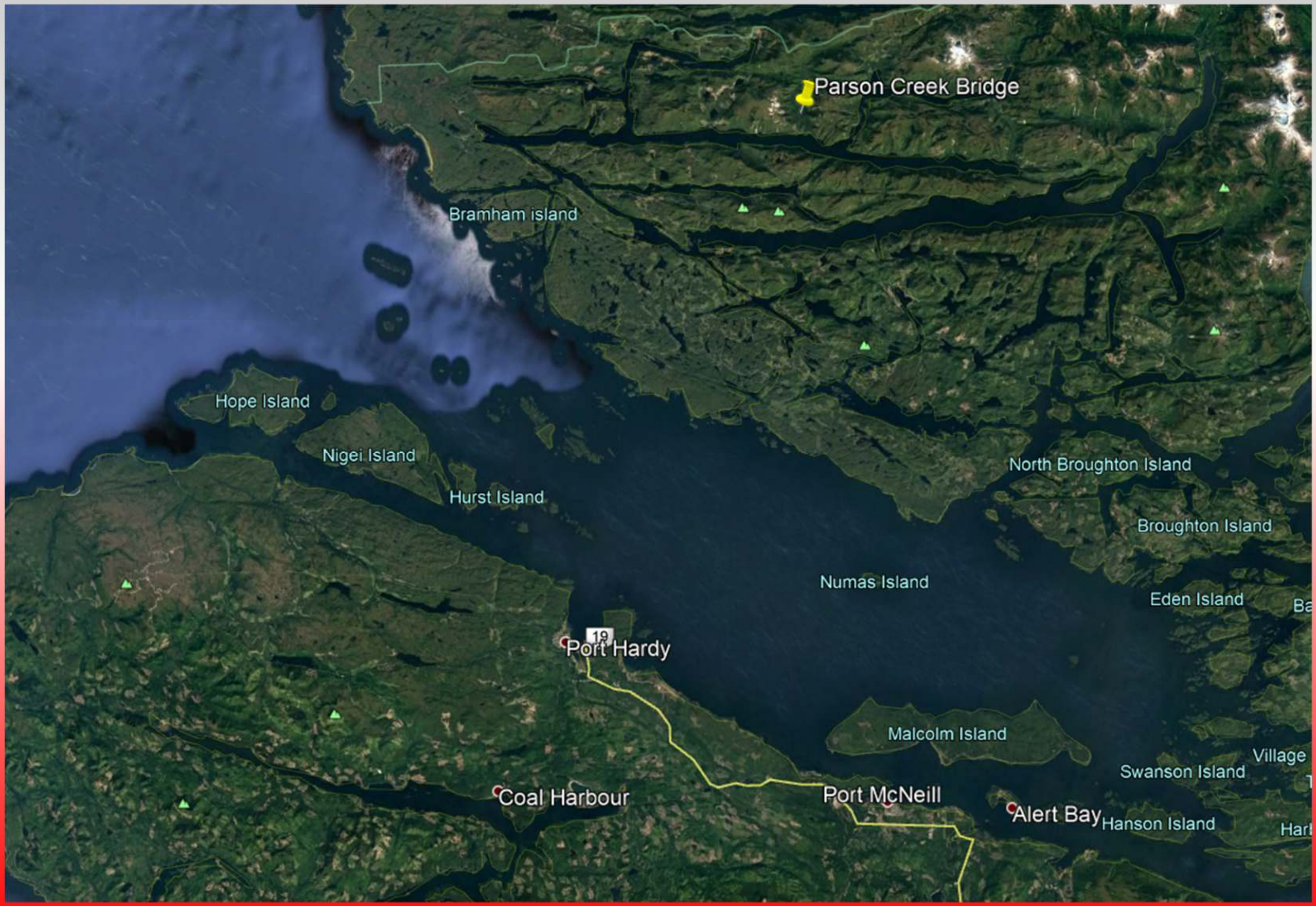
Drainage Area (km^2)	**Availability of Hydrometric Data**				
	None	Less than 5 years		5 years or more	
		On Site	Nearby Watershed	On Site	Nearby Watershed
<25, or <10 per MFLNRORD Bridge Manual	Rational Formula	Unit Hydrograph or Model	Unit Hydrograph transfer or Model	Frequency Analysis	Frequency Analysis
25-100	Regional	Unit Hydrograph or Regional	Regional	Frequency Analysis	Frequency Analysis and Regional
>100	Regional	Regional	Regional	Frequency Analysis and Regional	Frequency Analysis and Regional

Climate Change Considerations – Current Resource Industry Best Practice

- It is the responsibility of the qualified professional (POR) to be aware of current best projections (EGBC, 2018)
- Use publicly available Climate Tools (FPInnovations webinars!)
- Adjust expected flood magnitude and frequency according to the projected change in runoff during the design life of the project, **or by 20% in small drainage basins for which information of future local conditions is inadequate to provide reliable guidance**. Consider potential effects of land use change in the drainage basin (EGBC, 2018)

Parson Creek – Site Overview

- Located in Belize Inlet, 52 km North of Port Hardy
- 51°08’55.75“ N, 127°11’34.16“ W

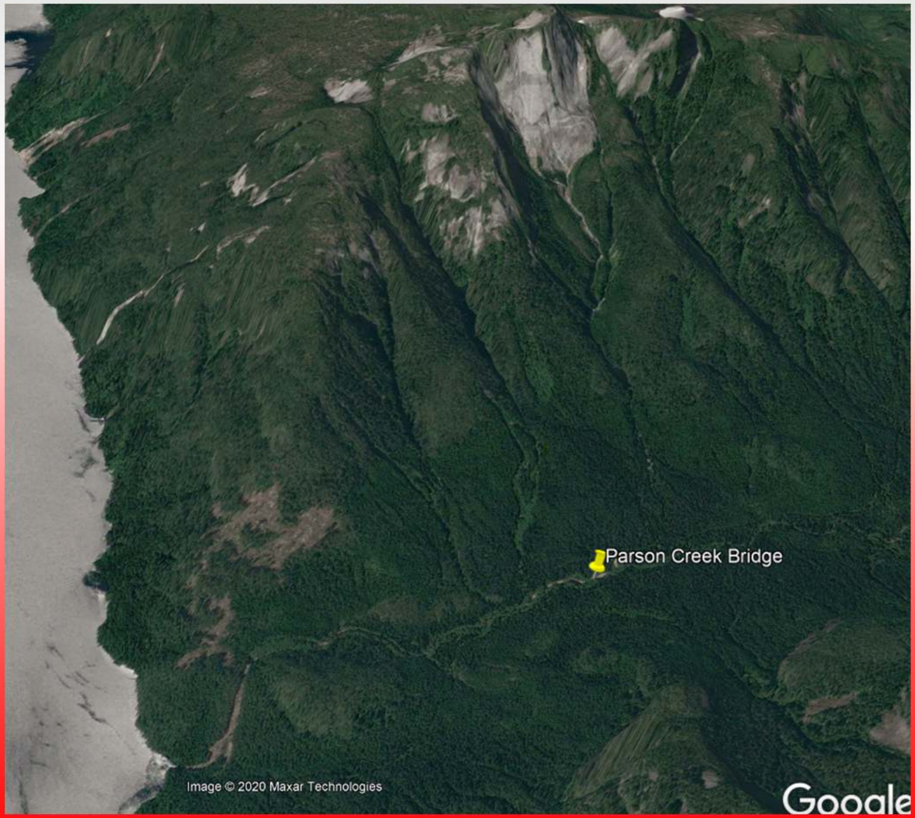


Parson Creek – Site Overview

- Drainage area ~3,390 ha ($34km^2$)
- No alpine or glaciers (rock and ice) in headwaters
- Parson Lake ~2km upstream
- Median elevation ~180m

Parson Creek – Site Overview

- Alluvial fans converge on both stream banks
- Evidence of historic debris flow deposits and bank erosion at crossing site

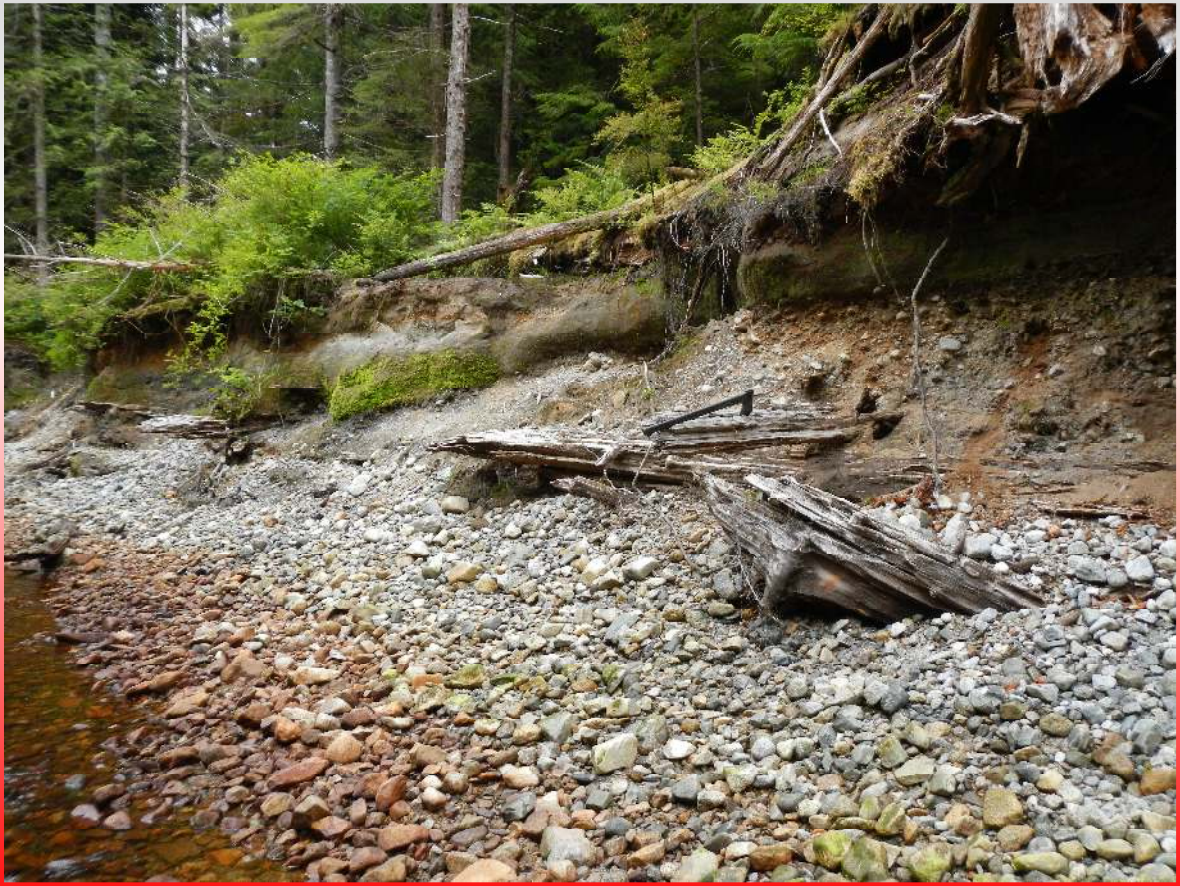


Parson Creek Development Overview (per BC Timber Sales)

- S2 fish stream in hanging valley – resident trout only
- Second growth, originally logged circa 1960's
- High development cost with limited operable timber
  - Low-value hemlock
  - 30,000m^3 initial sale
  - No second pass planned
  - GBR South Order – EBM 2
- Fisheries constraints
- Terrain stability considerations

Parson Creek – July 2013 Survey

Parson Creek – July 2013 Survey



- Originally surveyed July 2013
- Unstable camp bank undercut and erodible
- Evidence of multiple ancient debris flow deposits on camp/ left bank
- Recent debris and trees found in channel
- Temporary design completed for a 24m/ 80' Steel Deck Portable

Parson Creek – Debris/ Scour Prior to 2013

September 2010 Flood Event?




August 2013 Flood Event
North Island – Central Coast

"Pure" Rainfall Event Peak Flood

San Josef River, Holberg

Matsiu Creek, Knight Inlet

August 2013 Flood Event
North Island – Central Coast

“Pure” Rainfall Event Peak Flood

San Josef Tributary, Winter Harbour

Parson Creek – 2020 Site Visit

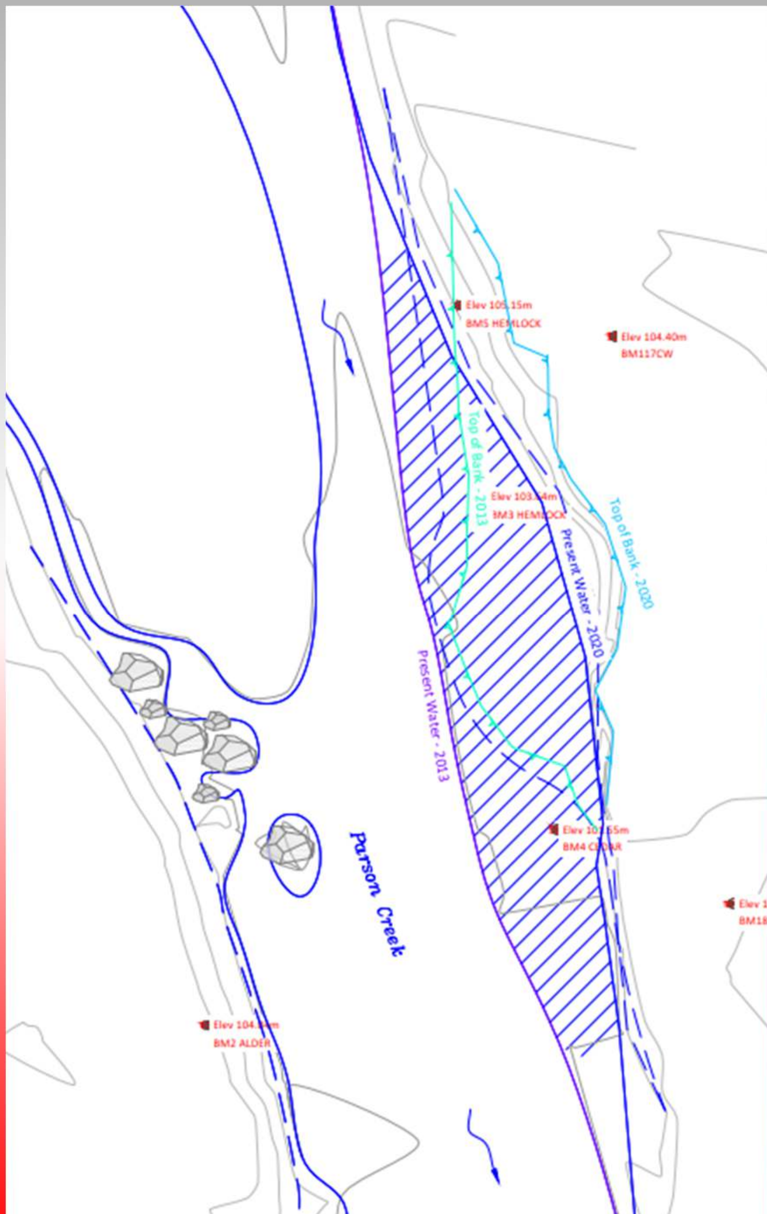
- Site visit in May 2020 to ground truth new salvaged 33m/ 110’ design prior to sealing
- Found 9-10m horizontal erosion of camp/ left bank since 2013
- August 2013 Flood?
- Original 24m/ 80’ portable bridge design not adequate to span current channel width
- New draft composite design also encroaching on current design CL

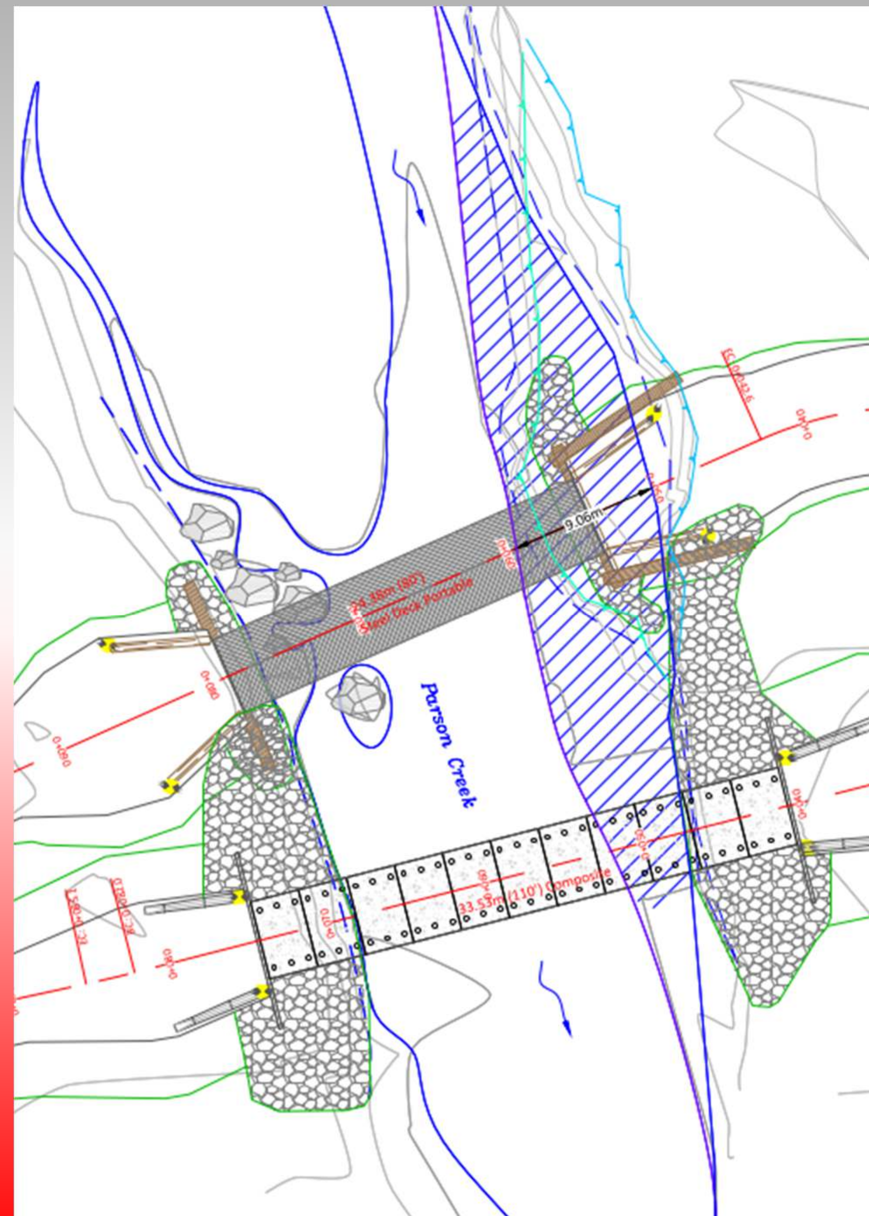
Parson Creek – Left/ Camp Bank Erosion

July 2013

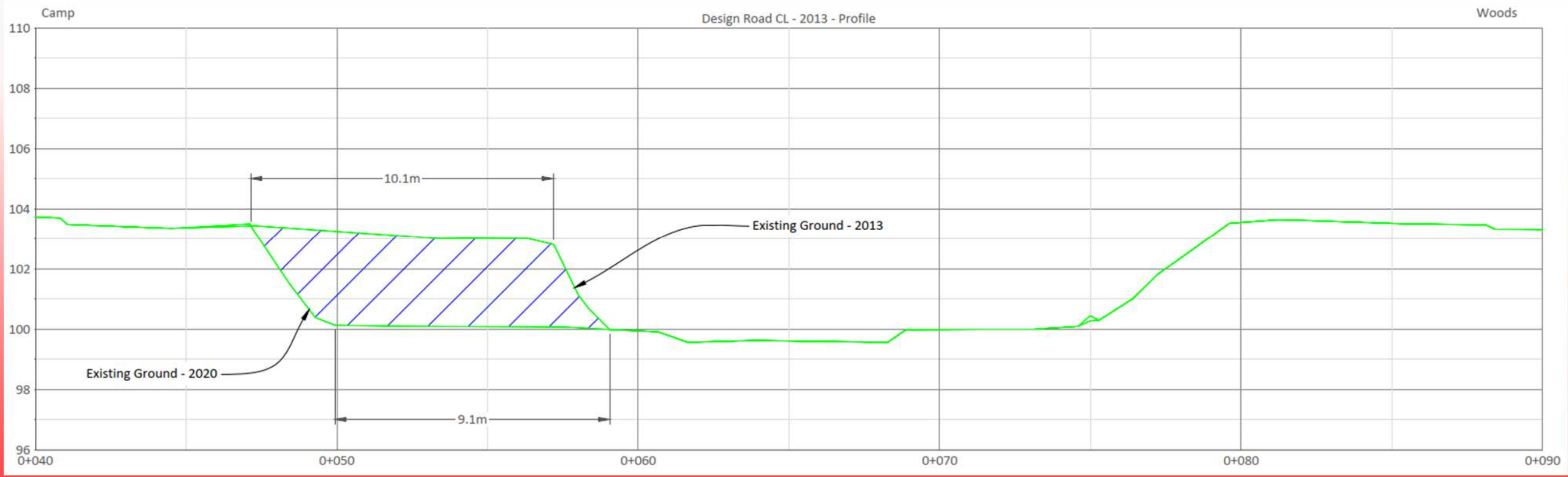
May 2020

Parson Creek – Left/ Camp Bank Erosion 2020





Parson Creek – Left/ Camp Bank Erosion 2020



DFH in the Resource Industry - Regional Method

Typically used for larger ungauged watersheds > 10-25 km^2

Limitations:

- Comparison of peak flows between basins of different drainage areas can be difficult. Smaller basins tend to have higher peak flows per unit area than larger basins (Eaton and Moore, 2010)
- Designers require a way to scale data from larger, gauged watersheds with adequate data to estimate peak flows for similar smaller, ungauged watersheds in the area
- Physiographic factors such as watershed storage capacity, shape, elevation, slope, aspect, drainage density, vegetative cover, geology and soils affect peak flows and transferability of data

DFH in the Resource Industry - Regional Method

- Preferred method is to look at a range of gauged watersheds in the area and use judgement to determine transferability to site in question

- Consider dominant peak flow regime for the area:
  - Snowmelt/ freshet in spring and summer (interior and some mainland coast)
  - Rain-on-Snow in late fall and winter (Vancouver Island and outer coastal areas with limited snowpack)
  - “Pure” rainfall events (Vancouver Island and outer coastal areas with limited snowpack)

DFH in the Resource Industry - Regional Method

Culvert BC website provides k values for mean annual peak floods for gauged watersheds, with a multiplier of the ratio of Q_2 to Q_{100} flood magnitude

Scaling effect is removed using a factor, k which expresses the mean annual peak flow per unit area

$$k = \frac{Q_{peak}}{(A_d)^{\beta}}$$

Where:

- Q_{peak} is the peak flow
- A_d is the drainage area
- β is an exponent to account for the scale effect, usually about 0.75 in British Columbia

Data used is out of date (late 1990's) – can still be used for a simple, quick check against other methods

Regional Method – BC Streamflow Inventory

PROVINCE OF BRITISH COLUMBIA
MINISTRY OF ENVIRONMENT
LANDS AND PARKS

BRITISH COLUMBIA

STREAMFLOW INVENTORY

C.H Coulson, P.Eng.
and
W. Obedkoff, P.Eng.

Water Inventory Section
Resources Inventory Branch

March 1998

BRITISH COLUMBIA

Ministry of Sustainable Resource Management

Streamflow in the Lower Mainland and Vancouver Island

W. Obedkoff, P.Eng.

Aquatic Information Branch

April 2003

DFH in the Resource Industry – Regional Method – Isolines

BC Streamflow Inventory Report mapped peak flow values (scaled for 100 km^2 watersheds) using isolines for 10-year and 100-year return period intervals across BC

These values can be interpolated from the maps and scaled to determine peak flows for watersheds of different sizes using:

$$Q_{peak} = Q(100\ km^2)\ x \left(\frac{A}{100}\right)^{0.785}$$

- Can be used for a simple, quick check against other methods

Limitations:

- Isolines are extrapolated from gauged watersheds within a region, despite significant variability of physiographic factors - some are not comparable – "black box" as it relates to transferability
- Q_{100} and Q_{10} Isolines can be ambiguous in some areas

Parson Creek – Q_{100} Isolines
Scaled to 100km² Drainage Size (BC Streamflow Inventory)

DFH in the Resource Industry - Regional Method

- Recommended method for regional analysis is scaling to an ungauged watershed from gauged local watershed(s) with similar physiography
- Professional judgement is required to decide which hydrometric stations are more representative of the ungauged watershed in question

$$Q_2 = Q_1 \, x \left(\frac{A_2}{A_1}\right)^n$$

Where:

- Q is the peak flow for a drainage
- A is the drainage basin area
- n is an exponent to account for the scale effect,
  usually about 0.75 in British Columbia –
  Range from 0.6 (“flashier”) to 1.0 (linear) – Eaton et al (2002)

DFH in the Resource Industry - Regional Method

BC Streamflow Inventory reports have been updated for some regions:

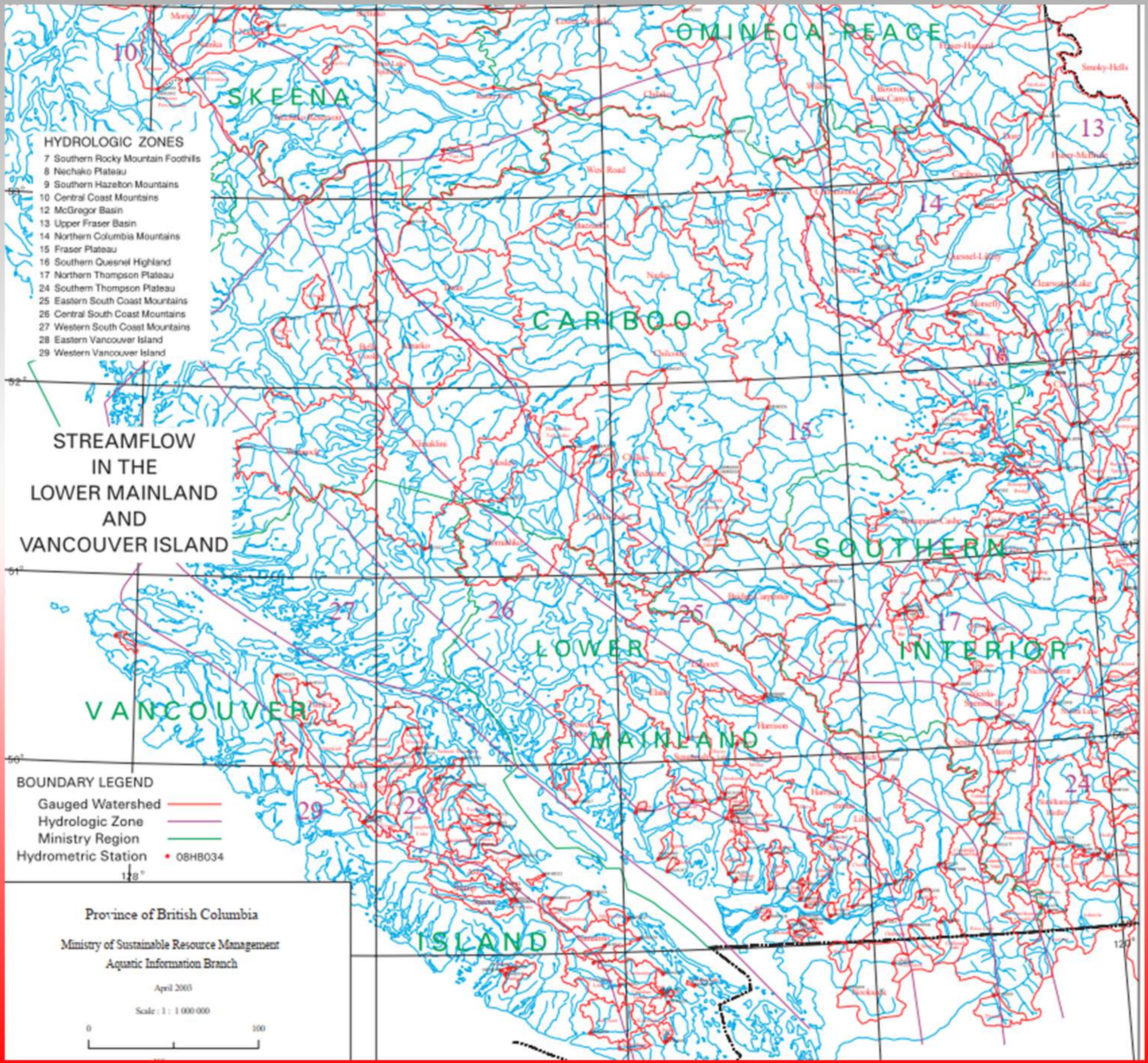
- Omenica and Northeast (2015)
- Skeena (2013)

Lower Mainland and Vancouver Island Region has not been updated since 2003 – Missing some potentially available statistical data

Issues:

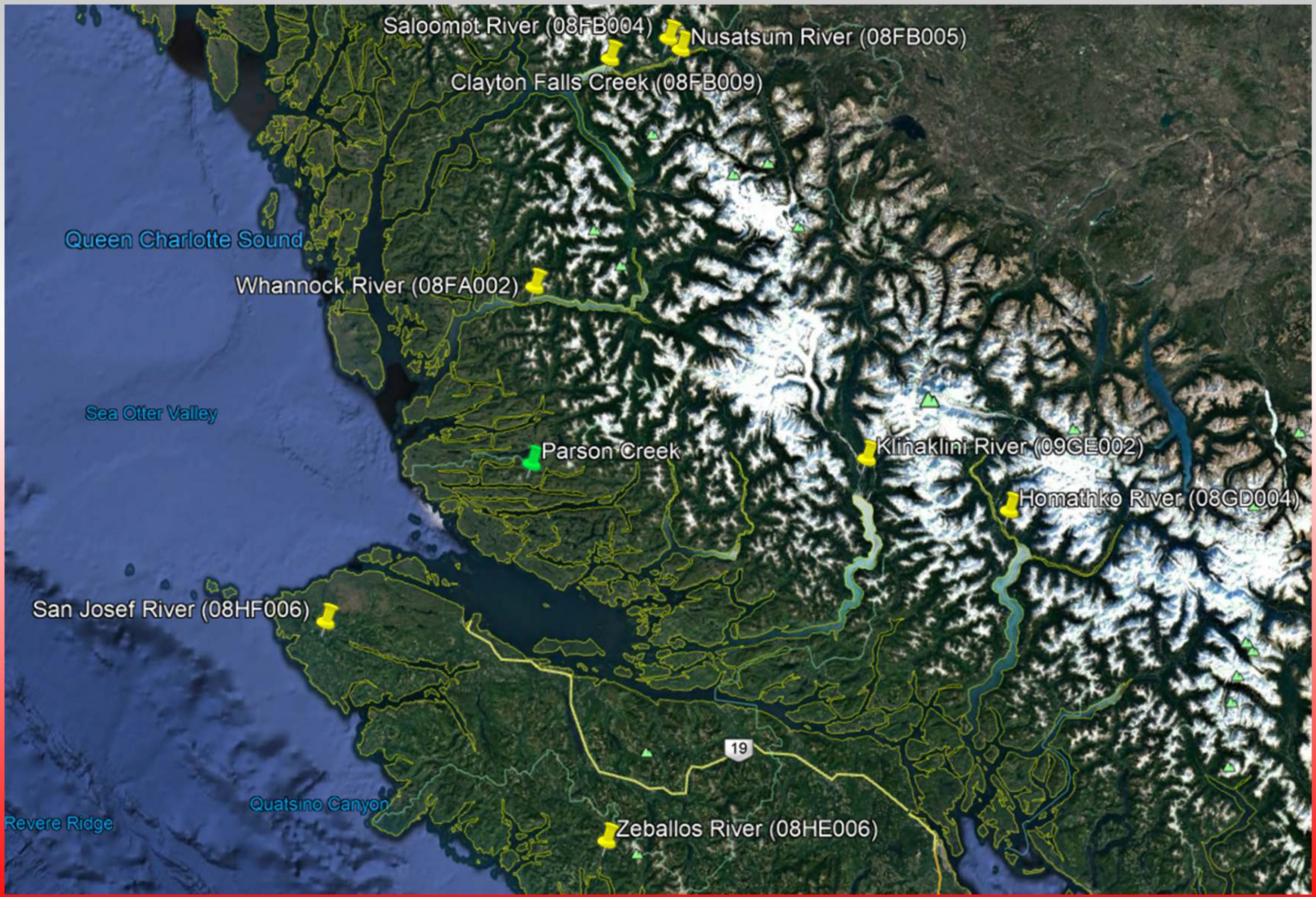
- Recent extreme flood events on the coast have not yet been accounted for in the statistical record: November 2006 (ROS), Sept 2010 (Rain), Sept 2011 (ROG), August 2013 (Rain), Fall 2020, etc.
- West coast of Vancouver Island and Central-North coast of BC severely underrepresented with gauged watersheds compared to other more accessible areas of BC

DFH in the Resource Industry - Regional Method



Parson Creek – Design Flood Hydrology Review

- Long distances from site to gauged hydrometric stations



Parson Creek – DFH Regional Analysis Summary

Stream	Hydrometric Station	Distance from Site (km)	# years n	Drainage Area (km^2)	Median elevation (m)	Instantaneous Peak Flow (m^3/s)					Gauged Drainage Notes	Q_{100} Unit Peak Flow
						Q_{200}	Q_{100}	Q_{50}	Q_{10}	Q_2		
San Josef River	08HF006	87	8	64	150	125	122	119	112	103	Rainfall peak flows. Northern Vancouver Island lowlands, no lake or glaciers	1.9
Parson Creek	Ungauged			34	180	78	76	74	70	64		
Zeballos River	08HE006	129	36	181	710	1,430	1,300	1,180	882	544	Rain-on-snow peak flows. Central Vancouver Island - Windward Rugged Mountains with alpine, Zeballos lake in headwaters	7.2
Parson Creek	Ungauged			34	180	408	371	337	252	155		
Wannock River below Owikeeno Lake	08FA002	59	36	3,940	1,220	3,019	2,720	2,449	1,850	1,251	Snowmelt peak flows. Mainland coast mountains, outlet of large lake, with large glacier-fed tributary rivers	0.7
Parson Creek	Ungauged			34	180	85	77	69	52	35		
Clayton Falls Creek	08FB009	138	17	112	1,240	146	139	133	112	78	Snowmelt peak flows. Mainland coast mountains, glaciers in headwaters	1.2
Parson Creek	Ungauged			34	180	60	57	54	46	32		
Nusatsum River (Bella Coola trib)	08FB005	147	31	275	1,420	347	320	292	230	144	Snowmelt peak flows. Mainland coast mountains, alpine glaciers in headwaters	1.2
Parson Creek	Ungauged			34	180	72	67	61	48	30		
Saloompt River (Bella Coola trib)	08FB004	149	36	158	1,160	198	189	181	152	106	Snowmelt peak flows. Mainland coast mountains, alpine glaciers in headwaters	1.2
Parson Creek	Ungauged			34	180	63	60	57	48	33		
Klinaklini River	08GE002	112	25	5,780	1,540	2,600	2,361	2,140	1,660	1,210	Snowmelt peak flows. Mainland coast mountains, alpine glaciers with headwaters in Chilcotin	0.4
Parson Creek	Ungauged			34	180	55	50	45	35	26		
Homathko River	08GD004	160	36	5,720	1,680	3,851	3,329	2,880	1,990	1,240	Snowmelt peak flows. Mainland coast mountains, alpine glaciers with headwaters in Chilcotin	0.6
Parson Creek	Ungauged			34	180	82	71	62	43	27		

Parson Creek – DFH Regional Analysis Summary

- Q100 (historic) design peak flow:

  77.5 m3/sec @ 2.8 m/s

- Compare calculated results to site observations to determine if fit is reasonable based on available evidence. This includes channel capacity, roughness, HW evidence and rafted debris from seasonal and extreme floods
- "Sniff" test using site data and professional judgement to check reliability of calculations:
  - On site HWM x-section checks: 19.3m^2, 22.8m^2, 26m^2
  - Calculated Q_2 existing channel area: 18.2m^2
  - Calculated Q_{10} existing channel area: 19.7m^2
  - Calculated Q_{50} existing channel area: 25.4m^2
  - Calculated Q_{100} existing channel area: 28.0m^2

Parson Creek – Climate Tools

Parson Creek – DFH Regional Analysis Summary

- Q100 (historic) design peak flow:

  77.5 m3/sec @ 2.8 m/s
- Climate Change Factor for 50-year design service life: 19%
- Q100 design peak flow (with Climate Change):

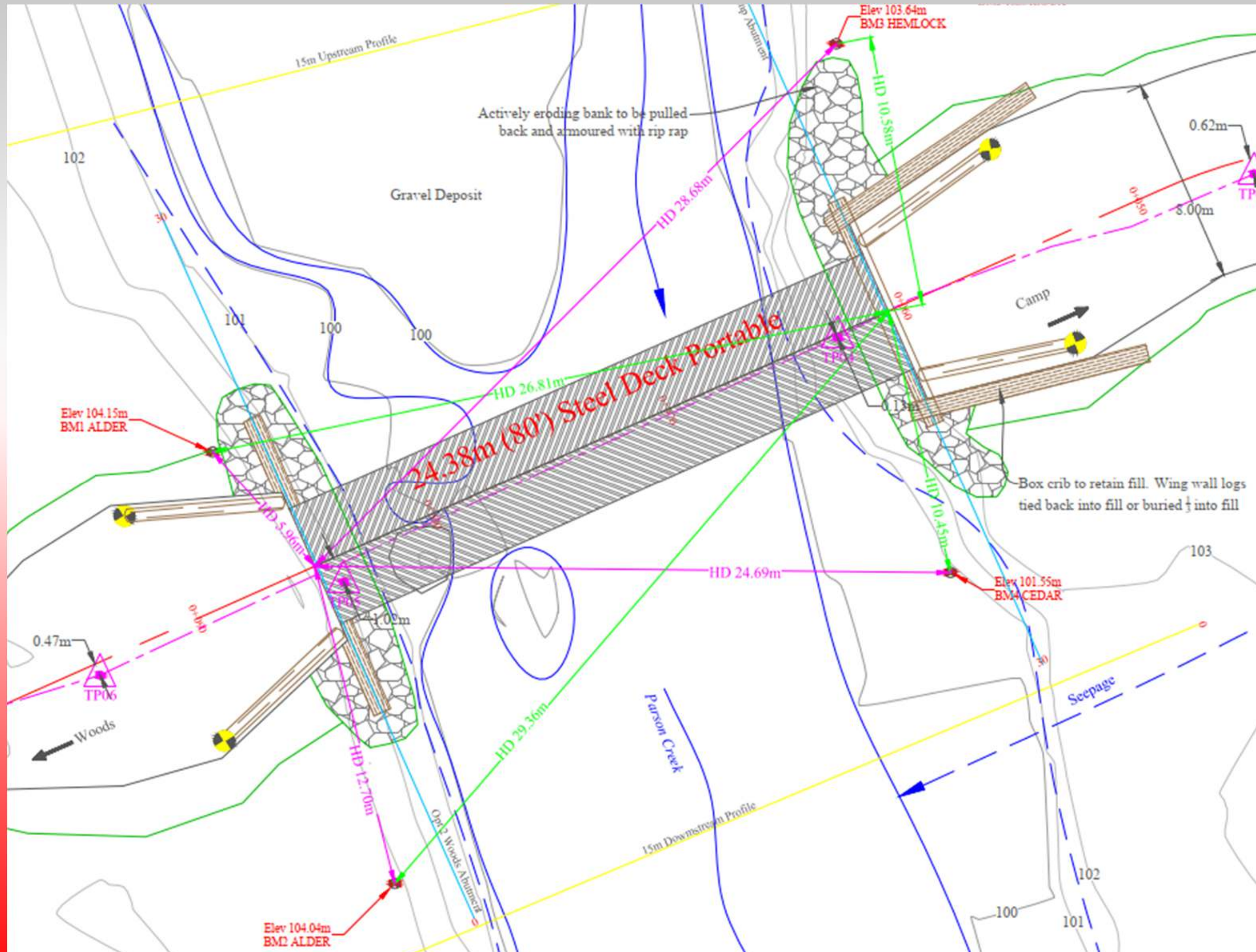
  92.3 m3/sec @ 2.6 m/s

Parson Creek – 2013 Temporary 24m/ 80’ Steel Deck Portable

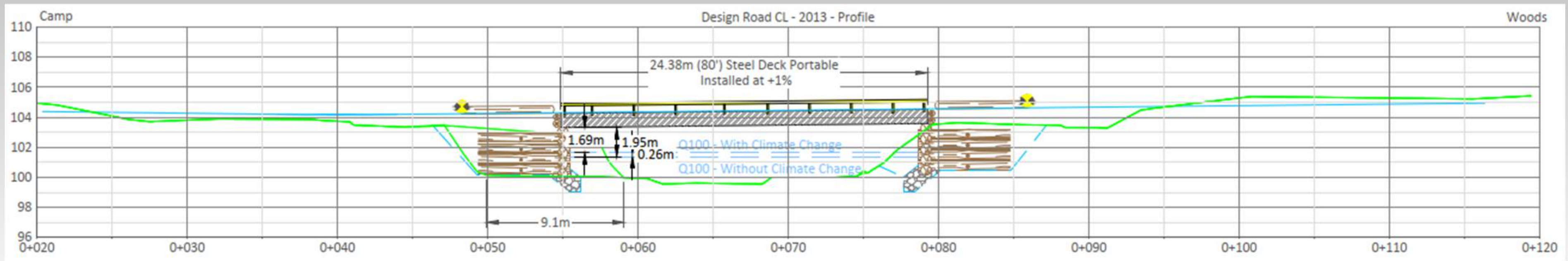
Design considerations:

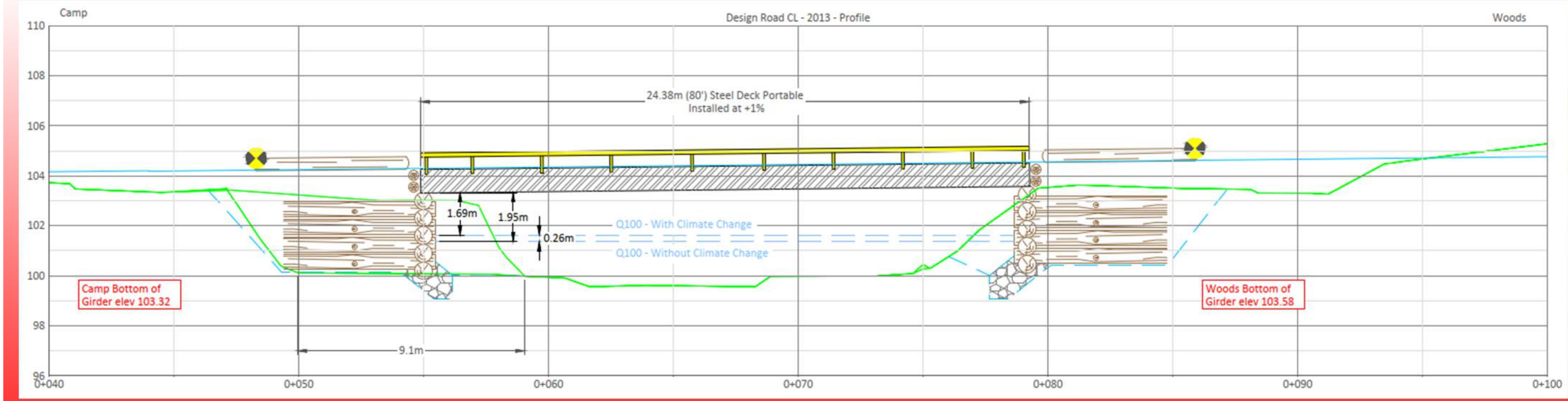
- Minimize cost (!)
- Desire to salvage superstructure after logging complete
- Span limited to 80’ by available lengths of common SDP (90’ available now)
- Vertical log box crib abutments with wing walls required to minimize span length and retain fill
- Can be installed with excavators
- Good “tight” fit prior to bank erosion – not feasible after
- No climate change consideration in 2013

Parson Creek – 2013 Temporary 24m/ 80’ Steel Deck Portable



Parson Creek – 2013 Temporary 24m/ 80' Steel Deck Portable

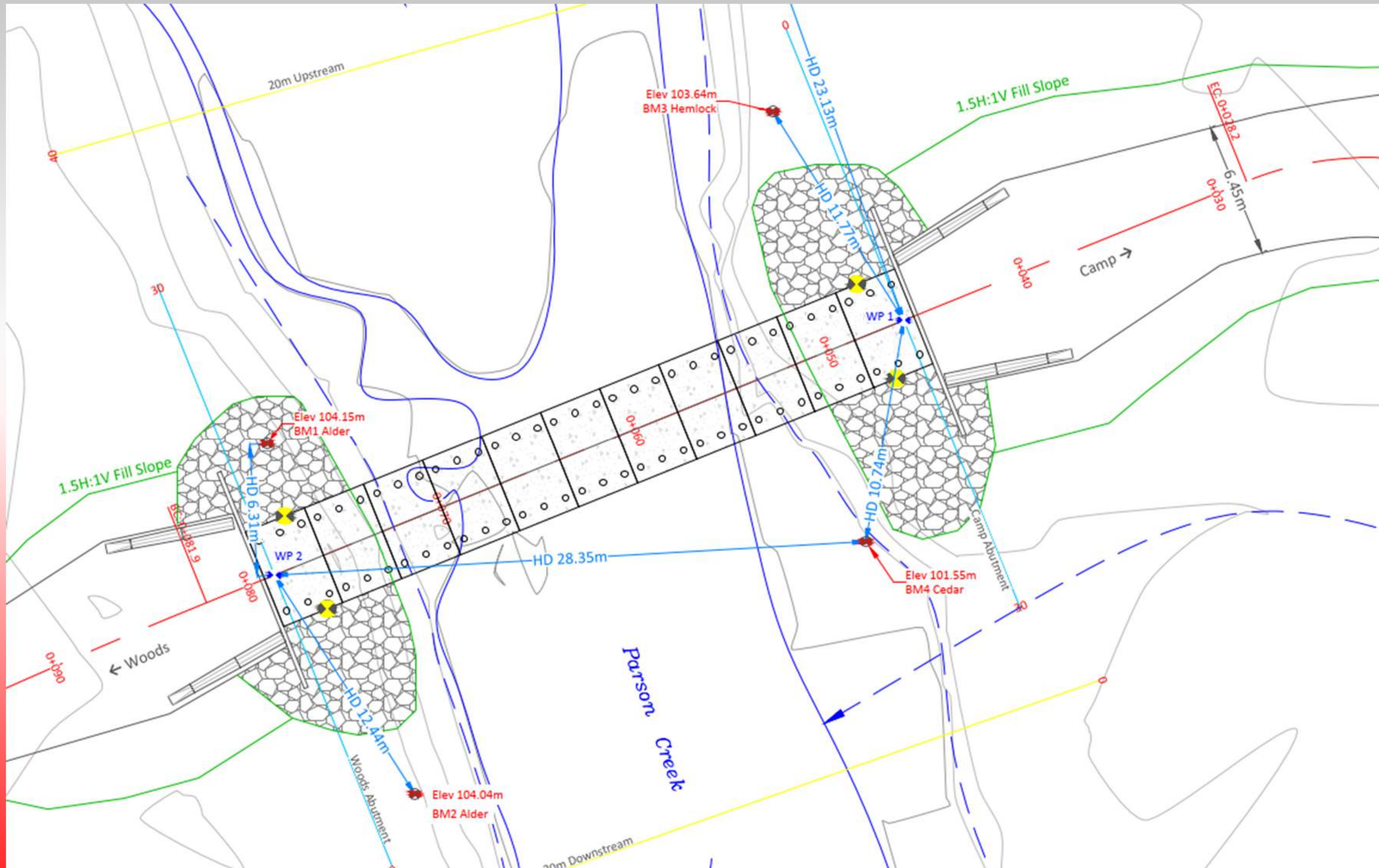




Parson Creek – 2020 Permanent Design for a retrofitted 33m/ 110’ Composite

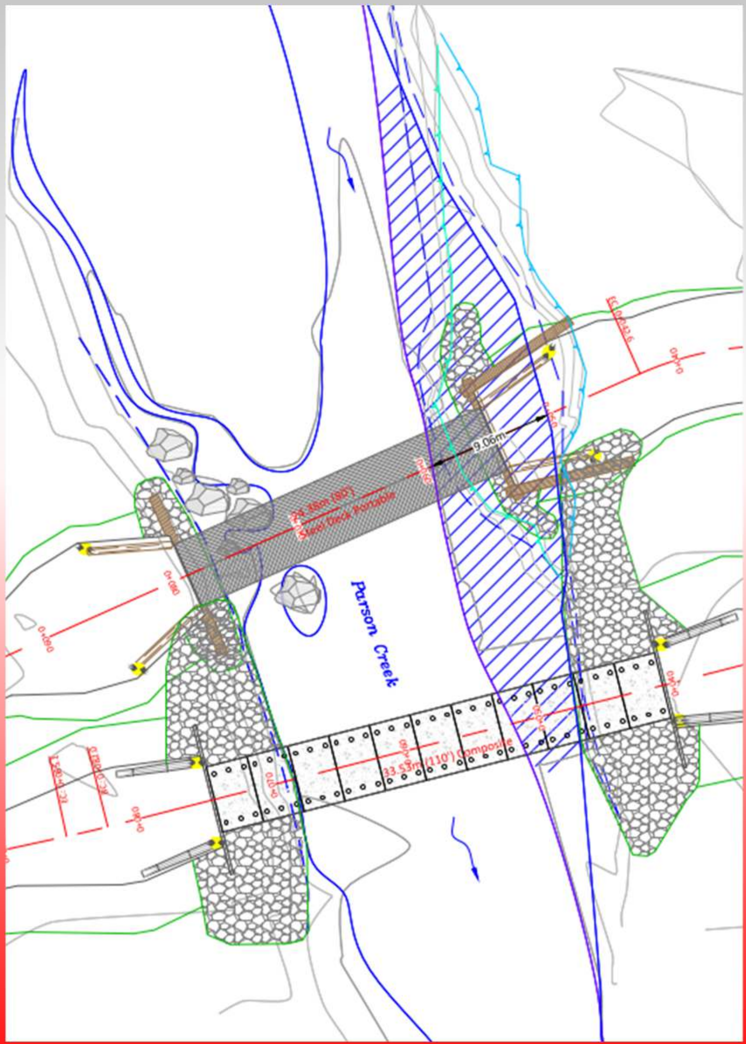
- BCTS owns salvaged 110’ steel composite girders from Wakeman River
- New concrete deck panels and abutments required
- Permanent bridge – difficult and expensive to salvage, consideration to leave in place for second growth in future
- Can be installed with excavators
- Longer span easily fit the 2013 alignment initially…

Parson Creek – 2020 Permanent Design for a retrofitted 33m/ 110’ Composite

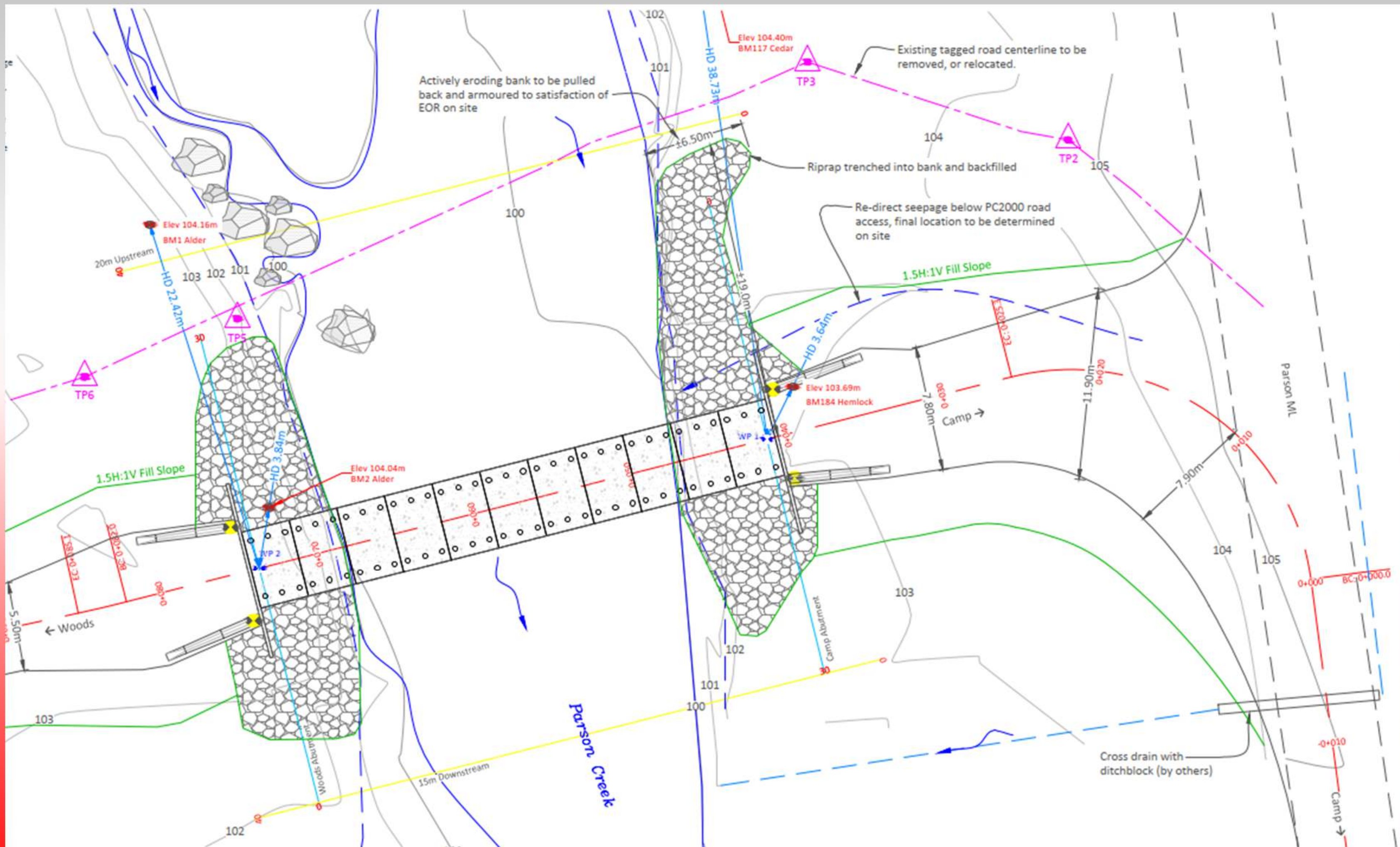


Parson Creek – 2020 Permanent Design for a retrofitted 33m/ 110’ Composite

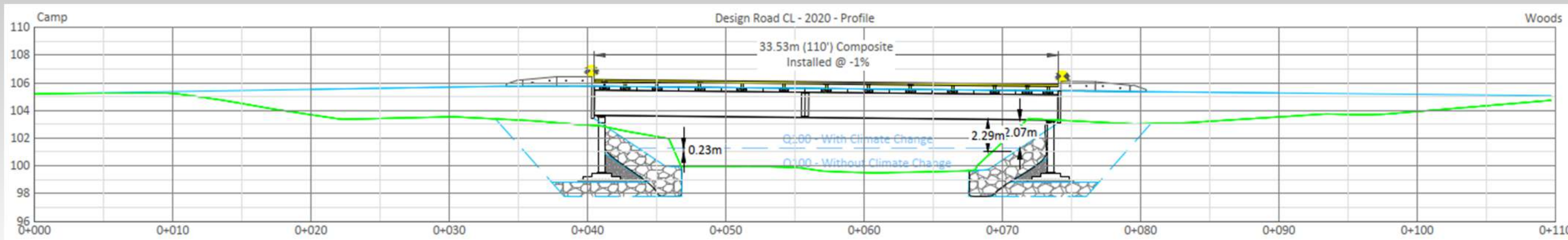
- Ground truth site/ proposed design after several years is a good idea!
- Original design centreline not feasible without major stream encroachment
- Better fit ~20m downstream for alternate alignment after bank erosion
- Future bank erosion? How will CC affect the crossing site?

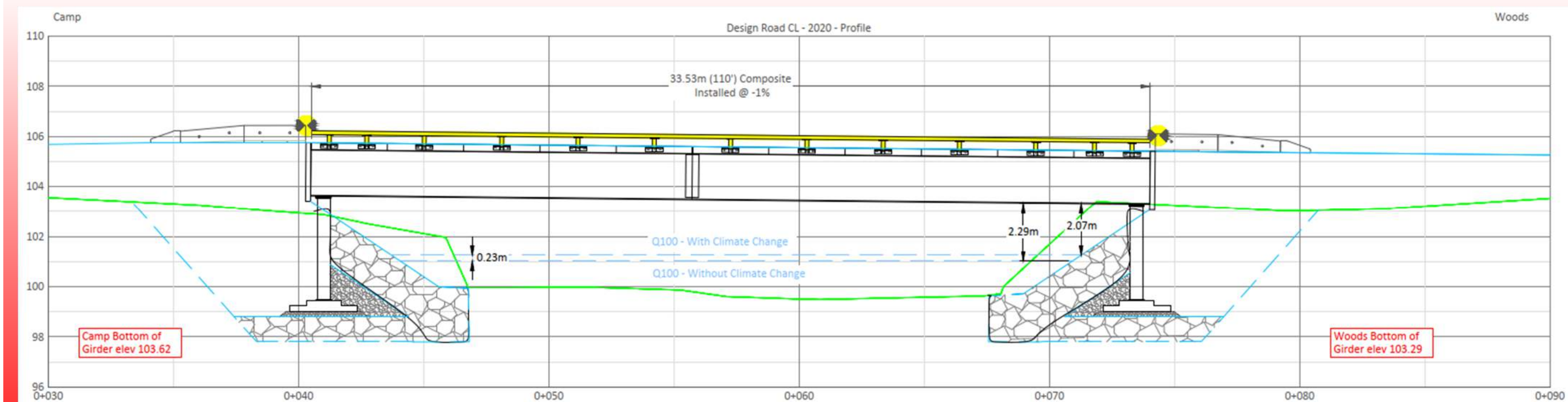


Parson Creek – 2020 Permanent Design for a retrofitted 33m/ 110' Composite



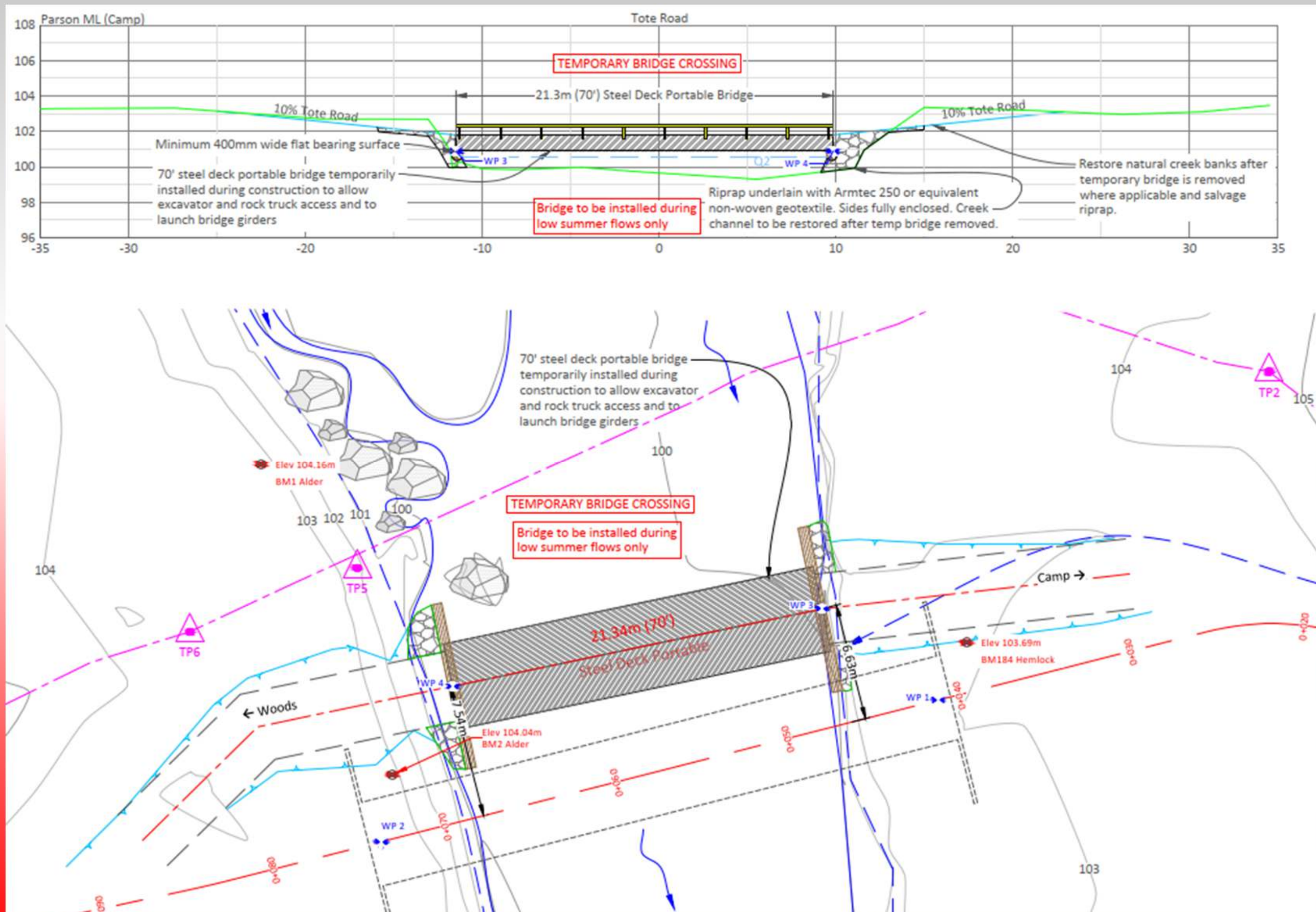
Parson Creek – 2020 Permanent Design for a retrofitted 33m/ 110' Composite





Parson Creek – 2020 Permanent Design for a retrofitted 33m/ 110’ Composite

Temporary portable crossing required for tote road



Parson Creek – Other Potential Options

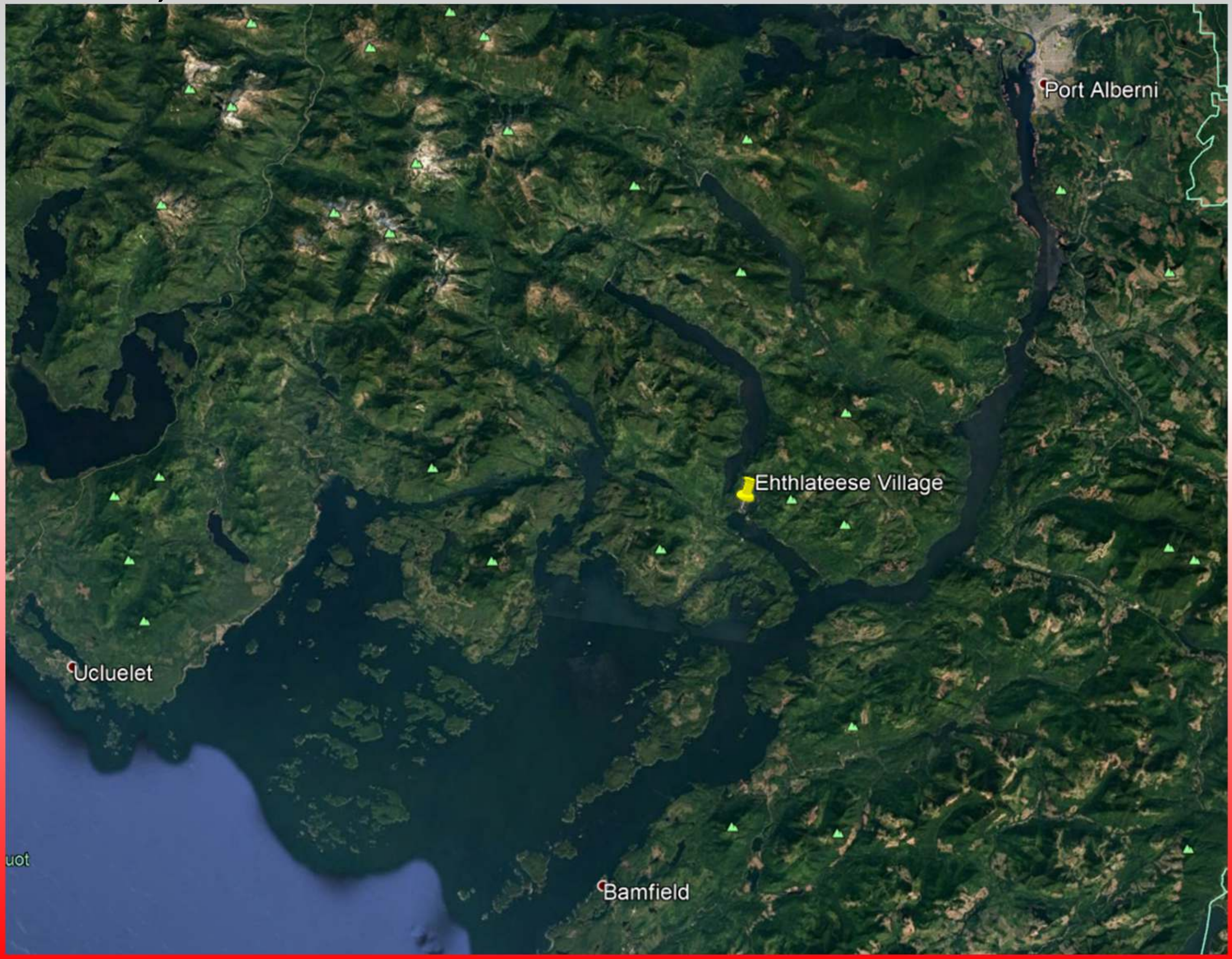
- Alternate crossing location?
- Temporary multi-span steel deck portables on driven pipe piles – need to mobilize crane >$200,000
- 27m/ 90’ SDP with vertical lock block abutments, GRS or log box cribbing with wing walls – need launch beam to avoid crane
- Steel girder non-composite with modular timber deck

Parson Creek Summary

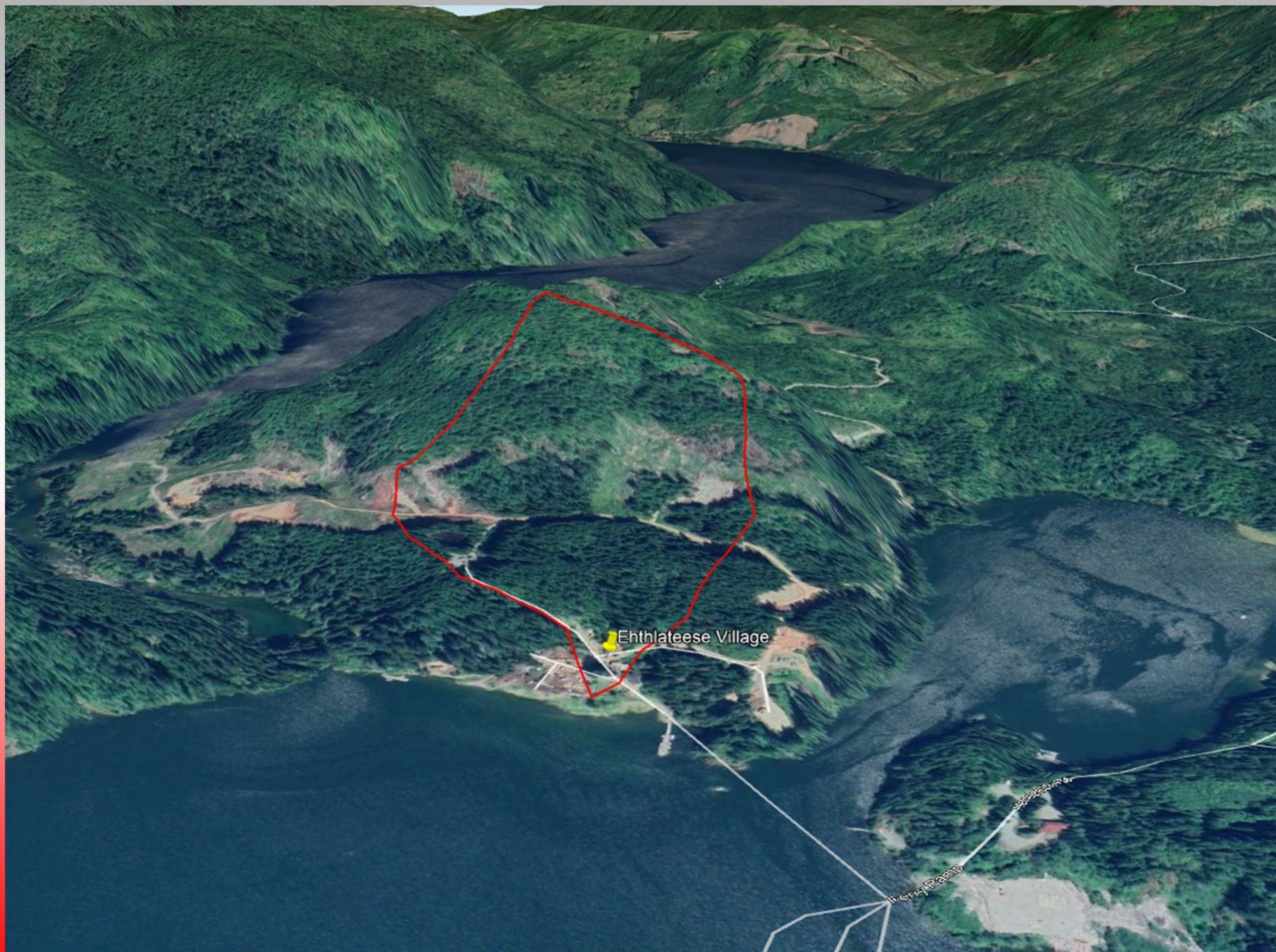
Development on hold due to marginal economics – need to wait for more second growth timber to mature or significant market value increase….

Ehthlateese Village Creek – Site Overview

- Located in Uchucklesaht Inlet (Kildonan) at mouth of Henderson Lake
- 29 km SSW of Port Alberni/ 38km NE of Ucluelet
- 49°01’15.04“ N, 125°02’15.93“ W



Ehthlateese Village Creek – Site Overview



Ehthlateese Village Creek – Site Overview

- Drainage area ~29ha (0.29km^2)
- Median elevation ~120m
- Drinking water reservoir upstream
- Windward/ onshore mountainous area
- Henderson Lake has highest recorded annual rainfall in Canadian history >9.3m (Ryzuk, 2020)

Ehthlateese Village Creek - Overview

- Civil Infrastructure project involving demolition and replacement of 15-20 houses and service buildings, underground service upgrades
- Upgrade roads, stream channel and crossing structures
- Sea walk/ armoured berm and raising boat ramp access road to prevent flooding
- Hydrotechnical design and stream channel armouring
- GA and structural designs for two vehicle crossings and one timber footbridge on stream

Ehthlateese Village Creek - Overview

- S6 (non-fish) above high tide due to lack of habitat
- 9% gradient with dry channel – surface flow only occurs during seasonally significant storm events
- Village located on gently to moderately sloping terrain with low risk of large scale slope failure or debris torrents/ flows. Smaller log/ debris jams may cause additional material migration towards the village (Ryzuk, 2020)
- Channel flow restrictions such as culverts are not recommended in order to convey channel flows, sediment and debris transport to Uchucklesaht Inlet (Ryzuk, 2020)

Ehthlateese Village – 2020

DFH in the Resource Industry - Rational Method

Used for smaller watersheds <10-25 km^2

From Coulson, 1991:

$$Q_p = \frac{0.28\, CPA}{T_c}$$

Where:

- Q_p is the peak flow in m^3/ sec
- C is the runoff coefficient
- P is the total precipitation in mm
- A is the drainage area in km^2
- T_c is the time of concentration in hours

DFH in the Resource Industry - Rational Method

Basic Assumptions for Rational Method:

- Extreme rainfall events lasting for a shorter duration are more intense than longer duration storms
- The peak flow is highest for a storm duration equal to the time of concentration T_c - Longer storm durations would not cause a greater peak flow but only prolong the runoff
- Rainfall intensity is constant for the storm duration and uniform across the entire watershed
- Watershed system is linear
- Overland flow is dominant drainage mechanism (not in forested basins)

These assumptions cannot be met for larger watersheds, so the formula is generally restricted to smaller drainages $<10\text{-}25 km^2$

DFH in the Resource Industry - Rational Method

Runoff Coefficient (C): Expresses the portion of the rainfall that is available as peak runoff

$C = 0.9 + 0.05 + 0.1 = 1.05$

Slope of channel	Physiography
S > 20%	Mountain
20% > S >= 10%	Steep
10% > S > 2.5%	Moderate
2.5% >= S >= 0.5%	Rolling
0.5% > S	Flat

PHYSIOGRAPHY \ SURFACE COVER	IMPERMEABLE	FORESTED	AGRICULTURAL	RURAL	URBAN
mountain	1.00	0.90	-	-	-
steep slope	0.95	0.80	-	-	-
moderate slope	0.90	0.65	0.50	0.75	0.85
rolling terrain	0.85	0.50	0.40	0.65	0.80
flat	0.80	0.40	0.30	0.55	0.75
RI 10-25 years	+0.05	+0.02	+0.07	+0.05	+0.05
RI > 25 years	+0.10	+0.05	+0.15	+0.10	+0.10
Snowmelt	+0.10	+0.10	+0.10	+0.10	+0.10

DFH in the Resource Industry - Rational Method

Time of Concentration (T_c):

- The time required for surface runoff from the most remote part of the drainage basin to reach the crossing location, i.e. the entire drainage basin area is contributing to the flow at the site.
- Various methods to calculate T_c:
  - Published tables (*Manual of Operational Hydrology*)
  - Kirpich, Kerby, Hathaway Formulas (urban, agricultural and impermeable basins)
- Results for T_c can vary substantially!
- May underestimate T_c due to shallow subsurface flow in forested terrain instead of overland flow

DFH in the Resource Industry - Rational Method

Time of Concentration T_c, for forested, rural and agricultural basins (Manual of Operation Hydrology in BC)

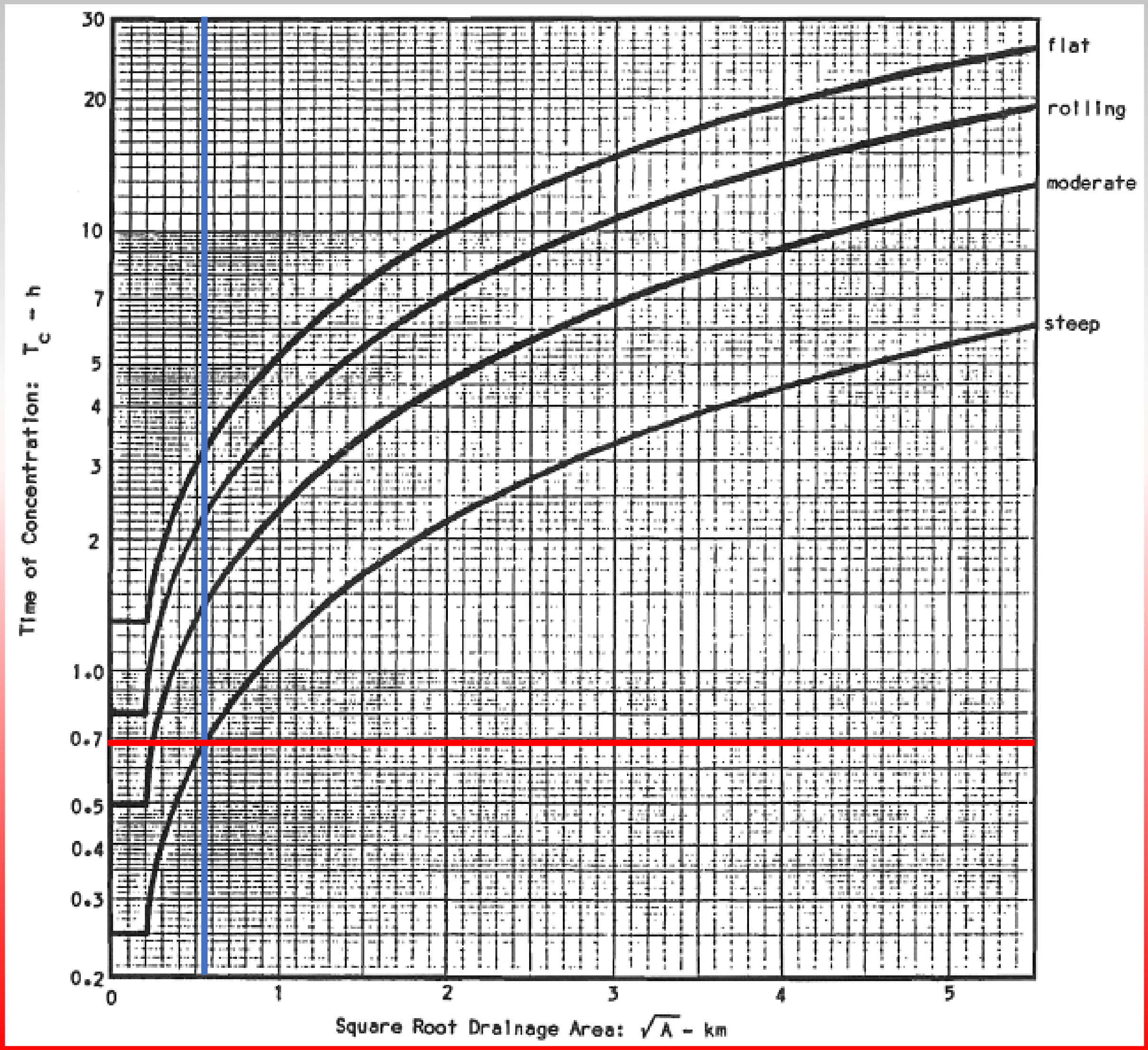
Note: >10% channel is considered "steep"!

>30% basin slope average

Drainage area: 0.29km^2

$\sqrt{0.29}$ = 0.54

T_c = 0.7 hours



DFH in the Resource Industry - Rational Method

Need to calculate the maximum rainfall intensity for a storm duration corresponding to our time of concentration (0.7 hours) with a return period equal to our design peak flow return period, e.g., 1 in 100-year rainfall event (i100)

Consider Orographic Precipitation effects for windward mountains (Coast Mountains Onshore/ Upslope).

Orographic precipitation is rain, snow, or other precipitation produced when moist air is lifted as it moves over a mountain range. As the air rises and cools, orographic clouds form and serve as the source of the precipitation, most of which falls upwind of the mountain ridge (Britannica).

Multiplier ranges (Rainfall Frequency Atlas for Canada):

1.5 (<2 hours storm duration), 1.8 (2-11 hours), 2.0 (>12 hours)

DFH Ehthlateese Village Creek - Rational Method

Rainfall Frequency Atlas for Canada

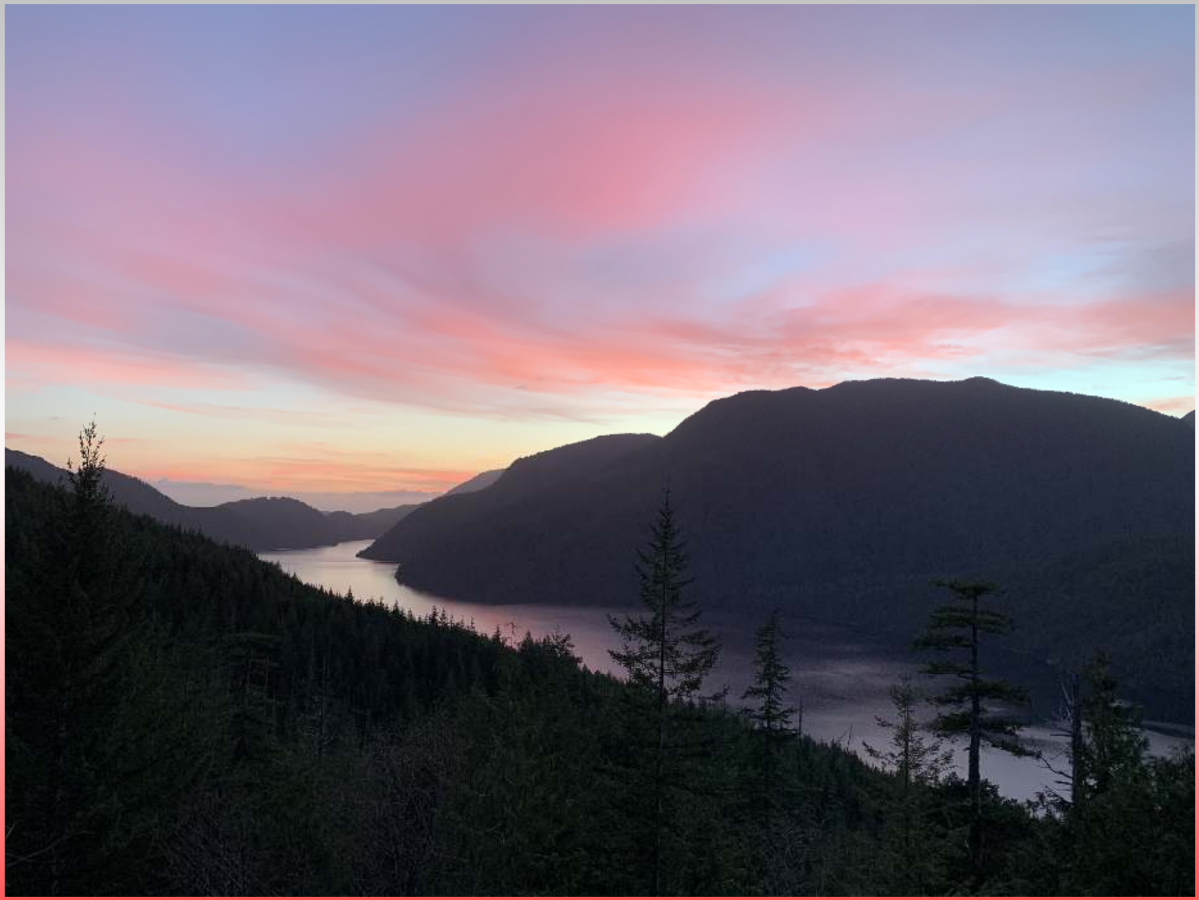
- i100 = 46mm/hr
- P = 46 x 1.5 x 0.7 = 48.3mm

IDF (Intensity-Duration-Frequency) curves

- i100 = 45mm/hr (Carnation Creek)
- P = 45 x 1.5 x 0.7 = 47.3mm

IDF_CC Tool 4.0

- i100 = 44mm/hr (historical value)
- P = 44 x 1.5 x 0.7 = 46.2mm



Henderson Lake

DFH Ehthlateese Village Creek - Rational Method

$$Q_p = \frac{0.28\,CPA}{T_c}$$

- C is the runoff coefficient = 1.05
- P is the total precipitation in mm = 48.3
- A is the drainage area in km^2 = 0.29
- T_c is the time of concentration in hours = 0.7

Q_p is the peak flow in m^3/ sec (historical) = 5.8 m^3/sec

DFH Ehthlateese Village Creek – Climate Tools

Applying climate tools: case study 2

IDF_CC Tool 4.0

2010-2039

RCP 8.5

2040-2069

RCP 8.5

Duration	25th perc.	Average	75th perc.
30 mins	**0%**	**5%**	**25%**
60 mins	**-2%**	**6%**	**25%**
30 mins	0%	10%	25%
60 mins	4%	13%	25%

PCIC Climate Explorer

Climate index	Average
Daily precipitation (50-year storm)	4 to 8%
Daily precipitation (50-year storm)	19 to 22%

DFH Ehthlateese Village Creek - Rational Method

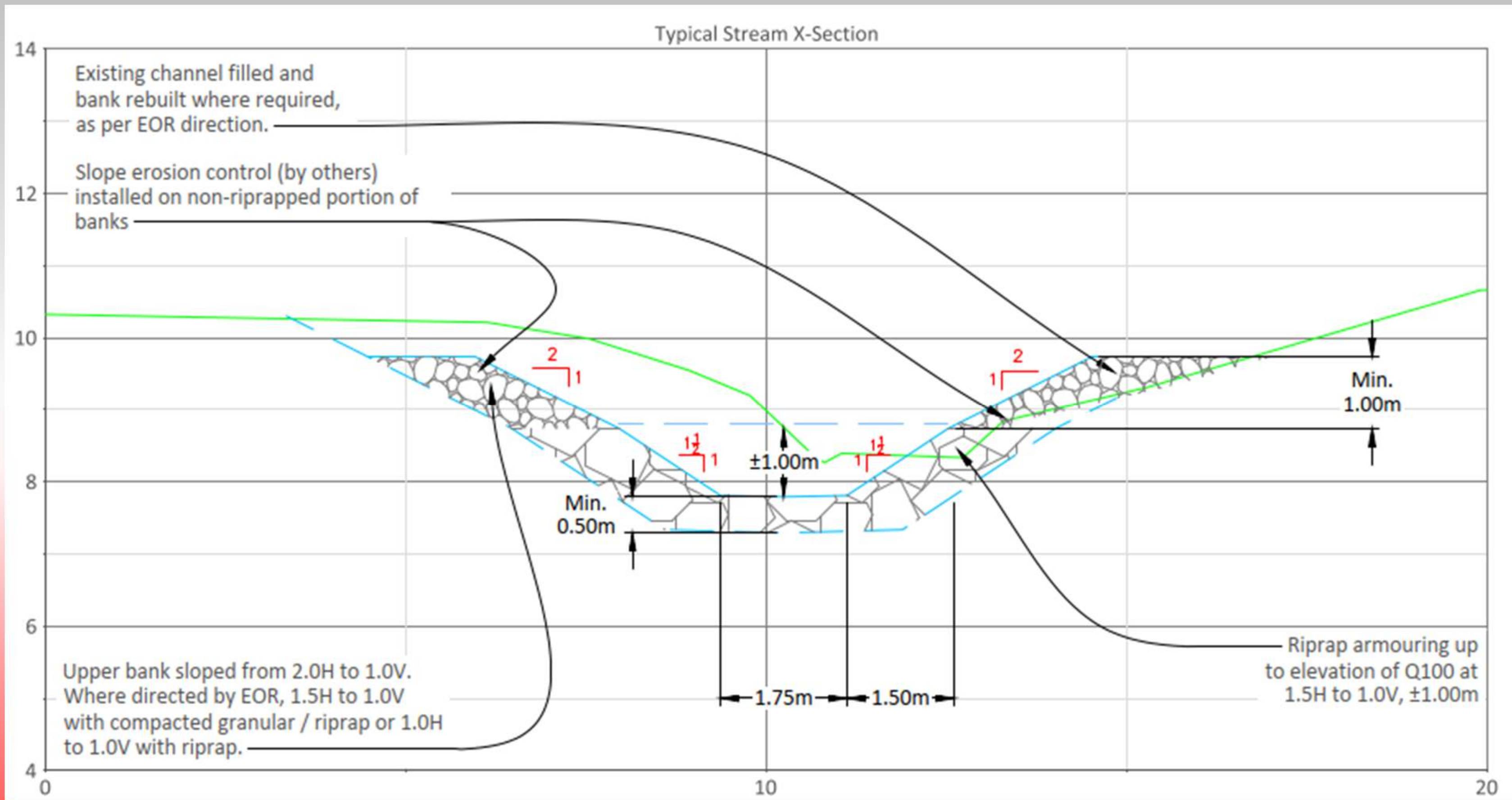
$$Q_p = \frac{0.28\,CPA}{T_c}$$

- C is the runoff coefficient = 1.05
- P is the total precipitation in mm = 48.3
- A is the drainage area in km^2 = 0.29
- T_c is the time of concentration in hours = 0.7

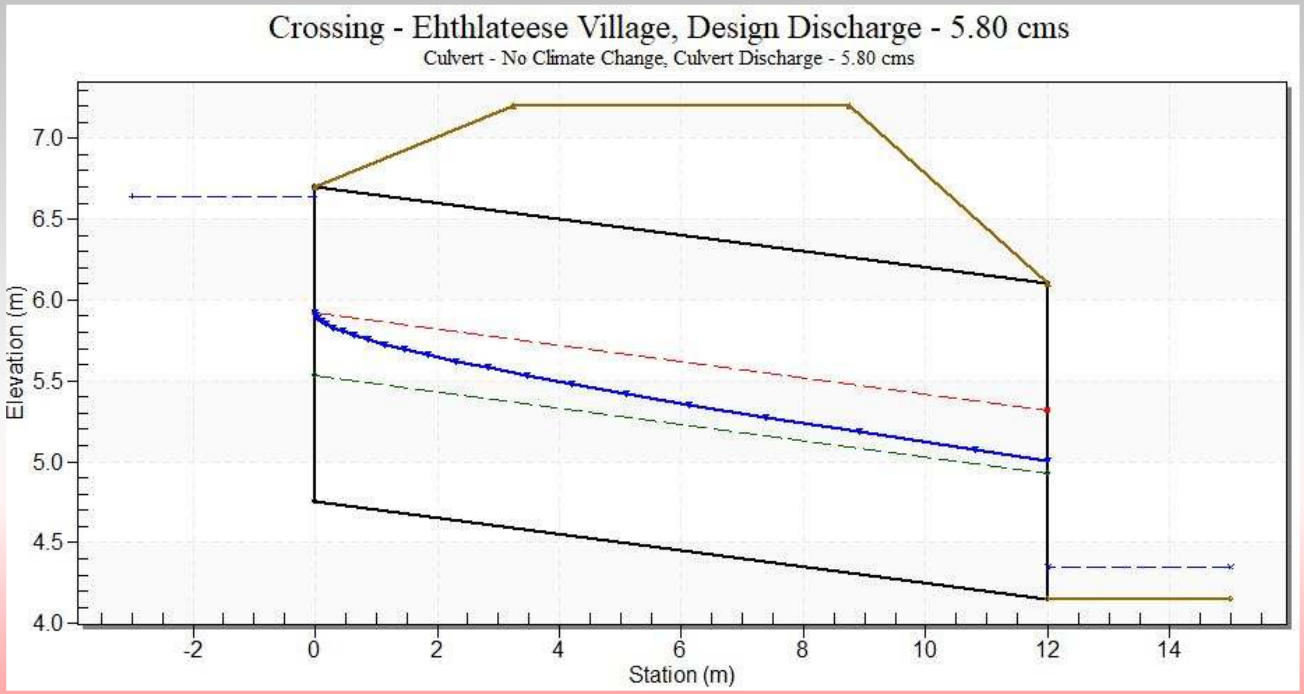
Q_p is the peak flow in m^3/ sec = 5.8 m^3/sec

Add 20% increase due to Climate Change = 7.0 m^3/sec

Ehthlateese Village – Stream Channel Design

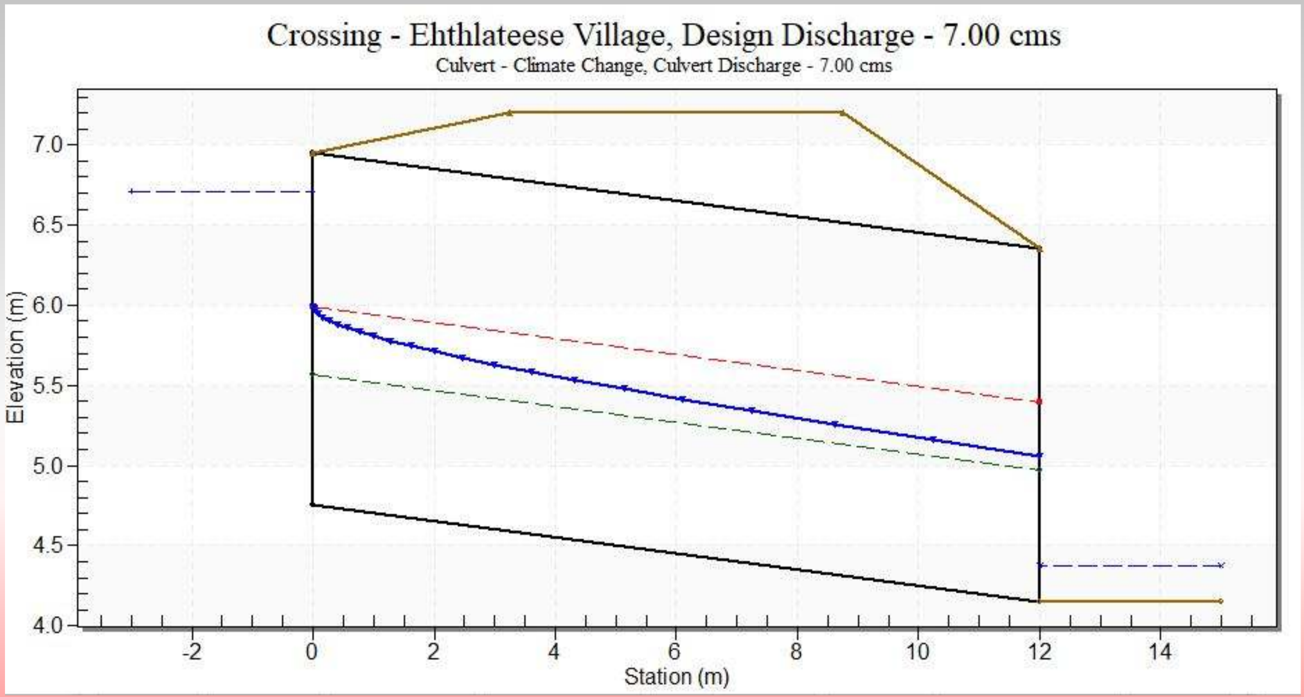


Ehthlateese Village Creek – HY-8 Hydraulic Analysis
No Climate Change: $Q_{100} = 5.8m^3/sec$
1,950mm diameter CSP



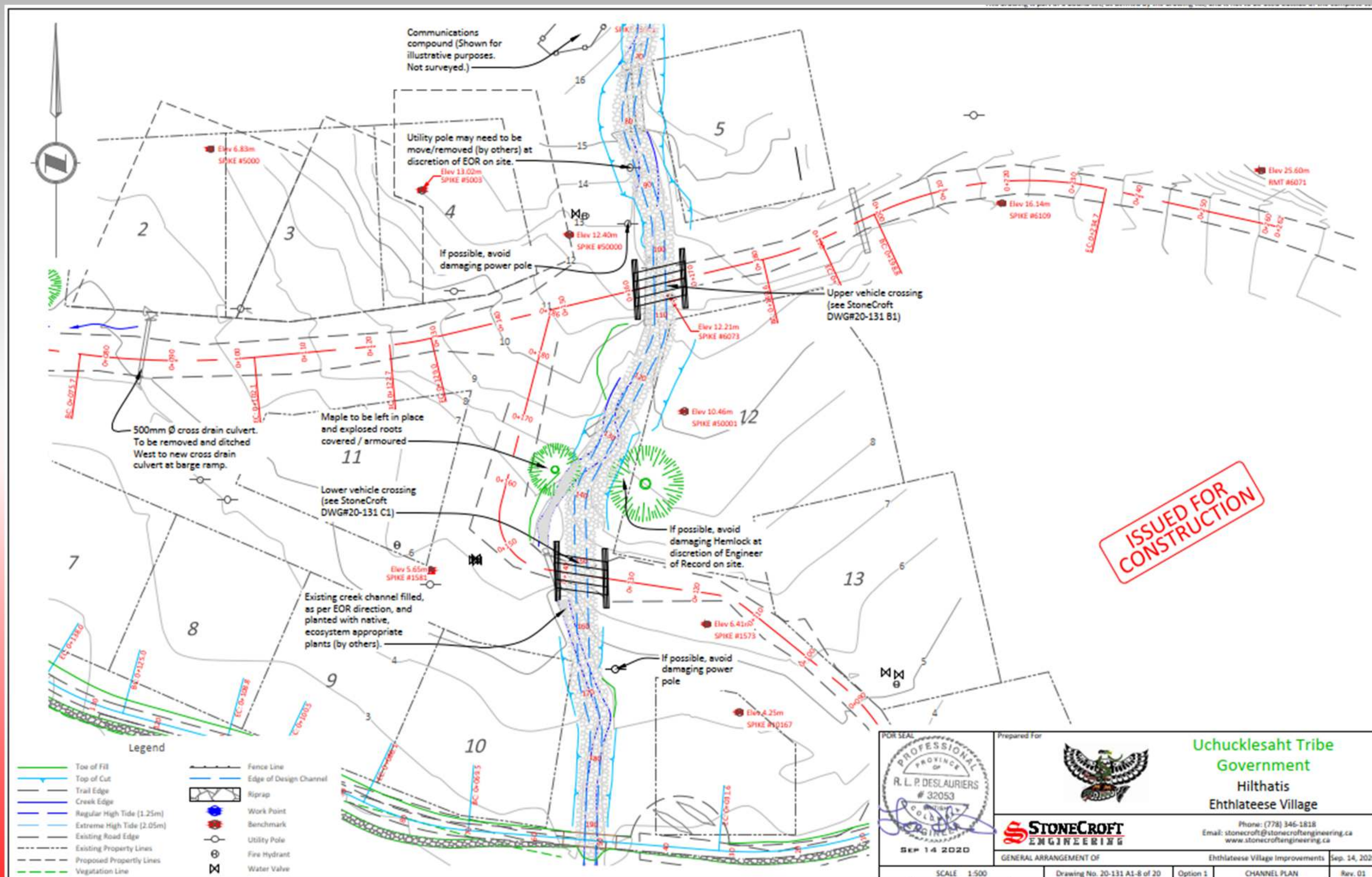
Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth(m)	Outlet Control Depth(m)	Flow Type	Length Full (m)	Length Free (m)
4.00	4.00	6.21	**1.46**	0.57	1-S2n	0.00	12.00
4.30	4.30	6.28	**1.53**	0.64	1-S2n	0.00	12.00
4.60	4.60	6.35	**1.60**	0.71	1-S2n	0.00	12.00
4.90	4.90	6.42	**1.67**	0.78	1-S2n	0.00	12.00
5.20	5.20	6.49	**1.74**	0.85	1-S2n	0.00	12.00
5.50	5.50	6.57	**1.82**	0.93	1-S2n	0.00	12.00
5.80	5.80	6.64	**1.89**	1.00	1-S2n	0.00	12.00
6.10	6.10	6.71	**1.96**	1.08	5-S2n	0.00	12.00
6.40	6.40	6.79	**2.04**	1.16	5-S2n	0.00	12.00
6.70	6.70	6.87	**2.12**	1.24	5-S2n	0.00	12.00
7.00	7.00	6.95	**2.20**	1.32	5-S2n	0.00	12.00

Ehthlateese Village Creek – HY-8 Hydraulic Analysis
20% Climate Change Factor: $Q_{100} = 7.0m^3/sec$
2,200mm diameter CSP

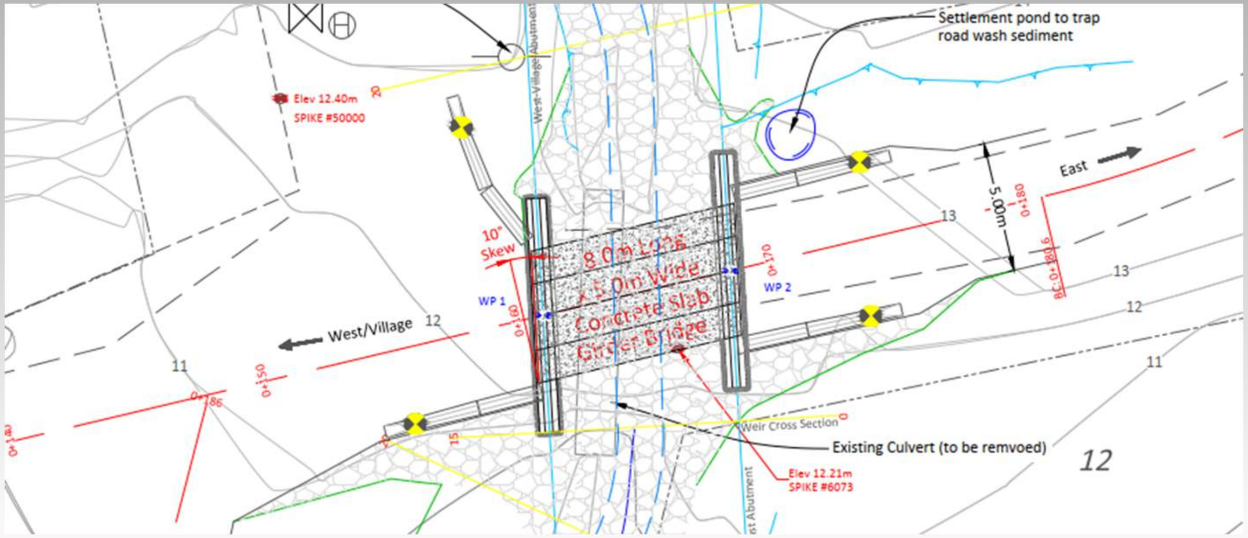


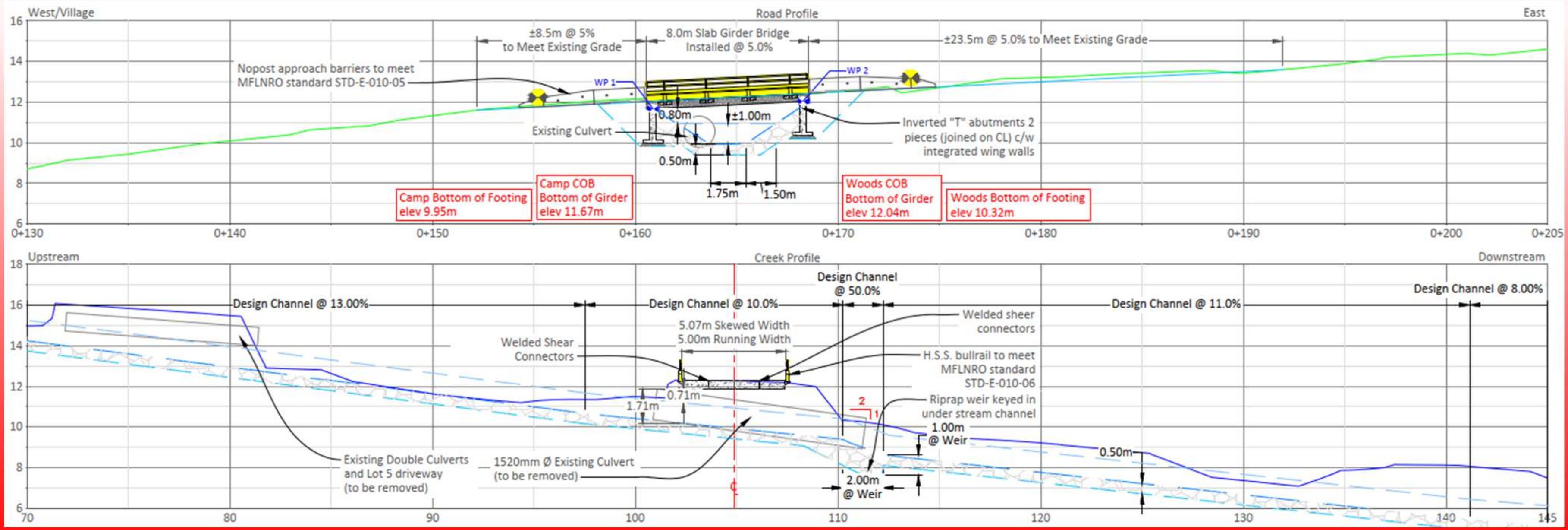
Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth(m)	Outlet Control Depth(m)	Flow Type	Length Full (m)	Length Free (m)
5.80	5.80	6.47	**1.72**	0.79	1-S2n	0.00	12.00
6.12	6.12	6.54	**1.79**	0.85	1-S2n	0.00	12.00
6.44	6.44	6.60	**1.85**	0.91	1-S2n	0.00	12.00
6.76	6.76	6.66	**1.91**	0.98	1-S2n	0.00	12.00
7.00	7.00	6.71	**1.96**	1.02	1-S2n	0.00	12.00
7.40	7.40	6.79	**2.04**	1.11	1-S2n	0.00	12.00
7.72	7.72	6.86	**2.11**	1.17	1-S2n	0.00	12.00
8.04	8.04	6.92	**2.17**	1.24	1-S2n	0.00	12.00
8.36	8.36	6.99	**2.24**	1.31	5-S2n	0.00	12.00
8.68	8.68	7.06	**2.31**	1.38	5-S2n	0.00	12.00
9.00	9.00	7.13	**2.38**	1.45	5-S2n	0.00	12.00

Ehthlateese Village – Stream Channel Design

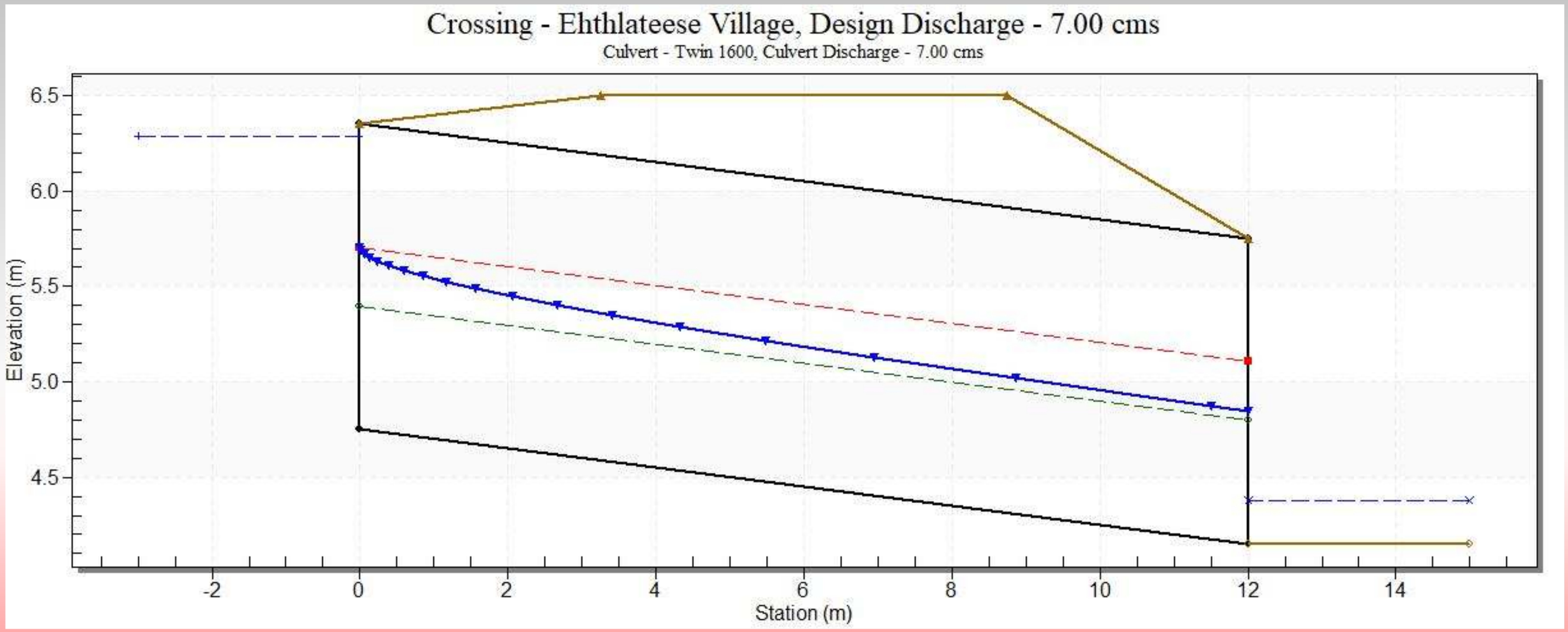


Ehthlateese Village – Permanent 8m Slab Girder Bridge



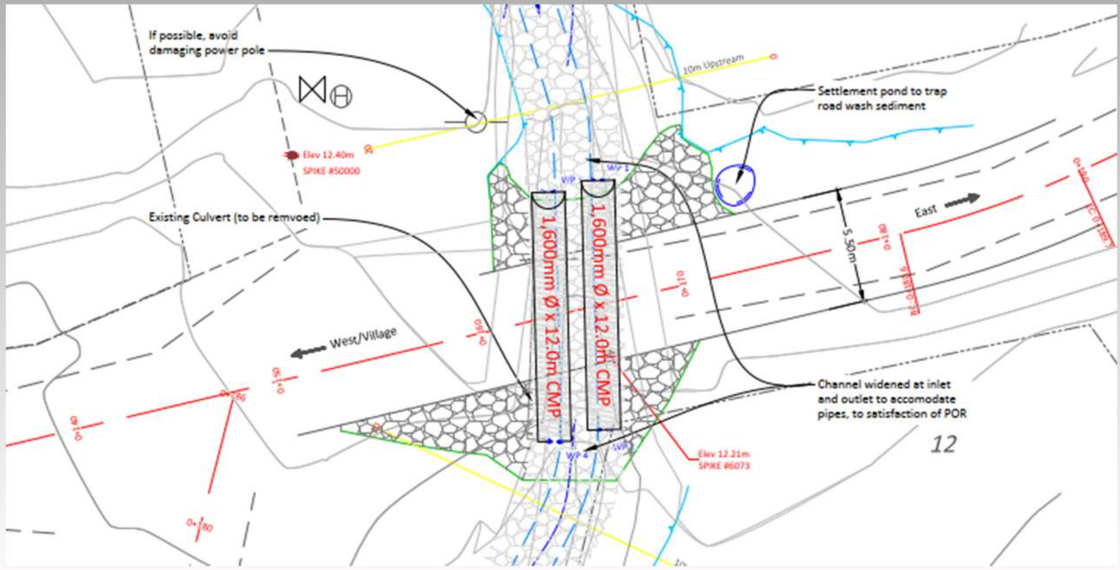


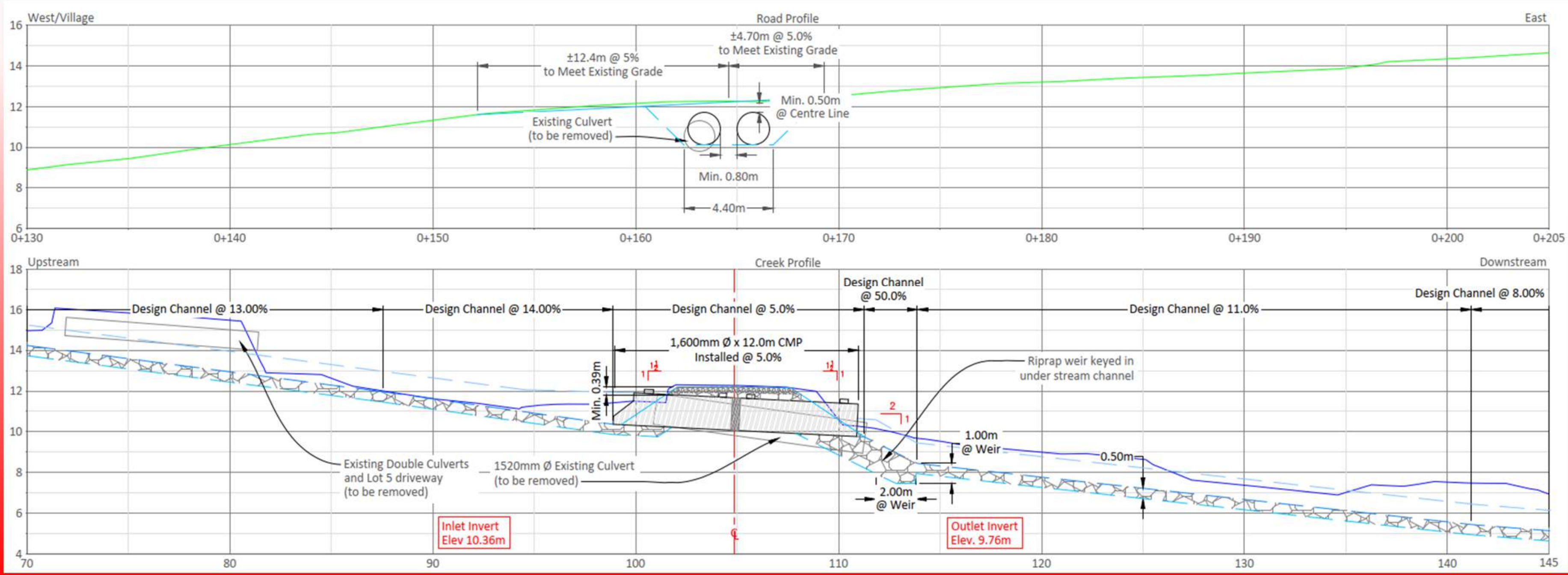
Ehthlateese Village Creek – HY-8 Hydraulic Analysis
20% Climate Change Factor: $Q_{100} = 7.0m^3/sec$
2x 1,600mm diameter CSP's



Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth(m)	Outlet Control Depth(m)	Flow Type	Length Full (m)	Length Free (m)
5.80	5.80	6.09	**1.34**	0.52	1-S2n	0.00	12.00
6.04	6.04	6.13	**1.38**	0.55	1-S2n	0.00	12.00
6.28	6.28	6.17	**1.42**	0.60	1-S2n	0.00	12.00
6.52	6.52	6.21	**1.46**	0.64	1-S2n	0.00	12.00
6.76	6.76	6.25	**1.50**	0.68	1-S2n	0.00	12.00
7.00	7.00	6.29	**1.54**	0.72	1-S2n	0.00	12.00
7.24	7.24	6.33	**1.58**	0.76	1-S2n	0.00	12.00
7.48	7.48	6.37	**1.62**	0.80	5-S2n	0.00	12.00
7.72	7.72	6.41	**1.66**	0.85	5-S2n	0.00	12.00
7.96	7.96	6.45	**1.70**	0.89	5-S2n	0.00	12.00
8.20	8.20	6.50	**1.75**	0.94	5-S2n	0.00	12.00

Ehthlateese Village – Temporary Twin 1,600mm CSP's





DFH in the Resource Industry – Summary

- Crossing designers in the resource sector use several different analytical methods to determine design peak flows, which can produce a very wide range of results. “DFH is not an exact science…”
- Professional judgement and experience is critical to determine which analytical method is the most reasonable
- Compare results to field observations to determine if fit is reasonable

Summary of Climate Change and Structure Resiliency Considerations

- Structure design resiliency must include consideration of anticipated “clear water” design floods and floating debris vs. debris floods/flows, in the context of a changing climate
- Risk-based design should include consideration of potential safety, environmental, structural and maintenance risks and associated costs over the design service life
- Level of design risk may depend on the tolerance and budget of the Owner and CRP, within reason.
- The POR must ensure that all relevant design assumptions, considerations and potential risks are clearly communicated in writing to the Owner/ CRP at the design stage!

Summary of Climate Change Tools and Considerations for DFH

- Climate change and resilience must be considered by the designer (POR) in crossing structure designs according to EGBC and new *Guidelines for Professional Services in the Forest Sector - Crossings V.3* (Draft)
- There is room for improvement on applicability of available climate change tools for determining future design peak flows; however, research and CC Tools are evolving quickly!
- Current Climate Tools using IDF curve projections to model future peak flows can provide a false sense of "accuracy" due to precision of outputs. More relevant for coastal DFH where rainfall or ROS is dominant peak flow mechanism
- More difficult to model snowmelt dominated peak flows

Summary of Climate Change Tools and Considerations for DFH

- Where Climate Tools are unreliable or ambiguous, consider adding 20% CC factor to design peak flows (EGBC, 2018)
- Climate Tools may be used to determine potential impacts over the design service life of the structure – POR may be able to justify using a smaller CC factor (if any) for a shorter service life
- More research and professional guidance are required for resource industry crossing designers to make informed, scientific, methodical and repeatable decisions in consideration of climate change impacts

Designing Resource Road Stream Crossings Considering Climate Change: Two Case Studies from Coastal BC

Thank you for taking the time to participate and share your knowledge!

Questions or comments?

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