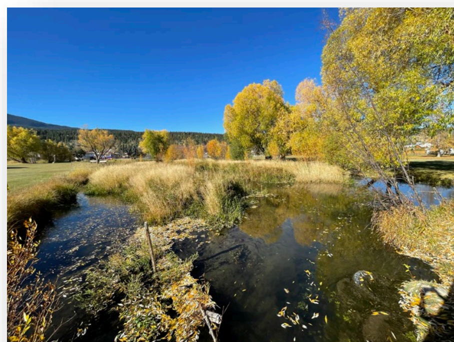
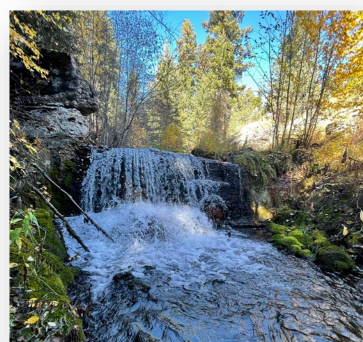
Flood Mitigation Plan

Village of Clinton





February 2025

Project No. 675-541

ENGINEERING ■ PLANNING ■ URBAN DESIGN ■ LAND SURVEYING

2089 Falcon Rd | Kamloops BC | V2C 4J2 | true.ca | tel 250.828.0881

Distribution List

# of Hard Copies	PDF Required	Association / Company Name
0	1	Village of Clinton

Revision Log

Revision #	Revised by	Date	Issue / Revision Description
1	DU	2025-01-28	Client Review
2	JW	2025-02-11	Final Report

Report Submission

Report Prepared By:

Johnathan Celeita, EIT

Report Reviewed By:

Permit to Practice No. 1000129

PROFESSIONAL PROVINCE OF J. P. WELKE # 35705 BRITISH COLUMBIA ENGINEER

2025-02-13

Jonathan Welke, P. Eng.
Senior Water Resources Engineer

R:\Clients\600-699\675\675-541\05 Reports\Flood Mitigation Plan\675-541-Clinton-Flood Mitigation Plan-February 2025.docx

Table of Contents

Appendices

List of Tables

List of Figures

Executive Summary

This flood mitigation plan is a strategic document designed to reduce the risk and impact of flooding within the Village of Clinton. It identifies vulnerabilities, assesses potential hazards, and recommends measures to mitigate flood-related damages. Reducing risk involves some complex detail and nuance, yet it fundamentally comes down to three straightforward steps: understand the hazard, understand the risk, and take action.

The Flood Mitigation Plan represents the Village of Clinton's first comprehensive effort to address flood risks. Although Clinton has not recently experienced significant flooding compared to neighboring communities like Cache Creek, findings from the 2019 Dam Break Analysis and the Flood Mapping highlight risks from infrequent but potentially severe flood events. While updating the previous Dam Break Analysis was not the primary focus of this study, data collected during this assignment revealed inaccuracies in the 2019 study. These include an underestimation of potential consequences and assumptions that overestimate the Village's emergency response capacity, potentially endangering community assets and lives.

As part of this project, the Flood Mapping enabled a detailed evaluation of flood-prone areas, critical infrastructure vulnerabilities, and community-wide risks. Key observations from previous studies are summarized in this report, with detailed documentation provided in the appendices.

A range of risk reduction projects has been identified and developed, encompassing both structural (infrastructure) and non-structural measures (policies and programs). Each project has been scoped out, accompanied by cost estimates to facilitate effective planning and budget allocation.

To prioritize these projects, a Multi-Criteria Analysis (MCA) was conducted, emphasizing social, environmental, and economic impacts alongside risk reduction. The P1 Flood Early Warning System (FEWS) emerged as the highest-priority project due to its ability to monitor water accumulation behind the CN Railway embankment and identify potential flood risks early. Other high-priority projects include P2 CN Railway Embankment Hydraulic Upgrades and P3 Clinton and Cutoff Creeks Hydrometric Stations, both addressing significant downstream risks and uncertainties in design flows under changing climate conditions. The P4 WWTP Floodproofing and Lagoon Road Upgrades project was also prioritized due to its importance to the community and potential environmental impacts.

Additional initiatives include non-structural strategies for floodplain management, along with structural projects such as Highway 97 drainage upgrades and the Wastewater Treatment Plant (WWTP) erosion protection. These measures aim to protect critical infrastructure and mitigate potential impacts from a 200yr flood scenario, which, while infrequent, could have severe consequences.

The following table summarizes the recommended flood mitigation projects.

TABLE 1 PROJECTS SUMMARY

PROJECT NO.	PROJECT TITLE	PRIORITY	TYPE	COST ESTIMATE
P1	Flood Early Warning System	**Very High**	Structural	$111,000
P2	CN Railway Embankment Hydraulic Upgrades	**High**	Structural	TBD
P3	Clinton and Cutoff Creeks Hydrometric Stations	**High**	Structural	$154,000
P4	WWTP Floodproofing and Lagoon Road Upgrades	**High**	Structural	$2,300,000
P5	Wastewater Treatment Plant (WWTP) Erosion Protection	Medium	Structural	$124,000
P6	Floodplain Land Use Regulation	Medium	Non-Structural	$145,000
P7	Flood Response Plan	Medium	Non-Structural	$147,000
P8	Clinton Creek Drainage Infrastructure Upgrades - MoTT	Medium	Structural	TBD
P9	Highway 97 Drainage Infrastructure Upgrades - MoTT	Medium	Structural	TBD
P10	Flood Education Program	Medium	Non-Structural	$55,000
P11	Cariboo Avenue Capacity Improvements	Low	Structural	$890,000
			Total	**$3,930,000**

Implementation of the Flood Mitigation Plan will require consideration of various factors, including funding availability, resource allocation, and community collaboration. The timeline for implementation will be contingent upon these elements, underscoring the need for flexibility and adaptive management strategies.

This plan is intended as a living document, continuously updated to reflect changing conditions and incorporate new data. By adopting an adaptive approach to flood management, the Village of Clinton will enhance its resilience and reduce flood risks, safeguarding both the community and critical infrastructure from future flood events.

1.0 Introduction

The Village of Clinton, a community with approximately 570 residents as of the 2021 census, is predominantly centered along the Highway 97 corridor. Although the Village has not experienced significant flood events in recent years, recent flood mapping and the characteristics of the upstream water supply reservoirs and railway embankment along Clinton Creek highlight significant risks from infrequent but potentially severe flood events. This project identifies infrastructure at risk based on the projected 200yr floodplain mapping and provides flood mitigation strategies to reduce impacts on community assets and decrease overall flood risk for the Village.

FIGURE 1-1: VILLAGE OF CLINTON (NICK ASTLE, 2024)

1.1 Background

The Village of Clinton's water system is supplied by two reservoirs located in the upper and lower sections of the Clinton Creek watershed, as illustrated in Figure 1-2. The Upper Reservoir is classified as a high-consequence structure under BC Government dam safety policies and regulations due to:

- The creek diversion pond downstream (Lower Clinton Creek Reservoir);
- Potential impacts on water treatment works;
- The creek crossing beneath a high railway embankment upstream of the Village of Clinton; and
- The creek's flow path through the Village itself.

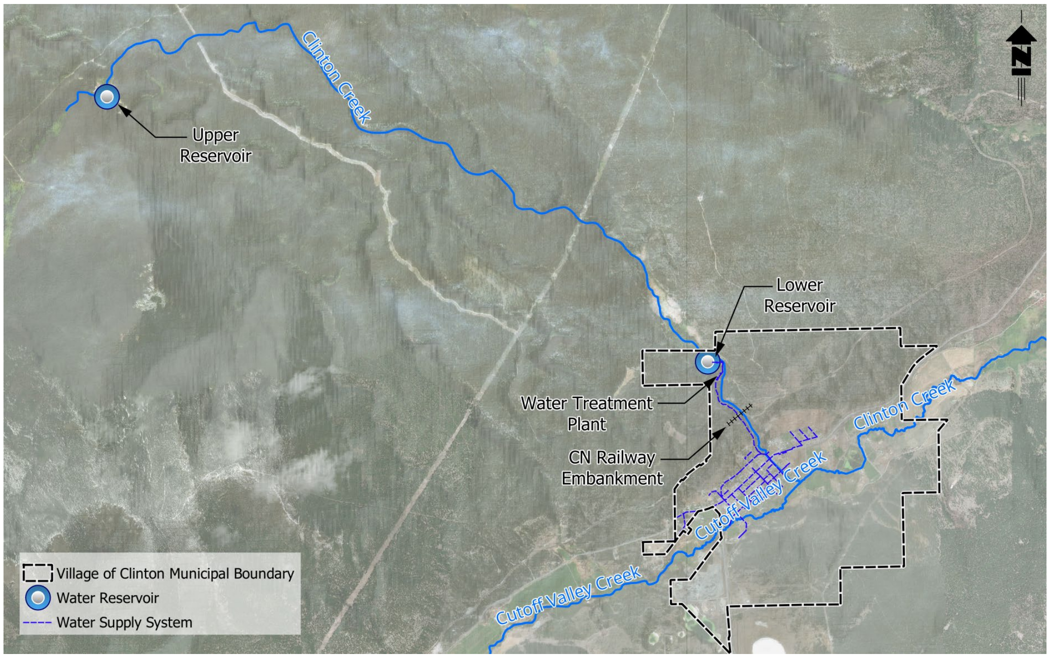


FIGURE 1-2 UPPER RESERVOIR AND LOWER RESERVOIR

The water reservoirs and CN Railway embankment along Clinton Creek have altered the creek's natural flow conditions, providing attenuation and storage but also increasing the hazard potential. A failure of such infrastructure could generate a wave, posing an immediate threat to Village properties downstream. Additionally, floodplain mapping has identified insufficient capacity in the existing drainage infrastructure to manage projected 200yr flows.

1.1.1 Previous studies

Three flood-related studies have been completed in the Village of Clinton, a summary of the main findings in the results are presented below:

1.1.1.1 Clinton Creek Reservoir Dam (D11020-00) Dam Break Analysis (AC Eagle, 2019)

The 2019 Dam Break Analysis by AC Eagle assessed potential dam break scenarios for the Upper and Lower Clinton Creek Reservoirs. However, it contained key inaccuracies and assumptions regarding the CN Railway embankment and its associated risks, which require further review.

Key observations include:

Geomorphological and Debris Considerations:

- Natural features, such as gullies along watercourses, could transport silt and woody debris downstream. If a dam break flood wave occurs, this debris could block the culvert under the CN Railway embankment, exacerbating flood risks. The accumulation of water behind the embankment could cause it to overtop, leading to erosion and potentially creating a second flood wave into the Village.

Flood Scenarios and Infrastructure Capacity:

- In the status quo scenario, the study assumed that the railway embankment could attenuate peak flows using a 1.8m culvert. In reality, the actual culvert diameter is 0.7m, which is insufficient to handle the modeled flows.
- In the worst-case scenario, it estimated a maximum water depth of 10m behind the embankment, but updated findings suggest the actual depth could reach closer to 20m. This discrepancy significantly increases the inundation extent and associated risks.
- The worst-case scenario assumed a culvert's blockage, combined with overtopping. The study estimated a peak flow of approximately 200 m³/s into the Village, resulting in flooding depths between 0.5m and 1.6m in areas such as Robertson Lane, McDonald, and Lebourdais Avenue. A 20-meter wave is expected to have greater impacts on the Village than those projected in the study's worst-case scenario.

The figures below illustrate the HECRAS profile used in the analysis and the projected inundation extent. In the inundation extent figure, the solid line represents the status quo scenario, while the dotted line depicts the worst-case scenario.

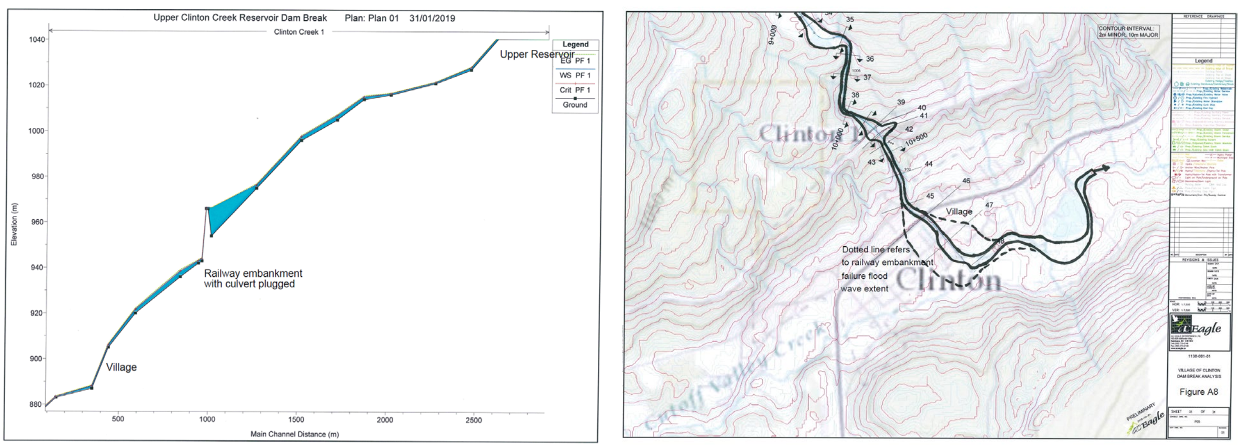


FIGURE 1-3 HECRAS PROFILE (LEFT), AND INUNDATION EXTENT (RIGHT)

Emergency Protocols and Response Capacity:

- The study assumes that emergency personnel from the Village could monitor water accumulation behind the railway embankment and potentially clear a blockage using an excavator. However, this assumption does not account for the absence of a Flood Early Warning System (FEWS), which is critical for timely identification and response to such scenarios.
- While the study concludes that fatalities would likely be minimal due to assumed evacuations, it overlooks the challenges posed by the lack of a formal emergency plan.

Without adequate warning and response systems, the Village's ability to mitigate damage and ensure community safety could be compromised.

- Extensive damage to homes and infrastructure in central Clinton is anticipated in the event of embankment failure.

Recommendations

Collaboration with CN Rail:

- The 2014 Dam Safety Review (DSR) highlighted the "bottleneck" risk at the CN Railway embankment, urging CN Railway to address the potential culvert blockage as a safety priority. The DSR recommended partnering with CN Railway to establish emergency protocols for debris removal, monitoring, and flood response should a blockage occur during a large flood event or dam break.

Emergency Protocols:

- Suggested actions include creating procedures for debris removal, issuing evacuation notices for downstream areas, and establishing monitoring systems for the embankment to identify potential blockages early. These protocols could be formalized with CN Railway using recent studies as a reference for discussions.

The 2019 analysis provides valuable insights into the flood risks posed by a potential dam break but includes inaccuracies regarding culvert dimensions, water depth, and response assumptions. Addressing these gaps through an updated Dam Break Analysis, collaboration with CN Rail, and the establishment of robust emergency protocols is essential to improve flood preparedness and community safety.

1.1.1.2 Thompson River Watershed Geohazard Risk Prioritization (BGC, 2019)

The Thompson River Watershed Geohazard Risk Prioritization aimed to identify, characterize, and rank flood, steep creek, and landslide hazards within the Thompson River Watershed (TRW) that could affect developed properties. For Clinton, the study highlighted historical events and associated risks:

Historical Flood Events:

- On June 1, 1873, heavy rain triggered a debris flow in Clinton, burying approximately 100 m of a secondary street near Mill Creek under up to 3 m of debris. Several buildings were damaged, resulting in $51,000 in losses. The debris flow was caused by the breach of a dam or log jam on Mill Creek (Septer, 2007).
- Debris flows in July and August 2018 that blocked Highways 1 and 97 in more than 40 places between Ashcroft and Clinton, BC (Figure 1-4). The debris flows were sourced from areas burnt by the 2017 Elephant Hill wildfire. The debris flows caused one fatality, and several houses were affected by debris.

FIGURE 1-4 DEBRIS FLOW BLOCKING HWY 97 SOUTH OF CLINTON, BC (MOTI, 2018/07/31)

Floodplain Prioritization and Risks:

The Village floodplain was classified as a “high” priority in the study. Screening-level floodplain mapping (Figure 1-5) highlighted critical infrastructure and properties at flood risk, including:

- The Wastewater Treatment Plant;
- Highway 97; and
- Areas of McDonald, Foster, and Lebourdais Avenues.

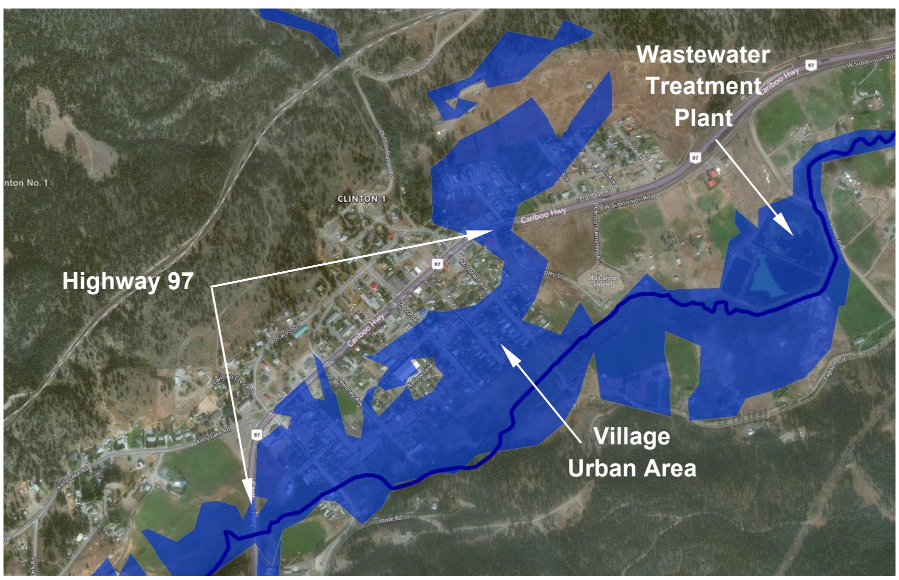


FIGURE 1-5 FLOODPLAIN SCREENING LEVEL (MODIFIED FROM BGC, 2019)

1.1.1.3 Floodplain Mapping Report (TRUE, 2024)

The scope of work includes completing a detailed floodplain mapping study within the municipal boundary of the Village of Clinton on Cutoff and Clinton Creeks, the two major watercourses. The study includes approximately 5.2 km of river and floodplain along the Cutoff and Clinton Creeks (east-west direction) and approximately 0.5 km of stream along the Clinton Creek (north-south direction). Detailed floodplain mapping is provided in Appendix B. The following section summarizes key elements of the flood mapping relevant to the Village.

Flow Summary

A Regional Flow Frequency Analysis was conducted to estimate the design flow for the Clinton Creek watershed. Traditional Flood Frequency Analysis methods were not used due to the lack of streamflow gauges with adequate data records for direct flow estimates. Instead:

- Relationships between instantaneous and daily flows were analyzed at neighboring flow stations to create a Regional Curve, enabling interpolation of peak instantaneous flows for Clinton Creek downstream of the Village boundary; and
- Inflows at Clinton Creek (CN Railway Embankment) and Cutoff Creek (upstream of the Village) were scaled using drainage area proportioning.

Climate change impacts were considered using a 20% adjustment factor for peak flow increases, aligned with EGBC (2018) guidelines for small watersheds with limited local data. This factor is consistent with prior floodplain mapping efforts in the region, including Cache Creek (TRUE, 2021). Additionally, the Pacific Climate Impacts Consortium's (PCIC) large-scale hydrologic modeling and its Climate Explorer (PCEX) tool were consulted. The PCEX tool, while limited by coarse grid resolution for smaller catchments, provided useful mean change factors under the RCP8.5 scenario, ranging from 1.05 (2020s) to 1.25 (2050s). These outputs supported the decision to apply the 20% increase in peak flow for Clinton Creek, ensuring consistency with regional analyses and established practices.

Peak flow estimates for Clinton Creek at the CN Railway Embankment and Cutoff Creek upstream the Village, are summarized in Table 2.

TABLE 2 PEAK FLOWS AT THE VILLAGE OF CLINTON (WITH 20% CLIMATE CHANGE)

RETURN PERIOD	CLINTON CREEK AT CN RAILWAY (M^3/S)	CUTOFF CREEK U/S THE VILLAGE (M^3/S)
2yr	1.4	3.5
5yr	2.4	5.9
10yr	3.2	7.9
20yr	4.0	10.0
50yr	5.4	13.2
100yr	6.5	16.2
200yr	7.8	19.4
500yr	9.9	24.4

Model Results Summary

The floodplain of Cutoff and Clinton Creeks within the municipal boundary remains vulnerable to impacts from snowmelt-driven spring freshets, typically occurring between May and June.

Key findings include:

- Clinton Creek: Upstream of the Village, the steep channel confines flows within its valley, but existing infrastructure, such as drinking water reservoirs and the CN Railway embankment, poses a potential future threat if compromised.
- Storm Sewer Capacity: The storm sewer along McDonald Avenue is undersized for 200yr flow conditions. During extreme events, some flow spills overland, with roads becoming pathways for shallow, fast-moving floodwaters.
- Cutoff Creek and Hwy 97: The existing culvert at the Hwy 97 crossing cannot accommodate 200yr flows, causing backwater flooding upstream of the embankment. Water depths behind the embankment rise significantly and eventually overtop the road, resulting in overland flooding to properties between Hwy 97 and Cariboo Avenue.
- Floodplain and Wastewater Treatment Plant (WWTP): The natural floodplain downstream of the Cutoff and Clinton Creek confluence is prone to flooding. The berms surrounding the WWTP are too low to contain 200yr floodwaters, leading to inundation of the lagoons. Additionally, the culvert at Lagoon Road is undersized, causing overtopping and flooding of the road during such events.

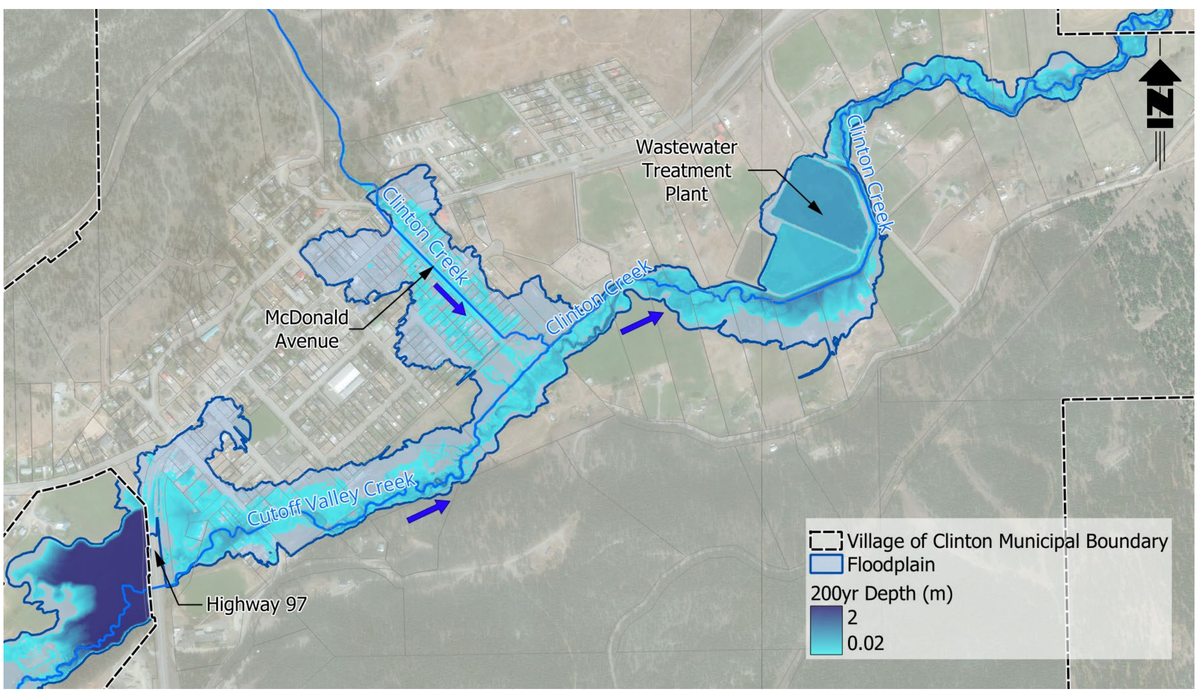


FIGURE 1-6 FLOODPLAIN 200YR

1.2 Project Objectives

Flood mitigation encompasses a series of actions, strategies, and measures oriented to minimize or prevent the adverse impacts of flooding. As demonstrated in the figure below, flood management is an adaptive cycle that incorporates continuous learning, monitoring, adjusting strategies to cope with uncertainty and variability. This flood mitigation plan works to build on previous analysis, modeling, and mapping, to better understand the exposure, hazard and vulnerability of the Village and provide recommendations to mitigate these risks.

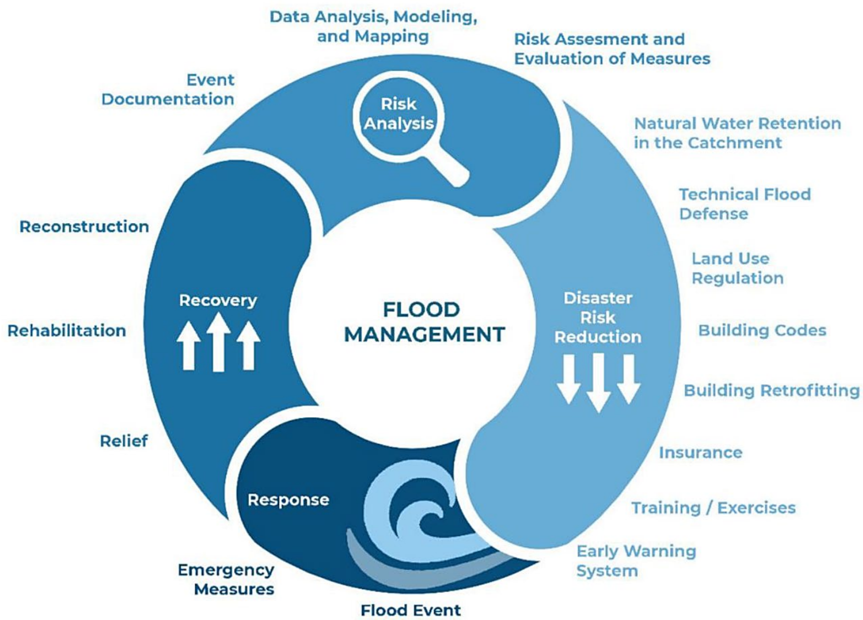


FIGURE 1-7: MANAGEMENT CYCLE IN FLOOD MANAGEMENT (MDPI,2021)

Adaptive flood management is not a one-time effort but a continuous cycle of implementation, monitoring, evaluation, and adjustment. This iterative process allows for learning from past experiences and improving future responses. This Flood Mitigation Plan should be considered a living document that will require updates over time to account for the changing conditions of the environment, climate, and socio-economic factors.

The objectives of this project are to identify areas and infrastructure throughout the Village that will be affected by flooding and complete an evaluation of the applicable long-term flood mitigation options. The evaluation process will provide an analysis of options to mitigate any flood impacts to the community. Feasible mitigation options determined from this analysis will be summarized in project sheets for highest priority areas and infrastructure along with high level cost estimates (Class D), provided in Appendix D. The result of this process and flood mitigation plan will enable the Village of Clinton to:

- Have a thorough understanding of the current and future flood risks facing the community.
- Have access to updated information to better respond to flooding events when they do occur.
- Have a comprehensive, long-term Flood Mitigation Plan to mitigate community flood risk with consideration for climate change.
- Have the conceptual designs completed to support implementation through incorporating recommended initiatives into the Village budget process as well as development of future funding applications.

1.3 Project Activities

A well-structured flood mitigation plan is essential to clearly understand flood risks and how the community can take action to reduce that risk. This scope of work outlines a community flood mitigation plan that focuses on creating and scoping effective mitigation strategies for implementation. The plan emphasizes a combination of structural measures (infrastructure) and non-structural measures (policy) to enhance the community's resilience against future flood events. These tasks include the following:

- Flood risk assessment;
- Analysis of flood risk reduction strategies;
- Development of implementable flood mitigation projects;
- Multi-criteria analysis and prioritization; and
- Final Reporting and presentation

2.0 Flood Risk Assessment

Flood risk assessment is the process by which the consequences and likelihoods of flooding are assessed. This allows communities to understand, manage, and mitigate the impacts of flooding, which can have devastating consequences for communities, economies, and ecosystems. By understanding the various elements that contribute to flood risk, planners, policymakers, and communities can develop effective strategies to reduce vulnerabilities, enhance preparedness, and ensure a swift and effective response to flooding. This comprehensive approach to flood risk assessment includes hazard analysis, exposure assessment, vulnerability assessment, and risk characterization.

Assessing risk involves a complex set of nuances, yet it fundamentally comes down to three straightforward steps: understand the hazard, understand the risk, and take action.

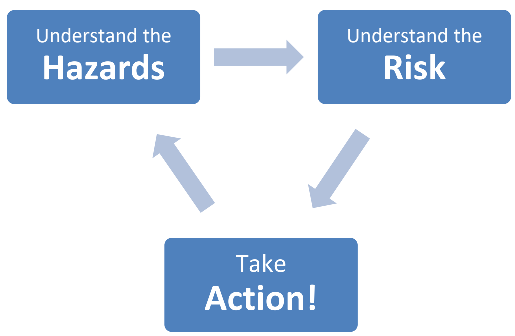


FIGURE 2-1: RISK MITIGATION CYCLE

Firstly, understanding the hazard entails identifying potential threats and their characteristics, such as frequency, severity, and potential impact. In the case of flooding, the hazard is identified through modelling and the resulting mapping of the floodplain. Additionally, joint hazards and failure modes must be considered, such as the potential for landslides triggered by flooding or the contamination of water supplies.

Secondly, understanding the risk involves evaluating the likelihood and consequences of these hazards materializing. This step requires analyzing vulnerability, exposure, and the capacity to respond, often using tools like risk matrices to evaluate potential outcomes.

Finally, taking action encompasses implementing strategies to mitigate, transfer, accept, or avoid the identified risks. This could involve creating emergency plans, strengthening infrastructure, educating the community, or land use planning.

This process is never complete; it is iterative and dynamic. Each cycle of assessment and action leads to increased resilience and a gradual reduction in community risk, as new information and experiences continuously refine the understanding of hazards and risks.

2.1 Existing Flood Management Infrastructure

Flood management infrastructure in the Village of Clinton includes stream crossings such as culverts, and road embankments. Notably, there are no regulated dikes within the municipal boundary. The Wastewater Treatment Plant (WWTP) and its sewage lagoons are located within the floodplain, just upstream of Lagoon Road.

Stream crossings in the Village commonly utilize Corrugated Steel Pipe (CSP) culverts, with diameters ranging from 0.5 m to 1.5 m. These crossings are summarized in Table 2-1, with additional details and photographic records provided in Appendix C.

TABLE 3 EXISTING CROSSINGS WITHIN VILLAGE LIMITS

LOCATION	STREAM	TYPE	OPENING DIMENSION	LENGTH	EMBANKMENT HEIGHT*	PHOTOGRAPHIC RECORD (INLET)
Hwy 97	Cutoff Creek	Circular	1.5 m dia.	52 m	10.2 m	
Cariboo Avenue	Cutoff Creek	Ellipsoid (double)	1.15 m span 0.82 m rise	13.5 m	1.9 m	
Dewdney Avenue	Cutoff Creek	Circular (double)	0.8 m dia.	5.2 m	N/A	
McDonald Avenue	Cutoff Creek	Circular (double)	1.2 m dia. 0.5 m dia.	9.0 m	2.6 m	

Location	Stream	Type	Opening Dimension	Length	Embankment Height*	Photographic Record (Inlet)
Lagoon Road	Clinton Creek	Circular	1.2 m dia.	14.4	3.3 m	
CN Railway	Clinton Creek	Circular	0.7 m dia.	102 m	20 m	
McDonald Avenue	Clinton Creek	Circular	1.2 m dia.	425 m	1.8 m	

2.2 Flooding Mechanism

The following flooding mechanisms are based on results from the Village's floodplain mapping. Risks associated with embankment failures at water reservoirs, or the CN Railway require a separate dam break analysis to update the 2019 study, address inaccuracies, and assess the Village's current emergency response capacity.

Flooding mechanisms are categorized by location and their impacts on public infrastructure and private properties.

2.2.1 Clinton Creek at the Village Urban Area

Between 1957 and 1967, Clinton Creek was realigned under Conditional Water License No. 23155 at the request of the Ministry of Transportation and Highways (now the Ministry of Transportation and Transit). The realignment included a 1200 mm-diameter culvert that channels Clinton Creek beneath McDonald Avenue.

According to floodplain mapping, the existing infrastructure is vulnerable to flooding during a 10yr event. At this level, the culvert reaches capacity, resulting in overland flooding across McDonald and Foster Avenues.

In a 200yr flood scenario, overland flow is expected to be fast (0.5–1.5 m/s) and shallow (approximately 0.2 m deep). These characteristics result from the 5% slope along the flow paths and the low roughness of the land cover, primarily asphalt and grass along McDonald Avenue.

Figure 2-2 illustrates the projected flow paths and water depths during a 200yr flood scenario for Clinton Creek.

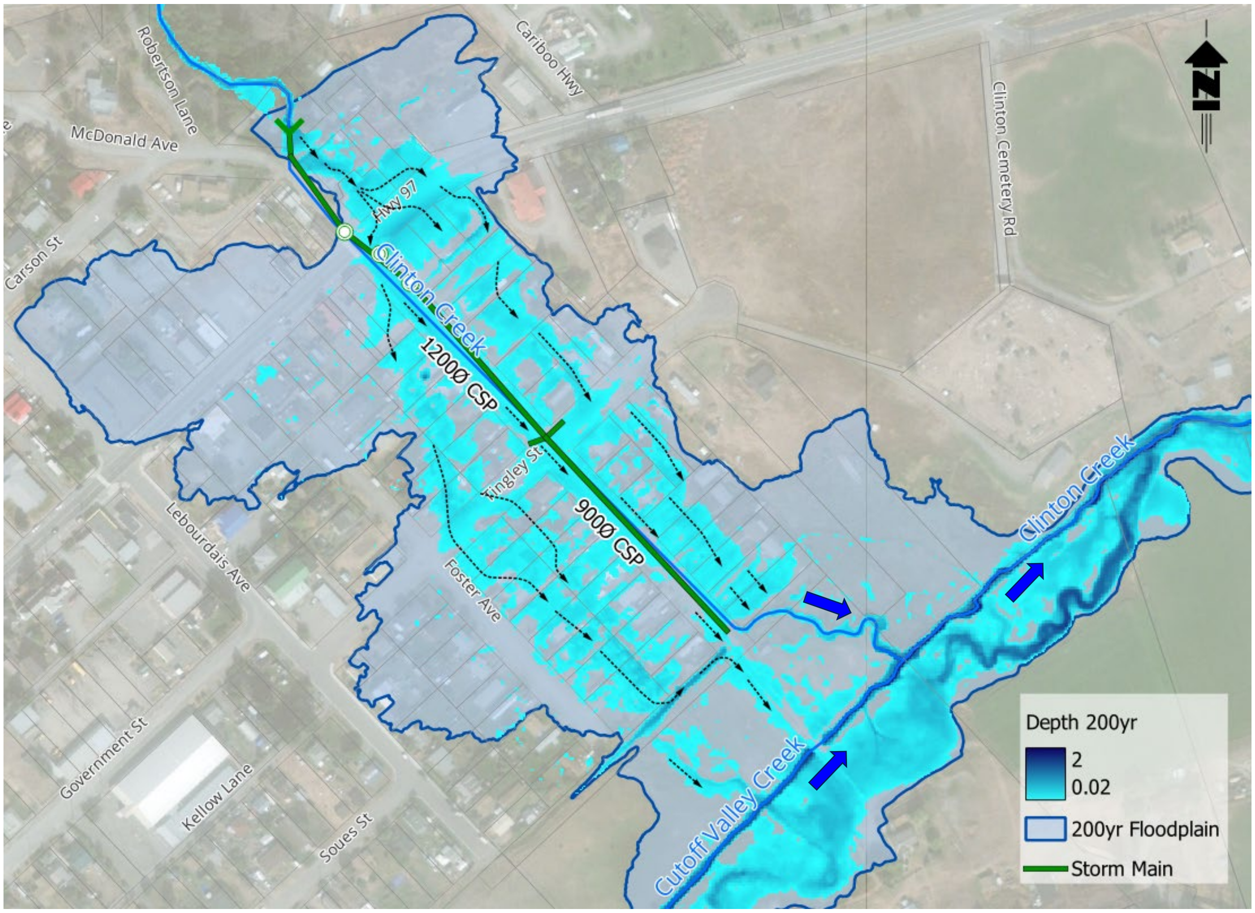


FIGURE 2-2 CLINTON CREEK AT THE VILLAGE URBAN AREA

2.2.2 Cutoff Creek at Highway 97

The 1500 mm culvert at the Highway 97 crossing is projected to exceed its capacity during a 10yr flood event. When this occurs, water will accumulate behind the highway embankment until it overtops the roadway at its lowest point, located 150 meters north of the culvert crossing.

This overtopping will result in overland flooding, impacting private properties and public infrastructure located between Highway 97 and Cariboo Avenue. While other crossings, such as Cariboo Avenue, are also projected to be overtopped, they are not anticipated to cause a significant backwater effect. Properties adjacent to the creek near these crossings are expected to experience water depths ranging from 0.3 to 0.6 meters.

Figure 2-3 illustrates the projected overtopping and resulting overland flooding for a 10yr flood scenario.

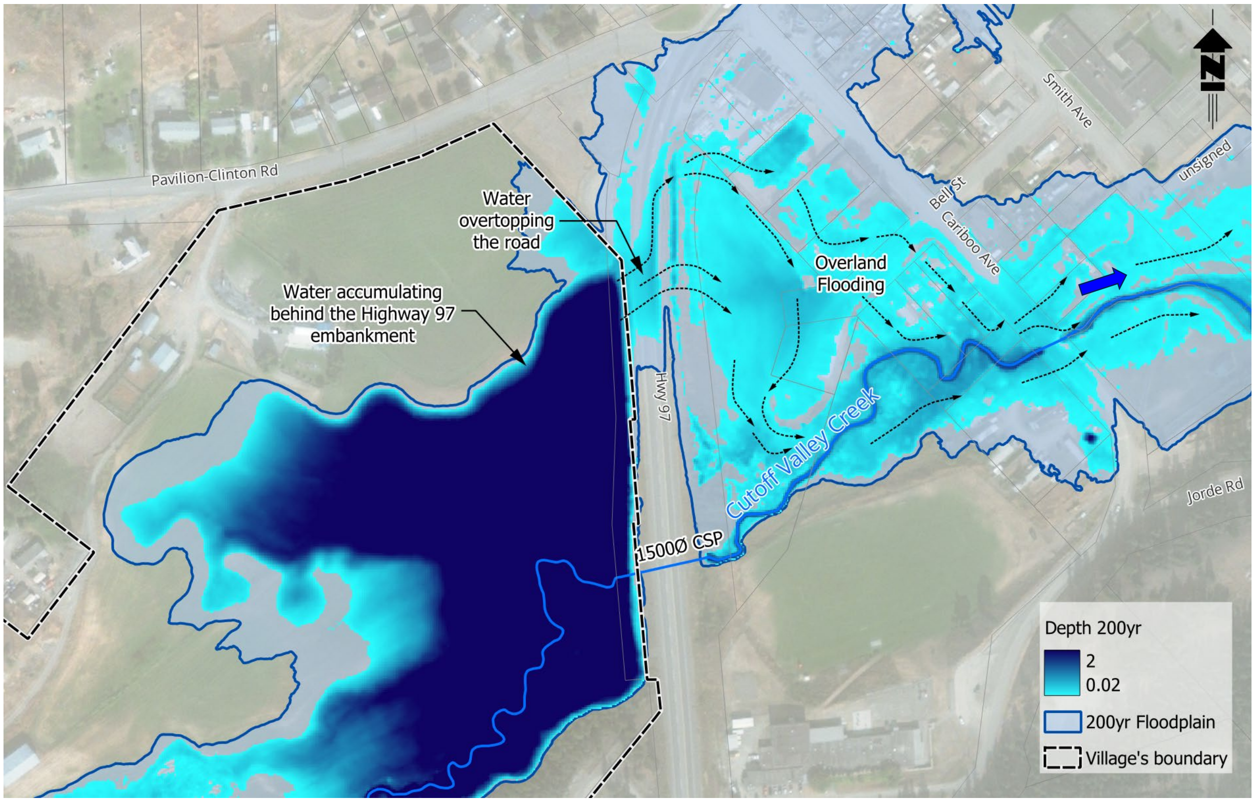


FIGURE 2-3 CUTOFF CREEK AT HIGHWAY 97

2.2.3 Clinton Creek at Wastewater Treatment Plant (WWTP)

Downstream of its confluence with Cutoff Creek, Clinton Creek is projected to overtop its banks near the Wastewater Treatment Plant (WWTP) during a 50yr flood event, inundating the facultative lagoon cells. This flooding is attributed to the limited capacity of the drainage infrastructure at Lagoon Road and a reduced floodplain adjacent to the WWTP berms.

The combination of these factors creates a backwater effect, elevating water levels until they exceed the height of the WWTP berms and overtop the crossing at Lagoon Road.

Figure 2-4 shows the projected flow paths and water depths near Clinton Creek at the WWTP for the 200yr flood scenario.

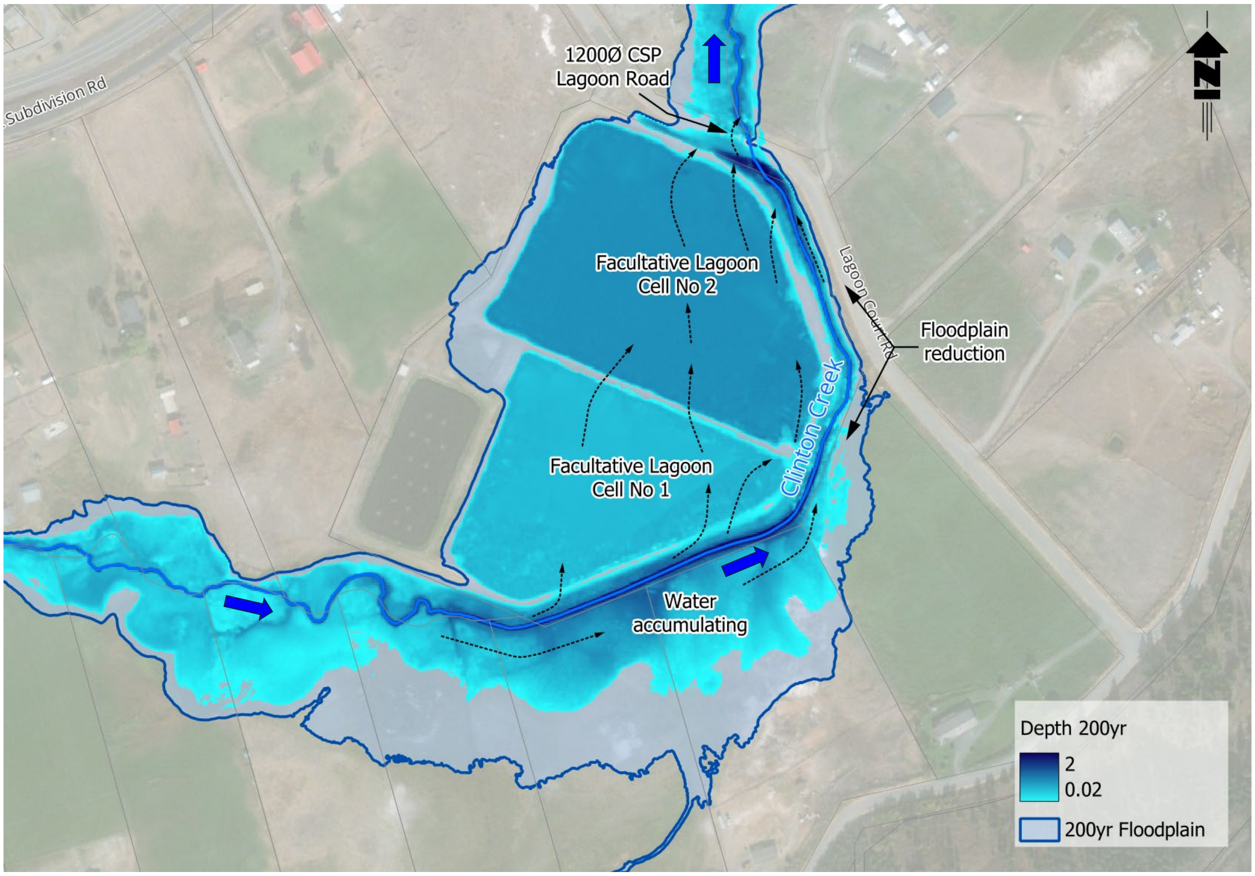


FIGURE 2-4 CLINTON CREEK AT WASTEWATER TREATMENT PLANT

2.3 Critical Infrastructure

The 200yr floodplain for Cutoff and Clinton Creeks is projected to affect public infrastructure, including sanitary facilities and transportation links. Some impacted facilities have been outlined in the Flooding Mechanisms section. For reference, the critical infrastructure located within the floodplain or at flood risk includes:

- Highway 97 at Clinton Creek;
- CN Railway embankment downstream of the lower reservoir;
- McDonald and Foster Avenue;
- Highway 97 at Cutoff Creek;
- Utilities serving David Stoddart School;
- Wastewater Treatment Plant; and
- Lagoon Court Road.

Figure 2-5 illustrates the locations of the Village's critical infrastructure in relation to the 200yr floodplain mapping.

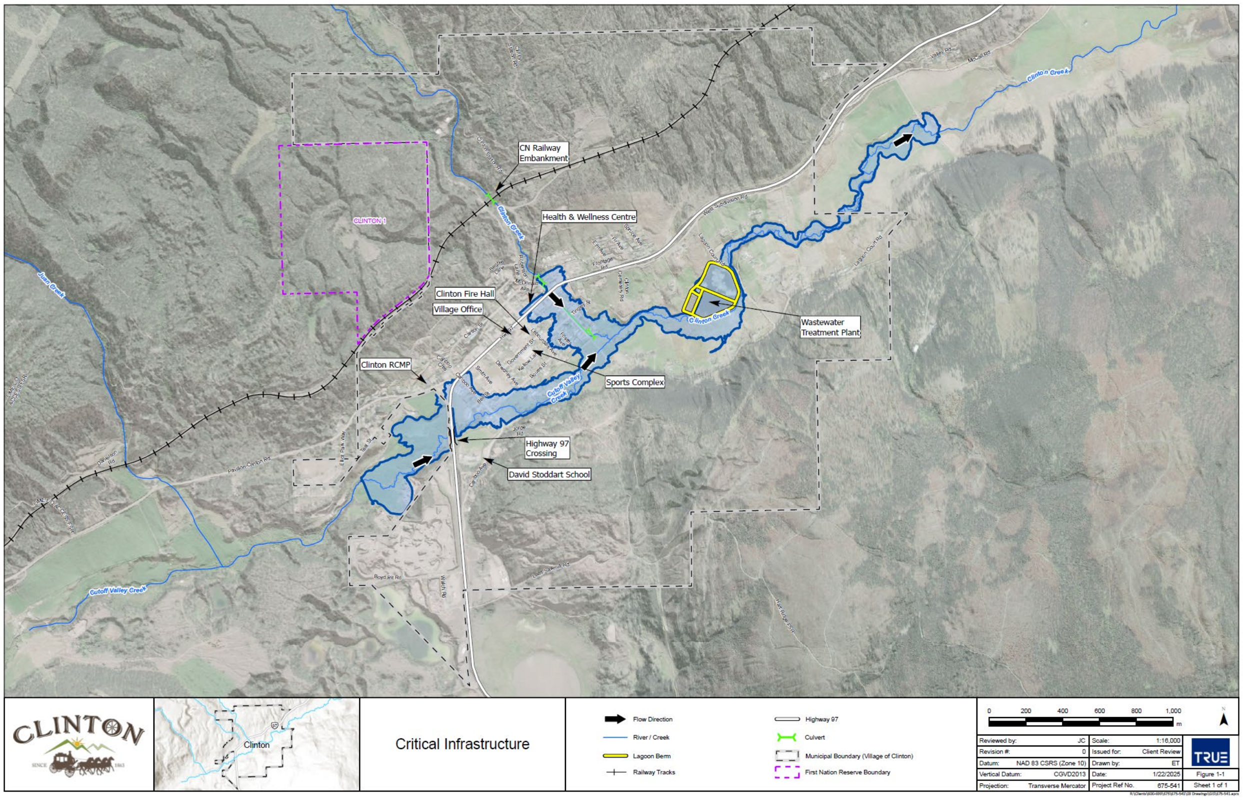


FIGURE 2-5 CRITICAL INFRASTRUCTURE

3.0 Flood Mitigation Strategies

Throughout history, societies have grappled with the challenge of controlling floods through various structural interventions. Historical practice has largely focused on controlling the water through dikes, channels, and culverts to redirect and contain floodwaters, offering some degree of protection to settlements and agricultural lands. However, these engineered solutions have their limits, often proving inadequate in the face of increasingly severe weather events exacerbated by climate change. There is now a growing recognition that solely relying on engineering solutions is insufficient. To effectively manage floods, a multifaceted approach is necessary, incorporating ecosystem-based strategies, land-use planning, and floodproofing measures alongside traditional flood defense structures. It's crucial to consider failure mechanisms; rather than relying on structures alone, we should aim for systems that fail slowly and predictably, mitigating the risk of flooding events. By embracing a diverse set of approaches, communities can better adapt to the challenges posed by floods in a changing climate.

3.1 Flood Mitigation Strategies Overview

The "Protect/Accommodate/Retreat/Avoid" or "PARA" framework, originally devised for climate change adaptation planning in communities confronting sea level rise, has become increasingly relevant as a useful framework for flood risk reduction and flood resilience (Doberstein et al, 2019).

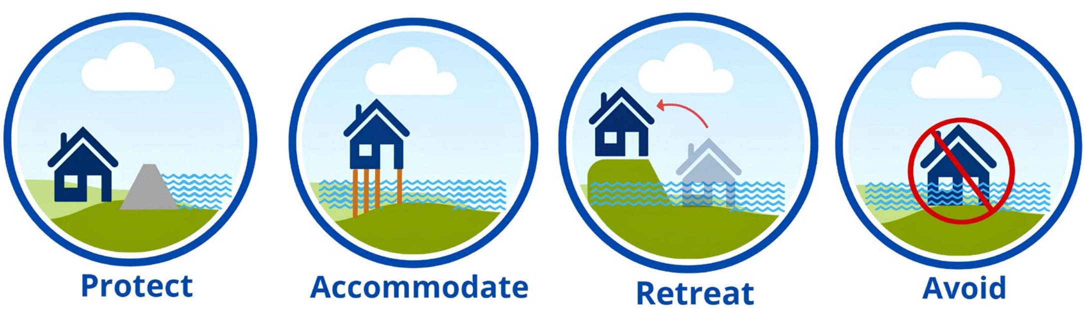


FIGURE 3-1: FLOOD MITIGATION APPROACHES

These four approaches from PARA framework are further described below

3.1.1 Protect

The Protect approach focuses on building physical barriers and infrastructure to defend against floods. This includes the construction of dikes, flood walls, sea walls, dams, and other engineered structures designed to prevent floodwaters from inundating populated or economically significant areas. These protective measures are often part of broader flood management systems that may include pumping stations, reservoirs, and drainage channels to manage and redirect water flows.

3.1.2 Accommodate

Accommodation involves allowing developed floodplain areas to persist, accepting periodic flooding as part of an adaptive approach to sustain the use of flood-prone areas. This strategy aims to enhance the resilience of valuable assets such as houses, facilities, and infrastructure to occasional floods. It includes adapting buildings, infrastructure, and landscapes by elevating structures above projected flood levels, using flood-resistant materials, or integrating flood-proof designs. The objective is to minimize flood damage and expedite recovery post-event. Tailored regulatory measures specific to each area are crucial to support and implement this approach effectively.

3.1.3 Retreat

In the past, the Retreat strategy has often been overlooked or dismissed due to various reasons. Historical development frequently encroached upon rivers and floodplains without fully assessing the associated risks or understanding the implications. Additionally, economic incentives and urban expansion priorities favored development in flood-prone areas, despite the inherent dangers. However, as climate change intensifies and the frequency of extreme weather events rises, there is now a growing recognition of the limitations of solely relying on traditional flood defenses. There is an acknowledgment that retreat can be a viable strategy for high-risk areas, emphasizing the need to reconsider development patterns and prioritize resilience. By acknowledging past oversights and embracing retreat strategies, communities can better protect themselves from future flood hazards and restore natural floodplain functions for long-term sustainability.

3.1.4 Avoid

The Avoid strategy aims to prevent development in flood-prone regions by employing proactive land-use planning, zoning regulations, and development restrictions. This approach is geared towards guiding urban growth and infrastructure to safer locations while safeguarding natural floodplains and reducing future flood vulnerabilities. Implementing the Avoid strategy involves enhancing regulatory frameworks like Official Community Plans (OCPs), Development Permit Areas (DPAs), zoning bylaws, or flood management bylaws. These regulations may include provisions that allow limited development in floodplains, emphasizing smarter, more resilient land-use practices by requiring Accommodate type measures.

3.2 Comparison PARA Approaches

Flood mitigation is a critical aspect of urban planning and environmental management, aimed at reducing the adverse impacts of flood events on communities, infrastructure, and ecosystems. The PARA framework—Protect, Accommodate, Retreat, and Avoid—offers a comprehensive set of approaches to manage flood risks. Each strategy presents unique methods for dealing with floods, balancing immediate protection, long-term resilience, environmental sustainability, and social considerations. Understanding the advantages and disadvantages of each approach can help policymakers, planners, and communities make informed decisions to enhance flood resilience and safety. Table 3-1 presents the advantages and disadvantages of each approach.

TABLE 3-1: ADVANTAGES AND DISADVANTAGES PARA APPROACHES

APPROACH	ADVANTAGES	DISADVANTAGES
	**Immediate Protection** Provides immediate and often substantial protection to areas at risk, safeguarding lives, property, and economic activities. **Economic Benefit** Protects critical infrastructure and assets, which can support local and regional economies. **Continued Use** Allows continued use and development of land in flood-prone areas, supporting economic growth and urbanization.	**High Costs** Requires significant investment for construction and ongoing maintenance. Failure to maintain can lead to catastrophic failures. **False Security** Can create a false sense of security, encouraging development in areas that are still at risk of catastrophic events if protections fail. **Environmental Impact** Often disrupts natural ecosystems and water flows, potentially leading to environmental degradation and loss of biodiversity.
	**Damage Reduction** Significantly reduces potential damage and disruption caused by floods, as structures and systems are designed to handle floodwaters. **Resilience** Enhances the resilience of communities by making them better equipped to withstand and recover from flood events. **Flexible Implementation** Can be applied incrementally and adapted to changing flood risks over time.	**Retrofit Costs** Retrofitting existing buildings and infrastructure can be expensive and logistically challenging. **Partial Mitigation** May not completely prevent flood damage, especially during extreme events. **Regulatory Requirements** Requires strong governance, planning, and enforcement to ensure compliance with zoning and land-use regulations
	**Risk Elimination** Completely removes the risk of flood damage for relocated areas, ensuring long-term safety. **Environmental Restoration** Allows for the restoration of natural floodplains, which can improve ecosystems and provide natural flood mitigation benefits. **Cost Savings** Over the long term, reduces costs associated with flood damage, emergency response, and repetitive reconstruction.	**High Initial Cost** Involves substantial financial costs for property acquisition, relocation, and compensation. **Social Disruption** Can disrupt communities, leading to loss of social networks, cultural heritage, and local identity. **Logistical Challenges** Requires careful planning and coordination and may face resistance from affected communities and property owners.

APPROACH	ADVANTAGES	DISADVANTAGES
 Avoid	**Prevention of Future Risks** By avoiding development in high-risk areas, it eliminates future exposure to flood hazards. **Environmental Benefits** Helps preserve natural floodplains and ecosystems, which can provide natural flood mitigation and other ecological benefit. **Cost Effective** Avoids the need for costly flood protection and recovery measures in the future.	**Development Limitation** Restricts land available for development, which can increase land prices and potentially hinder economic growth in certain areas. **Resistance** May face opposition from developers, property owners, and local governments who wish to utilize flood-prone land for development. **Regulatory Requirements** Requires strong governance, planning, and enforcement to ensure compliance with zoning and land-use regulations.

In summary, each of these approaches—Protect, Accommodate, Retreat, and Avoid—offers distinct methods and tools for mitigating flood risks. Combining these strategies, tailored to specific local conditions and needs, can provide a comprehensive and effective approach to flood management.

4.0 Flood Mitigation

In conjunction with PARA (Protect, Accommodate, Retreat, and Avoid) strategies, flood mitigation options can be classified into structural and non-structural categories. Structural mitigation focusses on reducing the flood hazard by preventing floodwaters from impacting communities. Non-structural mitigation, on the other hand, focuses reducing exposure and vulnerability to reduce flood risks without altering the physical landscape. Together, these measures can significantly enhance flood resilience. This integrated strategy aligns with the PARA) framework, ensuring a holistic approach that not only prevents and prepares for floods but also adapts to changing conditions and raises community awareness.

Non-Structural ***Reducing Exposure & Vulnerability***	**Structural** ***Reducing Flood Hazard***

▪ Hazard and risk assessment
▪ Land use planning
  • Zoning
  • Bylaws
  • Relocation or retreat
▪ Public awareness and education
▪ Emergency routing and safe zone delineation
▪ Emergency preparation and planning
  • Community flood response plan
  • Community Preparedness
  • Home and business response Plan
  • Individual preparedness
▪ Monitoring and warning systems
▪ Maintenance
	▪ Barrier to the hazard
	  • Dikes (new or improved)
	  • Flood gates
	▪ Armouring against hazard
	  • Riprap banks/dikes
	  • Spurs and groynes
	▪ Conveyance improvements
	  • Dredging
	  • Dike set back
	  • Enhancing drainage capacity
	  • Removing constrictions (culverts, bridges)
	  • Reducing channel roughness
	  • Pumps
	▪ Reduced flood flow
	  • Diversion of flow
	  • Upstream storage
	  • Infiltration

The subsequent sections provide a concise overview of the recommended flood mitigation projects tailored for the Village of Clinton. Each project is detailed in individual project sheets, which offer comprehensive insights into various aspects, including hazard and risk elements, anticipated impacts, critical considerations, and conceptual-level designs. These designs also incorporate Class D cost estimates to facilitate informed decision-making. For those seeking an in-depth understanding, the detailed project sheets are available in Appendix D, ensuring all relevant information is accessible for thorough evaluation and implementation planning. This structured approach ensures that Clinton is well-equipped to incorporate these projects into the overall priorities of the community through budgeting processes and application to funding programs.

4.1 Flood Mitigation Projects

This chapter provides a comprehensive overview of both structural and non-structural flood mitigation projects aimed at reducing flood risk in the Village of Clinton. Figure 4-2 illustrates the project's location, which include policies, flood protection structures, utilities, and transportation networks.

Below is a brief description of the projects, with more detailed information, including background, rationale, mitigation strategy, budget, and scope, available in Appendix D.

4.1.1 P1 – Flood Early Warning System

This project proposes installing a water level sensor and early warning system at the CN Railway embankment. The system will monitor water accumulation behind the embankment (Figure 4-1), identifying potential flood risks early. If significant water backup is detected, the system will automatically trigger alerts to notify the community and relevant authorities. This immediate notification enables timely actions, such as evacuations and preventive measures, to minimize impacts. By addressing the risks of embankment overtopping and flood wave propagation, the early warning system enhances community safety and resilience against severe flood events.

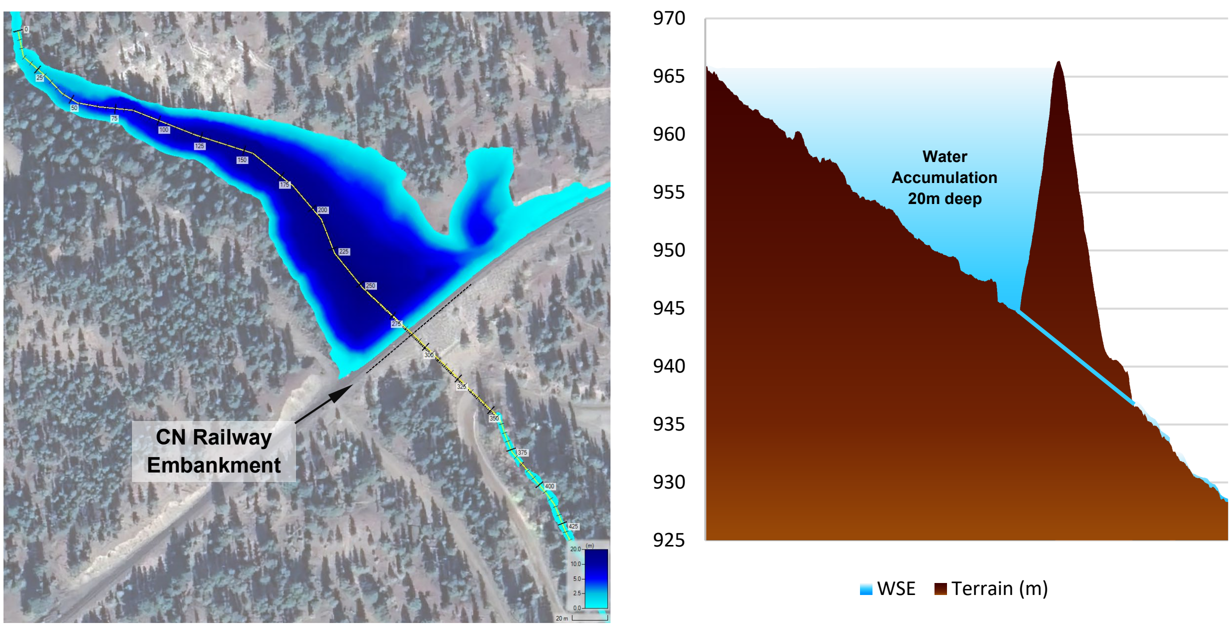


FIGURE 4-1 RAILWAY EMBANKMENT WATER ACCUMULATION EXTENT AND PROFILE

This strategy addresses gaps in the 2019 Dam Break Analysis, particularly concerning inaccurate assumptions and their potential consequences.

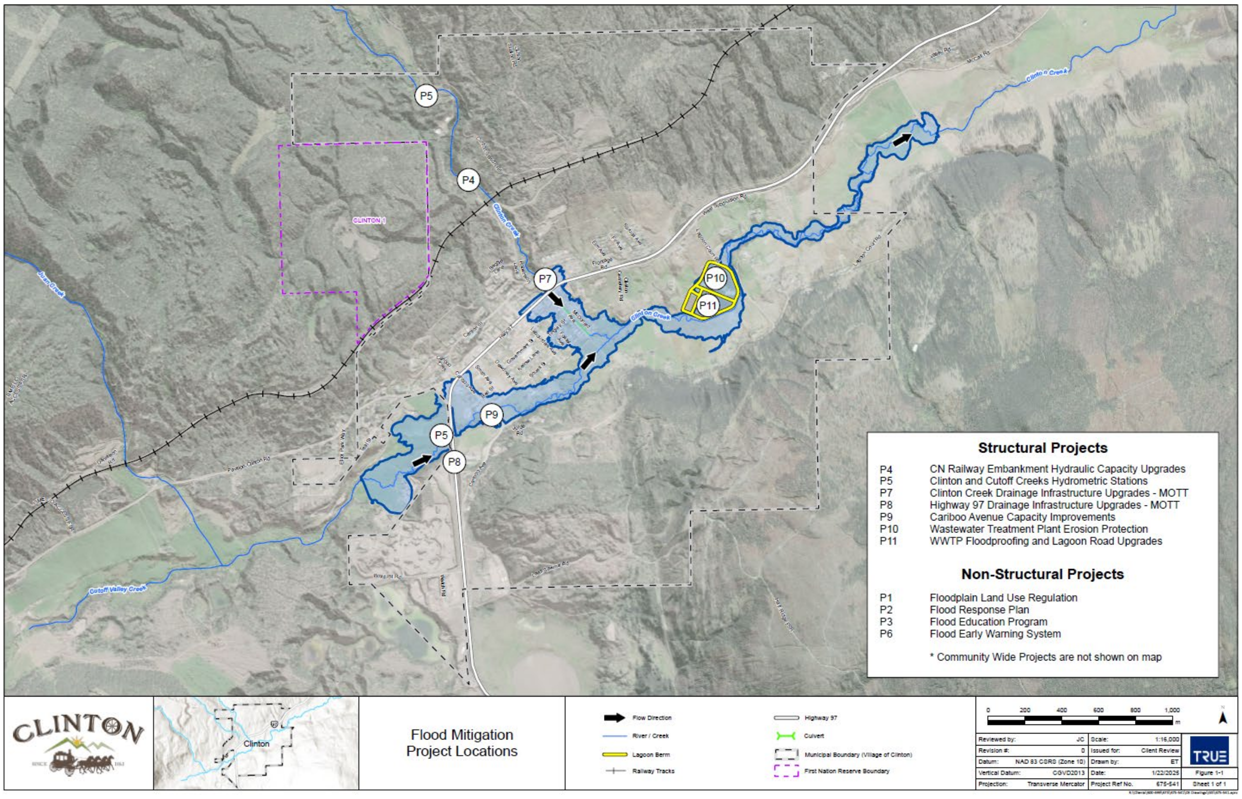


FIGURE 4-2: FLOOD MITIGATION PROJECTS LOCATION

TABLE 2 KEY INSIGHT FROM THE 2019 STUDY

ASPECT	ASSUMPTION	ACTUAL CONDITION	IMPACT
Culvert Size	1.8m diameter	0.7m diameter	Inadequate capacity to handle peak flows, increasing overtopping risk.
Water Depth Behind Embankment	10m	20m	Greater inundation extent and flood depths than predicted.
Emergency Preparedness	Assumed adequate	No formal Emergency protocols established	Highlighted need for a FEWS to ensure timely evacuation and preventive measures.

Benefits of FEWS Implementation:

- Real-Time Monitoring: Continuous observation of water levels at the CN Railway embankment.
- Automated Alerts: Early detection of water accumulation triggers immediate notifications for authorities and the community.
- Enhanced Community Safety: Protects lives and assets through timely action, minimizing potential damage.

Next Steps:

1. Apply for funding to install water-level sensors and real-time communication systems.
2. Develop community-focused training and protocols for response actions.
3. Integrate FEWS with other infrastructure monitoring systems to create a comprehensive flood resilience framework.

The FEWS represents a critical step toward mitigating flood risks and safeguarding the Village of Clinton.

4.1.2 P2 - CN Railway Embankment Hydraulic Capacity Upgrades

This flood mitigation strategy for Clinton highlights critical risks associated with the CN Railway embankment, particularly its inadequate hydraulic capacity and vulnerability to debris blockage. The 2019 Dam Break Analysis, while foundational, contains inaccuracies that necessitate attention. Specifically, the study overestimated the culvert size (1.8 m versus the actual 0.7 m) and underestimated water depths during a blockage scenario (10 m versus the updated 20 m). These discrepancies significantly affect risk assessments, particularly regarding water accumulation behind the embankment, overtopping potential, and the downstream impacts on Clinton’s urban areas.

A worst-case scenario indicates that a debris blockage could lead to overtopping, causing a secondary flood wave with peak flows of approximately 200 m^3/s. Such an event could result in severe flooding in areas like Robertson Lane, McDonald, and Lebourdais Avenue, with water depths exceeding prior estimates. The inaccuracies in the 2019 study underscore the need for updated dam break analysis to better inform of associated risks.

The proposed mitigation strategy includes upgrading the culvert to 2.1–2.5 m to accommodate 200yr flood flows and implementing monitoring systems for debris and flow conditions. Collaboration with CN Railway is essential to ensure compliance with Transport Canada's Grade Crossings Regulations and to establish emergency response protocols. Figure 4-3 illustrates the culvert and debris structure at the railway embankment.

FIGURE 4-3 CN RAILWAY CULVERT

Next Steps:

- Engage CN Railway to discuss infrastructure upgrades, emergency measures, and debris management.
- Update Dam Break Analysis to refine risk assessments.
- Educate the community about flood risks and preparedness to reduce vulnerability during high-flow events.

4.1.3 P3 – Clinton and Cutoff Creek s Hydrometric Stations

Installing hydrometric stations at Clinton and Cutoff Creeks is proposed to address the uncertainty in flood risk and water resource management due to climate change impacts. These stations aim to improve data accuracy, support mitigation projects, and enhance community preparedness.

Key benefits of implementing the hydrometric stations include:

- Enhanced Data Accuracy: Real-time flow monitoring will reduce uncertainties in hydrological models and flood risk assessments, ensuring infrastructure designs are optimized for future climate conditions.
- Flood and Drought Preparedness: The stations will track trends in streamflow and water availability, aiding in planning for extreme flood events and water scarcity scenarios.
- Cost-Effective Mitigation Planning: Accurate flow data will refine the design of capital-intensive flood mitigation projects, ensuring resources are effectively allocated.

Figure 4-4 illustrates the proposed locations for the hydrometric stations; key components and considerations include:

- Flow Measurement: Devices such as pressure transductor will monitor stream conditions.

- Real-Time Communication: A data logger with solar power and backup systems ensures continuous data transmission.
- Environmental Design: Robust construction will ensure durability under harsh weather and flood events.
- Strategic Placement: Sites will be chosen to minimize environmental impact while providing hydraulic representativeness.

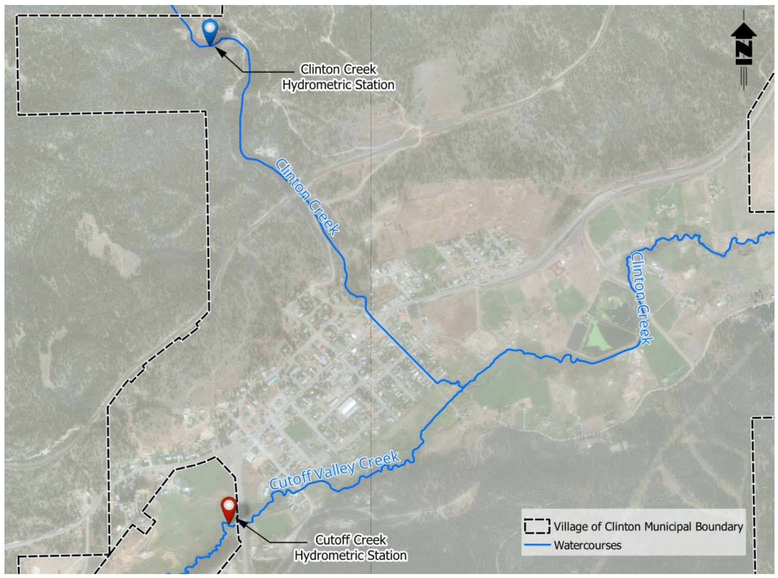


FIGURE 4-4 PROPOSED HYDROMETRIC STATIONS LOCATION

These stations will not only support Clinton's mitigation strategies but also integrate with early warning systems, enhancing the community's safety and resilience. Engagement with residents and stakeholders will ensure transparency, fostering local support for this initiative.

4.1.4 P4 – WWTP Floodproofing and Lagoon Road Upgrades

The Clinton Wastewater Treatment Plant (WWTP) and Lagoon Road are vulnerable to flooding during 50yr return periods and higher. These risks threaten the integrity of the treatment process, environmental safety, and community connectivity. Field inspections identified two primary concerns: the WWTP berms, which are at risk of overtopping, and Lagoon Road, which could wash out due to insufficient culvert capacity.

To address these vulnerabilities, two key mitigation strategies are proposed:

- Berm Raising: This involves increasing the height of the WWTP berms by 0.3 to 1.3 meters to manage 200yr flood flows. This measure will protect the treatment cells, ensuring wastewater treatment continues uninterrupted and preventing contamination.
- Creek Training Works: Enhancing Clinton Creek's capacity by realigning it into an 8-meter-wide, 2-meter-deep trapezoidal channel will reduce flood risks for both the WWTP and Lagoon Road.

The final solution will likely combine elements of both strategies, determined during the predesign phase through geotechnical studies, environmental permitting, and design refinements.

Figure 4-5 illustrates the projected extent of berm raising and creek training works.

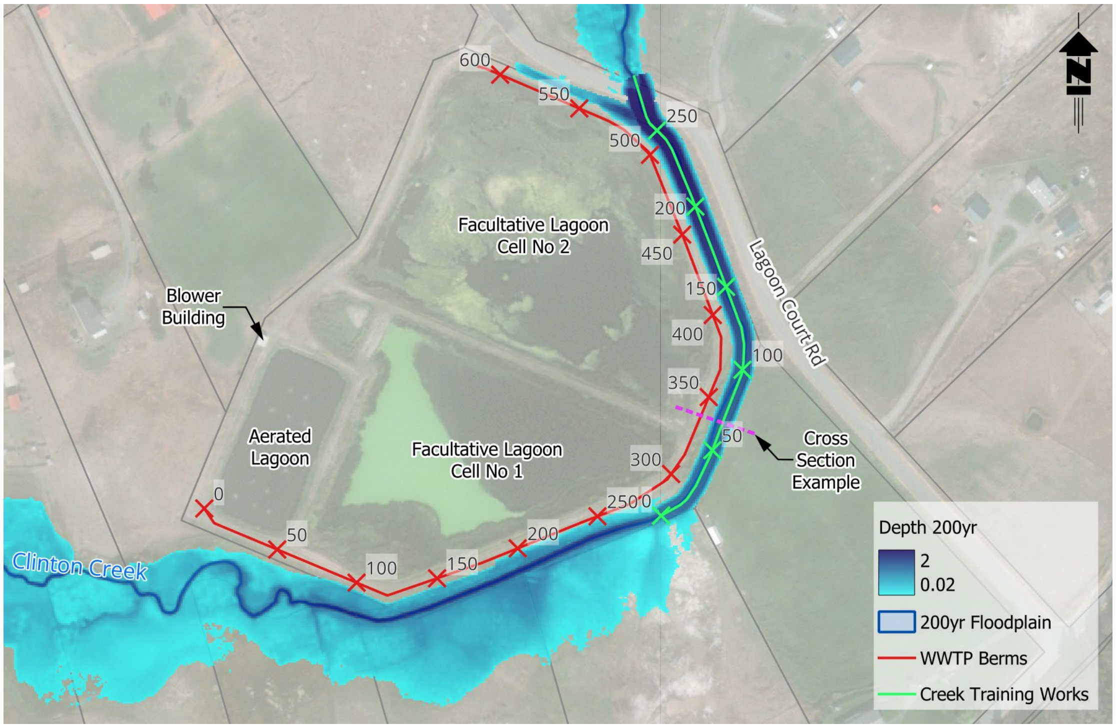


FIGURE 4-5 PROPOSED BERMS AND CREEK UPGRADES

To demonstrate the effectiveness of these strategies, Figure 4-6 compares water surface elevation profiles under existing conditions, berm-raising scenarios, and creek training works.

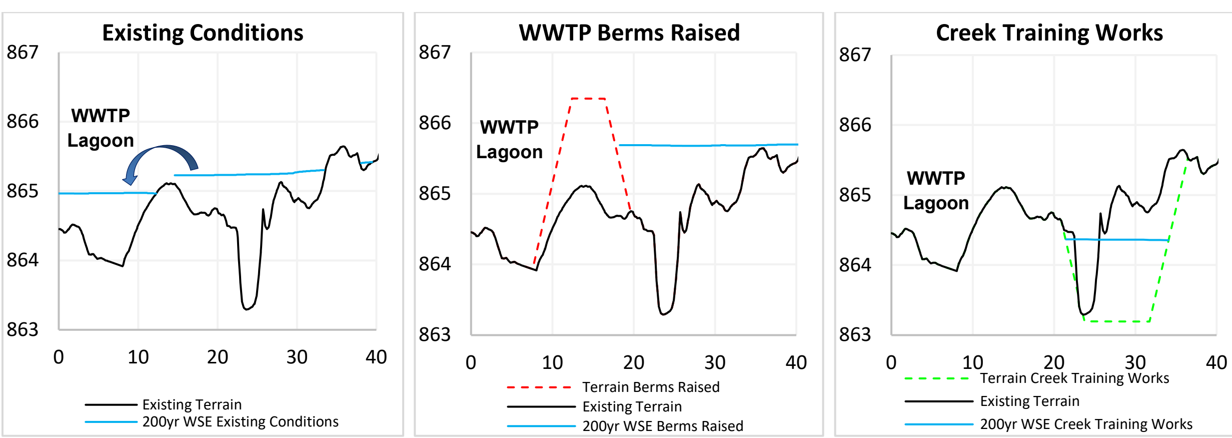


FIGURE 4-6 BERMS RAISING VS CREEK TRAINING WORKS COMPARISON

Any floodproofing measures implemented for the WWTP will also affect water levels at Lagoon Road. The current drainage infrastructure at Lagoon Road is inadequate for conveying projected 200yr flows. Climate-adapted flow conditions will require a structure approximately 4–5 meters wide and 2.5 meters high. The predesign phase will evaluate optimal solutions, such as bridge plates, arch culverts, or box culverts, and consider raising the road to align with the WWTP flood mitigation measures.

4.1.5 P5 - Wastewater Treatment Plant Erosion Protection

The Wastewater Treatment Plant (WWTP) in Clinton serves up to 3,000 residents under Effluent Permit No. 170, discharging up to 680 m³/day. While the aerated lagoon and blower building, is not directly exposed to flooding during a 200yr event, the south embankment is unprotected and vulnerable to erosion. The creek bend near the aerated lagoon is at risk of significant morphological changes during extreme flows. Current vegetation provides limited protection, but erosion could lead to embankment failure, jeopardizing WWTP operations and nearby areas.

The proposed mitigation strategy involves bio-engineering techniques to enhance embankment stability. Key measures include:

- Vegetative Stabilization: Installation of live stakes to reinforce the bank with natural vegetation.
- Toe Reinforcement: Placement of boulders and rocks along the creek toe to resist erosion and reduce flow impacts.

Figure 4-7 shows the velocities expected during the 200yr event and the proposed erosion protection.

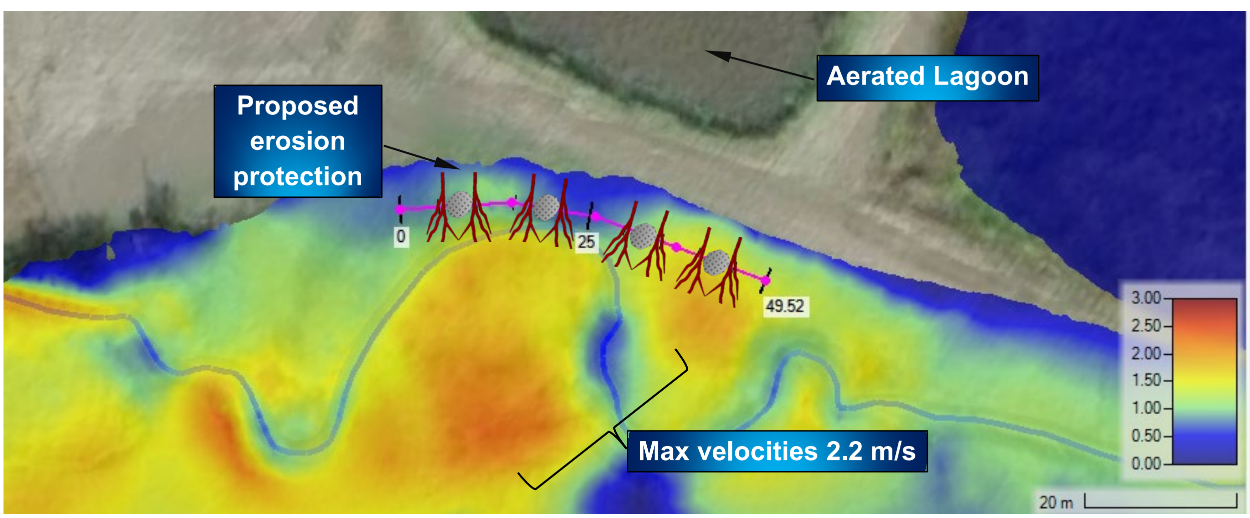


FIGURE 4-7 PROPOSED EROSION PROTECTION AND 200YR VELOCITIES

This approach balances hydraulic resilience and environmental sustainability. The final design will be informed by hydraulic modeling and refined during the predesign phase to align with ecological considerations. The enhancements aim to reduce erosion risks, protect the WWTP, and ensure its continued operation during extreme flood events. This solution not only mitigates immediate risks but also promotes sustainable flood protection practices

4.1.6 P6 - Floodplain Land Use Regulation

The Floodplain Mapping highlights the importance of incorporating flood risk into land-use planning. The Village's updated Official Community Plan (OCP) will act as a foundation for flood risk mitigation, ensuring future development aligns with hazard management objectives.

The current OCP includes provisions for managing development near watercourses under the B.C. Riparian Areas Regulation (RAR), requiring assessment by a Qualified Environmental Professional (QEP) for proposed developments within 30 meters of streams or ditches. Schedule C of the OCP maps streams and hazard lands, supporting compliance with these requirements. Section 7.1 of the OCP emphasizes the Village's commitment to reducing flood risk by limiting high-risk development and prioritizing appropriate preventative measures verified by registered professionals and government agencies.

To enhance resilience, the project proposes updating the OCP to incorporate floodplain mapping, forming the basis for a new flood land-use regulation tool. This tool aims to strengthen flood resilience and guide future development while engaging the community and encouraging flood-resilient construction practices.

FIGURE 4-8: EXAMPLE OF FCL EFFECTIVENESS (NBC)

As part of developing the land use regulation tool, the Village can adopt the most suitable regulatory approach from the following options:

- **Zoning Bylaw:** Controls the types of land use and imposes conditions like building setbacks and elevation requirements.
- **Development Permit Areas (DPAs):** Allows the Village to designate flood-prone areas with specific floodproofing guidelines.
- **Standalone Floodplain Bylaw:** Consolidates floodplain regulations into a single policy.

The Village should evaluate these tools and choose the best fit for the community to regulate floodplain land use effectively. Evaluating these tools and engaging the public will be essential for effectively updating the OCP and, in conjunction, implementing the necessary policies.

Special Considerations for Specific Areas

Certain areas within Clinton face distinct flood risks that must be integrated into the Land Use Regulation Framework. For instance:

- McDonald Avenue is prone to shallow flooding due to limitations in the Clinton Creek drainage system. However; in rare, high-intensity flood events, upstream embankment failures could generate significant wave heights, posing additional risks.

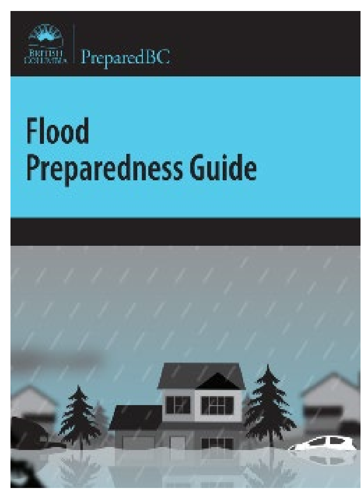
Addressing these localized risks will ensure that land use regulations are comprehensive and account for the varying flooding mechanisms within the Village

4.1.7 P7 - Flood Response Plan

The Village of Clinton, while primarily addressing wildfire risks in recent years, faces significant flood hazards from potential embankment failures at water reservoirs and the CN Railway, as highlighted by previous studies. A comprehensive Flood Response Plan is needed to address these risks and manage severe but infrequent flood events effectively.

Key components include:

- Emergency Coordination: Clearly defined roles, responsibilities, and resources to streamline flood response efforts and reduce liability.
- Early Warning System: Real-time monitoring of critical embankments (e.g., CN Railway, Highway 97) to support timely deployment of protection measures and evacuation alerts if needed.
- Temporary Flood Protection: Options such as sandbags, gabion baskets, and bladder dams to manage freshet-dominated flood risks; potential deployment sites include Highway 97, McDonald Avenue, and lagoon berms.
- Web Mapping Tools: Simulating flood scenarios to improve community awareness, emergency planning, and coordination.



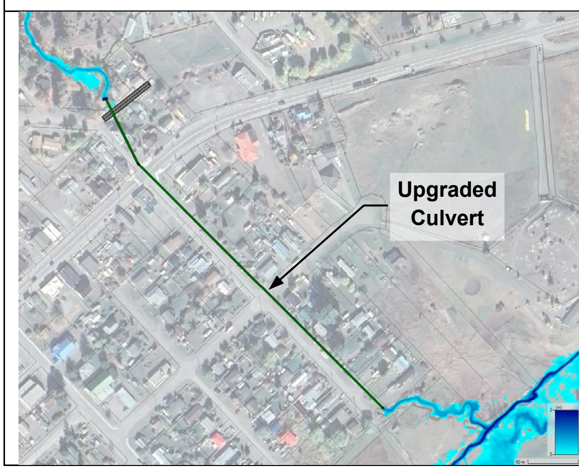
4.1.8 P8 - Clinton Creek Drainage Infrastructure Upgrades - MoTT

The Clinton Creek realignment, approved in 1957 and constructed in 1967, facilitated property development along McDonald Avenue. However, aging infrastructure and projected 200yr design flows now pose significant flood risks. The system, comprising a 1200mm corrugated steel pipe (CSP) that reduces to 900mm, is expected to be overwhelmed during extreme events. This would result in significant flooding at McDonald and Foster Avenues, affecting over five hectares of the Village with water depths up to 20 cm.

FIGURE 4-9 CLINTON CREEK INFRASTRUCTURE AT MCDONALD AVENUE

To mitigate the projected impacts of 200yr flows, two conceptual-level options are proposed as follows. These options provide a foundation for discussions between MoTT, the Village of Clinton, First Nations and other interested parties.

Table 3 Potential Flood Mitigation Options -Clinton Creek

Option A. Upgrades to Existing Alignment	Option B. Diversion to a New Alignment
Description: Upgrade the existing infrastructure to convey 200yr flood flows. Preliminary assessments indicate that a culvert-size between 2.1 and 2.4 meters in diameter will be required. **Advantages** ▪ No property acquisition required ▪ Aligns with overflow path ▪ Replaces aging infrastructure **Disadvantages** ▪ Potential utility conflicts ▪ Traffic disruptions during repairs ▪ Blockage risk ▪ Less flexibility for future upgrades if climate change impacts intensify	**Description:** Divert Clinton Creek to an alternative alignment that avoids the Village's denser area. Preliminary designs include a trapezoidal channel with a 3-meter bottom width, 2:1 side slope, and a depth of 1.2 meters. **Advantages** ▪ Habitat/Creek restoration ▪ Promotes natural systems ▪ Lower risk of blockages ▪ Resilient design, flexible for future upgrades ▪ Existing culvert could act as overflow ▪ Less utility conflicts ▪ Freeboard **Disadvantages** ▪ Requires property acquisition ▪ Longer flow path compared with option A ▪ Possible need for new water license
	

Recommended actions:

- Collaborative Approach: Coordination between MoTT and the Village is essential to effectively address the identified risk.
- Hydrometric Station Integration: Implement hydrometric stations in Clinton Creek (proposed in other projects) to improve design flow estimates and reduce uncertainty.
- Adaptive Risk Approach: Some alternatives, such as the diversion channel, could follow an adaptive risk approach, allowing incremental upgrades if future conditions necessitate further action.

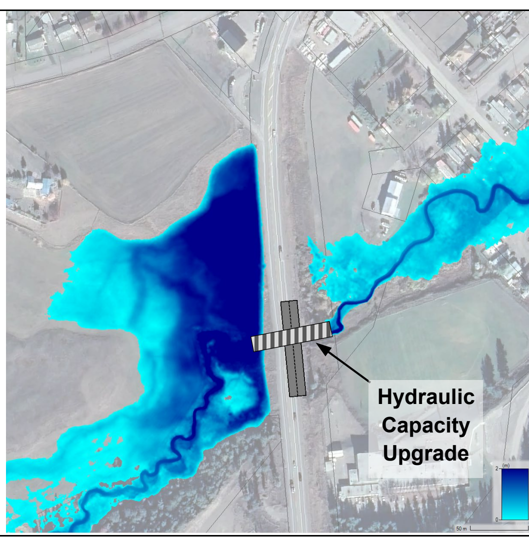
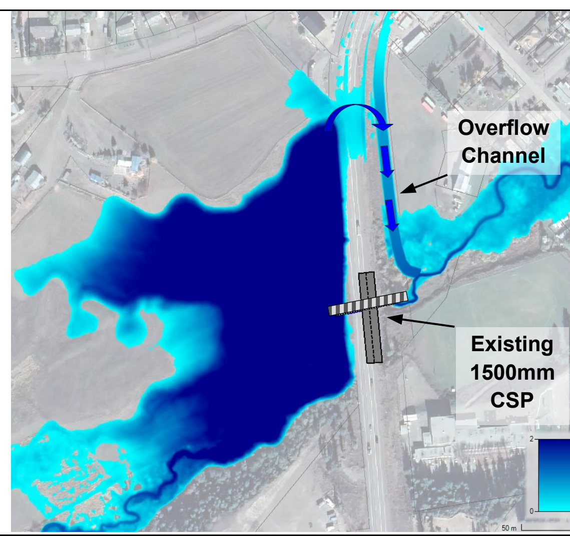
The proposed upgrades aim to reduce liability, enhance flood protection, and safeguard residents and critical infrastructure, ensuring resilience against future climate and flood challenges.

4.1.9 P9 – Highway 97 Drainage Infrastructure Upgrades - MoTT

The existing 1500 mm-diameter corrugated steel pipe (CSP) at Cutoff Creek & Highway 97 is insufficient to handle the projected 200yr flood flows. In such an event, water would accumulate behind the embankment, leading to overtopping and potential washout of the highway. This could result in widespread flooding in Clinton's residential and commercial areas.

Two complementary options are proposed to address the projected 200yr flood impacts. These options serve as the foundation for discussions with MoTT, the Village of Clinton, First Nations, and other interested parties.

TABLE 4 FLOOD MITIGATION OPTIONS CUTOFF CREEK

OPTION A1. HYDRAULIC CAPACITY IMPROVEMENT	OPTION A2. INTERIM / TEMPORARY OPTION
Description: Alternatives include upgrading the existing culvert or replacing it with a bridge opening for Cutoff Creek. Preliminary assessments indicate that a 2.7-3.0-meter-diameter culvert or box culvert would be required. **Advantages** ▪ Protects Hwy 97 integrity during floods ▪ Reduces residential property impacts ▪ Aligns with natural flow path ▪ Replaces aging infrastructure ▪ Lower blockage risk ▪ Permanent measure **Disadvantages** ▪ Traffic disruptions during repairs ▪ Higher cost	**Description:** This project focuses on reducing impacts to properties during a flood scenario. The strategy involves developing an overflow channel to redirect water overtopping Highway 97 as quickly as possible to the main Cutoff Creek channel. Preliminary assessments suggest an 8-meter-wide channel with 1.5:1 side slope and a depth of 1.2 meters would be necessary. **Advantages** ▪ Reduces flooding impact on properties ▪ Cost-effective ▪ Floodplain restoration in the overflow area **Disadvantages** ▪ Does not protect Highway 97 from washouts ▪ Impact to Hwy 97 as emergency corridor
	

Recommended Actions:

Collaboration between MoTT and the Village of Clinton is vital for implementing effective mitigation measures. This Flood Mitigation Plan should serve as a foundation for addressing risks and flood impacts in urban areas.

4.1.10 P10-Flood Education Program

The B.C. Flood Strategy 2035 emphasizes flood resilience through integrated hazard management and public awareness. Action 1.3 focuses on raising awareness with tools like ClimateReadyBC, the Flood Preparedness Guide, and FloodWise. Although Clinton has not faced recent major floods, the Village aligns with this strategy by addressing risks identified in the Dam Break Analysis and Floodplain Mapping through initiatives like an Online Flood Hub and educational pamphlets. These resources aim to improve community understanding of flood risks and mitigation strategies.

The Flood Education Program seeks to build community resilience by equipping individuals and businesses with the knowledge to manage flood risks and respond effectively. Both online tools (e.g., story maps and flood hubs) and traditional methods (e.g., pamphlets and seasonal reminders) will be used to deliver key messages, including:

- Better inform residents of flood-prone areas in the community.
- Explain responsibilities for flood risk reduction, both individual and different levels of government.
- Advise on personal flood risk reduction methods, like flood-proofing homes.
- Provide publicly accessible flood forecasting information for Clinton.
- Offer guidance on preparing for imminent floods, such as sandbagging and evacuation.
- Share Clinton's flood risk reduction efforts and next steps for mitigation.
- Inform about available support after flood events, such as Disaster Financial Assistance (DFA).

Online Tools:

- Use digital platforms like story maps and flood hubs to share flood hazard information.
- Complement online tools with community media (social and traditional), public meetings, and seasonal reminders.

Disaster Financial Assistance (DFA) helps cover essential recovery costs not covered by insurance. Educating the community about acquiring flood insurance improves post-disaster recovery. These initiatives ensure a well-informed and prepared community.

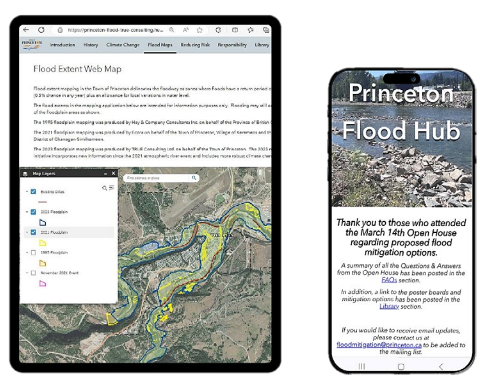


FIGURE 4-10: EXAMPLE OF AN ONLINE FLOOD EDUCATION TOOL

4.1.11 P11 – Cariboo Avenue Capacity Improvements

Floodplain mapping has identified that the Cutoff Creek main channel lacks sufficient capacity to manage projected climate-adapted flows, even with the implementation of Highway 97 drainage upgrades. As a result, properties near Cariboo Avenue remain vulnerable to flooding during major flow events. The Cariboo Avenue crossing, currently consisting of two ellipsoid culverts, acts as a constriction in the channel, further exacerbating the risk.

To address these issues, the project proposes the following measures:

- Culvert Replacement: Replace the existing culverts with a concrete box girder (6m span, 1.5m depth).
- Creek Bed Deepening: Excavate 0.6m deeper into the creek bed over a 325m stretch to improve flow capacity.
- Creek Bank Expansion: Widen the creek by 1m on each side.

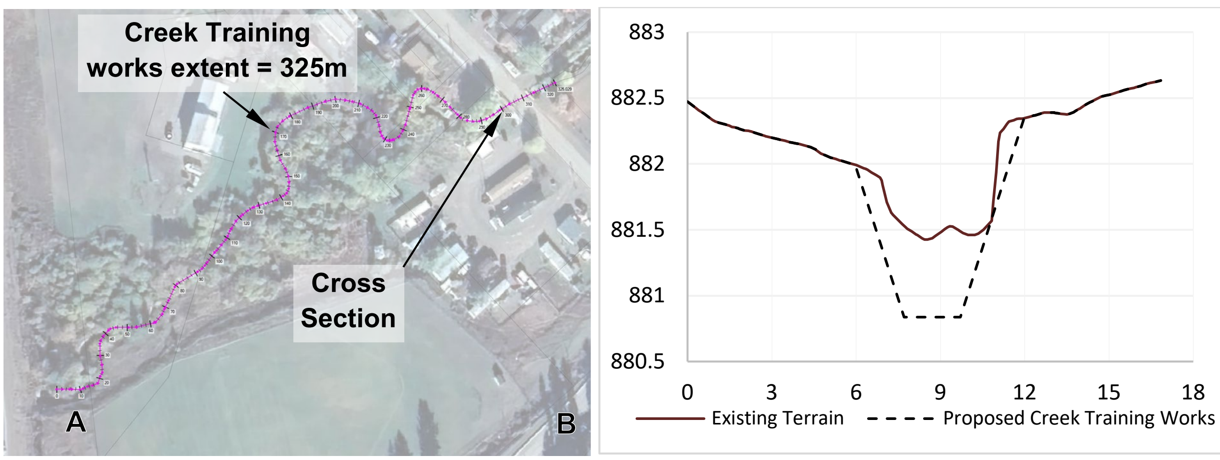


FIGURE 4-11 A) PLAN VIEW AND B) CROSS SECTION OF THE PROPOSED WORKS

These upgrades are expected to reduce water depth by 0.4m, avoiding property impacts for flood events up to the 20yr return period. While flooding may still occur during 200yr events, the extent will be reduced compared to the base scenario. Designing to the 200yr flood event is deemed impractical due to existing utilities and watercourse constraints, which make accommodating such extreme flows challenging and resource intensive.

Utility conflicts at the crossing, including risks to water and sanitary services, will require careful consideration during the predesign phase. Utility rerouting or replacement will be essential to protect infrastructure, such as residential services and David Stoddart School, during floods.

5.0 Projects Prioritization & Implementation

A simplified Multi-Criteria Analysis (MCA) was chosen as the most suitable tool to prioritize the proposed projects. This approach aims to account for social, technical, economic, and environmental aspects, classifying projects into high, medium, and low priority in a straightforward and comprehensible manner.

5.1 Multi-Criteria Analysis

A multi-criteria analysis (MCA) is a method to evaluate and prioritize strategies and projects effectively. When using MCA, decision-makers can choose between detailed and simple methods. While detailed methods offer certain advantages, the benefits of using a simpler, more qualitative, approach is particularly compelling for many practical situations. Unlike complex models that require extensive quantitative data and technical expertise, a simplified approach focuses on qualitative assessments of key criteria. A simple MCA prioritizes clarity and practicality, making it accessible and understandable to a broader range of stakeholders and decision-makers.

The following key criteria were established and are detailed as follows:

Community Impact

This criterion focuses on the less intangible aspects of each flood risk reduction project beyond the physical aspects. These include social disruption and stress caused by flooding, which can significantly affect residents' well-being and community cohesion. Economic impacts, both immediate and long-term, on businesses and employment should be minimized, while attention to psychological well-being is essential due to the mental health effects of living in flood-prone areas. Equity and social justice considerations must ensure that vulnerable populations are adequately protected, addressing disparities in flood impact.

Current Flood Risk and Reduction Effectiveness

Assessing the current risk posed by flooding is crucial for prioritizing mitigation efforts. Qualitative considerations include evaluating the severity of potential impacts on lives, property, and infrastructure. Analyzing the vulnerability of different areas within the community based on factors such as elevation, drainage systems, and land use. Additionally, this category assesses the tangible and physical impacts of each mitigation project. While still qualitative, it evaluates how effectively each strategy reduces flood hazards, vulnerabilities, and damages. Considering the projects resilience to various flood scenarios and their adaptability to future climate change impacts. By qualitatively scoring these aspects, this criterion prioritizes strategies that not only mitigate current flood risks but also strengthen community resilience against future challenges.

Construction and Technical Feasibility

The construction and technical feasibility of the proposed flood mitigation projects is a key factor in implementation success. This criterion assesses the ease of construction, construction risk, and Village disruptions in each scenario, providing higher scores to simple and conservative strategies, while risky and complex projects are scored lower. Additionally, the criterion also considers the interference of the proposed projects with existing infrastructure such as roads, sidewalks, sanitary sewer systems or water supply networks.

Cost Benefit

Evaluating the cost-effectiveness of mitigation strategies is essential for making efficient use of resources. Qualitative considerations include assessing initial implementation costs, as well as long-term operational and maintenance expenses. We also consider and prioritize the level or risk reduction derived from each strategy relative to its costs, ensuring that investments yield significant flood risk reduction per unit of expenditure. By qualitatively scoring these factors, we prioritize strategies that offer the greatest overall benefit to the community while optimizing financial resources.

Environment Protection and Sustainable Development

The proposed flood mitigation options implement different approaches to reducing flood risk for the Village of Clinton. This criterion focuses on protecting and enhancing the environment while integrating a sustainable development perspective into some of the projected strategies.

The following scale was implemented to evaluate the individual contribution of each indicator to achieve the global objective.

TABLE 5-1: MULTI-CRITERIA ANALYSIS SCORING SCALE

MCA RATING	SCORE	DESCRIPTION
Strong positive	5	Strong, positive impact on the criteria or measure
Moderate positive	4	Moderate, positive impact on the criteria or measure
No significant impact	3	No significant positive or negative impact
Moderate negative	2	Moderate, negative impact on the criteria or measure
Strong negative	1	Strong, negative impact on the criteria or measure

Each project was evaluated individually against each criterion to guide decision-making. Using primarily judgment-based scoring, technical, environmental, economic, and social factors were considered in prioritizing the projects. The scoring and resulting prioritization are summarized in the following table:

TABLE 5-2: MULTI-CRITERIA ANALYSIS MATRIX

PROJECT TITLE	COMMUNITY IMPACT	CURRENT FLOOD RISK AND REDUCTION EFFECTIVENESS	CONSTRUCTION AND TECHNICAL FEASIBILITY	COST BENEFIT	ENVIRONMENT PROTECTION AND SUSTAINABLE DEVELOPMENT	SCORE	PRIORITY
	20%	35%	15%	20%	10%	100%	
P1 -Flood Early Warning System	5.0	5.0	5.0	5.0	4.0	**4.9**	**Very High**
P2 -CN Railway Embankment Hydraulic Upgrades	5.0	5.0	3.0	4.0	4.0	**4.4**	**High**
P3 - Clinton and Cutoff Creeks Hydrometric Stations	4.0	4.0	5.0	4.0	5.0	**4.3**	**High**
P4 - WWTP Floodproofing and Lagoon Road Upgrades	5.0	4.0	3.0	4.0	3.0	**4.0**	**High**
P5 - Wastewater Treatment Plant (WWTP) Erosion Protection	4.5	3.0	4.0	4.0	5.0	**3.9**	Medium
P6 - Floodplain Land Use Regulation	4.0	3.0	4.0	5.0	4.0	**3.9**	Medium
P7 - Flood Response Plan	4.0	4.0	4.0	4.0	3.0	**3.9**	Medium
P8 - Clinton Creek Drainage Infrastructure Upgrades - MoTT	4.0	4.0	3.0	4.0	4.0	**3.9**	Medium
P9 - Highway 97 Drainage Infrastructure Upgrades - MoTT	4.0	4.0	3.0	4.0	4.0	**3.9**	Medium
P10 - Flood Education Program	4.0	3.0	4.0	4.0	4.0	**3.7**	Medium
P11 - Cariboo Avenue Capacity Improvements	2.0	3.0	3.0	3.0	2.0	**2.7**	Low

Based on the MCA results, the P1 Flood Early Warning System (FEWS) emerged as the highest-priority project due to its ability to monitor water accumulation behind the CN Railway embankment and identify potential flood risks early. Other high-priority projects include P2 CN Railway Embankment Hydraulic Upgrades and P3 Clinton and Cutoff Creeks Hydrometric Stations, both addressing significant downstream risks and uncertainties in design flows under changing climate conditions. The P4 WWTP Floodproofing and Lagoon Road Upgrades project was also prioritized due to its importance to the community and potential environmental impacts.

Additional initiatives include non-structural strategies for floodplain management, along with structural projects such as Highway 97 drainage upgrades and the Wastewater Treatment Plant (WWTP) erosion protection. These measures aim to protect critical infrastructure and mitigate potential impacts from a 200yr flood scenario, which, while infrequent, could have severe consequences.

5.2 Projects Summary

Table 5-3 provides an overall summary of the recommended flood mitigation projects. A project sheet, complete with a Class D cost estimate, has been developed for each project and is available in Appendix D. These sheets include a brief project description and a high-level cost estimate to assist the Village in planning, budgeting, and implementing the projects, while also preparing for funding applications.

TABLE 5-3: PROJECTS SUMMARY

PROJECT NO.	PROJECT TITLE	PRIORITY	TYPE	COST ESTIMATE
P1	Flood Early Warning System	Very High	Structural	$ 111,000
P2	CN Railway Embankment Hydraulic Upgrades	High	Structural	TBD
P3	Clinton and Cutoff Creeks Hydrometric Stations	High	Structural	$ 154,000
P4	WWTP Floodproofing and Lagoon Road Upgrades	High	Structural	$ 2,300,000
P5	Wastewater Treatment Plant (WWTP) Erosion Protection	Medium	Structural	$ 124,000
P6	Floodplain Land Use Regulation	Medium	Non-Structural	$ 145,000
P7	Flood Response Plan	Medium	Non-Structural	$ 147,000
P8	Clinton Creek Drainage Infrastructure Upgrades - MoTT	Medium	Structural	TBD
P9	Highway 97 Drainage Infrastructure Upgrades - MoTT	Medium	Structural	TBD
P10	Flood Education Program	Medium	Non-Structural	$ 55,000
P11	Cariboo Avenue Capacity Improvements	Low	Structural	$ 890,000
Total				**$ 3,930,000**

5.3 Implementation Considerations

As previously described, effective flood management is not a one-time effort but a continuous cycle of implementation, monitoring, evaluation, and adjustment. This iterative process allows for learning from past experiences and improving future responses. This Flood Mitigation Plan should be considered a living document that will require updates over time to account for the changing conditions of the environment, climate, and socio-economic factors.

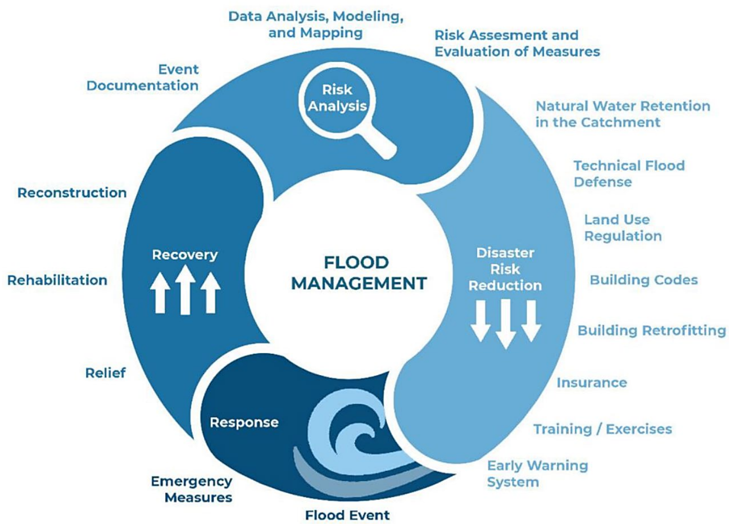


FIGURE 5-1: FLOOD MANAGEMENT CYCLE (MDPI, 2021)

Implementing individual flood mitigation projects identified in this version of the plan, will take time due to the complexity of the various components. The timeframe for implementation will depend on the availability of funding and the capacity to complete the design and construction of individual projects, as well as the creation and adoption of new land regulation tool.

The remainder of this section summarizes some considerations for successful implementation including integrating into the 5-year capital plan, regulatory issues, cultural considerations, and funding sources.

5.3.1 Integration into Council Strategic Priorities

Incorporating flood mitigation principles and objectives into the Council's Strategic Priorities should be considered. The 2024-2026 Strategic Plan includes the following strategic priorities:

- Diverse Economy
- Partnership / Collaborations
- Community
- Housing

This flood mitigation plan supports all four areas in various ways. Addressing flood management in more detail at the strategic level ensures it remains a priority, increases awareness among the Council and community, promotes accountability, and allows flood management to integrate with other community initiatives and priorities.

Integrating flood mitigation into the Council's strategic priorities is a proactive approach that promotes safety, economic stability, environmental health, and community resilience. It ensures that reducing flood risk remains a central focus while empowering staff to align capital planning, resources, and capacity for successful implementation.

5.3.2 Incorporation into Capital Plan

Incorporating mitigation projects into the capital plan enables prioritization alongside other projects, ensuring the most critical initiatives receive the necessary attention. This approach also helps identify potential synergies with other projects, optimizing resource use and maximizing benefits.

Many mitigation projects have extended timelines due to complex permitting and consultation requirements, often more intricate than other capital projects. These timelines should be considered during the budgeting process, with adaptive measures in place for potential delays. Effectively integrating these projects into annual capital planning will ensure steady progress toward enhanced community resilience and safety.

5.3.3 Permitting and Regulatory Considerations

Addressing permitting and regulatory considerations starts by identifying all required permits and approvals from relevant regulatory bodies, which is particularly crucial for projects located near water bodies. Due to their proximity to water, these projects typically require more permits compared to others. Depending on the project's nature, multiple permits from higher levels of government are likely necessary for approval. This process entails thorough planning and coordination to navigate regulatory requirements effectively and ensure compliance at every stage of project development.

5.3.4 Archaeology and First Nations Consultation

Considering archaeological and First Nations perspectives is vital and supports reconciliation efforts. This involves conducting archaeological assessments of project sites to identify potential historical or cultural artifacts and developing measures to protect any discovered artifacts.

Engagement with local First Nations communities should start early to build relationships and trust. As part of predesign, projects should consider and respect the cultural and historical significance of sites to First Nations. Resources and capacity funding have been included in the scope of relevant projects to ensure First Nations input and concerns are addressed throughout the project lifecycle.

5.3.5 Grant Funding

Developing thorough grant proposals involves outlining project specifics such as descriptions, objectives, timelines, budgets, and anticipated results. The detailed project sheets within this flood mitigation plan summarizes most of the information needed to support various grant applications.

Numerous grant programs currently emphasize emergency management, climate adaptation, and community risk reduction. These programs are expected to persist as flood risk mitigation and community protection remain priorities for both Provincial and Federal governments.

The Village has already achieved success in securing grants to bolster flood mitigation efforts. The Community Emergency Preparedness Fund is a notable example, which provided funding to support the development of this plan.

Implementing defined flood mitigation projects requires a strategic approach that integrates these initiatives into the municipal framework, addresses regulatory and cultural considerations, and secures necessary funding. By following these steps, municipalities can effectively implement flood risk reduction and enhance community resilience.

References

AC Eagle (2019) Clinton Creek Reservoir Dam Breach Analysis, Technical Report prepared on behalf of the Village of Clinton by AC Eagle Consultants, February, 2019.

APEGBC (2017). Flood Mapping in BC – Professional Practice Guidelines, The Association of Professional Engineers and Geoscientists of British Columbia, Burnaby, 2017.

BGC (2019) BGC Engineering Inc. Thompson River Watershed Geohazard Risk Prioritization Report. Technical Report prepared for Fraser Basin Council by BGC Engineering Ltd., March 2019.

EGBC (2018) Legislated Flood Assessments in a Changing Climate in BC, Engineers & Geoscientists British Columbia (EGBC) – Professional Practice Guidelines, Version 2.1, August 2018.

M'akola Development Services et al. (2021) Housing Needs Report, Village of Clinton. Technical Report prepared by M'akola Development Services and Turner Drake & Partners Ltd. for the Thompson-Nicola Regional District, February 2021.

PCEX (2024) Pacific Climate Impacts Consortium, Climate Data Explorer, URL https://pacificclimate.org/analysis-tools/pcic-climate-explorer, Last accessed Sept 24, 2024.

PCIC (2024) Pacific Climate Impacts Consortium, Station Hydrologic Model Output, URL https://pacificclimate.org/data/station-hydrologic-model-output, Last accessed Sept 24, 2024.

Perera et. Al. (2019) Flood Early Warning Systems: A Review Of Benefits, Challenges And Prospects. UNU-INWEH Report Series, Issue 08. United Nations University Institute for Water, Environment and Health, Hamilton, Canada.

Roden (2018) Highway 97 now fully reopen between Cache Creek and Clinton, 100 Mile Free Press, 2018.

Septer, D. (2007) Flooding and landslide events: southern British Columbia, 1808-2006. Victoria, British Columbia: Province of British Columbia, Ministry of Environment.

TRUE (2021) Floodplain Mapping Report, Village of Cache Creek. Technical Report 310-161 Prepared for the Village of Cache Creek by TRUE Consulting, September, 2021.

TRUE (2024) Floodplain Mapping Report, Prepared by TRUE Consulting on behalf of the Village of Clinton, 2024.

Village of Clinton (2016) Official Community Plan, February 2016.

Village of Clinton (2024) Strategic Plan 2024-2026.

APPENDIX A

Dam Break Analysis (AC Eagle, 2019)

202-925 McMaster Way
Kamloops, BC V2C6K2
Tel (250) 372-2149
Fax (250) 374-2129

February 12, 2019

Public Works Superintendent
PO Box 309
Clinton, BC V0K 1K0

VIA EMAIL (khansen@village.clinton.bc.ca)

Attention: Karl Hansen

Re: VILLAGE OF CLINTON: CLINTON CREEK RESERVOIR DAM (D11020-00): DAM BREAK ANALYSIS

Herewith a report on the potential dam breach scenarios, flood routing and inundation analysis for the Village of Clinton.

INTRODUCTION

The Upper Clinton Creek Reservoir Dam is located 8.4 km northwest of Clinton, BC. By road, one has to travel 9 km up Highway 97, another 6.3 km northwest on the Big Bar Road and approximately 11.8 km on a forestry road (**Figure 1**).

The 5.6 m high earthfill dam lies on Crown Land in the upper watershed of the Clinton Creek, which runs eastwards through the Village of Clinton to the Bonaparte River. The Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) water storage licence number for the Upper Clinton Creek Reservoir and downstream creek system is C051995. Water is released from the reservoir down the Clinton Creek to supplement the main diversion/storage point (licence C29776).

The actual total volume of water in the reservoir at Full Supply Level (FSL) is 49,000 m^3 (39.7 AF). Live storage at FSL is almost the same at 46,000 m^3 (37.3 AF).

The Upper Clinton Creek Reservoir itself has a watershed size of 35 km^2 (**Figure 2**).

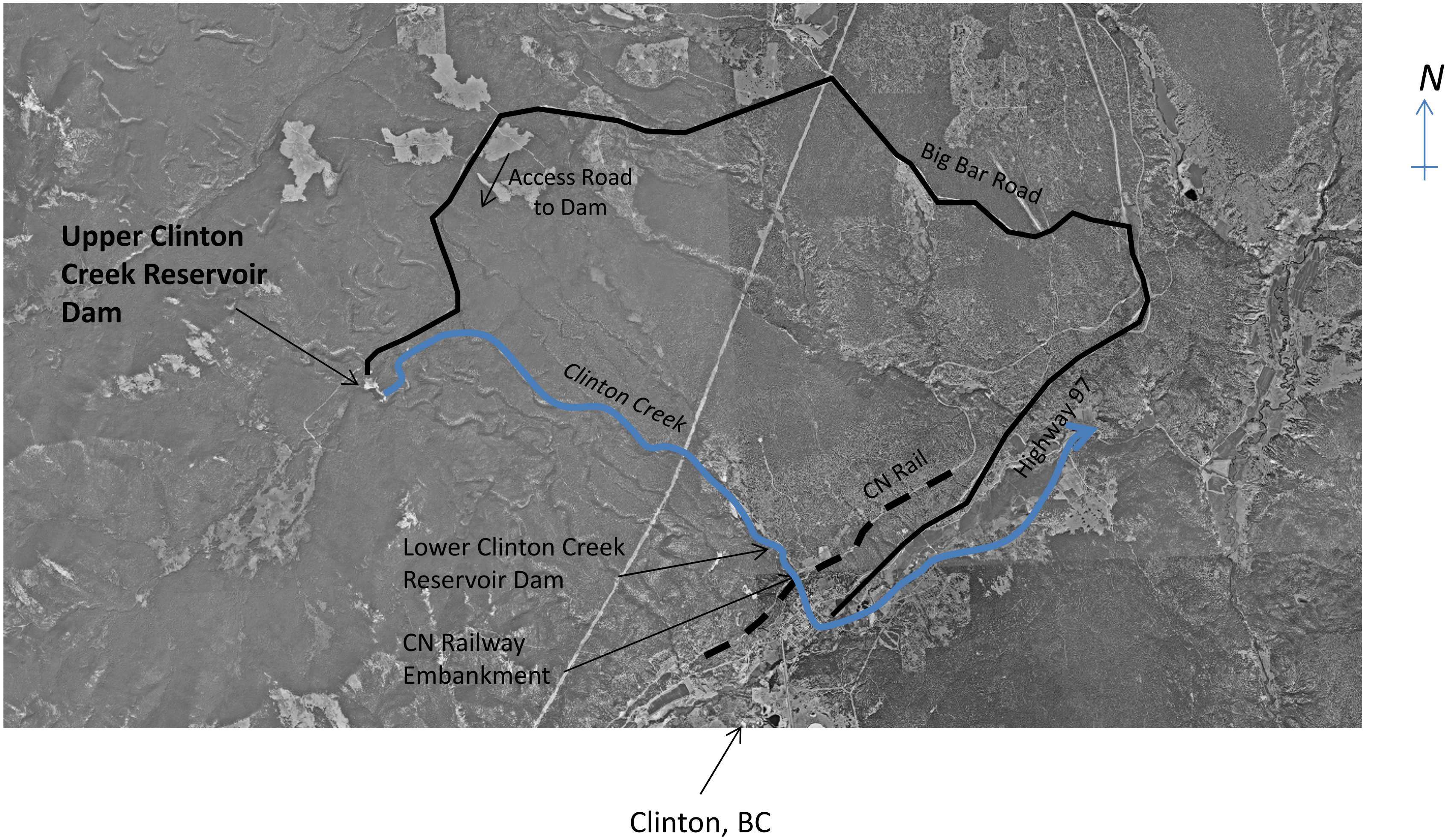


Figure 1

Upper Clinton Creek Reservoir Dam Break Analysis:
General Locality and Access Road

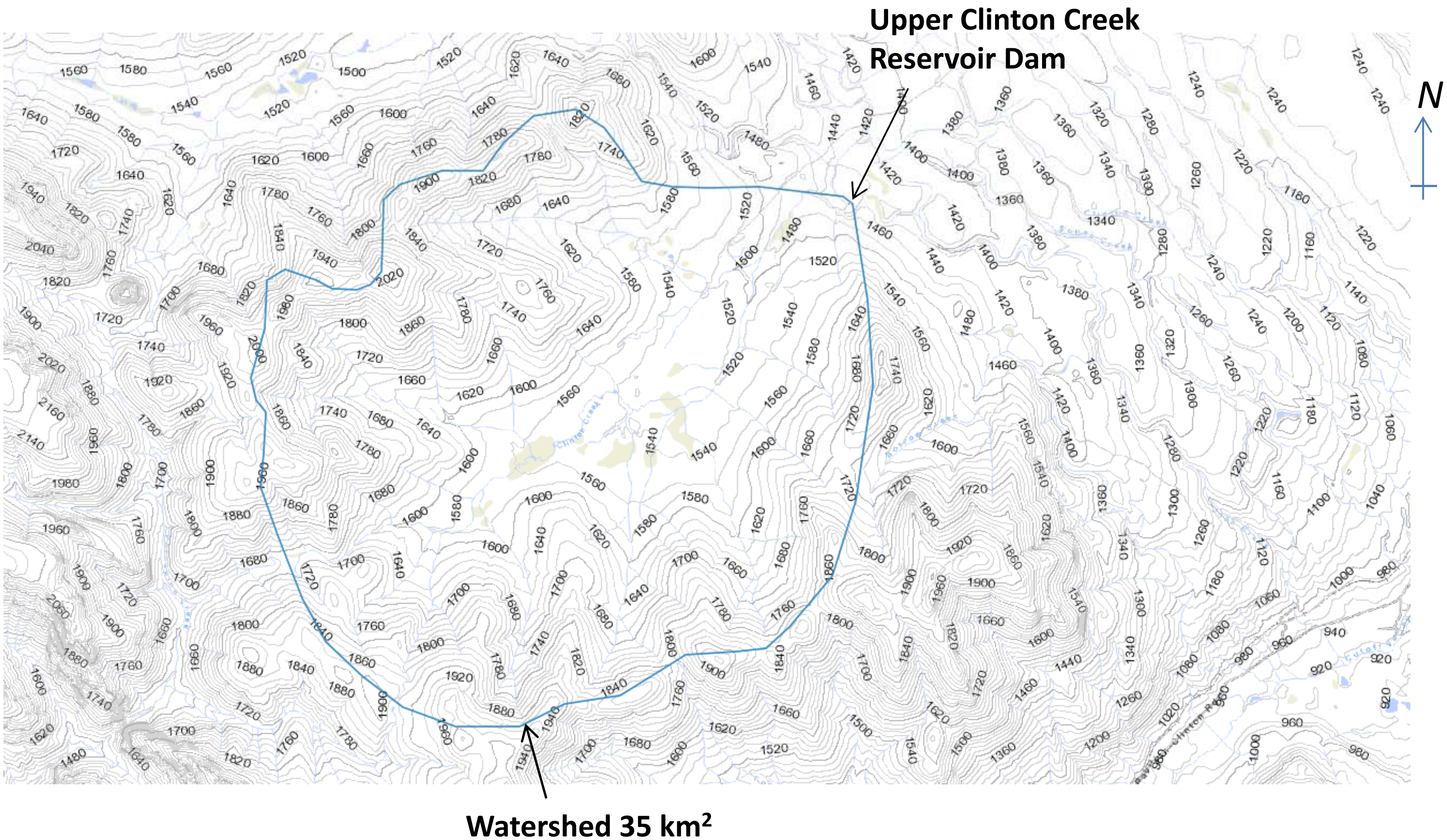


Figure 2

Upper Clinton Creek Reservoir Dam Break Analysis:
Watershed

Upper Clinton Creek Reservoir Dam has previously been classified as a High Consequence structure according to the BC Government's dam safety policies and regulation. This is mainly due to: the creek diversion pond downstream (the Lower Clinton Creek Reservoir); the negative impact on the water treatment works; the creek crossing underneath a high railway embankment that is located just upstream of the Village of Clinton; and that the creek flows down through Village itself (**Figure 3**).

This report investigates the impacts of a potential dam break analysis and downstream inundation impacts.

OBJECTIVE

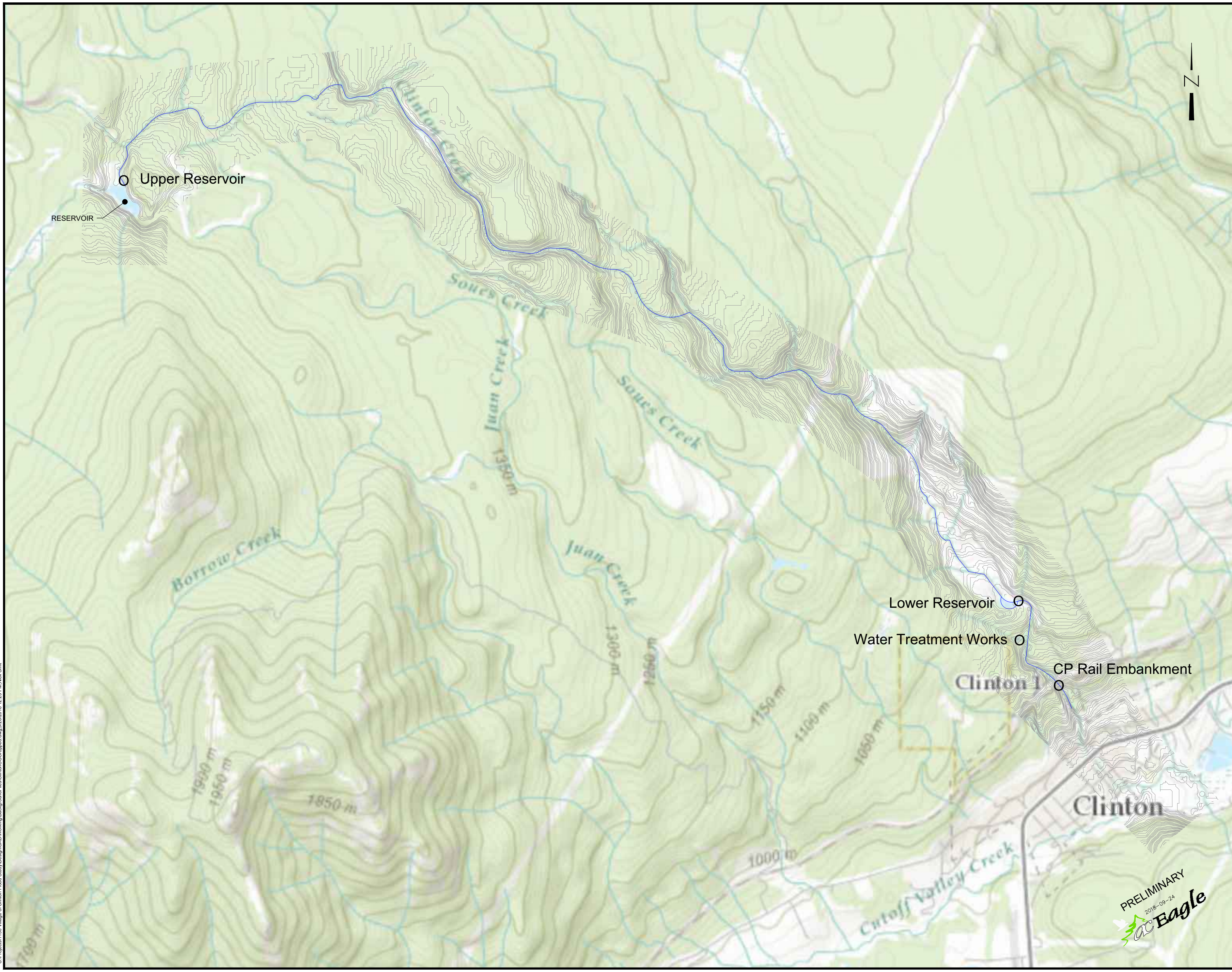
As part of normal dam safety management tasks, the Village of Clinton is required to conduct a dam break (or breach) analysis and to provide and provide an indication of the dam break inundation down the valley below the dam.

One important deliverable was identified in the 2014 Dam Safety Review (DSR), namely:

> "In submitting this DSR report to the MFLNRO's Dam Safety Officer, also present a formal letter highlighting the existing "bottleneck" in the Clinton Creek behind the CN Rail. Small floods can potentially block the culvert under the embankment, which could weaken the embankment and possibly bring a wall of water down on the Village township. This is not solely a dam break responsibility and should be addressed by CN Rail as a major safety issue.

The intention would be to partner with CN Rail in agreeing to emergency protocols should a normal large flood or a dam break flood block the railway embankment culvert with debris (i.e. a set of procedures to deal with debris removal, evacuation notices downstream, monitoring of the embankment if the culvert is blocked).

This current 2018 dam letter report can be used to open discussions with CN Rail.



REFERENCE DRAWINGS

Legend

Existing Edge of Asphalt
Existing edge of Gravel
Existing Fence
Existing Top of Slope
Existing Toe of Slope
Existing Hedge/Treeline
Existing Deciduous/Coniferous/Shrub
Prop./Existing Watermain
Prop./Existing Water Service
Prop/Ajdusted/Existing Water Valve
Prop./Existing Fire Hydrant
Prop./Existing Water Standpipe
Prop./Existing Curb Stop
Prop./Existing End Cap
Prop./Existing Sanitary Sewer
Prop./Existing Sanitary Forcemain
Prop./Existing Sanitary Service
Prop./Adjusted/Existing Sanitary Manhole
Prop./Existing Inspection Chamber
Prop./Existing Storm Sewer
Prop./Existing Storm Forcemain
Prop./Existing Storm Service
Prop./Existing Culvert
Prop./Adjusted/Existing Storm Manhole
Prop./Existing Catch Basin
Prop./Existing Side Inlet Catch Basin
Gas
Hydro Power
Telephone
Municipal Elec.
Vault
Junction Box
Cable
Hydro /Telephone Manhole
Anchor Wire/Anchor Pole
Hydro/ Telephone /Hydro-Tel Pole
Hydro/Hydro-Tel Pole with Transformer
Light on Pole/Underground on Pole
Decorative/Davit Light
Parking Meter
MB Mail Box
Prop./Existing Traffic Sign
Prop./Existing Stop Sign
MON/OIP/ Monument/Iron Pin/Survey Control

NO.	DATE	DESCRIPTION	BY	APPD

REVISIONS & ISSUES

DESIGN DKA DATE:
DRAWN NCS DATE:
CHECK DKA DATE:
APPD BY CONSULT. DATE:
APPD BY CITY DATE:
PROFESSIONAL SEAL

SCALE
HOR: 1: 20,000 (0 200 400 600 800 m)
VER: 1: 20,000 (0 200 400 600 800 m)

AC EAGLE ENTERPRISES LTD.
102-925 McMaster Way
Kamloops, BC V2E 6K2
Tel (250) 372-2149
Fax (250) 374-2129
www.aceagle.ca

1130-001-01

VILLAGE OF CLINTON
DAM BREAK ANALYSIS

Figure 3

SHEET 01 OF 01
CONSULT. DWG. NO. P01
CITY DWG. NO.
REVISION 01

S:\Projects\1130 Village of Clinton Flood Study\Design\CAD\Working\Background\Files\ClintonOCropped.dwg 9/26/2018 12:25 PM Nick Smit

SCOPE OF WORK

The following modules of work were conducted.

- TASK 1: Data Collection. Information from the previous dam safety review in 2014 was collated and used as a basis for this review. An effort was made to try and obtain detailed contour mapping from the Provincial Government. Unfortunately, the Provincial mapping data was only at a scale of 20 m contours which proved too crude to obtain a good cross-section model to use in hydrotechnical analysis.

  The Federal Government's Geogratis database was accessed and a 2.5 m contour interval was obtained. Conducting a more detailed on the ground topographical and even a drone survey would have proved to be very expensive.

  The Geogratis mapping data was therefore selected and processed in our Civil 3D program to obtain a three dimensional model of the creek below the dam. This was then used to obtain cross-sectional data that was used in the GeoHecRas and HECRAS river hydraulic models.

- TASK 2: Field verification. An aerial flight was not conducted as originally planned. Only specific site visits to the key areas, namely: the downstream dam and the CN Railway embankment were made. The original site visit to the Clinton Creek Reservoir Dam was used as reference in this study.

- TASK 3: Routing a flood through the reservoir and a 'sunny day' dam failure due to non-flood related reasons. Determining the consequences of failure of the dams and evaluating the current safety classifications.

- TASK 4: Dam Break Characteristics and Parameters. This included reviewing the causes and types of dam failure. This gave an indication of how quickly a dam breach would occur, which in turn, determined the size of the flood wave that we would analyzed downstream.

- TASK 5: Setting up the HECRAS Model.

- TASK 6: Running the model and evaluating the flood routing results and ironing out any modelling issues. Downstream storage and attenuation was considered. The downstream dam (Lower Reservoir) and the railway embankment and their safety were two areas that needed more consideration. Timing of the flood and warning times were determined.

- TASK 7: An outline of the expected dam break wave's inundation was produced.with more attention being paid to the Lower Reservoir and domestic water intake down to the other side of Clinton. Note that this mapping is not intended to be used for insurance property classification or other similar legal purposes. Much more detailed floodplain mapping studies would have to be conducted to achieve those purposes. This information in this report focuses on the realm of dam safety, the classification of the upper dam and what flood safety issues need to be addressed.

- TASK 8: Incremental impacts to infrastructure, the environment, the economy, the highway connectivity where determined.
- TASK 9: This Dam Break Analysis Report.

BACKGROUND

The main dam is an earthfill embankment with an uncontrolled concrete spillway on the right flank.

A secondary or saddle earthfill dam is located on the eastern side of the reservoir (**Figure 4**).

If one of these two structures breach, the resultant flood wave will still flow down the Clinton Creek. In the case of the saddle dam, the flood discharge may be attenuated a little more, due to the area directly downstream being more open and marshy than downstream of the saddle dam.

As such, it has been decided to focus on a dam break at the main dam as that will yield the most significant impact downstream.

Table 5a below provides some details associated with the main dam structure. Note that the reservoir is relatively small (2.4 ha) and that the reservoirs total storage is under 50,000 m^3.

Table 5a: Fact Sheet: Upper Clinton Creek Reservoir Dam and Reservoir

General	
Location	As the crow flies, 8.4 km west of Clinton, BC
Coordinates	51° 07' 50" N; 121° 41' 12" W
Purpose	Augmentation of domestic water supplies to the Village
Originally constructed	Dam built in 1981 and upgraded in 1983
Outlet pipe	300 mm or 12" diameter concrete pipe
Owners	Village of Clinton
Type of Dam	Earthfill dam with concrete spillway section
Height	5.6 m (non-overflow crest to riverbed below outlet works)
Classification	High
Length	132 m (including spillways on right flank)
Crest Width	5 m
Base Width	37 m
Upstream Slope	1 in 3 ../continued

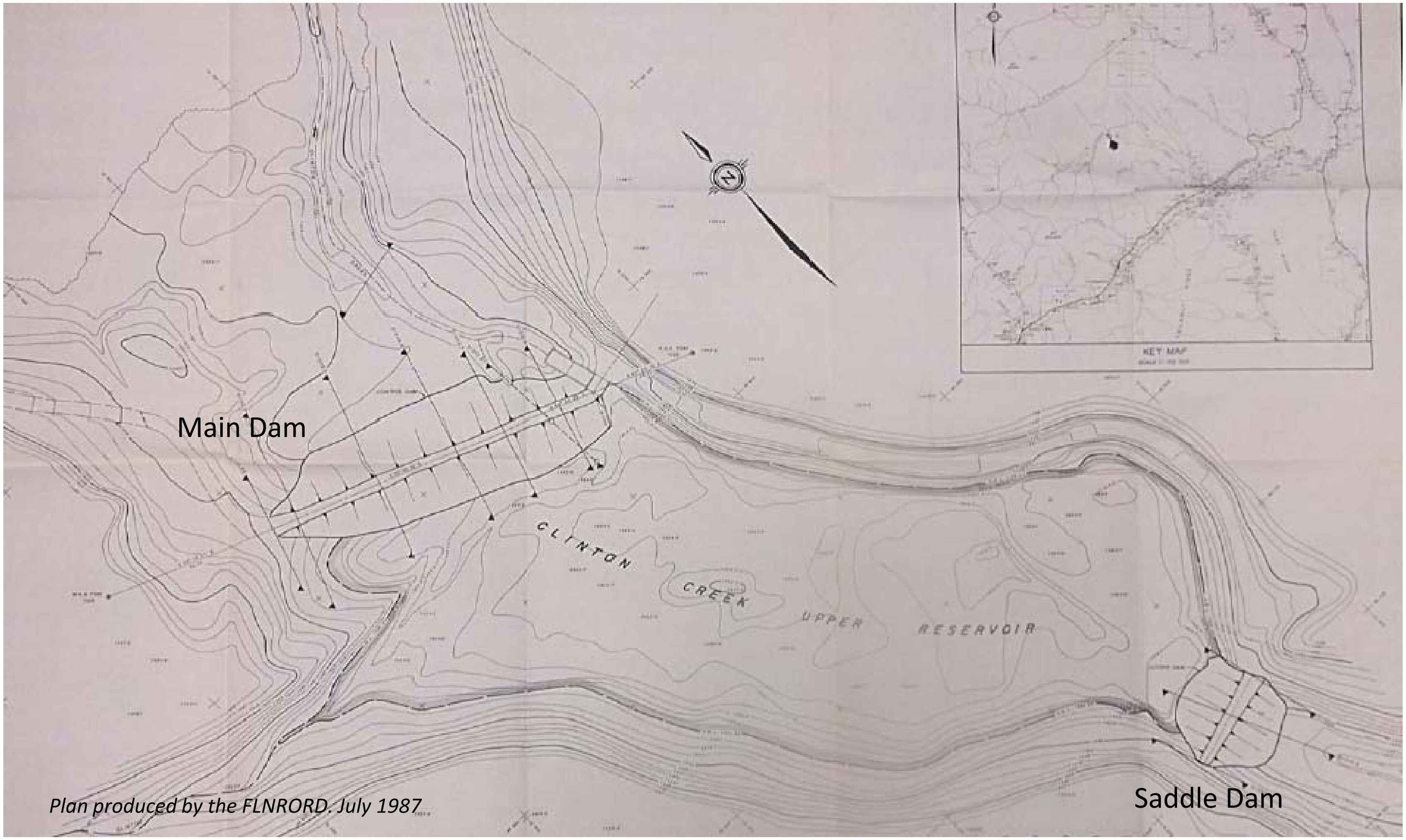


Figure 4

Upper Clinton Creek Reservoir: Dam Break Analysis

Layout of Upper Reservoir

Downstream Slope	1 in 2.5
Crest Elevation	Elevation amsl at crest 1,438.97 m
Impounds	Upper Clinton Creek
Type of Spillway	Main concrete spillway (4.95 m wide, 27 m long, and 2.75 m high) with culvert shaped bridge, ogee crest and chute, a concrete stilling basin, and rock armoured toe
Spillway Crest Elevation (FSL)	1,036.34 m amsl (FSL = Full Supply Level of lake).
Freeboard	Maximum freeboard 2.63 m; minimum freeboard 0.9 m
Spillway Capacity	46 m^3/s with a freeboard of 0.9 m
Reservoir and Outlet Works	
Creates	Upper Clinton Creek Reservoir
Surface Area	2.4 ha (5.9 acres) (at FSL) from MFLNRO survey in App. C
Live Storage Capacity	46,000 m^3 (40 AF)
Dead Storage Capacity	3,000 m^3 (2.4 AF)
Maximum Water Depth	2.31 m at FSL
Catchment Area	35 km^2. Determined using BCiMap v2 (2014)
Reservoir Length	207 m fetch; however sheltered in old glacial depression

The watershed above and around the dam has been designated a Community Watershed with the view of preserving the water resources for the Village of Clinton. Although logging has taken place in the past, tree cover is good. Even so, the geology of the area (Cache Creek Terrane), and as noted on aerial photographs, indicates that the soils along the Clinton Creek and its tributaries are fairly erodible.

Gulleys and other forms of natural geomorphological processes are prevalent along some of the natural water courses. A dam break flood wave would most probably pick up quite a bit of silt and woody debris on its way down the hill. This could possibly block up the culvert under the CN railway embankment. If the embankment is eroded by the water dammed behind it, or overtopping it, this event could create a second flood wave down into the Village. Due to its close proximity to the Village, there may be very little notice of this pending disaster through the centre of town.

HYDROLOGICAL ANALYSIS

Flood hydrology and spillway design investigations were conducted in the year 1980 and 1981 as part of the design process by Golder Associates. This information was reviewed by AC Eagle in the 2014 Dam Safety Review.

The following determinations have been assumed for the instantaneous flood discharge events in the current dam break analysis:

- Page 10

Q_{10} = 0.9 m^3/s Q_{100} = 1.6 m^3/s Q_{1000} = 2.4 m^3/s Q_{PMF} = 56 m^3/s
Inflow Design Flood IDF = 20 m^3/s.

The dam's spillway capacity is 46 m^3/s with a freeboard of 0.9 m.

SELECTION OF RESERVOIR CONDITIONS FOR BREACH ANALYSIS

A dam failure due to overtopping of the Upper Reservoir main earth embankment was considered to be the most dire condition. This could be due to:

- a sunny day failure, where debris is blocking the spillway, and the water level in the reservoir is raised to overtopping levels;
- or where a meteorological event and debris blockage causes the same overtopping erosion and dam failure. In this case, water from other tributaries to the Clinton Creek would also add a base flood flow to the system.

ESTIMATION OF DAM BREAK CHARACTERISTICS AND PARAMETERS

Attachment A to this report provides a more detailed estimation of the parameters considered.

In the case of a dam break at the upper reservoir approximately 61,674 m^3 (or 50 AF) of water will be released from the dam. It was estimated that this overtopping flow will take approximately 24 minutes to erode down to a level 5.5 m below the current crest of the dam. The wedge eroded has been estimated to be on average 3.28 m wide.

ESTIMATION OF DAM BREACH PEAK DISCHARGE

The assessment contained in Attachment A estimated the dam breach peak discharge to be 55 m^3/s just downstream of the Upper Reservoir Lake Dam at full breach.

DOWNSTREAM MODELLING OF DAM BREACH FLOOD

Initially, a simplified method was used to determine downstream impacts (Attachment A). This was later refined using the HECRAS computer model.

The results showed that the peak of the flood may well be attenuated to a point that it can be accommodated through the 1.8 m diameter culvert below the railway line embankment. The inundation mapping shown below show the estimated floodlines with water flowing beneath the railway embankment; and also building up behind the embankment without a failure.

However, the worst case scenario was also evaluated.

- Page 11

This scenario assumes that the Upper Reservoir dam break flood wave would take about an hour and a half to reach the railway embankment and would bring with it a large volume of debris and silt that would plug up the culvert below the embankment. It may also even take out the Lower Reservoir adding slightly to the volume behind the rail embankment.

Water would then build up behind the embankment (10 m deep) until it overtops it and starts eroding the embankment on its downstream face. Calculations show that the embankment may last an hour before it fails completely.

The reservoir of flood water behind the embankment would release and cause a secondary flood wave down into the Village. The peak of this flood wave would be around 200 m^3/s. The outline of this flood wave has been shown as dotted lines on the figures in Attachment A.

ESTIMATED EXTENT OF DOWNSTREAM INUNDATION

Figures A5 through A9 in Attachment A show the estimated extents of the Upper Reservoir dam break flood wave. In this initial scenario, the impacts would be relatively minor with about 10 to 15 m^3/s flowing through the culvert under the railway embankment.

Impacts would be similar to recent flooding events through the Village. About 30 homes and 4 businesses would be affected by flood waters (depth of 0.3m to 0.9 m in places), with most of the water flowing down Robertson Lane, McDonald Crescent and McDonald Avenue to the confluence of the Clinton and Cutoff Valley Creeks. With early warning and evacuation systems in place, triggered by the flood wave growing in size, it is unlikely that human lives will be taken; and if so, it will fall into the dam safety rating category of less than 10 lives lost.

Figure A8 shows the extent of inundation if the railway embankment fails as described in the second or worst case scenario described in the previous section of this report. Depth of flows range from 0.5 m to 1.6 m in places down the Robertson Lane, McDonald and Lebourdais Avenue corridors.

In this worst case scenario, the flood waters of 10 to 15 m^3/s would have started flowing down through the existing 1.8 m diameter culvert under the railway embankment. These flows would have started flooding of the Village along Robertson Lane, McDonald Crescent and McDonald Avenue. Which, in turn, would have triggered an emergency, and preparations for household evacuations

At the same time, emergency personnel from the Village would be checking the build-up of flood waters behind the railway embankment. There could be time to clear a blockage of the culvert with an excavator. If not, at least the Village can be warned of the waters damming behind the railway embankment. If the embankment does, for some reason, fail due to flood waters, it is the author's opinion that the death toll will be minimal as people would have been evacuated and the highway closed. Extensive damage would be done to houses and infrastructure in the central part of the Village of Clinton.

This potential hazard will need to be discussed with CN Rail. The first strategy would be to respond to a blockage of the culvert. An alternative strategy would be to develop a diversion structure above the embankment that could sift out any debris and silt material.

CONCLUSION

This assessment showed that:

a) The Upper Clinton Creek Reservoir dam break flood wave would not have as severe an impact as originally believed.

b) Reasons for this could be the relatively small volume of stored and surcharged water in the reservoir (61, 000 m^3 or 50 AF at non-overflow crest level elevation); and the attenuating effects of the Clinton Creek Valley down its 11 km long watercourse to the Village.

c) Water will reach the railway embankment a few hundred metres above the Village. The relatively small culvert can pass about 16 m^3/s, which is more than it was thought to.

d) As such, a large portion of the first flood wave flows should pass through the culvert creating initial flooding along the Robertson Lane, McDonald Crescent and McDonald Avenue corridor as has happened with normal flooding that occurred a number of years ago. It is the author's opinion that this warning will allow Village emergency personnel time to implement an evacuation protocol and to investigate any build up of water behind the railway embankment.

e) CN Rail would be part of these emergency notifications; and together with the Village would attempt to keep the culvert from plugging (e.g. by using an excavator, or a pre-designed settling pond). A plugged entrance to the culvert could cause an unwanted backwater storage effect behind the railway embankment.

f) If for some reason, the culvert is plugged and water is building up behind the embankment, the Village would implement a slightly wider evacuation order to avoid loss of life should the railway embankment fail and release a large flood wave down into the valley.

g) Traffic on the Cariboo Highway would need to be temporarily closed, with the potential of flooding of a 80 m length of roadway. The Ministry of Transportation and Infrastructure will need to be notified regarding the threats to the closure of the main Cariboo Highway through the Village.

h) There are about 30 to 40 houses on either side of the flood flow down Robertson Lane, McDonald Crescent, McDonald and Lebourdais Avenue that could be affected by the larger flood wave associated with a failure of the railway embankment.

i) Loss of life is expected to be from zero to 10 people.

j) Based on: the consequence rating evaluation in Attachment B; the table in Schedule 1 of the BC Dam Safety Regulation; and the selections made previously by the DSO; it is the author's opinion that the Upper Clinton Creek Reservoir Dam safety classification should remain as "High".

In summary, this study has been carried out to support the 2014 Dam Safety Review. After conducting the Dam Break Analysis, no new evidence has been found to indicate that the classification of the Upper Clinton Creek Reservoir should change from its current rating.

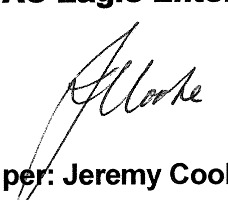
RECOMMENDATIONS AND FUTURE ACTIONS

Once a large flood is detected in the Village and flood emergency protocols are implemented, Village personnel should monitor the culvert under the railway embankment to ensure that it does not become plugged and is storing water behind the embankment. Close contact should be maintained with CN Rail at this stage. This should be built into the Village's Emergency Response Action Plan.

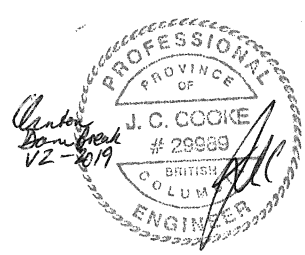
Secondly, this Dam Break Analysis report should be forwarded to the Dam Safety Officer in Kamloops as part of the dam safety management responsibilities of the Village of Clinton.

Yours truly,

AC Eagle Enterprises Ltd.



per: Jeremy Cooke, P.Eng.
Director



ATTACHMENT A

Upper Clinton Reservoir Dam Break Assessment

1. Estimation of Dam Breach Parameters for Earthfill Dams

Work by MacDonald and Landridge-Monopolis[1] were successful in relating breaching characteristics of earthfill dams to measurable characteristics of the dam and reservoir. Specifically, a relationship exists between the volume of material eroded in the breach and the Breach Formation Factor (BFF):

$BFF = V_w (H) = 50 * 19.5 = 975$

where:

V_w = Volume of water stored in the reservoir (acre-ft) at the water surface elevation under consideration = 50 acre-ft

H = Height of water (feet) over the base elevation of the breach = 19.5 ft

Interpretation of data (MacDonald, 1984) suggests that the estimates of material eroded from earthfill dams may be taken to be:

$V_m = 2.50 (BFF)^{0.77}$ for Erosion Resistant Embankment Materials $= 2.5 * (975)^{0.77} = 500$ yds^3

where:

V_m = Volume of material in breach (yds^3) which is eroded

Using the geometry of the dam and assuming a trapezoidal breach with side slopes of (Z_b:1) the base width of the breach can be computed (MacDonald, 1984) as a function of the eroded volume of material as:

$W_b = [27V_m – H^2 (CZ_b + HZ_bZ_3/3)] / [H (C + HZ_3/2)]$

$= 2.36$ ft (or 0.72 m)

Where:

Wb = Width of breach (feet) at base elevation of breach

C = Crest Width of dam (feet) = 18 ft

$Z_3 = Z_1 + Z_2 = 5.5$

Z_1 = Slope (Z_1:1) of upstream face of dam = 3

Z_2 = Slope (Z_2:1) of downstream face of dam = 2.5

Z_b = Side slope (Z_b:1) = 0.5

The time of breach development (τ) in hours, has been related to the volume of eroded material. Interpretation of data suggests that the time for breach development can be estimated by:

$\tau = 0.042\ Vm^{0.36}$ for Erosion Resistant Embankment Materials = 0.39 hours (or 24 minutes).

[1] *Quoted in FLNRORD's Estimating Dam Break Downstream Inundation. January 2016*

2. Estimation of Dam Breach Peak Discharge

Estimation of the peak discharge from a dam breach is computed as:

$$Qp = 3.1\ W\ H^{1.5}\ [\ A / (A + \tau\ H^{0.5})]^{3}$$

$$= 1{,}940 \text{ cfs (or } 55\ m^3/s)$$

Where:

Qp = Dam breach discharge (cfs)
W = Average breach width (feet) W = Wb + ZbH = 10.47 ft
H = Initial height of water (feet) over the base elevation of the breach = 19.5 ft
τ = Elapsed time for breach development (hours) = 0.39 hrs
A = 23.4 Sa / W = 13.41
Sa = Surface area of reservoir (acres) at level corresponding to depth H = 6 acres

This is seen as a fairly conservative estimate of discharge as the materials and construction methods used would indicate more resistance to erosion than has been assumed in this Fread estimating technique. A DAMBRK program could be run to refine this number, but the cost of this exercise is not warranted for a dam of this small size and that the flood wave discharge is not expected to change dramatically.

This was checked using the simplified method – Table 2 in the FLNRORD downstream inundation guidelines. This is shown on Table E1 below.

Table E1:

Dam Breach Discharge Estimates
for Earthfill Dams Constructed of Erosion Resistant Materials

Dam Breach Peak Discharge (m3/s)

Dam Height (meters)	Reservoir Surface Area (hectares) 1	2	3	4	5	10	15	20	40
1.2	4.5	7.8	11						
2	8.8	15	21	26	31		Breach Width > 5xDam Height		
3	15	25	34	41	49	81			
4	22	35	46	57	67	110	148	183	
5		45	59	72	84	138	185	228	
6		56	72	88	102	165	221	272	452
7			85	103	119	192	256	315	521
8			98	118	136	218	290	356	587
9				132	153	244	323	396	651
11					184	292	385	471	771
13		Partial Breach				336	443	541	881
15						376	496	605	983

3. Downstream Routing of Dam Breach Flood

As the dam breach flood wave travels downstream there is usually a reduction in the peak flow.

This effect is governed by factors such as:

- the channel bedslope,
- the cross-sectional area and geometry of the channel and overbank areas,
- the roughness of the main channel and overbank,
- the existence of storage for floodwaters in off-channel areas, and
- the shape of the flood hydrograph.

Large attenuation is associated with:

- small reservoir volume,
- broad floodplain and/or off-channel storage areas,
- mild channel slopes, and
- large frictional resistance in channel and overbank areas.

Two methods for modelling the attenuation of peak flow as the breach flood wave travels downstream were used. The simplified one using the FLNRORD guideline; and the more detailed HEC-RAS program are the two basic methods of modelling the attenuation.

Detailed contours were sourced from the Government's GeoGratis data bank. This was processed in ArcGIS and cross-sections generated over 11 km of Clinton Creek from the dam to the Village.

3.1 Simplified Method

A simplified dam break method was used first to obtain ball park results. A more detailed HECRAS method based on a 2 m contour map was then used to analyze various parameters and calibrate the numerical model.

Simplified Method recommended by FLNRORD; The following sets of curves were generated by the Kamloops Dam Safety Office using HEC-RAS to show how the peak flood flow changes with distance downstream from the dam (Figures A1 and A2). The curves are all based on a typical stream in central BC, but have assumed different average bed slopes. The curves were generated by assuming that the stream was a "U"-shaped stream with average side slopes of 2V:1H, with a Manning roughness of 0.08 for the channel and 0.10 for the overbanks. This roughness assumes that some of the flow is significantly affected by vegetation growing above the normal high-water level.

It should be noted that the Clinton Creek has a:

a) 1% to 2% average downhill grade over the first 4 km.

b) After this the creek picks up to a slope of between 5% and 7% on average. See Figure A3 for a long section.

c) The long section of the creek below the Lower Clinton Creek Reservoir is shown on Figure A4.

Figures A1 and A2 are arranged in terms of reservoir storage. They show flood attenuation in terms of peak dam breach discharge (Qp) at the dam site and peak discharge (Qx) at some distance downstream.

Figure A1: Hydrograph Attenuation Curves – 1% Average Channel Slopes

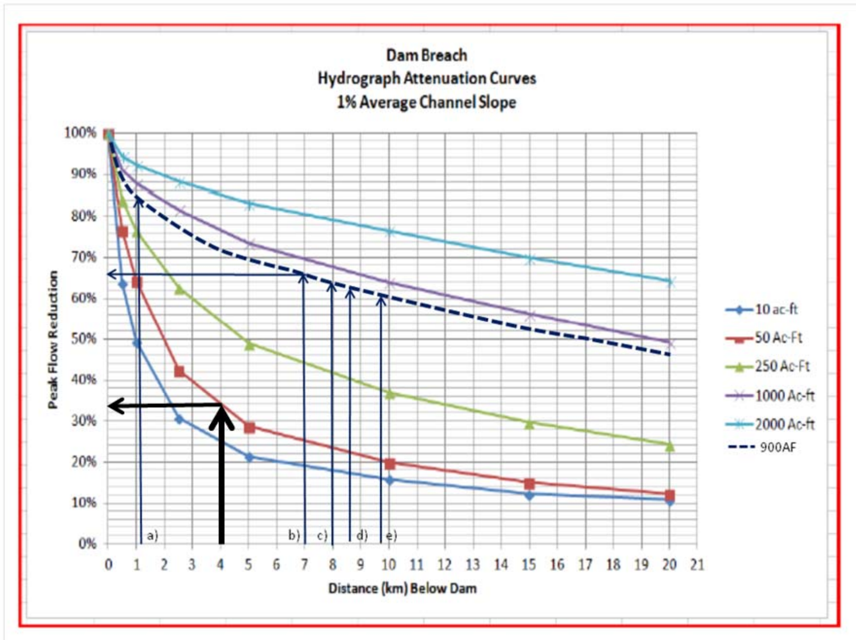
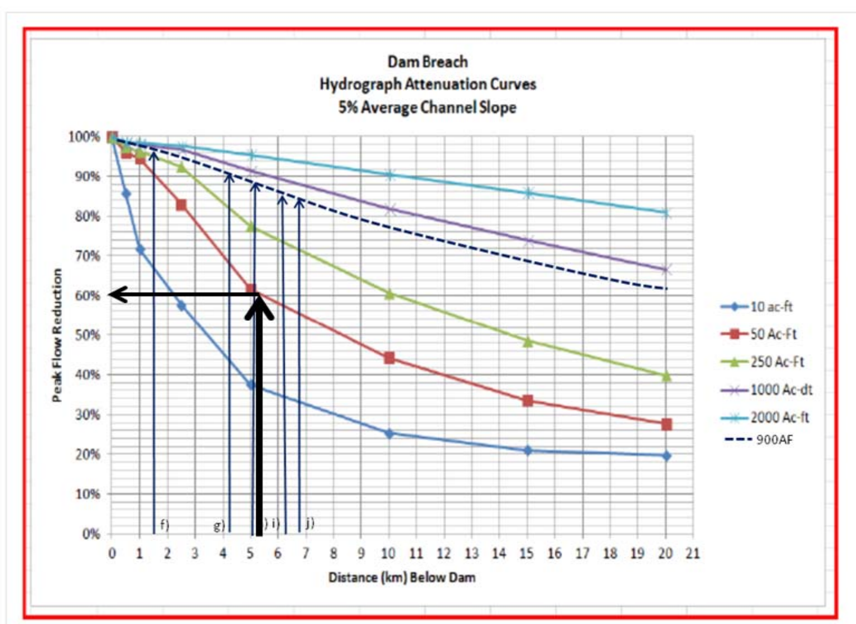


Figure A2: Hydrograph Attenuation Curves – 5% Average Channel Slopes



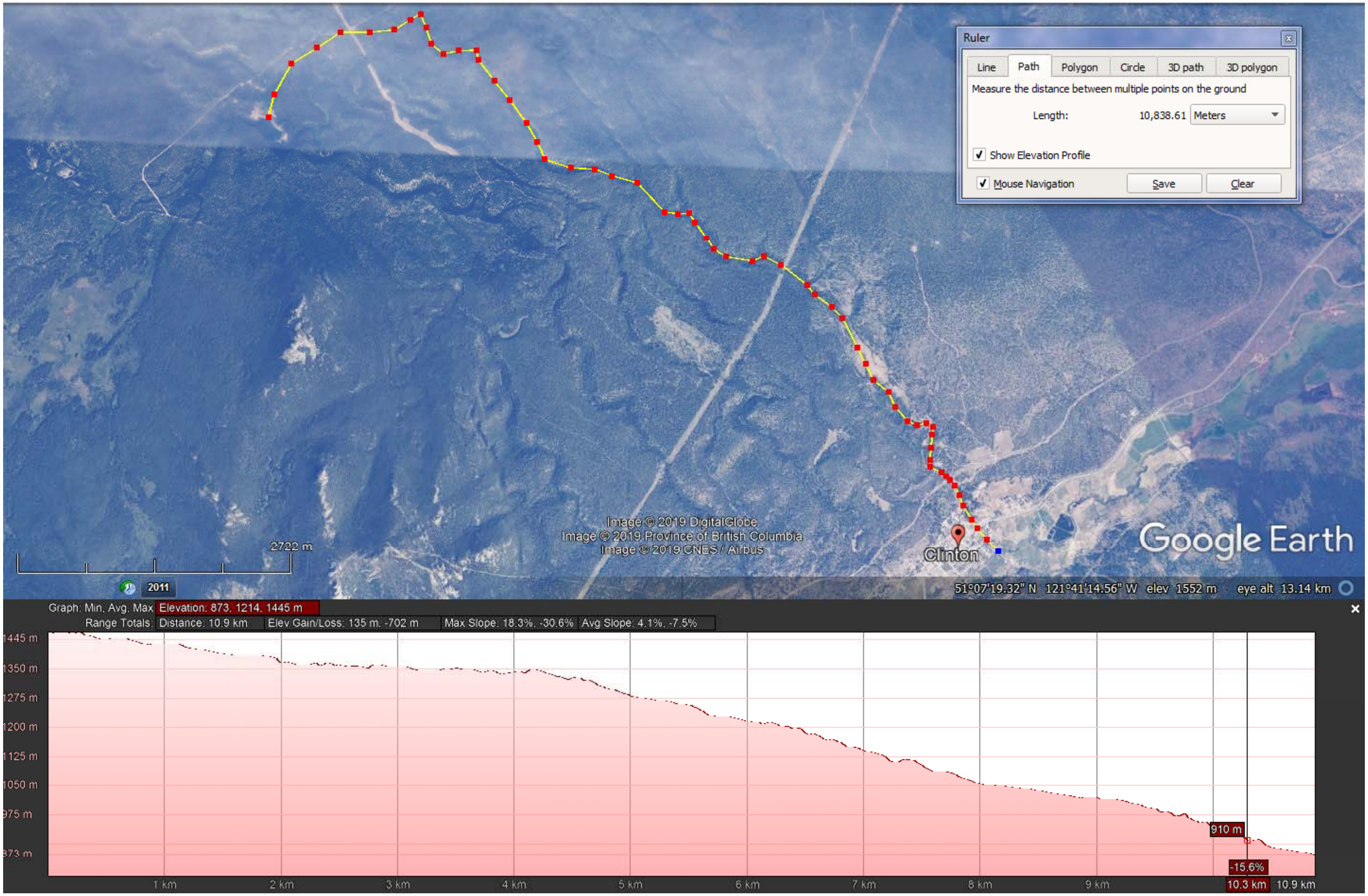

Ruler
Line
Path
Polygon
Circle
3D path
3D polygon
Measure the distance between multiple points on the ground
Length: 10,838.61 Meters
Show Elevation Profile
Mouse Navigation
Save
Clear
Image © 2019 DigitalGlobe
Image © 2019 Province of British Columbia
Image © 2019 CNES / Airbus
Clinton
Google Earth
2722 m
2011
51°07'19.32" N 121°41'14.56" W elev 1552 m eye alt 13.14 km
Graph: Min, Avg, Max Elevation: 873, 1214, 1445 m
Range Totals: Distance: 10.9 km Elev Gain/Loss: 135 m, -702 m Max Slope: 18.3%, -30.6% Avg Slope: 4.1%, -7.5%
910 m
-15.6%
10.3 km
10.9 km

Figure A3

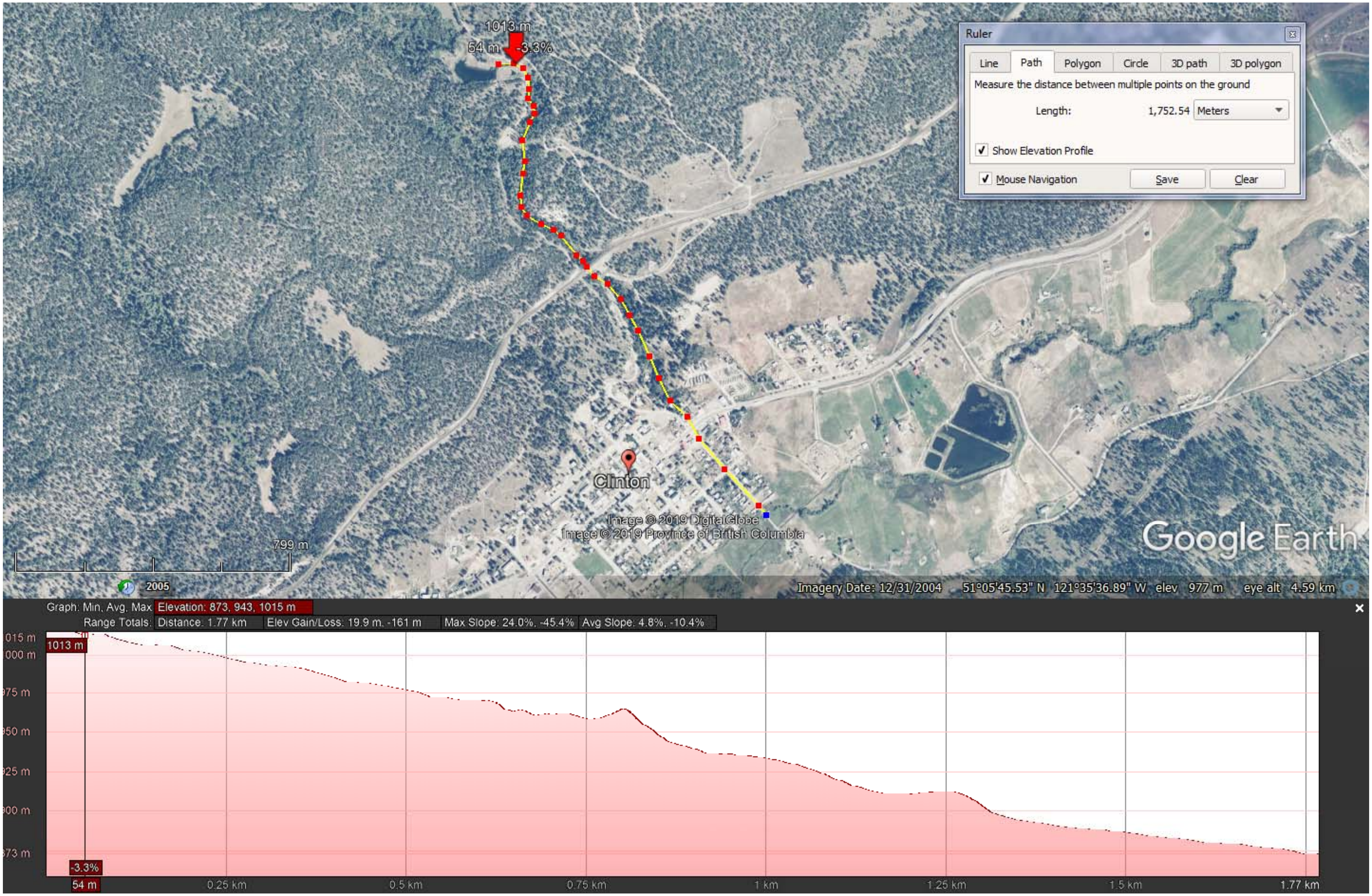

1013 m
54 m
-3.3%
Ruler
Line
Path
Polygon
Circle
3D path
3D polygon
Measure the distance between multiple points on the ground
Length: 1,752.54 Meters
Show Elevation Profile
Mouse Navigation
Save
Clear
Clinton
Image © 2019 DigitalGlobe
Image © 2019 Province of British Columbia
Google Earth
799 m
2005
Imagery Date: 12/31/2004
51°05'45.53" N 121°35'36.89" W elev 977 m eye alt 4.59 km
Graph: Min, Avg, Max Elevation: 873, 943, 1015 m
Range Totals: Distance: 1.77 km
Elev Gain/Loss: 19.9 m, -161 m
Max Slope: 24.0%, -45.4%
Avg Slope: 4.8%, -10.4%
0.25 km
0.5 km
0.75 km
1 km
1.25 km
1.5 km
1.77 km

Figure A4

Flood routing should be continued to a point downstream where the dam break flood no longer poses a risk to life and there is limited potential for further property damage or when the flood has attenuated.

In the case of this study, this point has been Tingley Street in the Village and where the Clinton Creek confluences with the Cutoff Valley Creek. It has been assumed that the valley here is reasonably flat and that the dam break flood attenuates in this floodplain; to a point that it does not pose a major risk to life. The creek downstream flows through reasonably uninhabited agricultural fields before it enters the Bonaparte River. As such, this lower portion of the creek below the Village was not analyzed.

We arrived at peak flood wave discharges as follows:

Using Figure A1 for the first 4 km below the Upper Clinton Creek Reservoir Dam (Section 14)

a) (0.35 * 50 m^3/s) = 17.5 m^3/s.

This is possible given the way the creek bed widens out and the density of the forest vegetation on the banks.

However, the end volume associated with the dam break hydrograph will still propagate downstream, so this reduction put forward by the simplified method is only taken under advisement in the analysis of this dam break wave down the Clinton Creek.

Between the 8.2 km and 8.8 km marks (sections 29 to 33) where the festival camping occurs on occasion – use Figure A2 for an average 5% slope

b) (0.70 * 17.5 m^3/s) = 12.25 m^3/s.

Where the channel slope starts getting – use Figure A2 for an average 5% slope

c) Down to the railway embankment at 10.3 km below the dam = (0.60 * 17.5 m^3/s) = 10.5 m^3/s.

An approximation of the inundation at a given location can be made using:

a) Peak dam breach discharge at various key point along the channel as indicated above;

b) Site specific channel cross-section data (obtained from DEM coverage collected during this assessment); and

c) Representative flow velocities from Table A1 below.

Table A1 – Representative Flow Velocities for Use in Estimating Inundation from Dam Break Floods

Channel Type	1		2		3	
Main Channel	Gravel		Gravel, cobbles		Gravel, cobbles & boulders	
Overbanks	Grass, pasture		Irregular brush & scattered shrubs		Wooded	
	Bedslope %	Velocity m/s	Bedslope %	Velocity m/s	Bedslope %	Velocity m/s
	0.1%	0.7	0.1%	0.5	0.1%	0.4
	0.2%	1.0	0.2%	0.7	0.2%	0.6
	0.3%	1.2	0.3%	0.9	0.3%	0.7
	0.4%	1.5	0.4%	1.1	0.4%	0.8
	0.6%	1.8	0.6%	1.3	0.6%	1.0
	0.8%	2.0	0.8%	1.5	0.8%	1.2
	1.1%	2.5	1.1%	1.8	1.1%	1.4
	1.5%	2.9	1.5%	2.1	1.5%	1.6
	1.9%	3.2	1.9%	2.3	1.9%	1.9
	3.8%	3.7	3.8%	3.3	3.8%	2.6
	5.7%	3.7	5.7%	3.7	5.7%	3.2
	7.6%	3.7	7.6%	3.7	7.6%	3.7

Using the MFLNRO simplified method in Table A1, the following velocities have been selected:

a) Upper portion (4 km below the dam) = 1.8 m/s

b) Lower reach to the CN Railway line (10.3 km mark) = 3.7 m/s

(Note: These average velocities were checked in HECRAS later and are a little on the high side for the lower portion of this creek).

The cross sectional channel area required to pass the flood would be:

$$A = Qx / V$$

where:

A = Cross-sectional area of channel and overbank (m^2)

Qx = Peak flood discharge (m^3/s)

V = Representative average velocity (m/s) at the cross-section

The resulting inundation mapping is expected to represent a conservative estimate of the consequences of a dam failure.

This translates to the following:

a) At the 4 km mark = 17.5 m^3/s (and 50 m^3/s assuming very little attenuation)
$A = Qx / V = 17.5/1.8 = 9.72\ m^2$ (and $50/1.8 = 20.8\ m^2$)

Using the GIS generated cross-section – the average depth is = 1.2 m at this point (or 2 m).

b) At the 8.3 km mark where temporary campers reside during a music festival once a year = 12.25 m^3/s (and 50 m^3/s assuming very little attenuation)
A = Qx / V = 12.25/3.7 = 3.31 m^2 (and 50/3.7 = 13.5 m^2)
Using cross-section 30, the depth is between 0.1 and 0.7 m at this point (or 0.1 to 1.6 m at different places in the campground and creek bed).

c) Upstream of the railway embankment (Section 38 c above the backwater elevation caused by the railway embankment) = 10.5 m^3/s (and 50 m^3/s assuming very little attenuation)
A = 10/3.7 = 2.7 m^2 (and 50/3.7 = 13.5 m^2)
Depth = 0.3 m at this point (or 1.42 m)

These depths and elevations were checked using HECRAS and were found to be representative. They were then transferred to the attached inundation maps.

It may be possible that the dam break flood undermines the spillway and a portion of the 3m high dam wall at the Lower Clinton Creek Reservoir. These two flows could impound behind the railway line embankment if the 1.8 m diameter culvert becomes blocked with debris.

In this case, there is a chance that the embankment will hold water until the impounded waters start flowing over the embankment and erode the downstream face of the embankment. If erosion is severe and cuts back through the embankment, this would result in a dam break scenario of its own with bigger consequences to the Village than the dam break flood wave from an Upper Clinton Creek Reservoir dam breach.

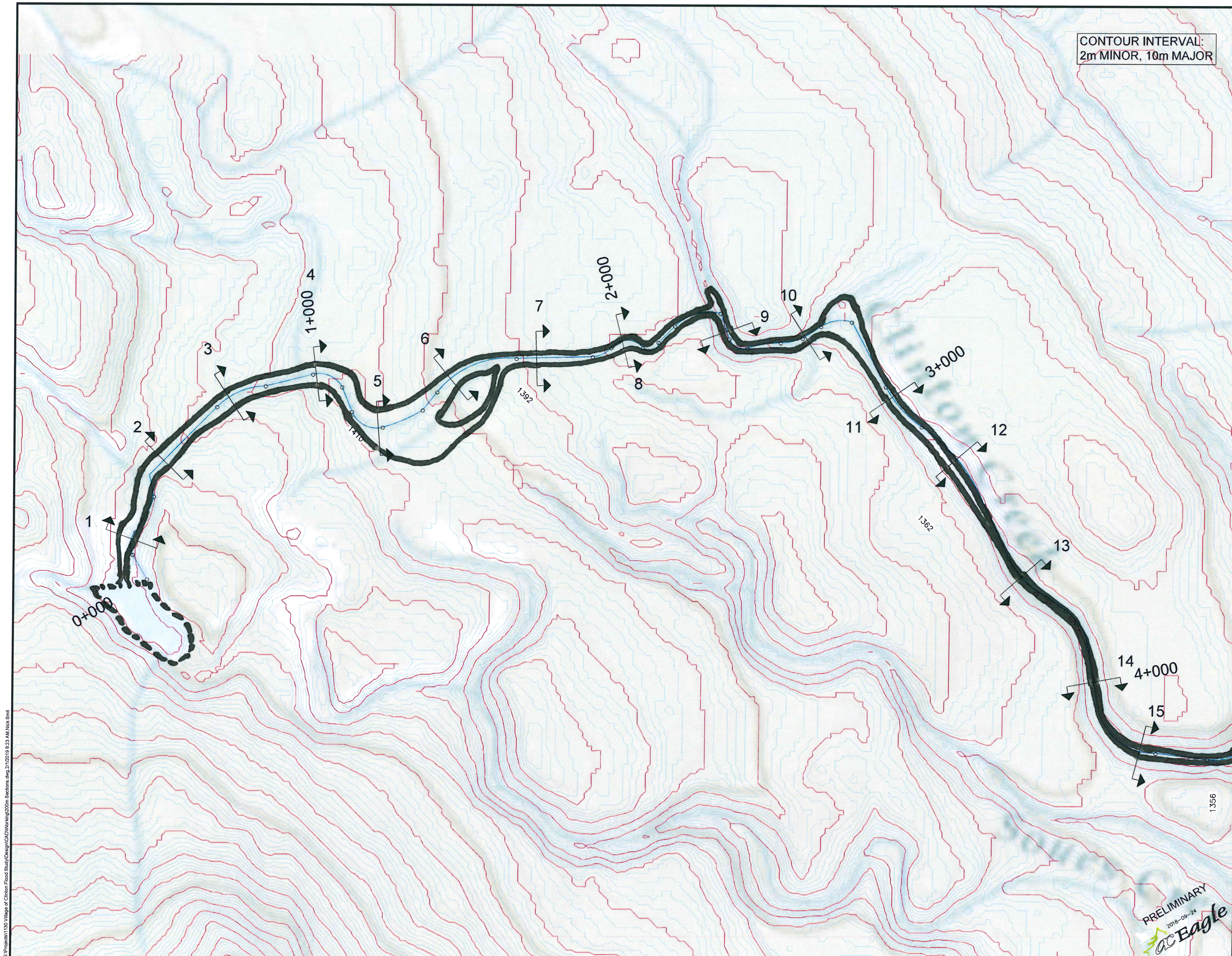
In the case where the culvert is not blocked, a culvert flow of 16 m^3/s would enter the Village and run down the streets as it has done in the past. This would be an early warning for emergency personnel to check the damming of water behind the railway embankment. If there is significant build up of water behind the embankment (including if the culvert is plugged by debris), emergency personnel would have to create an evacuation order in the Village.

3.2 HECRAS Method

The 48 cross-sections utilized in this evaluation were entered into the HECRAS model and reach assessments and flow runs conducted.

Although the resolution of velocities were more refined due to the larger number of cross-sections utilized, it did not change the peak flood wave depths and velocities significantly at the two key areas mentioned above.

Figures A.5 to A9 show profiles of the reach tested.



REFERENCE DRAWINGS

Legend

NO.	DATE	DESCRIPTION	BY	APPD

REVISIONS & ISSUES

PROFESSIONAL SEAL

DESIGN DKA
DATE:
DRAWN NCS
DATE:
CHECK DKA
DATE:
APPD BY CONSULT.
DATE:
APPD BY CITY
DATE:

SCALE
HOR: 1:7,500 (0 75 150 225 300 m)
VER: 1:7,500 (0 75 150 225 300 m)

AC EAGLE ENTERPRISES LTD.
102-925 McMaster Way
Kamloops, BC V2E 6K2
Tel (250) 372-2149
Fax (250) 374-2129
www.aceagle.ca

1130-001-01

VILLAGE OF CLINTON
DAM BREAK ANALYSIS

SHEET 01 OF 01
CONSULT. DWG. NO. P02
CITY DWG. NO.
REVISION 01

REFERENCE DRAWINGS

Legend

Existing Edge of Asphalt
Existing edge of Gravel
Existing Fence
Existing Top of Slope
Existing Toe of Slope
Existing Hedge/Treeline
Existing Deciduous/Coniferous/Shrub
Prop./Existing Watermain
Prop./Existing Water Service
Prop./Adjusted/Existing Water Valve
Prop./Existing Fire Hydrant
Prop./Existing Water Standpipe
Prop./Existing Curb Stop
Prop./Existing End Cap
Prop./Existing Sanitary Sewer
Prop./Existing Sanitary Forcemain
Prop./Existing Sanitary Service
Prop./Adjusted/Existing Sanitary Manhole
Prop./Existing Inspection Chamber
Prop./Existing Storm Sewer
Prop./Existing Storm Forcemain
Prop./Existing Storm Service
Prop./Existing Culvert
Prop./Adjusted/Existing Storm Manhole
Prop./Existing Catch Basin
Prop./Existing Side Inlet Catch Basin
Gas
Telephone
Vault
Junction Box
Hydro Power
Municipal Elec
Cable
Hydro /Telephone Manhole
Anchor Wire/Anchor Pole
Hydro/ Telephone /Hydro-Tel Pole
Hydro/Hydro-Tel Pole with Transformer
Light on Pole/Underground on Pole
Decorative/Davit Light
Parking Meter
Mail Box
Prop./Existing Traffic Sign
Prop./Existing Slope Sign
Monument/Iron Pin/Survey Control

NO.	DATE	DESCRIPTION	BY	APP'D

REVISIONS & ISSUES

DESIGN DKA
DATE:
DRAWN NCS
DATE:
CHECK DKA
DATE:
APPD BY CONSULT.
DATE:
APPD BY CITY
DATE:

PROFESSIONAL SEAL

SCALE
HOR: 1:7,500 — 0 75 150 225 300 m
VER: 1:7,500 — 0 75 150 225 300 m

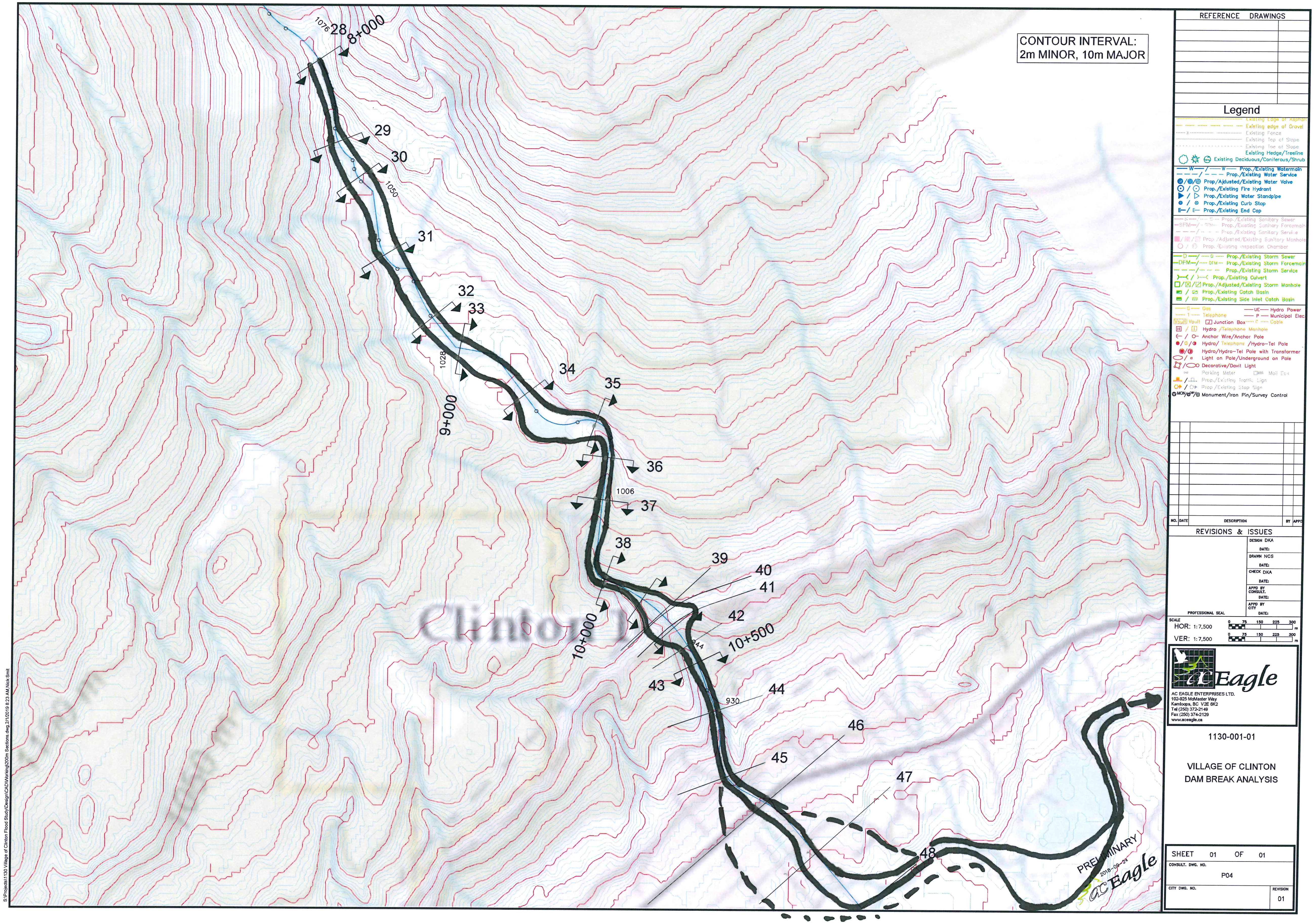
AC Eagle

AC EAGLE ENTERPRISES LTD.
102-925 McMaster Way
Kamloops, BC V2E 6K2
Tel (250) 373-2149
Fax (250) 374-2129
www.aceagle.ca

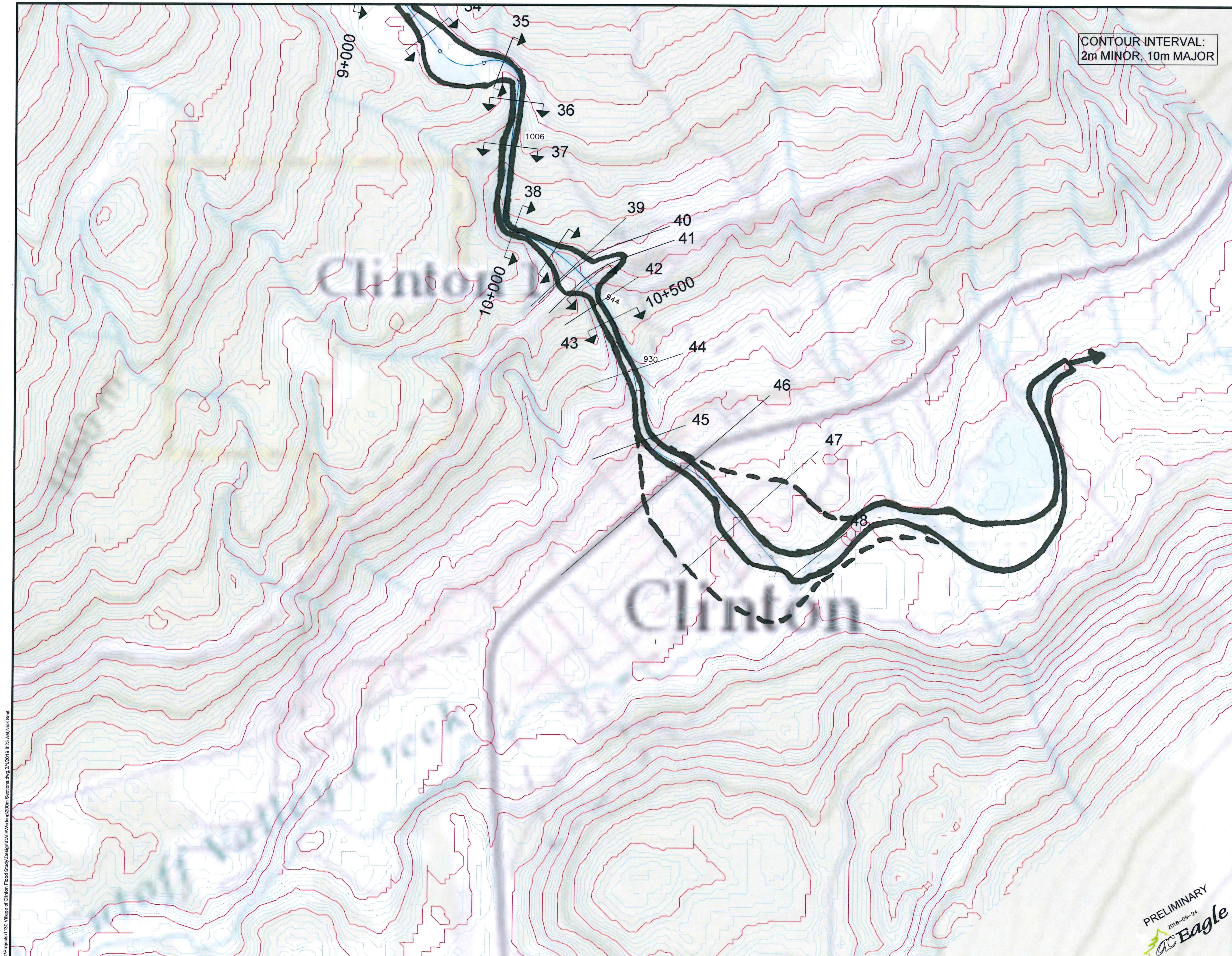
1130-001-01

VILLAGE OF CLINTON
DAM BREAK ANALYSIS

SHEET 01 OF 01
CONSULT. DWG. NO.
P03
CITY DWG. NO.
REVISION
01



CONTOUR INTERVAL:
2m MINOR, 10m MAJOR
8+000
9+000
10+000
10+500
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
1076
1050
1028
1006
930
Clinton
PRELIMINARY
Eagle
REFERENCE DRAWINGS
Legend
Existing Deciduous/Coniferous/Shrub
Prop./Existing Watermain
Prop./Existing Water Service
Prop./Adjusted/Existing Water Valve
Prop./Existing Fire Hydrant
Prop./Existing Water Standpipe
Prop./Existing Curb Stop
Prop./Existing End Cap
Prop./Existing Storm Sewer
Prop./Existing Storm Forcemain
Prop./Existing Storm Service
Prop./Existing Culvert
Prop./Adjusted/Existing Storm Manhole
Prop./Existing Catch Basin
Prop./Existing Side Inlet Catch Basin
Hydro Power
Municipal Elec
Junction Box
Hydro /Telephone Manhole
Anchor Wire/Anchor Pole
Hydro/Hydro-Tel Pole with Transformer
Light on Pole/Underground on Pole
Decorative/Davit Light
Monument/Iron Pin/Survey Control
REVISIONS & ISSUES
DESIGN DKA
DRAWN NCS
CHECK DKA
PROFESSIONAL SEAL
SCALE
HOR: 1:7,500
VER: 1:7,500
AC EAGLE ENTERPRISES LTD.
Kamloops, BC
www.aceagle.ca
1130-001-01
VILLAGE OF CLINTON
DAM BREAK ANALYSIS
SHEET 01 OF 01
P04
REVISION
01



REFERENCE DRAWINGS

Legend

Existing Edge of Asphalt
Existing edge of Gravel
Existing Fence
Existing Top of Slope
Existing Toe of Slope
Existing Hedge/Treeline
Existing Deciduous/Coniferous/Shrub
Prop./Existing Watermain
Prop./Existing Water Service
Prop/Ajdusted/Existing Water Valve
Prop./Existing Fire Hydrant
Prop./Existing Water Standpipe
Prop./Existing Curb Stop
Prop./Existing End Cap
Prop./Existing Sanitary Sewer
Prop./Existing Sanitary Forcemain
Prop./Existing Sanitary Service
Prop./Adjusted/Existing Sanitary Manhole
Prop./Existing Inspection Chamber
Prop./Existing Storm Sewer
Prop./Existing Storm Forcemain
Prop./Existing Storm Service
Prop./Existing Culvert
Prop./Adjusted/Existing Storm Manhole
Prop./Existing Catch Basin
Prop./Existing Side Inlet Catch Basin
Gas
Hydro Power
Telephone
Municipal Elec.
Vault
Junction Box
Cable
Hydro /Telephone Manhole
Anchor Wire/Anchor Pole
Hydro/ Telephone /Hydro-Tel Pole
Hydro/Hydro-Tel Pole with Transformer
Light on Pole/Underground on Pole
Decorative/Davit Light
Parking Meter
Mail Box
Prop./Existing Traffic Sign
Prop./Existing Stop Sign
Monument/Iron Pin/Survey Control

NO.	DATE	DESCRIPTION	BY	APPD

REVISIONS & ISSUES

PROFESSIONAL SEAL

DESIGN DKA DATE:
DRAWN NCS DATE:
CHECK DKA DATE:
APPD BY CONSULT. DATE:
APPD BY CITY DATE:

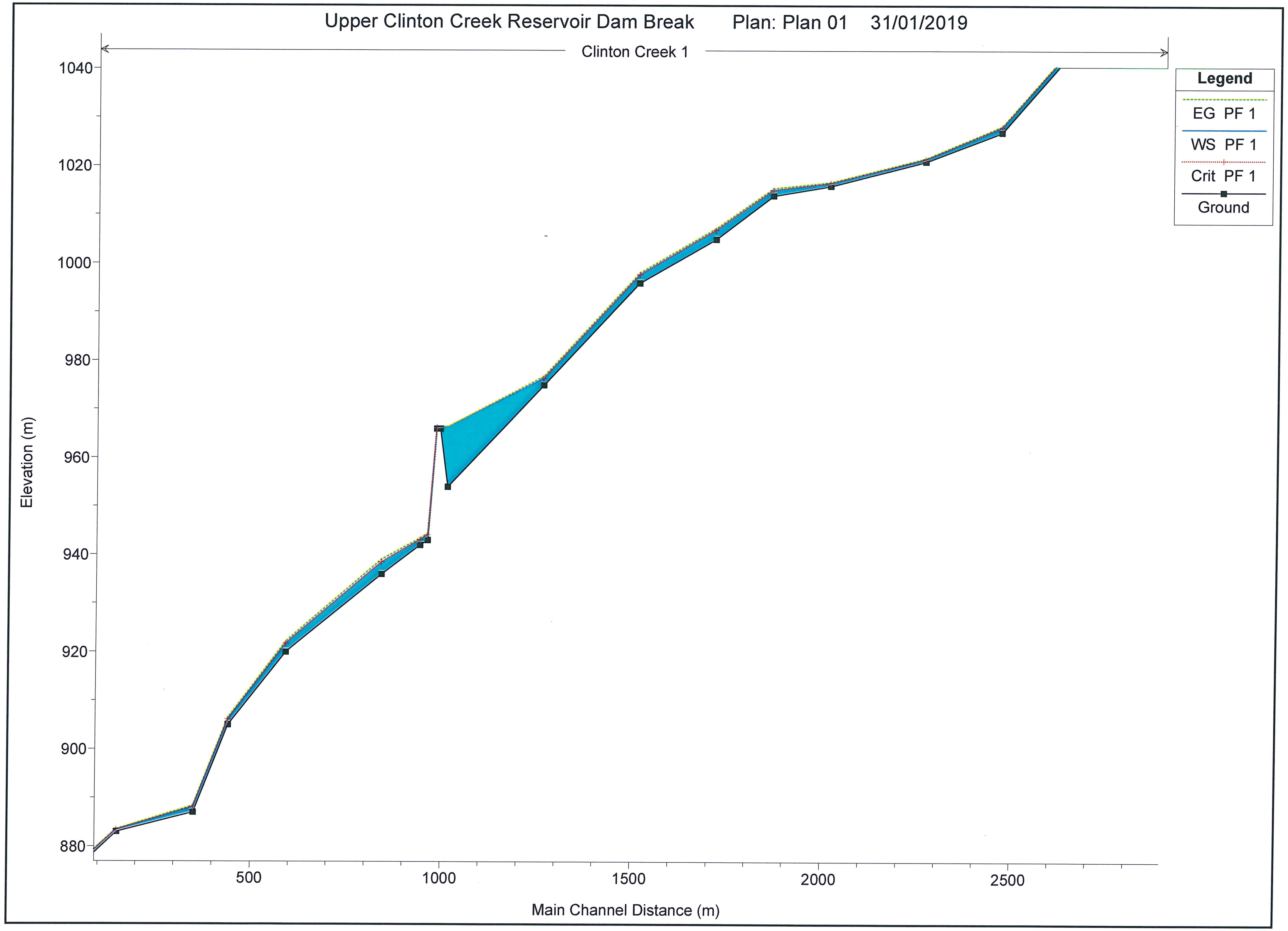
SCALE
HOR: 1:7,500 (0 75 150 225 300 m)
VER: 1:7,500 (0 75 150 225 300 m)

AC EAGLE ENTERPRISES LTD.
102-925 McMaster Way
Kamloops, BC V2E 6K2
Tel (250) 372-2149
Fax (250) 374-2129
www.aceagle.ca

1130-001-01

VILLAGE OF CLINTON
DAM BREAK ANALYSIS

SHEET 01 OF 01
CONSULT. DWG. NO. P05
CITY DWG. NO.
REVISION 01



Upper Clinton Creek Reservoir Dam Break   Plan: Plan 01   31/01/2019
Clinton Creek 1
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Elevation (m)
1040
1020
1000
980
960
940
920
900
880
500
1000
1500
2000
2500
Main Channel Distance (m)

The Village is located on the alluvial fan of the Clinton Creek.

Figure A9 provides an indication of the dam break flooding in the Village associated with the attenuation created by the railway line embankment (i.e. culvert flow); and an embankment failure associated with overtopping or other undermining of water impounded behind it.

Caveat: Note that these flood lines are not to be utilized for house insurance and other legal processes. This is solely a rough indication of inundation that can be caused by a dam break flood caused by the failure of the Upper Clinton Creek Reservoir Dam, as well as a cascade effect of the Lower Clinton Creek Reservoir Dam and the railway embankment failures creating a secondary flood wave.

3.3 Peak Flood Wave Inundation Mapping

Shown on Figures A5 to A9 to determine the extent of the flood wave on the creek, the environment, housing and other infrastructure.

The consequence rating was revisited based on the impacts identified (see Attachment B)

3.4 Warning Times

Another important piece of information when estimating consequences is how much warning time will there be before the flood arrives, and perhaps how long will the area be under water. Certainly the warning time will affect the estimate of the loss of life.

Given the relatively small volume of live storage that would be released by a dam break, the flood hydrograph is only expected to last for a few hours.

There is a remote chance that the dam could break while the festival(s) are underway. Campers located near the thalwegs on the campground would be affected. The rest of the campground (wide valley) would only experience a flood depth of around 0.1 to 0.3 m deep during the dam break scenario. At night this would be difficult to detect, but it is unlikely that a large number of people may lose their lives.

It will start slowly as the dam starts failing, reaching the peak discharge of approximately 50 m^3/s after about half an hour. This slow rise in water level plus the one and a half hours or so it would take to travel downstream to the Village should allow some form of warning to residents here during waking hours.

At night, water flowing over the main highway through town should trigger 911 calls fairly soon. The alternative would be to have some form of electronic early warning system in the Clinton Creek at the Lower Clinton Creek Reservoir Dam, or next to the Village's Water Treatment Works at the 9.75 km mark, that alerts key roleplayers and first responders. This system could pick up larger meteorological events as well as the dam break flood wave.

The large flows that would be limited to around 16 m^3/s or slightly more through the culvert would enter town first and give pre-warning of water possibly impounding behind the railway embankment. The severity of this impounding (say half to three quarters of the way up the embankment) should be a cause for concern and issuing evacuation orders in the flood path through the Village (Figure A9).

ATTACHMENT B: UPPER CLINTON CREEK RESERVOIR DAM SAFETY CLASSIFICATION RATING (2019 update)

1. Objective

The responsibility for classifying a dam in BC remains with the Ministry of Forests, Lands, and Natural Resource Operations Dam Safety Officer (DSO). The Upper Clinton Creek Reservoir Dam has previously been classified as having a “High” dam safety consequence rating.

The BC Dam Safety Regulation (Reg. 44/2000 including amendments up to BC Reg. 163/2011) calls for an annual evaluation of this rating by the Dam Owner. In other words, it is the Dam Owner’s responsibility to observe downstream development and to report any notable changes to the DSO.

2. Summary of Findings

In considering a catastrophic dam failure at Upper Clinton Creek Reservoir Dam, there has been no changes in downstream loss of life consequences, infrastructure and economic impacts, and environmental consequences, since the Village of Clinton filed their 2018 inspection report.

Based on the table in Schedule 1 of the BC Dam Safety Regulation, and selections made previously by the DSO; it is the authors opinion that the Upper Clinton Creek Reservoir Dam safety classification should remain as “High”, based on the recent 2018 dam breach and flood routing analysis.

3. Review of Downstream Conditions

3.1 General
Attachment A provides the details of the dam break analysis.

3.2 Initial Conditions
A “sunny-day”[1] dam failure and a “flood-induced”[2] failure have been considered at Upper Clinton Creek Reservoir Dam.

Dealing with the flood-induced scenario first. The Upper Clinton Creek Reservoir Dam has adequately sized spillway and low level outlet discharge capacities. By the time that flood flows reach the level of the Inflow Design Flood (IDF), with 0.9 m of freeboard to spare, most of the water flowing down the various Clinton Creek tributaries as well as neighbouring watersheds will have caused flood mayhem to downstream infrastructure and the environment.

As such, the focus of this consequence evaluation shifts towards the sunny-day failure. The dam break may be slow with an escalating flow rate as the dam wall or spillway fails. Since it

---

[1] “Sunny-day” failure refers to a sudden failure that results during normal operations and may be caused by an earthquake, mis-operation of the dam, or other event.
[2] “Flood-induced” failures occur together with a flood of magnitude greater than the dam can safely pass.

probably will not be noticed before a large flood strikes the railway embankment and the Village, the maximum flow rate of 50 to 55 m^3/s has been assumed just downstream of the dam wall (Attachment A).

The related assumption is that this flow rate takes place through a 5 m wide and 3 m deep breach through the earthfill wall adjacent to the concrete spillway. At the 50 m^3/s peak and a diminishing flow rate, it would take about 30 minutes to draw down the live storage of the lake (i.e. the water held back by the dam).

3.3 Possible Impacts

A wall of water in the range of 2.5 m to 3 m could leave the dam and make its way down the Clinton Creek water course for 9.2 km before it reaches the Lower Reservoir Dam.

This flood wave would pick up a lot of wood and silty burden that would be deposited in the Lower Reservoir and behind the railway embankment that is located about 900 m downstream.

If the 1.8 m diameter culvert under the railway embankment becomes plugged with debris, the build-up of water behind this embankment poses an enormous risk to the Village and the strategic continuity of rail traffic on this line. Water overtopping of the embankment could cause erosion of the 10 m high earthfill embankment.

These type of embankments are not usually designed to impound water behind them and failure would send a wall of water and debris into the Village located a few hundred metres downstream. HECRAS modelling showed that the flood attenuates to a depth of 2.5 m in the valley directly below the embankment and then down to around a metre depth on average through the Village on the creek’s alluvial fan.

The stream flows another 350 m beyond the CN Rail embankment before running between houses in the Village and eventually through a 4 ft diameter culvert to the lower part of the townsite.

There are a number of houses that are located in the path of the creek and an overland flow down McDonald Avenue if the 4 ft diameter culvert in the Village becomes plugged or out of capacity.

Further afield, the Village’s wastewater treatment works, downstream farm outbuildings, stored hay, livestock and portions of hay fields may be affected by the flood as well.

Flood waters would eventually make their way into the Bonaparte River, which is fish bearing.

3.4 Dam Failure Consequences

In all the discussion below, the premise has been made that there has been no change in the downstream conditions since the MFLNRO Dam Safety Officer (DSO) has selected the “High” rating for the Upper Clinton Creek Reservoir Dam.

3.4.1 Loss of Life

It has been assumed that roughly the same number of people are resident downstream as there were in 2018. Also the DSO’s decision that there is a relatively “low potential for multiple loss of life” (less than 10 people) was adopted in the 2014 Dam Safety evaluation.

To provide early public warning and to lower the risk to human life in the case of a dam break, it imperative that the Dam Owners maintain their dedicated Emergency Preparedness Plan for Upper Clinton Creek Reservoir Dam and the creek system below. This plan should be forwarded to local First Responders as well as CN Rail and the Ministry of Transportation and Infrastructure.

3.4.2 Economic Impacts

Other than a few forestry roads, there is no economic development until the 8.4 km mark at the Lower Clinton Creek Reservoir Dam. Road access to the water treatment plant may be disrupted by a major flood.

Highway 97 that runs through Clinton and the Village township itself is other infrastructure that could be affected.

3.4.3 Environmental and Cultural Consequences

In the past, it has been assumed that these flood events would damage the riparian corridor, and that it would re-establish over time.

4. Classification of Upper Clinton Creek Reservoir Dam

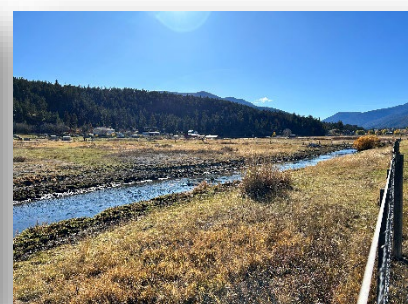
Based on the above-mentioned input and comparing it to Schedule 1 of the BC Dam Safety Regulation, it is believed fair that the MFLNRO has classified the Upper Clinton Creek Reservoir Dam in the “High” Consequence rating category. Dams are classified to provide guidance on the standard of care expected from Dam Owners.

APPENDIX B

Floodplain Mapping Report

Floodplain Mapping Report

Village of Clinton



February 2025

Project No. 675-541

ENGINEERING ■ PLANNING ■ URBAN DESIGN ■ LAND SURVEYING

2089 Falcon Rd | Kamloops BC | V2C 4J2 | true.ca | tel 250.828.0881

Distribution List

# of Hard Copies	PDF Required	Association / Company Name

Revision Log

Revision #	Revised by	Date	Issue / Revision Description
1	PP	Sept 26, 2024	Draft, Issued for Client Comment
2	PP	Feb 12, 2025	Final

Report Submission

Report Prepared By:

PROFESSIONAL PROVINCE OF P. PRODANOVIC # 52340 BRITISH COLUMBIA ENGINEER

Permit to Practice
No. 1000129
2025-02-12

Pat Prodanovic, Ph.D., P. Eng.
Project Engineer

Report Reviewed By:

PROFESSIONAL PROVINCE OF J. P. WELKE # 35705 BRITISH COLUMBIA ENGINEER

2025-02-11

Jonathan Welke, P. Eng.
Project Engineer

R:\Clients\600-699\675\675-541\05 Reports\Floodplain Mapping Report\675-541 Village of Clinton-Floodplain Mapping Report-February 2025.docx

Table of Contents

Appendices

List of Tables

List of Figures

1.0 Introduction

The main objective of this work is to summarize hydrotechnical analyses carried out as part of a floodplain mapping initiative undertaken on behalf of the Village of Clinton, British Columbia. Funding for this project has been provided through the Community Emergency Preparedness Fund (CEPF), which is a suite of funding streams intended to enhance the resiliency of local governments, First Nations, and communities in responding to emergencies.

This report summarizes data, methodology, results, and main findings of the floodplain mapping exercise. The end product of the study is a series of maps (flood inundation map, flood hazard map, and a series of flood construction levels). This mapping is intended to provide support to the Village of Clinton in making informed decisions for future planning, policies and mitigation works related to projects along Clinton and Cutoff Creeks, the two main watercourses that flow through the village.

1.1 Project Background

Village of Clinton is located approximately 40 km northwest of the Village of Cache Creek along the Highway 97 corridor of the South-Central Interior of British Columbia. The Village was incorporated in 1963, and is a community located in an agricultural valley surrounded by mountains. Table 1-1 provides an overview of the Village's community profile.

TABLE 1-1 VILLAGE OF CLINTON COMMUNITY PROFILE

VILLAGE OF CLINTON - COMMUNITY PROFILE	
Regional District	Thompson-Nicola
Coordinates	Lon: 121° 35' 12" W Lat: 51° 05' 34" N
Median Elevation	1465 m
Municipal Area	8.1 km²
2021 Population	570 people
Annual precipitation	415 mm

Strategically positioned on Highway 97 midway between Vancouver and Prince George, Village of Clinton has a rich history spanning over 150 years dating back to the Cariboo Gold Rush. The community's economy is presently driven by the forest industry, complemented by contributions from the public sector, retail trade, and tourism.

The Village of Clinton has encountered past debris flood events triggered by its primary watercourses: Cutoff and Clinton Creeks. The local watercourses are categorized as freshet dominated streams, where the annual maximum runoff results from snowmelt and occurs between late May and early June each year.

Risk to future wildfires remains a strong threat for the Village of Clinton and its upstream watersheds, which could significantly impact extreme river flows in the immediate (post-burn) periods.

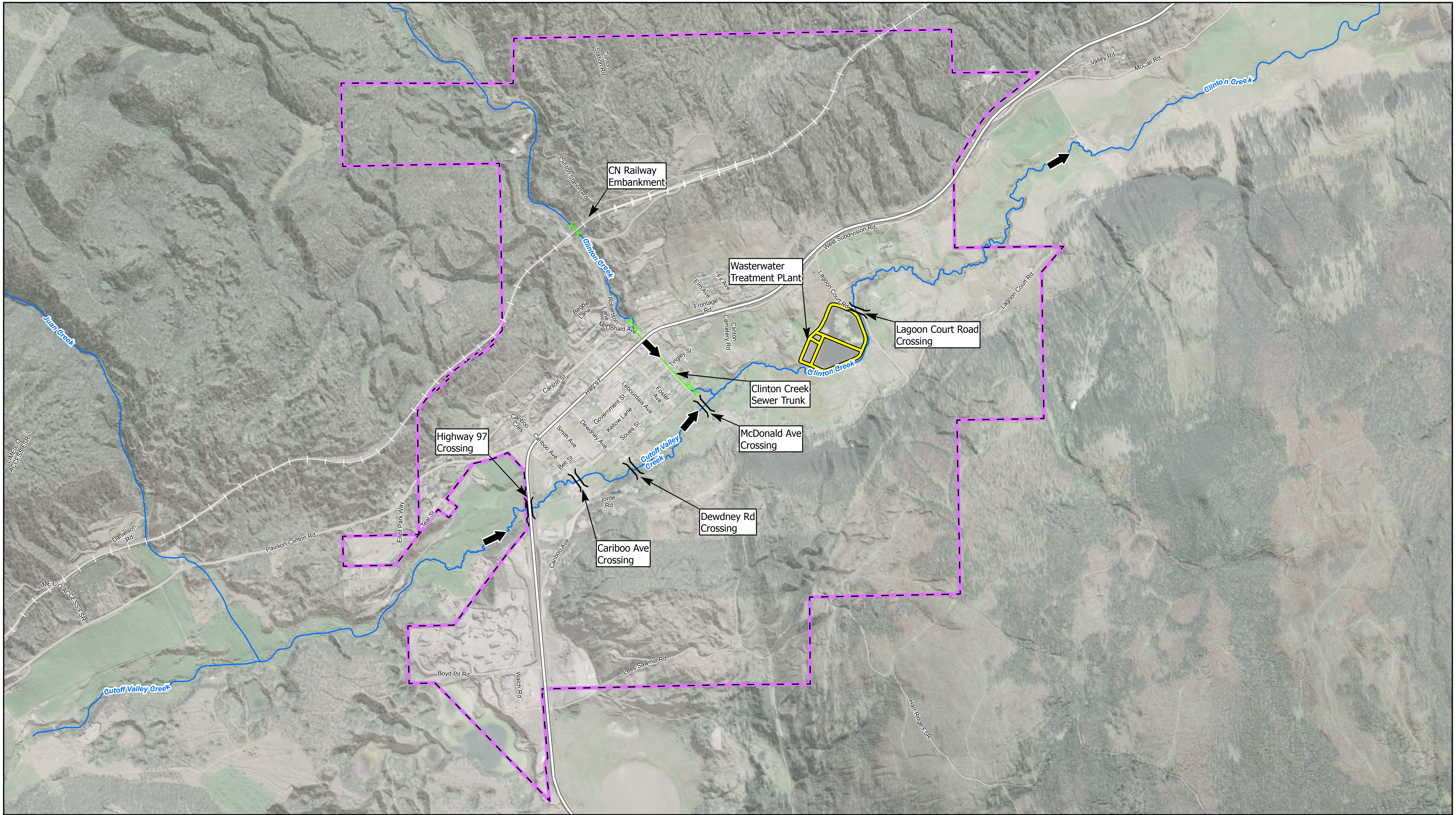
Village of Clinton had not been included in past floodplain mapping initiatives. In 2019 however, Fraser Basin Council (FBC) led an initiative that assessed clear-water floods, steep creek events (debris floods and debris flows), and landslide-dam floods in the Thompson River Watershed (BGC, 2019). The BGC (2019) study identified the Village of Clinton as a High Priority site.

1.2 Scope of Work

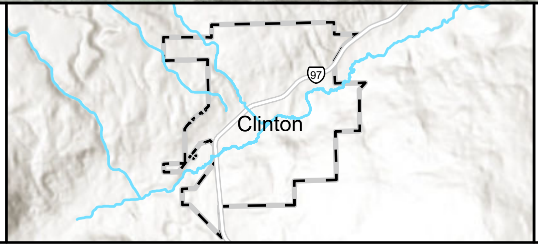
The scope of work includes completing a detailed floodplain mapping study within the municipal boundary of the Village of Clinton on Cutoff and Clinton Creeks, the two major watercourses. The study includes approximately 5.2 km of river and floodplain along the Cutoff and Clinton Creeks (east-west direction) and approximately 0.5 km of stream along the Clinton Creek (north-south direction). Study requirements for floodplain mapping include:

- Background review and data collection (historic flooding, previous studies, large scale topographic data, aerial photography, etc.),
- Field investigations (completion of topographic and bathymetric surveys),
- Digital terrain modelling (merging large scale topographic data with in-river bathymetry),
- Hydrologic assessment (establishing design flows, including consideration of climate change),
- Hydraulic assessment (determining flooding inundation limits, flood hazards and flood construction levels using hydraulic modeling),
- Floodplain mapping (developing relevant floodplain maps), and
- Reporting (summarizing study recommendation and conclusions).

The study area for the present assignment is shown in Figure 1-1, and includes the floodplain of the Clinton and Cutoff Creeks within the municipal boundary of the Village of Clinton.



CLINTON
SINCE 1863



Village of Clinton Study Area

Legend	
Flow Direction	Highway 97
River / Creek	Culvert
Lagoon Berm	Municipal Boundary (Village of Clinton)
Railway Tracks	

0 200 400 600 800 1,000 m

N

Reviewed by:	PP	Scale:	1:16,000
Revision #:	0	Issued for:	Review
Datum:	NAD 83 CSRS (Zone 10)	Drawn by:	RK
Vertical Datum:	CGVD2013	Date:	9/25/2024
Projection:	Transverse Mercator	Project Ref No.	675-541

TRUE

Figure 1-1

Sheet 1 of 1

R:\Clients\600-699\675\675-541\03 Drawings\GIS\675-541.aprx

1.3 Horizontal and Vertical Control

In this assignment, the horizontal reference plane used is NAD83(CSRS)/UTM Zone 10N. The vertical datum used is the Canadian Geodetic Vertical Datum 2013 (CGVD 2013). All topographic and bathymetric surveys, maps, inundation boundaries, flood elevations, and all other references are made to the above-noted standard. The project uses SI units, with dimensions reported in meters (m), and discharges reported in meters cubed per second (m^3/s).

2.0 Background Review and Data Collection

This section documents previous flood studies, historical flood events, and existing flood management infrastructure within the Village of Clinton. Data collection activities undertaken for the purposes of this assignment are also documented.

2.1 Previous Studies

Historical flooding documents and/or floodplain mapping within the limits of the study area include the following:

2.1.1 2019 Thompson River Watershed Geohazard Risk Prioritization (BGC, 2019)

Fraser Basin Council (FBC) retained BGC Engineering Inc. to carry out a clear-water flood, steep creek (debris flood and debris flow), and landslide-dam flood risk prioritization of the Thompson River watershed (Clinton Creek is a tributary of the Bonaparte River, which is a tributary of the Thompson River). Funding for the 2019 project was provided by Emergency Management BC (EMBC) and Public Safety Canada under Stream 1 of the Natural Disaster Mitigation Program (NDMP). The complete flood risk prioritization report is summarized in BGC (2019).

The primary objective of BGC (2019) was to characterize and prioritize flood, steep creek, and landslide hazards in the Thompson River watershed that might impact presently developed properties. Flood risk prioritization summary for the Village of Clinton confirms that two watercourses (Clinton Creek and Cutoff Creek) fall under high priority level when it comes to clear-water flooding. BGC (2019) identified that Clinton Creek watercourse has a high impact likelihood, exposure, and consequence rating with a potential impact on 217 parcels and 19 businesses.

2.1.2 2019 Clinton Creek Reservoir Dam Breach Analysis (AC Eagle, 2019)

The Village of Clinton has two reservoirs that supply and store raw water for the municipality. Both reservoirs are located on the Clinton Creek, above the Village. Furthest from the Village is the Upper Reservoir, which has been previously classified as a High Consequence structure according to the Provincial dam safety regulation. The Upper Reservoir is an earthen embankment structure that is 132 m long, 5.6 m high, with a 5 m wide crest that was constructed in 1981 (and upgraded in 1983).

The study by AC Eagle (2019) focused on the hydrotechnical analysis which assessed the consequence of a dam breach of the Upper Reservoir. An estimate of the peak flow during the dam breach was established, as were inundation limits from the reservoir to the Village limits. The main study finding was that the CN Railway embankment crossing Clinton Creek (which is approximately 20 m high with a 0.7 m diameter outlet culvert) represents a significant hazard should a breach of the Upper Reservoir take place. The culvert at the CN Railway embankment could easily be plugged during a dam breach (or an extreme flood), which implies that its 20 m high earthen embankment would act as a dam. Should the CN Railway embankment fail, a significant volume of water would be released downstream, which would cause wide spread flooding through the Village. AC Eagle (2019) states that approximately 30 to 40 houses on Robertson Lane, McDonald Crescent, and McDonald and Labourdais Avenue could be affected.

2.2 Historical Flood Events

The Village of Clinton is located a mountainous region frequently subject to damaging floods that can result in property damage, loss of life, and the interruption of transportation routes during times of hazards. Throughout its history, the Village of Clinton has faced clear water floods and debris flows, resulting in property damage and impact to municipal infrastructure. BGC (2019) has identified two major historic flood events at Clinton:

- **June 1, 1873,** where heavy rain caused a debris flow in Clinton. About 100 m of the street was buried by up to 3 m of debris, damaging several buildings. The debris flow was released by the breach of a dam or log jam (Septer, 2007).
- **July 31 – August 4, 2018,** where an intense rainstorm west of the Highway 97/Highway 99 intersection induced at least 17 post-wildfire debris flows along a 10 km stretch of Highway 99. Mudslides led to the closure of Highway 97 in both directions between Clinton and Cache Creek, causing traffic disruptions from July 31 to August 4, after which the road was fully reopened (Roden, 2018).

In the summer of 2017, the Bonaparte River watershed (which the Clinton Creek empties into) was impacted by the Elephant Hill wildfire. The Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) had the area of fire assessed for post-wildfire hazards and risks which was completed by SNT (2017). The resulting report concluded that approximately 60% of the total Bonaparte watershed area was burned.

Wildfire impacts hydrologic regime of the watershed due to rapid changes in forest cover and soil infiltration. Increased flood hazard is a function of the burned area at high and moderate severity. As well, due to logging, the Bonaparte watershed already had a relatively high ECA (Equivalent Clearcut Area) which also increases downstream flows. The wildfire burned most of the higher elevation areas (not logged) within the watershed increasing the effective ECA to very high.

Post-burn areas have a high potential in significantly impacting immediate to near-term hydrologic response of the watershed (which was experienced in 2018 after the wildfires of 2017). Existing literature on post-burn hydrologic response suggests that infiltration can reduce, and peak flow can significantly increase. As the watershed heals, its hydrologic response tends to approach the original pre-burn hydrologic state.

A photograph of the 2018 mudslide on Hwy 97 is shown in Figure 2-1.

FIGURE 2-1: 2018 MUDSLIDE ON HWY 97 BETWEEN CLINTON AND CACHE CREEK

2.3 Existing Flood Management Infrastructure

Flood management infrastructure in the Village of Clinton consists of existing stream crossings (bridges, culverts and embankments through existing roadways). There are no regulated dikes within Village's municipal boundary. An existing Waste Water Treatment Plan (WWTP) and its sewage lagoons are located within the floodplain just upstream of Lagoon Court Road.

Many stream crossings in Clinton have Corrugated Steel Pipe (CSP) culverts which range from 0.5 m to 1.5 m in diameter. Details of the stream crossings are shown in Table 2-1.

TABLE 2-1: EXISTING CROSSINGS WITHIN VILLAGE LIMITS

LOCATION	STREAM	TYPE	OPENING DIMENSION	LENGTH	EMBANKMENT HEIGHT*
Hwy 97	Cutoff Creek	Circular	1.5 m dia.	52 m	10.2 m
Cariboo Avenue	Cutoff Creek	Ellipsoidal	1.15 m span 0.82 m rise	13.5 m	1.9 m
Dewdney Avenue	Cutoff Creek	Circular	0.8 m dia.	5.2 m	N/A
McDonald Avenue	Cutoff Creek	Circular (double)	1.2 m dia. 0.5 m dia.	9.0 m	2.6 m
Lagoon Road	Clinton Creek	Circular	1.2 m dia.	14.4	3.3 m
CN Railway	Clinton Creek	Circular	0.7 m dia.	102 m	20 m
Parallel to McDonald Avenue	Clinton Creek	Circular	1.2 m dia.	425 m	1.8 m

Notes:
*Embankment height measured from lowest elevation of the channel bed to the roadway crest

The CN Railway embankment, located upstream of the town on the steep portion of the Clinton Creek, has an earthen embankment that is 20 m high. The culvert through the CN Railway embankment is 0.7 m in diameter and is approximately 102 m long. The CN Railway culvert has a high chance of being plugged with debris during a major flood event.

The culvert crossing Hwy 97 is the largest diameter, has a length of 52, with an embankment that is 10.2 m high. The Hwy 97 embankment has the potential to cause backwater on upstream portions of Cutoff Creek. During high flow events overtopping of the Hwy 97 is possible, which can generate overland flow for areas downstream. Channel downstream of the Hwy 97 is shown in Figure 2-2.

An existing storm sewer running parallel to McDonald Avenue is 1.2 m in diameter and approximately 425 m long. All flow from the upstream catchment of Clinton Creek runs through this storm sewer. Channel downstream of McDonald Avenue is shown in Figure 2-3.In case the capacity of the storm sewer is not sufficient to convey the flow volume, the culvert will surcharge and overland flooding will result. The overland slope along McDonald Avenue is about 5%, meaning that overland flow is anticipated to be shallow, but fast.

FIGURE 2-2: CUTOFF CREEK DOWNSTREAM OF HWY 97

FIGURE 2-3: CLINTON CREEK AT OUTLET OF MACDONALD AVE

2.4 LiDAR Topography and Imagery

In 2019 Fraser Basin Council (FBC) commissioned a campaign that collected LiDAR (Light Detection And Ranging) and ortho photography (geo-referenced aerial photographs) for several areas within the Thompson River watershed (including the present study area). LiDAR techniques use a laser beam to measure the duration of light reflecting from an object to its receiver. When mounted on an aircraft, a LiDAR instrument can collect high-resolution topographic (above water) data for large areas.

The Clinton floodplain within the Village limits was included in the FBC's LiDAR and orthophotography data collection campaigns of 2019. As such, the 2019 LiDAR and orthophotography represent the best available large-scale topographic and aerial photography data within the study area. FBC has supplied said data to TRUE Consulting for use in this floodplain mapping project. The supplied data includes:

- Classified LiDAR point cloud,
- 1.0 m pixel size Digital Elevation Model (DEM), and
- 0.15 m pixel size geo-referenced aerial photographs.

2.5 Topographic Data

Site specific topographic survey data was collected as part of this assignment. The survey was carried out using a Real Time Kinematic Global Navigation Satellite System (RTK-GNSS) unit, having instrument accuracy of 10 mm in the horizontal and 20 mm in the vertical plane. Vertical datum used was CGVD2013 and is thus consistent with the LiDAR data.

All survey work was performed by TRUE staff on April 19-20, 2023, and on November 2, 2023. Due to low flows in the creeks at the time of surveys, all field work could be safely completed using a field crew of two equipped with chest waders. The survey crew collected approximately 1,300 survey points within the study limit, many of which were in-water and/or along the shoreline.

A survey crew of two collected the following data:

- Photograph of the opening,
- Crest elevation of the bridge deck or road crossing,
- Measurement from the bridge deck to the underside of the soffit,
- Dimensions of structure opening (culvert diameter, invert elevations on upstream and downstream sides)
- Geometry of the creek's cross section, and
- Number and size of piers (if present).

A summary of the stream crossing information is presented in Table 2-1, where pertinent details collected during the survey field campaign are shown. In addition to stream crossings, the survey crew also collected stream bathymetry at several cross sections in both creeks. Data collected was used to incorporate bathymetry into the LiDAR digital elevation model.

3.0 Digital Terrain Modeling

LiDAR derived digital terrain models are used for hydraulic modeling as they efficiently capture geometry of terrain for large areas. However, the LiDAR sensors are not able to penetrate sufficiently through the water's surface, thus resulting in reduced accuracy for terrain surface below the water line. Geometry of the terrain under the water's surface is thus not captured using typical LiDAR products but is required for accurate assessments of river hydraulics for floodplain mapping purposes.

This section outlines the methodology employed that combines the LiDAR derived Digital Elevation Model (DEM) with digital terrain models and DEMs derived from topographic and bathymetric surveying. The combining of LiDAR with the survey derived DEMs are used to construct a hydraulic model ready DEM. The end product thus includes a digital surface accurate for both above and below water portions of the river and is used in all subsequent hydraulic modeling and floodplain mapping in this work.

3.1 LiDAR Digital Elevation Model

The 2019 LiDAR data set was provided by Fraser Basin Council (FBC) for use in this assignment. The LiDAR data provided included a DEM having a horizontal resolution of 1.0 m, as well as a classified LiDAR point cloud. The horizontal reference system and vertical datum of the provided LiDAR data were consistent with specifications outlined at the beginning of this report.

Given that existing channel widths in existing watercourses are small, the provided 1.0 m grid cell spacing provides limited number of grid cells across the channel. Since the LiDAR data was provided as a classified point cloud, staff from TRUE re-processed the LiDAR point cloud to create bare ground 0.25 m grid cell size DEM for use in the project. Smaller resolution grid size DEM was found to capture the channel geometry of the Cutoff and Clinton watercourses much better than the original (1.0 m) DEM.

The LiDAR DEM provides consistent information for the above water portion of the terrain to sufficient resolution to be used in the present undertaking. The topographic surveys within the study area were used to compare elevations between data collected using survey grade instrumentation and the LiDAR DEM product. In areas where the two sources of data overlapped, comparisons showed that on the ground measurements of elevations were consistent with the LiDAR DEM product, thus providing confidence in use of the LiDAR DEM elevations.

As noted earlier, the limitation of the LiDAR DEM is that underwater portions of the terrain are not captured. A method of capturing terrain below water's surface is discussed next.

3.2 In-Stream Digital Elevation Model

For Cutoff and Clinton Creeks surveyed channel geometries were used to create a Triangulated Irregular Network (TIN) model of the riverbed below the water surface. A customized procedure, similar to one provided by Merwade et. al. (2005), was used to transform the river alignment and the survey geometry from a Cartesian to a curvilinear orthogonal system. The reason for the coordinate transformation is that construction of a TIN surface using cross section-based river geometry is much simpler in the curvilinear orthogonal system than in the Cartesian system. After construction of the TIN surface in the curvilinear orthogonal system was completed, the surface was converted back to the Cartesian system, and used to construct an in-stream only DEM.

3.3 Hydraulic Model Ready Digital Elevation Model

The DEM of in-stream bathymetry was “burned into” (or merged with) the overland LiDAR DEM, ultimately producing a hydraulic model ready DEM that accurately captures the above and below water terrain of the river (required for accurate floodplain modeling). The merged digital surfaces, consisting of LiDAR topography and surveyed bathymetry, include the best available geometric data for the study area.

4.0 Hydrologic Assessment

This section provides the description of the study area, documents flow characterization methodology, details climate change analyses, and establishes design flows used in the floodplain mapping.

4.1 Watershed Description

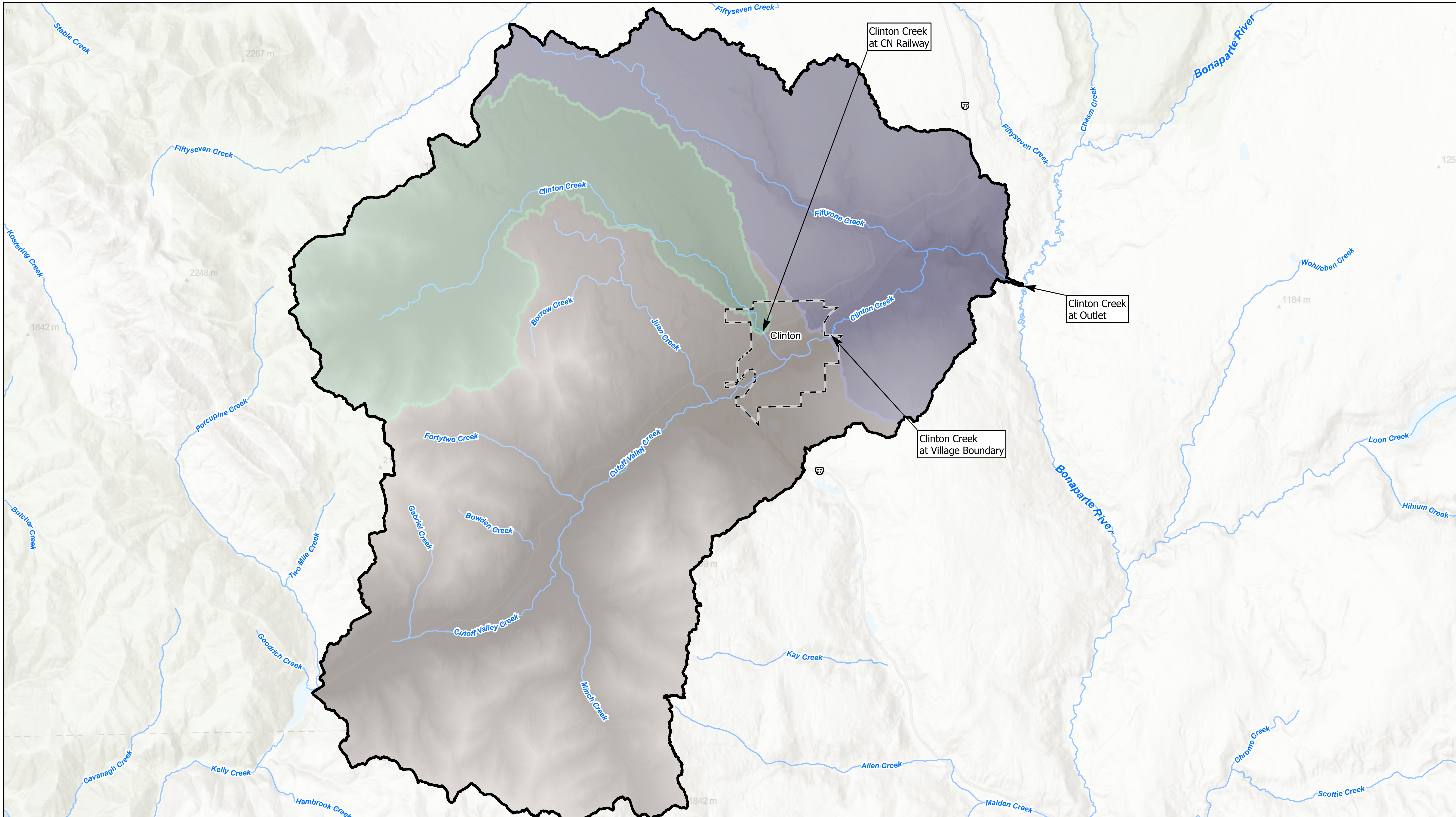
Clinton Creek is a tributary of the Bonaparte River, which is a tributary of the Thompson River, and lies within Southern Interior region of British Columbia. The Clinton Creek watershed has the following characteristics:

- Drainage area of approximately 288 km^2 at the outlet,
- Elevations ranging from 850 m to 2170 m above sea level (with a median of 1470 m),
- Mean annual precipitation of 415 mm, and
- A nival flow regime (where snowmelt dominates the flood peaks).

Urban and rural land development in the watershed is limited to the valley bottoms adjacent to creeks which supports irrigation as well as natural vegetation. Along much of the study reach the valley is dominated by the Interior Bunchgrass Zone vegetation with forested land at higher elevations. At the confluence of Cutoff and Clinton Creeks lies the Village of Clinton. Drainage areas at key locations within the study area (estimated using the LiDAR DEM) are summarized in Table 4-1, and are shown graphically in Figure 4-1.

TABLE 4-1: DRAINAGE AREA DELINEATION WITHIN STUDY AREA

DRAINAGE AREA (KM^2)	DESCRIPTION
63	Clinton Creek at CN Railway embankment
155	Cutoff Creek upstream of the confluence with Clinton Creek
218	Clinton Creek at d/s limit of municipal boundary
288	Clinton Creek at Bonaparte River (outlet)



CLINTON
SINCE 1863

Clinton Creek Watershed Delineation

- Clinton Creek at Village Boundary
- Clinton Creek at Outlet
- Clinton Creek at CN Railway
- Municipal Boundary (Village of Clinton)
- River / Creek

0 1,000 2,000 3,000 4,000 5,000 m

N

Reviewed by: PP	Scale: 1:100,000		TRUE
Revision #: 0	Issued for: Review		
Datum: NAD 83 CSRS (Zone 10)	Drawn by: RK		
Vertical Datum: CGVD2013	Date: 9/25/2024	Figure 4-1	
Projection: Transverse Mercator	Project Ref No. 675-541	Sheet 1 of 1	

R:\Clients\600-699\675\675-541\03 Drawings\GIS\675-541.aprx

4.2 Flood Frequency Analysis

Detailed hydrologic flow characterization is carried out establish design flows. The analysis documented here includes regional flow frequency analyses, as there are no streamflow gauges with sufficient length of record that could be used to estimate flow characteristics directly in the Clinton Creek watershed.

Climate change analyses for the Bonaparte River were previously assessed using outputs from a large-scale hydrologic modeling carried out by the Pacific Climate Impacts Consortium (PCIC). Floodplain mapping recently completed for the Village of Cache Creek was reviewed, and similar values adopted.

4.2.1 Regional Flow Frequency Analysis

Several regional flow frequency analyses were used in this work. The analyses include using different methodologies to estimate peak flows for the study area, including both past and recent studies. Further, a site-specific regional analysis is also carried out, using a smaller (and more representative) set of streamflow stations with the desire to establish most appropriate flow characterization for the study area.

Each regional analysis carried out is summarized below.

NHC (2021) Multiple Regression Analysis

As part of a larger project to streamline flow characterization for dam safety projects in BC, NHC (2021) carried out a multiple regression analysis for all major basins in the Province. The multiple regression equations were developed for each Ecozone/Ecoprovince that allows estimation of 200-yr flow. For the Clinton Creek watershed the following parameters were used i) drainage area (218 km^2 at the downstream limit of municipal boundary on Clinton creek), ii) mean annual precipitation (415 mm), and ii) median basin elevation (1465 m above sea level). Regression coefficient for Ecoprovice region 14.3 were used, as Clinton Creek watershed is located in that region. Applying the provided regression equations with above specified parameters produces a 200-yr peak flow magnitude of 23.9 m^3/s (after applying a peaking factor of 1.2 to convert daily to peak flow).

NHC (2021) Regional Log Pearson 3 Distribution

NHC (2021) provided a set of regional Log Pearson 3 parameters for use in peak flow estimation. Using the regional parameters for Ecoprovince region 14.3 allow for the estimation of the regional mean of the Log Pearson 3 statistical distribution. From the plots of regional standard deviation and regional skewness parameters for region 14.3, parameters were selected that are within the median range among available data. After applying a peaking factor of 1.2 (which computes peak flow from daily averaged flow), 200-yr peak flow was calculated as 20.7 m^3/s for Clinton Creek at the downstream limit of the municipal boundary. This value compares favourably with one determined above using the multiple regression technique.

Wang (2000) Regional L-Moment Analysis

Wang (2000) used the method of L-moments to delineate homogeneous regions, identify and fit regional distributions, and develop regional functions to transfer hydrologic characterization to ungauged watersheds for various locations in British Columbia. The Province was divided into 19 homogeneous regions for which regional equations were provided based on catchment size. By knowing the physical location of the catchment and its drainage area, flow characteristics at ungauged sites could be estimated. Using the drainage area of 218 km^2 (at the downstream limit of the municipal boundary) and Non-Mixture Region 1-1 equations (region in which Clinton Creek watershed is located) produces a 200-yr peak flow value of 20.8 m^3/s (after applying a 1.2 peaking factor as above). Again, this peak flow value is similar to estimates noted above.

Site Specific Regional Analysis

In an effort to determine site-specific regional flow estimates directly applicable for watercourses within the Village of Clinton, a total of eight streamflow gauging stations were downloaded from the Water Survey of Canada database (see Table 4-2) and initially used. The stations were selected based on similar catchment area as the Clinton Creek watershed, and being in a similar hydrologic regime. The flow data was inspected, which identified that peak annual floods result from snowmelt that occurs in the spring. Rainfall induced flooding was not identified as a mechanism causing flooding.

TABLE 4-2: STREAMFLOW GAUGES NEAR CLINTON

WSC GAUGE ID [-]	DRAINAGE AREA [KM^2]	DESCRIPTION [-]
08LA027	365	Bridge Creek below Dekka Creek
08LB050	289	Mann Creek near Blackpool
08LE112	297	Chase Creek above the mouth
08LF094	99	Joe Ross Creek near the mouth
08LF099	51	Arrowstone Crek near the mouth
08LG056	78	Guichon Creek above Tunkwa Lake Diversion
08MB007	232	Big Creek below Graveyard Creek
08ME027	312	Hurley River below Lone Goat Creek

Single station frequency analysis was used to compute daily flow statistics of each gauge selected. The freshet annual maximum daily flows for each gauge was fit using the Generalized Extreme Value (GEV) distribution, with the parameters estimated using L-Moments. Data up to the end of 2022 was used. Note that it was found that the GEV distribution had a superior fit compared to other distributions tested, hence its used. A sample statistical fit plot for the Bridge Creek gauge is shown in Figure 4-2)

Water Survey of Canada instantaneous flow data (i.e., peak flow data) was used to relate daily to instantaneous flows. A linear fit was used to describe the relationship between daily and instantaneous flow for each gauge in the study area. Establishing daily to instantaneous relationship flow allows for estimation of peak flows statistics from daily data. The instantaneous peak flow statistics were developed by converting daily flow statistics to peak flows via the relationship developed (a different relationship for each gauge was developed). A sample plot of daily to instantaneous curve for the Bridge Creek gauge is shown in Figure 4-3. The same procedure was repeated for all gauges initially selected.

Next, a regional curve was attempted using results from statistical analysis for all gauges listed in Table 4-2. However, Mann Creek, Chase Creek, Big Creek and Hurley Creek gauges showed significantly higher flow magnitudes (in the order of 75-80 m^3/s for 200-yr flows). Such flow magnitudes are not consistent with regional analyses results from NHC (2021) multiple regression, or with Wang (2000) regional flow analyses. Further, historical flooding experienced in the Village have not experienced such high flow magnitudes, indicating that the noted gauges are inappropriate for use in a site-specific regional analysis. For this reason, these streamflow gauges were discarded from further analyses. By process of elimination, gauges at Bridge Creek, Joe Ross Creek, Arrowstone Creek and Guichon Creek were used.

Table 4-3 shows the derived instantaneous peak flows for each of the selected gauges in the site-specific regional analysis, along with their corresponding catchment area. A sample regional curve for the 200-yr peak flow is shown in Figure 4-4 (regional curves for all other return periods were developed and are shown in Appendix A). It is noted that the slope of the regional curve is directly impacted by the magnitude of the gauge with the highest catchment area (Bridge Creek below Dekka Creek in this instance).

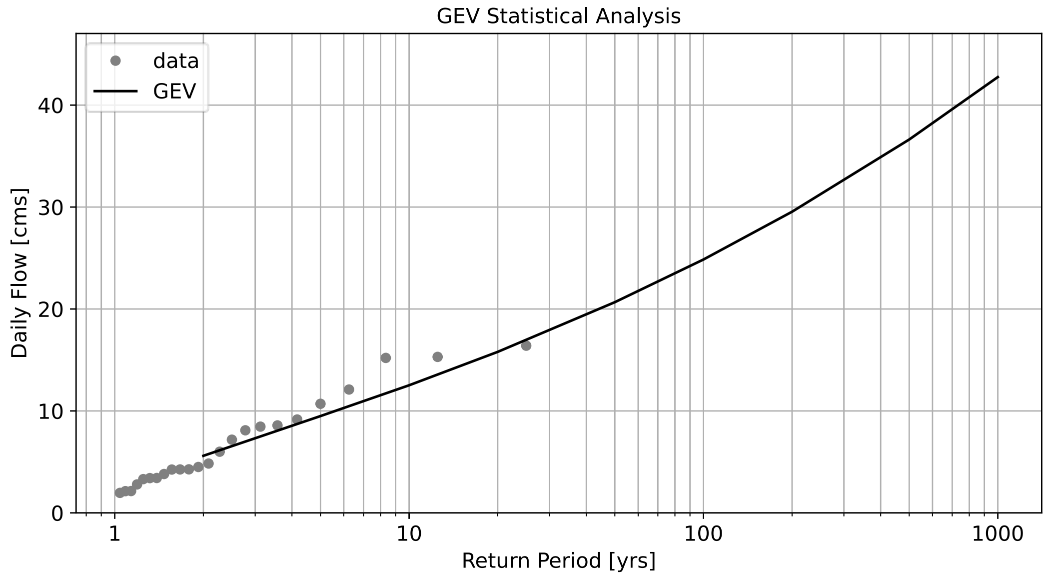


FIGURE 4-2: STATISTICAL FIT FOR BRIDGE CREEK BELOW DEKKA CREEK GAUGE

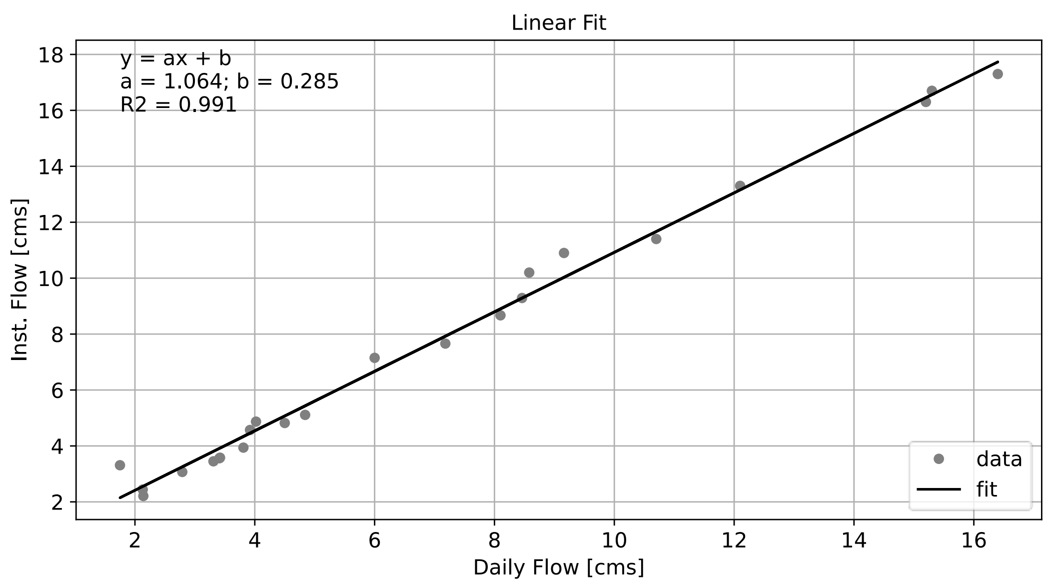


FIGURE 4-3: DAILY TO INSTANTANEOUS RELATIONSHIP FOR BRIDGE CREEK BELOW DEKKA CREEK

TABLE 4-3: REGIONAL FLOW ANALYSIS FOR CLINTON CREEK WATERSHED

GAUGE ID	NAME	PEAK INSTANTANEOUS FLOW (M^3/S) / RETURN PERIOD [YRS]								
		DA KM^2	2	5	10	20	50	100	200	500
08LA027	Bridge Creek below Dekka Creek	365	6.2	10.4	13.6	17.1	22.3	26.7	31.7	39.3
09LF094	Joe Ross Creek near the mouth	99	2.9	5.1	6.9	9.0	12.2	15.1	18.5	23.8
08LF099	Arrowstone Creek near the mouth	51	1.5	3.3	4.9	6.9	10.2	13.4	17.4	24.3
08LG056	Guichon Creek above Tunkwa Lake diversion	78	1.4	2.3	3.0	3.7	4.7	5.5	6.3	7.5
-	Clinton Creek at d/s limit of municipal boundary	218	4.1	6.9	9.2	11.7	15.5	18.9	22.7	28.6

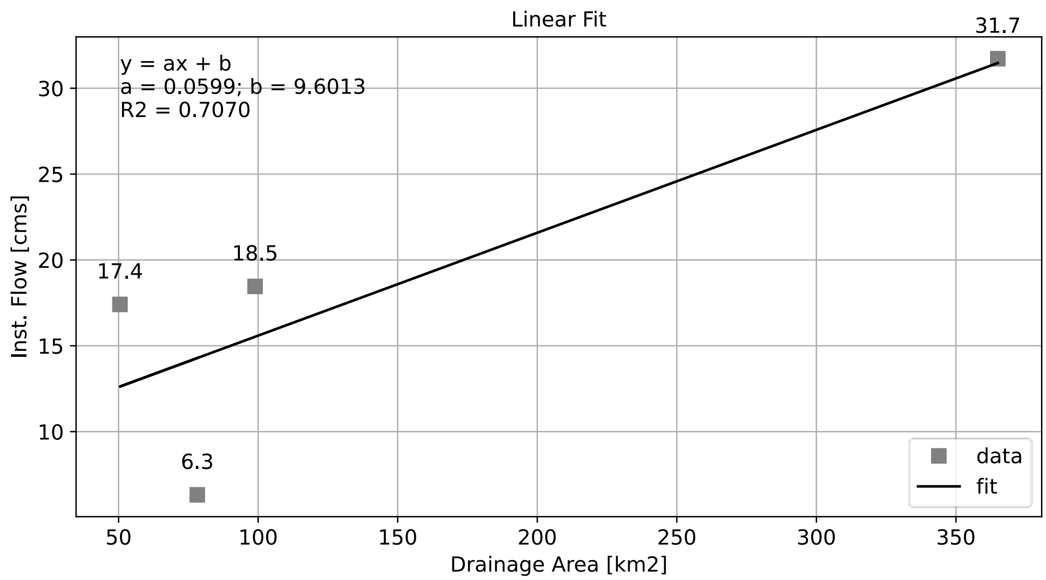


FIGURE 4-4: REGIONAL CURVE FOR 200-YR PEAK FLOWS

TABLE 4-4: REGIONAL ANALYSES COMPARISON

ANALYSIS SOURCE	TYPE	200-YR FLOW [M^3/S]
Wang (2000)	Non-Mixture Region 8-1	20.8
NHC (2021)	Multiple Regression	23.9
NHC (2021)	Log Pearson 3 Regional Curve	20.7
(this work)	**GEV Site-specific regional Curve**	**22.7**

A summary table showing results from all regional analyses is shown in Table 4-4, applicable for Clinton Creek at the downstream limit of the Village's municipal boundary. Different analyses carried out produce different peak flows, and this is to be expected. The site-specific regional analysis produced reasonable values, but it also heavily relied on the catchment characteristics of a single neighbouring streamflow gauge (Bridge Creek below Dekka Creek) that is believed to be representative. For this reason, it is recommended that a 200-yr peak flow of 22.7 m^3/s be used in this work.

For hydraulic modeling the flow at Clinton Creek at the downstream limit of its municipal boundary is adjusted using simple drainage area proportioning to determine flows in the upstream areas of the Village. The scaling approach allows flow characteristics at one location (where flows are known) to be scaled to another location (where flows are needed) based on simple drainage area proportioning. The drainage scaling relationship is provided in equation (1) below:

$$Q_2 = Q_1 \times (DA_2 / DA_1) \qquad (1)$$

where Q_1 and DA_1 are peak flow and drainage area where flow characteristics are known (from above regional analysis), and Q_2 and DA_2 are flow and drainage area where flow characteristics are to be determined.

4.2.2 Climate Change Analysis

Previous floodplain mapping assignments on the Bonaparte River by TRUE (2021) and BGC (2023) used a 10% adjustment factor to capture future effects of climate change. The quoted adjustment factor was obtained via analysis of Pacific Climate Impacts Consortium's (PCIC) large scale hydrologic modeling that included precipitation and temperature inputs obtained from several global climate models (PCIC, 2024). The PCIC simulation outputs are available as timeseries of daily flow data, but only for larger watersheds in BC (such as the Bonaparte, which has a catchment area of 5,020 km^2). The Clinton Creek watershed is much smaller (catchment area of 288 km^2), thus the same climate change adjustment factor does not directly apply.

According to the EGBC (2018) technical guidelines smaller drainage basin, for which information on future local conditions is inadequate to provide reliable local guidance, flood magnitudes should be increased by 20% (p. 27). For the floodplain mapping at Cache Creek (TRUE, 2021) a climate change adjustment factor of 20% was used.

PCIC Climate Explorer (PCEX, 2024) tool was also used to investigate impacts from climate change on future streamflow conditions in the study area. The PCEX tool includes outputs from long term hydrologic modeling under climate change of the Fraser River and its tributaries (Clinton Creek is a tributary of the Bonaparte, which is a tributary of the Thompson, which is a tributary of the Fraser River). The grid cell size in the PCEX database is rather coarse, since it was originally intended for study of watersheds that are much larger than the study catchment. The entire Clinton Creek watershed is represented by five grid cells in the PCEX database, which is not sufficient to capture accurately streamflow characteristics (regional analyses summarized in this study are deemed more accurate). However, the PCEX database is useful as it includes a summary of streamflow change factors under the RCP8.5 high emissions scenario and various return periods.

Using the PCEX tool at the outlet of the Clinton Creek watershed, suggests that mean change factors for the 200-yr annual maximum streamflow range from 1.05 (2020's) to 1.25 (2050's) and 1.1 (2080's).

Climate Change Factor

For the purposes of completing the present floodplain mapping assignment, an increase in peak flow by 20% is adopted in this work. This value is consistent with previous climate change factors from the neighbouring Cache Creek watershed (TRUE, 2021) and with outputs of the PCEX database (see above).

4.2.3 Design Flow Summary

Simple flow proportioning procedure is applied to determine the amount of flow at Clinton and Cutoff Creeks. Flow characteristics downstream of the confluence (obtained from regional analysis) are used to scale flows based on drainage area. Design flows for the 200-yr return period are shown in Table 4-5, while results for return periods ranging from 2-yr to 500-yr are presented in the Appendix A.

The flow identified at Clinton Creek via flow proportioning is believed to be appropriate. The flows developed on Clinton Creek are consistent with flow characteristics at Guichon Creek gauge (which has similar hydrologic characteristics), thus validating use of the simple drainage area proportioning.

TABLE 4-5: 200-YR PEAK FLOWS AT THE VILLAGE OF CLINTON (W/ CLIMATE CHANGE)

DRAINAGE AREA [KM^2)	200-YR PEAK FLOW, W/O CC (M^3/S)	200-YR PEAK FLOW, W/ CC (M^3/S)	DESCRIPTION (-)
63	6.5	7.8	Clinton Creek at CN Railway embankment
155	16.2	19.4	Cutoff Creek upstream of the confluence with Clinton Creek
218	22.7	27.2	Clinton Creek at d/s limit of municipal boundary

5.0 Hydraulic Assessment

This section focuses on hydraulic modeling and provides details on data and analytical tools used in the assessment. Hydraulic models are analytical tools that evaluate characteristics of movement of water over time and space. They use existing geometry of river/floodplain with specified design flows to determine water surface elevation profiles and inundation depths/extents for a river reach in question.

Hydraulic modeling in this assignment is completed using 2D numerical modeling. The 2D analyses allow for accurate assessment of spatial and temporal characteristics of flooding processes, and its resulting overland flow inundation patterns in greater detail than older 1D analyses.

5.1 Model Description

The hydraulic analysis carried out in this assessment uses the Hydrologic Modeling Center's River Analysis Systems (HEC-RAS), developed and maintained by the US Army Corps of Engineers. The HEC-RAS model is currently the standard hydraulic model widely used in North America and beyond. HEC-RAS allows its users to carry out river hydraulic analyses, using steady or unsteady techniques. Version 6.5 of the HEC-RAS model is used in this work, as it was latest at the time of this writing.

In this work a 2D variant of the HEC-RAS hydraulic model is used to quantify detailed behavior of the hydraulics within the study area. The ability of the model to capture river and floodplain hydrodynamics makes it ideal for the study where 2D effects dominate (such places where flow is suddenly released into relatively flat areas). HEC-RAS 2D model uses the theory of sub-grid finite volumes to solve the governing flow equations and capture governing flow phenomena.

2D models uses a large number (in the tens or hundreds of thousand) of discrete elements to represent the geometry (river and floodplain) of the study area. Using such a large number of elements allows for capturing geometry of the physical system with high degree of accuracy. The advantage of 2D modeling is that a range of flood flows (from small to extreme) can be assessed, while making a minimum number of assumptions.

By definition, 2D hydrodynamic models are depth averaged, implying that computations of flow velocity are averaged along the water column. For relatively shallow flows and wide flooded areas capturing vertical velocity is not necessary to represent the problem under consideration.

Required data for 2D modeling includes:

a) Terrain surface that captures key geometric features within the river and floodplain (i.e., hydraulic model ready DEM),

b) Model grid or mesh that discretizes the study area into a large number of computational elements,
c) Hydraulic structures (bridges, culverts, weirs, dikes, etc.),
d) Initial and boundary conditions (flows and levels), and
e) Manning's roughness coefficients for the main channel and the overbank areas.

5.2 Model Development

HEC-RAS 2D hydraulic modeling is used to develop simulation models for this work. One distinct modeling domain is developed for the Cutoff and Clinton Creeks within the municipal boundary of the Village of Clinton. The hydraulic modeling domain includes river and floodplain areas from upstream of Hwy 97 Bridge on Cutoff Creek, Clinton Creek from the CN Railway embankment to the confluence, and Clinton Creek from the confluence to the downstream limit of the municipal boundary.

5.2.1 Digital Surface and Hydraulic Roughness Data

The hydraulic model ready DEM, documented above, is used as the basic terrain surface data for the 2D modeling work. The DEM used includes best available data for above and below water floodplain geometry of the study area.

Hydraulic roughness in terms of Manning's coefficient is derived using 2019 aerial photography within the study areas. Values used in the modeling were based on typical roughness values correlated with the surface treatment. Table 5-1 shows the roughness values used and are consistent with standard practice for similar land use classes.

TABLE 5-1: HYDRAULIC ROUGHNESS VALUES

LAND USE TYPE	MANNING'S N VALUE
Channels	0.035
Grasses	0.030
Forests	0.100
Residential	0.060
Barren	0.025
Shrublands	0.070

5.2.2 Model Mesh and Breaklines

Model grid for the study area is constructed using unstructured elements of varying geometric proportions. To adequately represent river and floodplain geometry within study area the modeling domain is discretized using elements of various sizes. Fine resolution mesh is used in areas that were deemed to control flow characteristics, like main channels, bridges approaches, dikes, roadways, top and bottom of slopes, etc. Coarser resolution mesh is used elsewhere in the model domain in areas that are not anticipated to control flow propagation but could still be inundated. Care was taken to include appropriate grid resolution in the model to capture relevant features, and still keep computation times to a minimum.

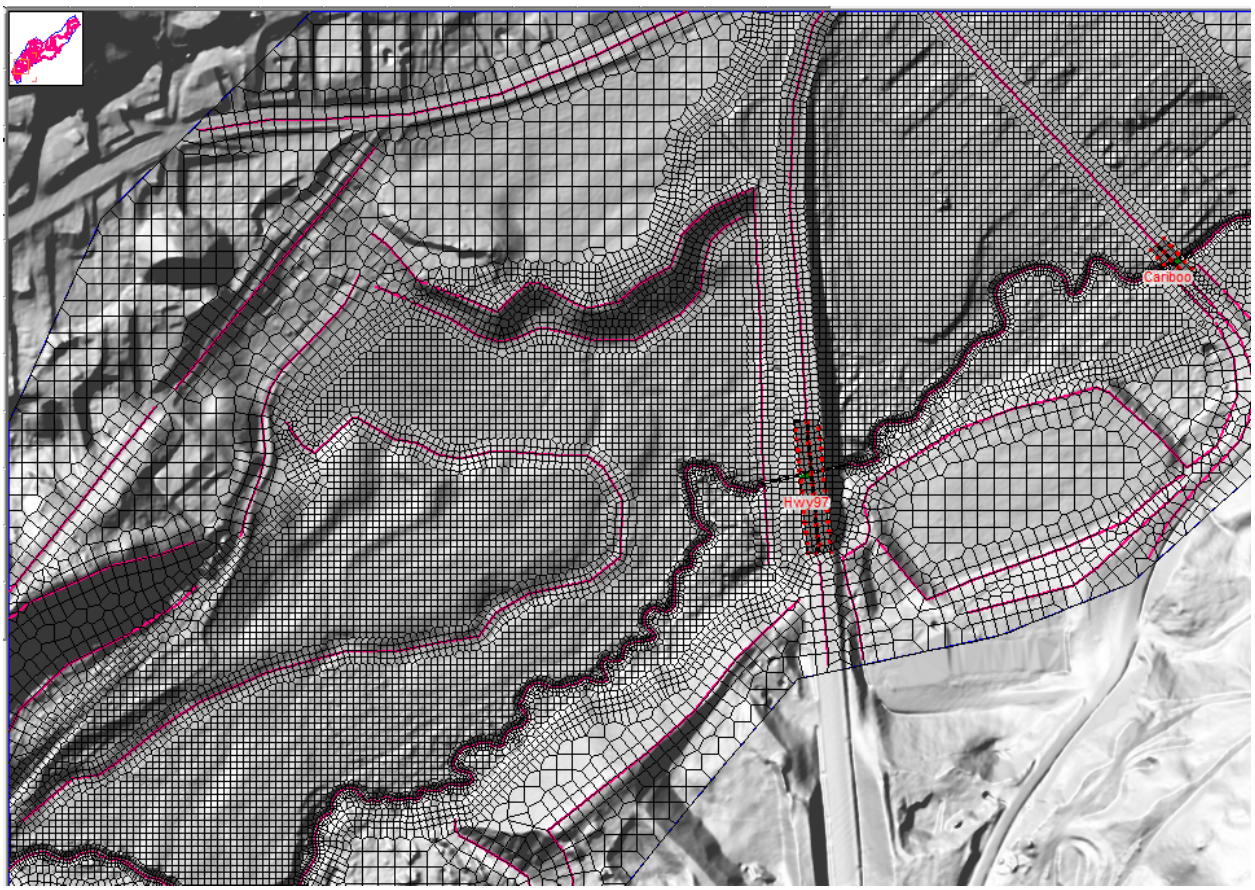


FIGURE 5-1: HEC-RAS 2D MODEL GRID NEAR HWY 97 CROSSING

A HEC-RAS 2D model schematic is presented in Figure 5-1, where the numerical model grid is shown, along with breaklines and hydraulic structures. Generally, areas within the 2D model domain that are anticipated to carry bulk of the flow are discretized with finer elements (such as main channels and hydraulic structures). Areas farther away were assigned larger grid cells, as these areas will likely not govern in controlling flow behavior (such as open fields for example). Model breaklines were placed at locations where geometry changes slope (like top of channel banks, tops, and bottoms of slopes, etc). When used properly, breaklines allow the model to limit the number of grid cells (and thus reduce computational time), while capturing relevant flow hydraulics.

5.2.3 Hydraulic Structures

Hydraulic structures within the modeling study area were coded in the HEC-RAS model. Hydraulic structures listed in Table 2-1 are included in the modeling, except for the Dewdney Avenue crossing. This crossing consists of a simple timber surface spanning the banks of the creek. It is anticipated that during high flow events this span would wash out, and would not influence or otherwise impact river hydraulics. For this reason, the Dewdney Avenue crossing is not included in the hydraulic modeling.

Geometry at each crossing was obtained from site specific topographic surveys, which was used to include hydraulic structures into the HEC-RAS 2D model. Culvert geometry data summarized in Table 2-1 was used to code in geometry of each opening into the hydraulic model.

5.2.4 Initial and Boundary Conditions

Initial conditions in the HEC-RAS 2D model domain were set to dry bed conditions (i.e., no water in the river). The finite volume flow solvers are flexible enough to allow such starting conditions. Flow was gradually ramped up to establish base flow conditions at each stream (taken as 10% of the design flows).

Design flows were added at the upstream model boundary to simulate peak flow conditions. As the present analyses involves floodplain mapping only, a constant steady design flow is used. The design flow is applied sufficiently long to achieve steady state conditions in the system and thus obtain maximum water surface profiles.

An inflow boundary condition was set at upstream limits at Cutoff and Clinton Creeks, as per Table 4-5. Flows factored for climate change were used in the floodplain mapping for the 200-yr condition. The downstream boundary condition was set as normal depth, computed from the cross section of the river and floodplain, along with the creek gradient.

5.3 Calibration and Verification

Measured water surface profiles during high flow events on Cutoff and Clinton Creeks within the Village of Clinton were not available. It is for this reason that calibration and verification exercises could not be carried out. Should this data become available in the future during high magnitude flood events, calibration and verification tasks could be carried out to ground truth the hydraulic model simulations. For the present assignment, and until calibration and verification data become available, surface roughness values within the model are set to reasonable values and used in the simulations. The model output was inspected for consistency, ensuring results obtained are reasonable and representative for the study area.

5.4 Model Limitations

The modeling effort used in the development of the HEC-RAS 2D hydraulic modeling represents accepted engineering practice. However, all models and methodologies have inherent limitations that should clearly be acknowledged and understood. Some of the noted limitations include the following:

- The modeling assumes rigid bed conditions and neglects possible effects of channel migration and riverbed scouring during extreme events,
- Channel and floodplain are assumed to flow under clear water conditions, with potential influence of debris neglected from the simulations,
- Calibration data for the study area was not available, and therefore could not be carried out, and
- Further refinement to the modeling may be required for localized and/or site-specific hydraulic assessments and design work. Consultation with a Qualified Professional is required for such cases.

5.5 Model Results

With existing infrastructure in place, floodplain of Cutoff and Clinton Creeks within the municipal boundary will continue to be vulnerable to flood impacts. The nature of flooding will result from snowmelt of spring freshets that typically occur between May and June each year.

Clinton Creek upstream of the Village is a steep mountainous watercourse, which does not have a natural floodplain that requires mapping (all flows stay within the main channel and its valley slopes). The existing infrastructure along the Clinton Creek upstream of the Village (drinking water reservoirs and the CN Railway embankment) pose serious threat in case if it becomes compromised in the future.

The storm sewer that runs parallel to McDonald Avenue is undersized for the 200-yr flow condition, meaning that it does not have sufficient capacity to convey design flows. Analysis shows that during design flows a portion of the flow will spill overland and will eventually finds its way to the confluence. The overland flooding results is demonstrated to be shallow and fast, where the paved roads end up being used to convey flood waters during extreme flooding (see Figure 5-2).

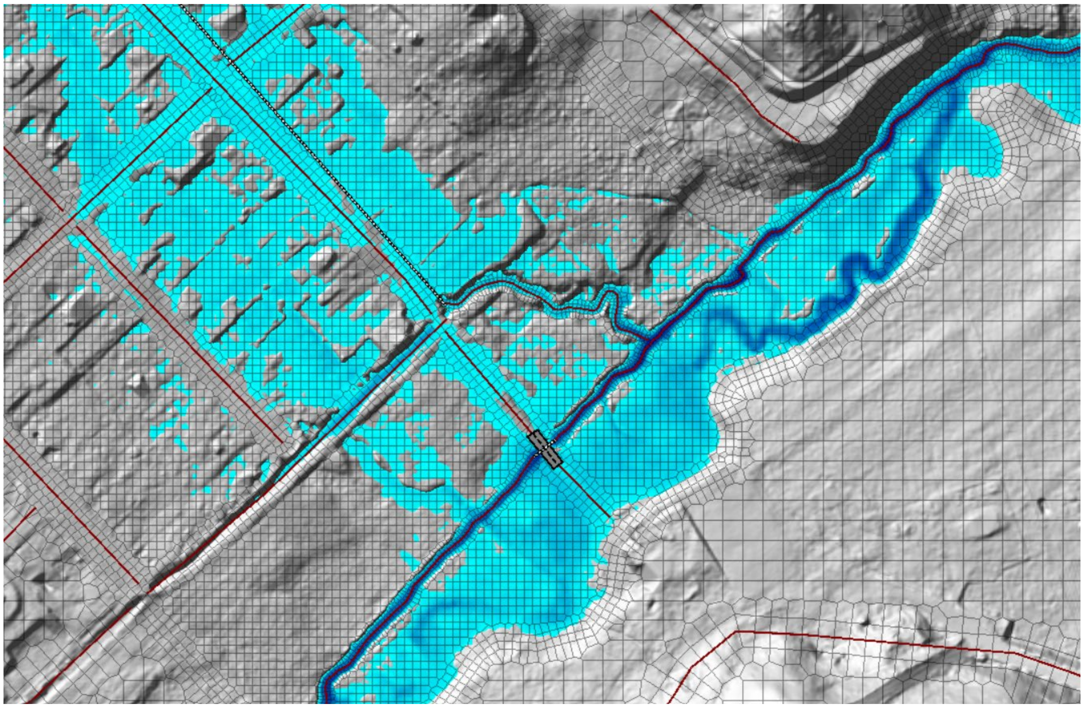


FIGURE 5-2: FLOOD INUNDATION NEAR THE CONFLUENCE OF CLINTON AND CUTOFF CREEKS

Cutoff Creek in the area upstream of the Hwy 97 crossing (where the largest culvert opening exists in the Village) experiences backwater flooding. The backwater flooding results from the inability of the existing culvert to pass the 200-yr design flow. As the height of the Hwy 97 embankment is approximately 10 m, significant water depths upstream of the Hwy 97 bridge are to be expected (marked by deep blue colour in Figure 5-3). Eventually the water trapped behind the Hwy 97 embankment finds its way across the crest of the road north of the culvert, and causes overland flooding to the properties between Hwy 97 and Cariboo Avenue (see Figure 5-3).

The floodplain downstream of the confluence of Cutoff and Clinton Creeks generally follows the natural floodplain. The other major finding is that existing Waste Water Treatment Plant lagoons are anticipated to be flooded during the 200-yr design event. Existing berms around the Waste Water Treatment Plant are not sufficiently high to contain the floodwaters simulated. The Lagoon Road, also from having a culvert opening that is insufficient to pass 200-yr flows, causes water levels to rise and ultimately overtop the road's crest (see Figure 5-4).

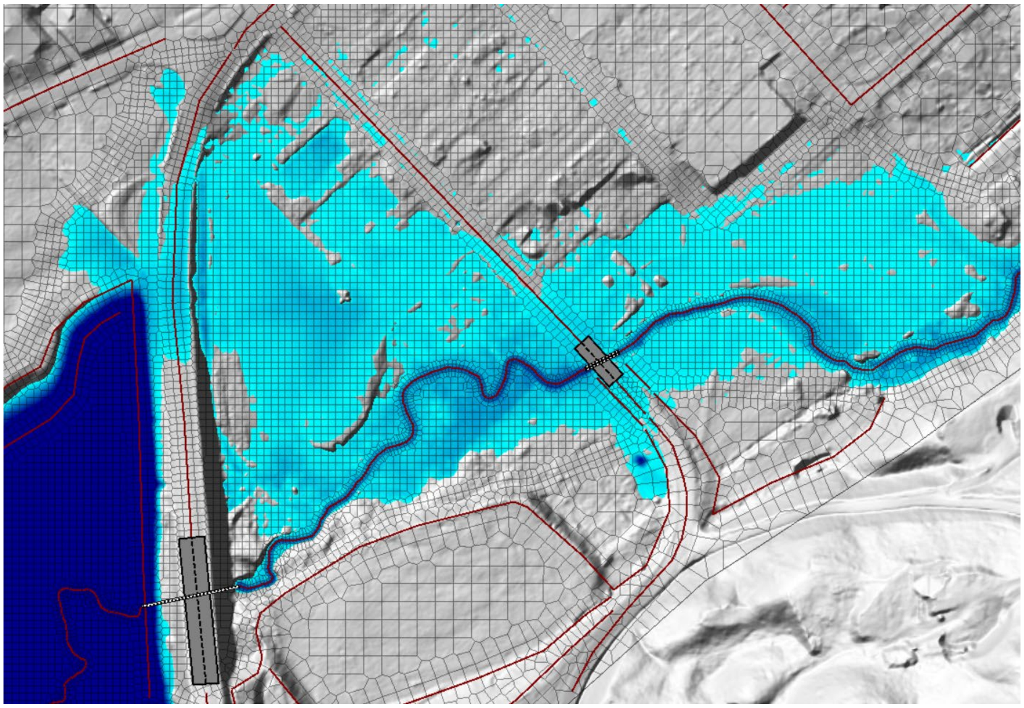


FIGURE 5-3: FLOOD INUNDATION DOWNSTREAM OF THE HWY 97 CROSSING

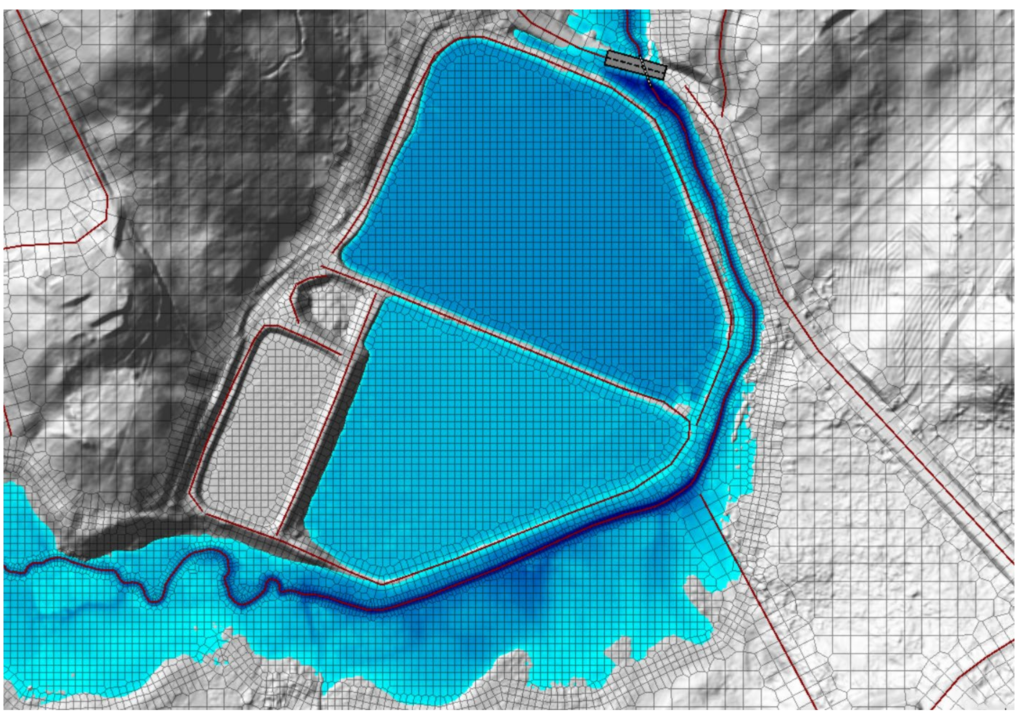


FIGURE 5-4: FLOOD INUNDATION ADJACENT TO THE WWTP

6.0 Floodplain Mapping

Results from the hydraulic modeling carried out in this work are presented, as are procedures used to develop flood inundation, flood hazards, and flood construction levels.

6.1 Floodplain Mapping Standards

The applicable standard followed in this work is the EGBC (2018) publication, titled 'Professional Practice Guidelines for Legislated Flood Assessments in a Changing Climate in British Columbia'. Maps developed follow standards defined in APEGBC (2017), as well as the recently produced Flood Mapping Standards (NHC, 2020).

6.2 Flood Inundation Mapping

Flood inundation mapping was produced that combines impacts from the Cutoff and Clinton Creek watercourses within the municipal boundary of the Village of Clinton. The inundation map does not include freeboard, but instead shows areas that are expected to be flooded by a 200-yr flood (including climate change) and assuming existing infrastructure is in place.

The prepared flood inundation mapping shows the anticipated extent of flooding within the Village. The flooding is most prominent downstream of the Hwy 97 crossing (and upstream of Cariboo Avenue), and along the overland flow route along McDonald Road (where the Clinton Creek runs under the Village). In both instances, existing culverts are insufficient to pass the 200-yr design flows, and are anticipated to cause flooding. Also, the existing berms around the Waste Water Treatment Plan are anticipated to overtop during the 200-yr design event. Further, Lagoon Road is likewise anticipated to be overtopped, which will make access to the Plant challenging during the times of a flood emergency.

6.3 Flood Hazard Mapping

A Flood Hazard maps are created based on the predicted flood depths and velocities obtained from the hydraulic model simulations of Cutoff and Clinton Creeks. The hazard rating is calculated based on the following formula:

HR = d x (v + 0.5) + DF (2)

where:

HR = Flood hazard level,

d = depth of flooding (m),

v = velocity of floodwater (m/s)

DF = debris factor (=0, 0.5, 1 depending on probability)

TABLE 6-1: HAZARD RATING CLASSIFICATION

HAZARD RATING (HR)	HAZARD CLASSIFICATION
< 0.75	Low Hazard (Caution)
0.75 to 1.25	Hazards for Some (includes children, the elderly and the infirm)
1.25 to 2.0	Danger for Most (includes the general public)
> 2.0	Danger for All (includes emergency services)

The 200-year Flood Hazard Map indicates that the main channels for both Cutoff and Clinton Creeks are hazardous with a rating of “Danger for All”. Outside the main channels the there are few areas that are classified as “Danger for Some” with the majority of areas receiving a low hazard rating.

6.4 Flood Construction Level Mapping

Floodplain maps are used by local governments for regulatory purposes, such as developing floodplain bylaws. The most common regulatory application is where inundation mapping is incremented by a freeboard allowance to establish a Flood Construction Level (FCL). The concept of FCL has a long history of use in BC and is used to establish the elevation of the underside of a wooden floor system or top of a concrete slab for habitable structures.

Flood construction levels and setbacks only take effect if a local government adopts a floodplain by-law, or uses another tool (e.g., development permit areas) to restrict development. Production of the floodplain and FCL maps is only an interim step in the process. The Village must adopt specific land use regulations for regulatory mapping to take effect.

A floodplain map has been developed for potential adoption into a regulatory framework. FCL maps including the effects of climate change scenarios have been developed.

FCLs within the Village limits were estimated by adding 0.6 m of freeboard to the design flood profile produced via hydraulic modeling. Including freeboard on a flood map not only increases the flood depth, but also increase the potential inundated area. Including freeboard is common practice and accounts for inherent uncertainties in the base data and analysis.

The aerial extents of the flooding with freeboard added was generated via post-processing which included extending the FCL inundation limits to places of higher ground. The generated flood extents and flood contours were validated and manually adjusted to account for disconnected flooded ponding areas and high ground areas. To estimate the FCL inundation limits the developed water surface elevation raster (produced via hydraulic modeling) was raised by 0.6 m to accommodate the freeboard criteria. The raised water's surface was converted to 1.0 m interval contours, with each contour assigned a respective elevation (i.e., the FCL). These contours are also referred to as FCL isolines. The raised contours were then used to develop a TIN model representing an entire FCL surface. Intersecting the FCL surface with the hydraulic model ready DEM produced the spatial extent of the FCL, which is shown in the provided mapping.

Note that any changes and/or development in the main channel and floodplain can alter the flood levels and extent of flooding (especially if road crests are altered, or if existing culverts are upgraded). Should future development encroach into the defined floodplain, hydraulic models and mapping should be updated, and the floodplain and FCL maps accordingly revised.

Detailed FCL boundary maps are contained in Appendix B.

References

AC Eagle (2019) Clinton Creek Reservoir Dam Breach Analysis, Technical Report prepared on behalf of the Village of Clinton by AC Eagle Consultants, February, 2019.

APEGBC (2017). Flood Mapping in BC – Professional Practice Guidelines, The Association of Professional Engineers and Geoscientists of British Columbia, Burnaby, 2017.

BGC (2019) BGC Engineering Inc. Thompson River Watershed Geohazard Risk Prioritization Report. Technical Report prepared for Fraser Basin Council by BGC Engineering Ltd., March 2019.

BGC (2023) Lower Bonaparte River and Thompson River at Ashcroft, Detailed Flood Mapping Study. Technical Report prepared for Fraser Basin Council by BGC Engineering Ltd., February 2023.

EGBC (2018) Legislated Flood Assessments in a Changing Climate in BC, Engineers & Geoscientists British Columbia (EGBC) – Professional Practice Guidelines, Version 2.1, August 2018.

Merwade, AH, Maidment, DR and Hodges, BR. (2005) "Geospatial Representation of River Channels", ASCE Journal of Hydrologic Engineering, Vol 10, p. 243-251.

NHC (2020) Okanagan Floodplain Mapping Standards, Technical Report No. 3004430 prepared by Northwest Hydraulics Consultants, March, 2020.

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, March 2021.

PCIC (2024) Pacific Climate Impacts Consortium, Station Hydrologic Model Output, URL https://pacificclimate.org/data/station-hydrologic-model-output, Last accessed Sept 24, 2024.

PCEX (2024) Pacific Climate Impacts Consortium, Climate Data Explorer, URL https://pacificclimate.org/analysis-tools/pcic-climate-explorer, Last accessed Sept 24, 2024.

Roden (2018) Highway 97 now fully reopen between Cache Creek and Clinton, 100 Mile Free Press, 2018.

Septer, D. (2007) Flooding and landslide events: southern British Columbia, 1808-2006. Victoria, British Columbia: Province of British Columbia, Ministry of Environment.

SNT (2017) Post-wildfire natural hazard risk analysis, Elephant Hill fire (K20637, 2017), Technical Report No. 511.17.30 prepared by SNT Geotechnical Ltd., December 2017.

TRUE (2021) Floodplain Mapping Report, Village of Cache Creek. Technical Report 310-161 Prepared for the Village of Cache Creek by TRUE Consulting, September, 2021.

APPENDIX A

Flood Frequency Analysis Supplemental Data

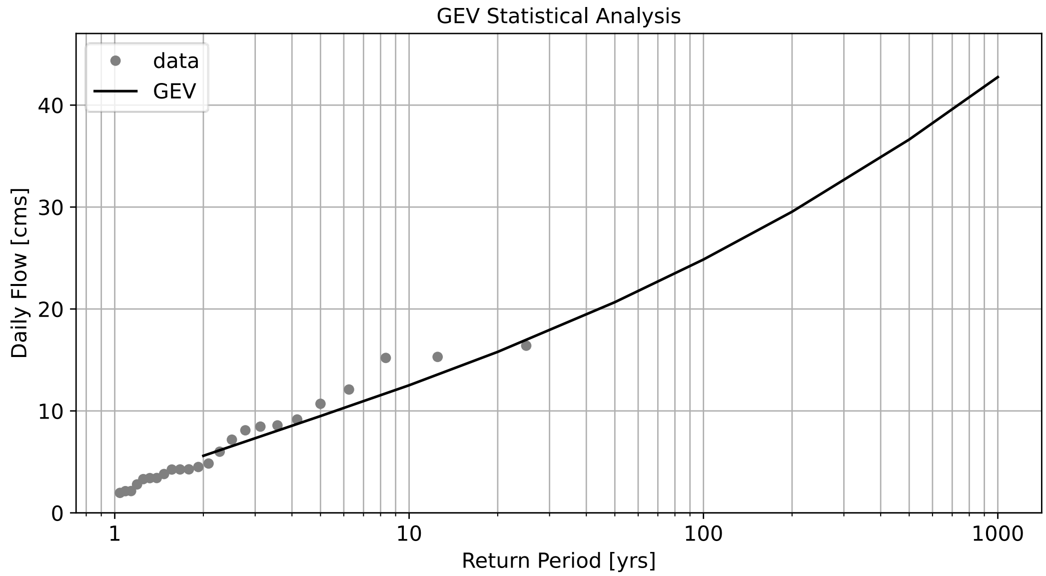


Figure A-1: Statistical Fit for Gauge 08LA027 Bridge Creek below Dekka Creek

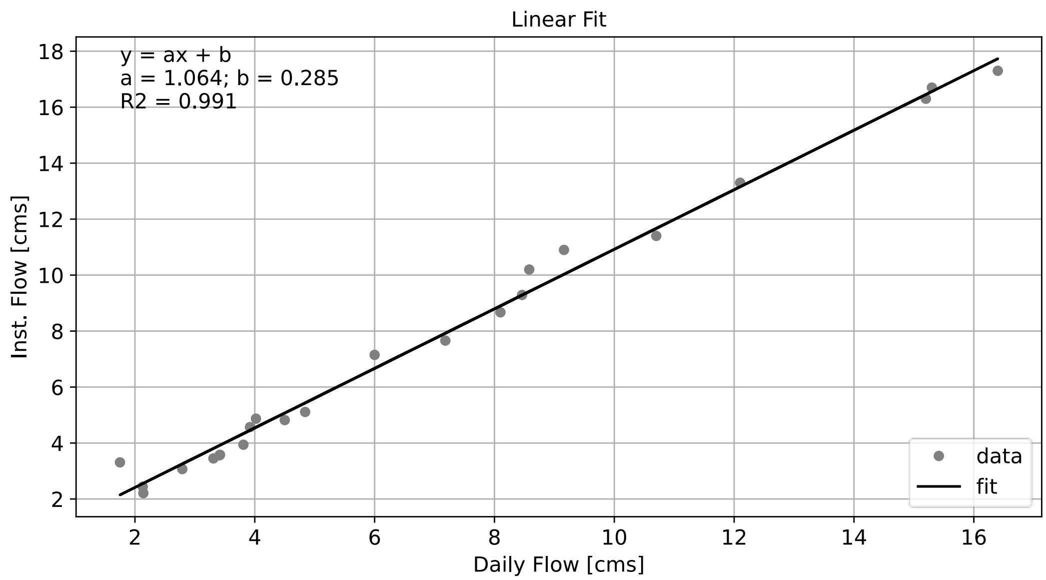


Figure A-2: Daily to Instantaneous Relationship Gauge 08LA027 Bridge Creek below Dekka Creek

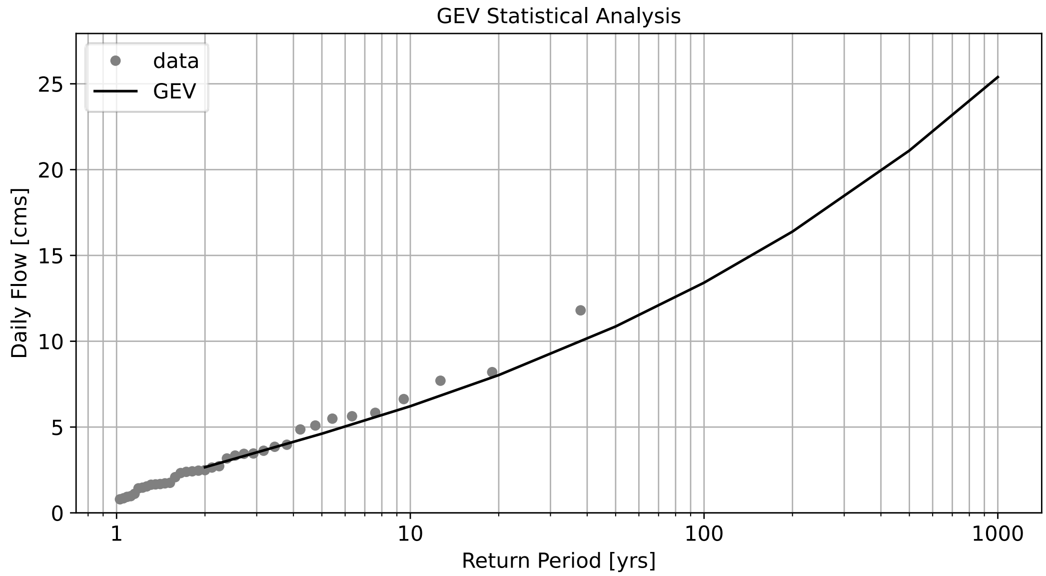


Figure A-3: Statistical Fit for Gauge 08LF094 Joe Ross Creek Near the Mouth

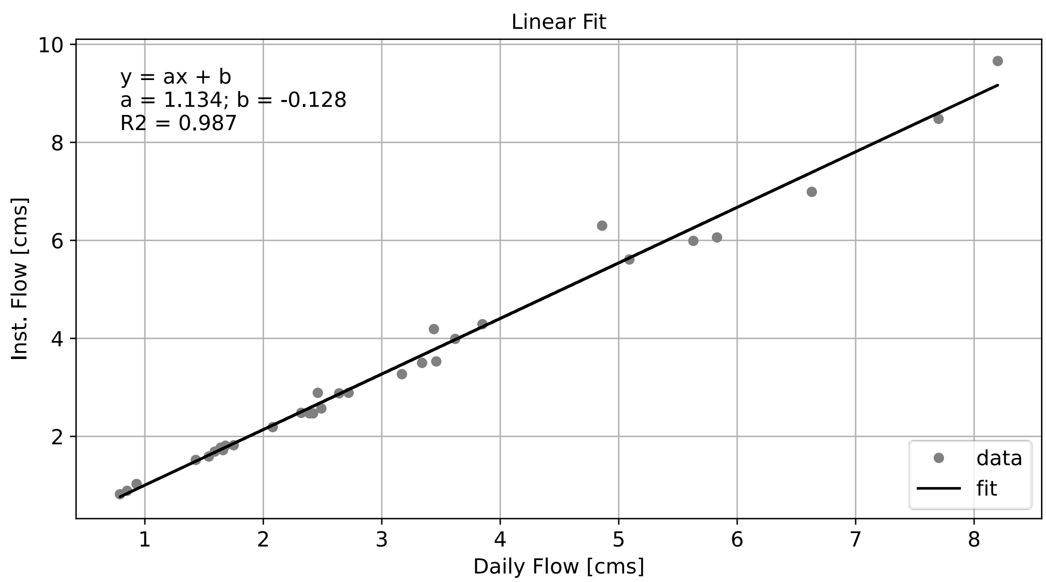


Figure A-4: Daily to Instantaneous Relationship Gauge 08LF094 Joe Ross Creek Near the Mouth

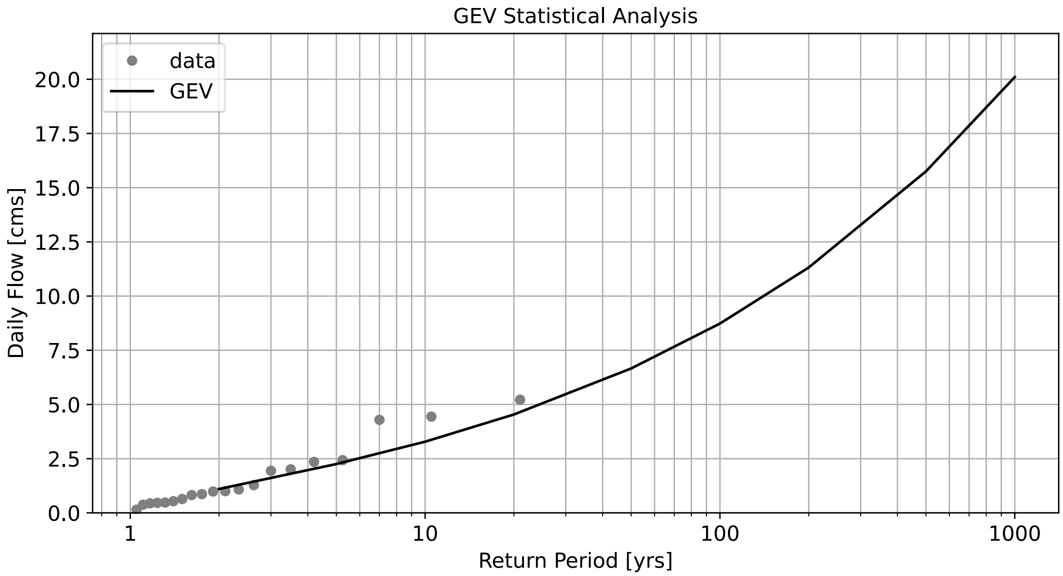


Figure A-5: Statistical Fit for Gauge 08LF099 Arrowstone Creek Near the Mouth

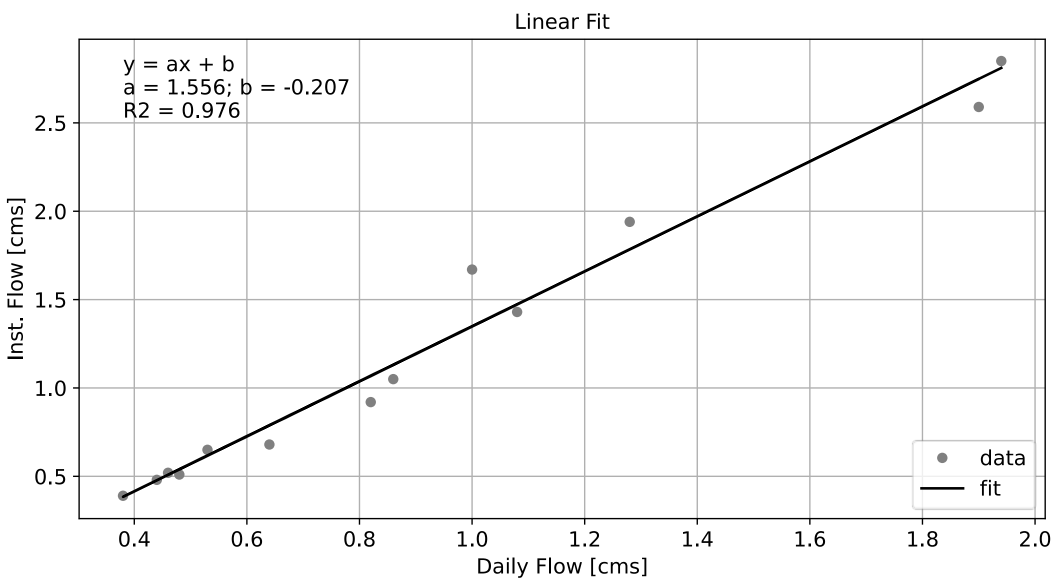


Figure A-6: Daily to Instantaneous Relationship Gauge 08LF099 Arrowstone Creek Near the Mouth

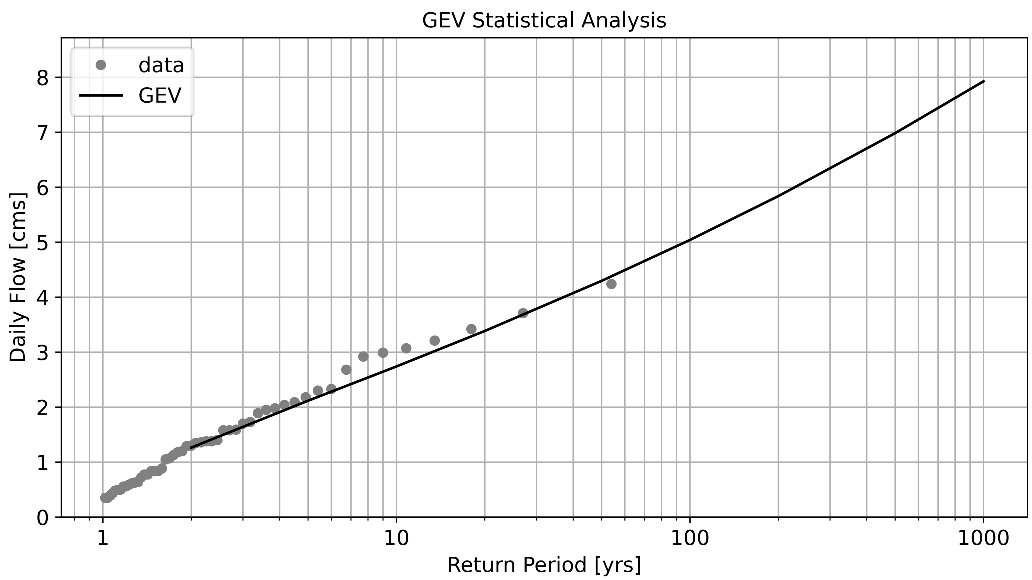


Figure A-7: Statistical Fit for Gauge 08LG056 Guichon Creek above Tunkwa Lake Diversion

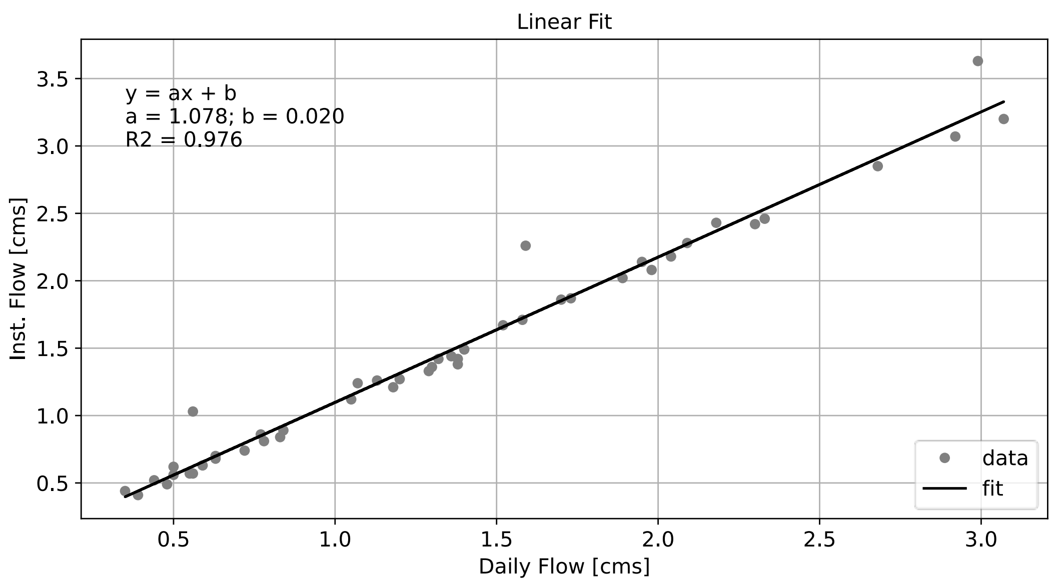


Figure A-8: Daily to Instantaneous Relationship Gauge 08LG056 Guichon Creek above Tunkwa Lake Diversion

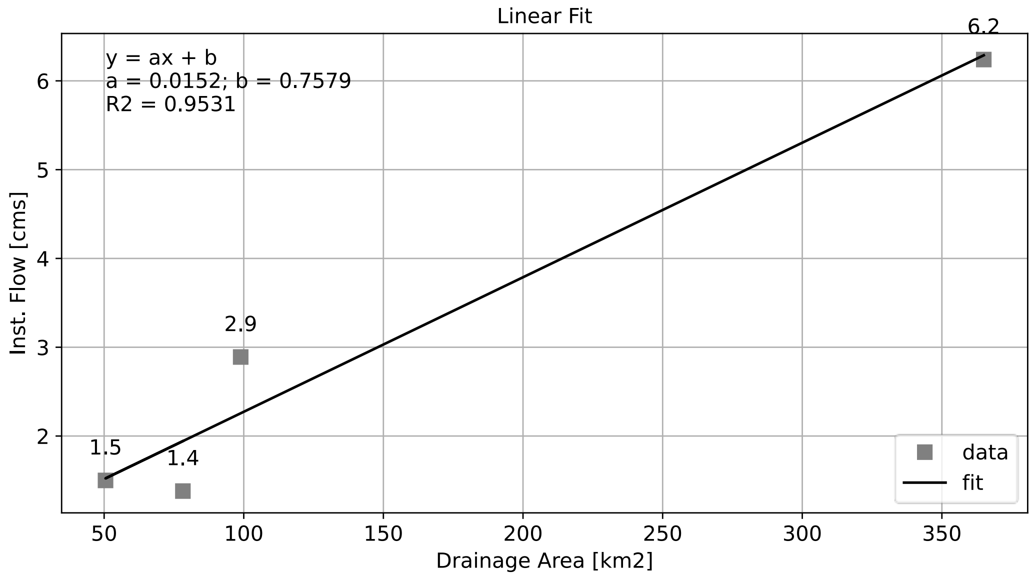


Figure A-9: Regional Curve for 2-yr Flows

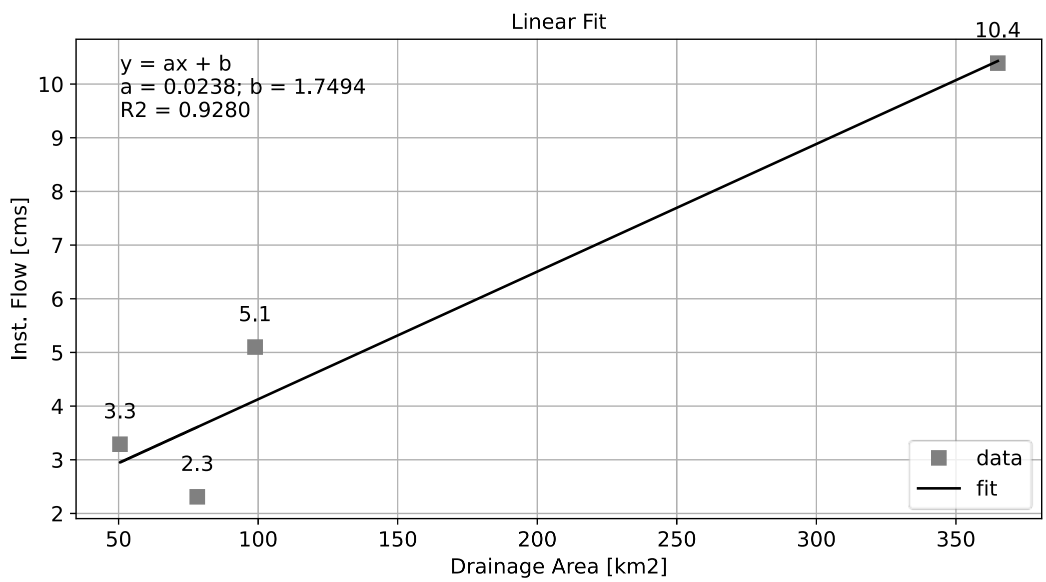


Figure A-10: Regional Curve for 5-yr Flows

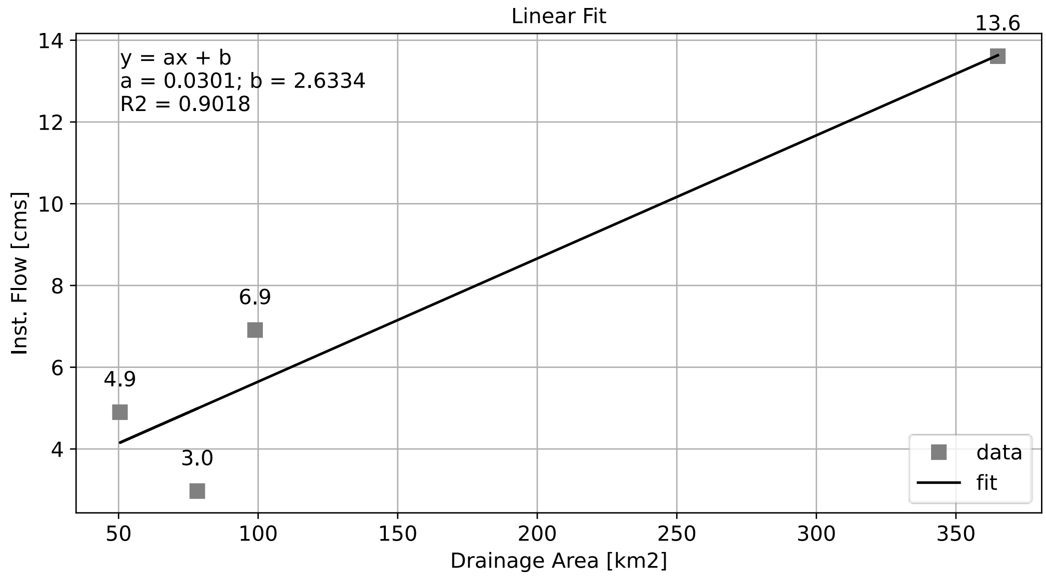


Figure A-11: Regional Curve for 10-yr Flows

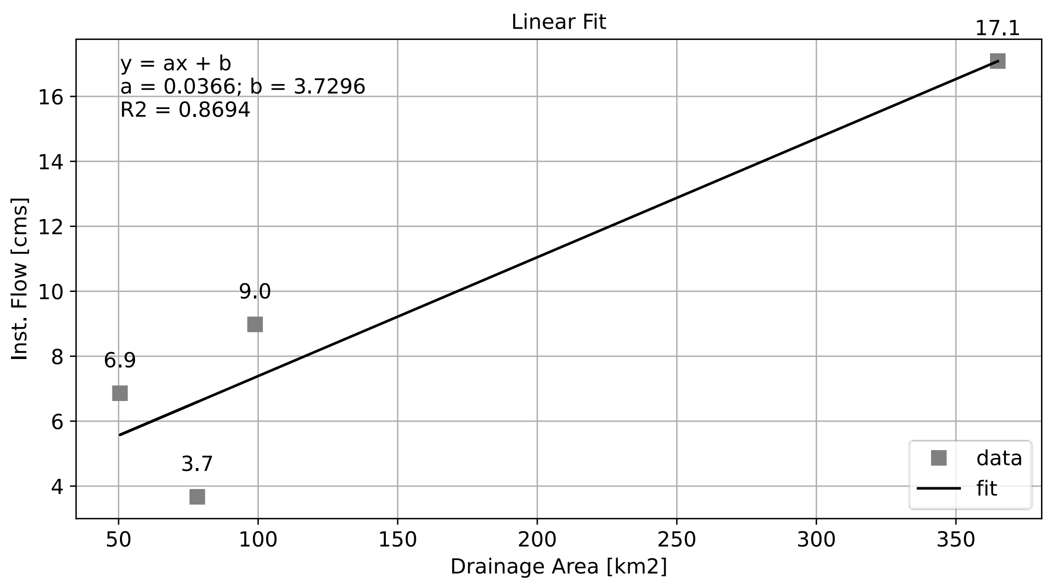


Figure A-12: Regional Curve for 20-yr Flows

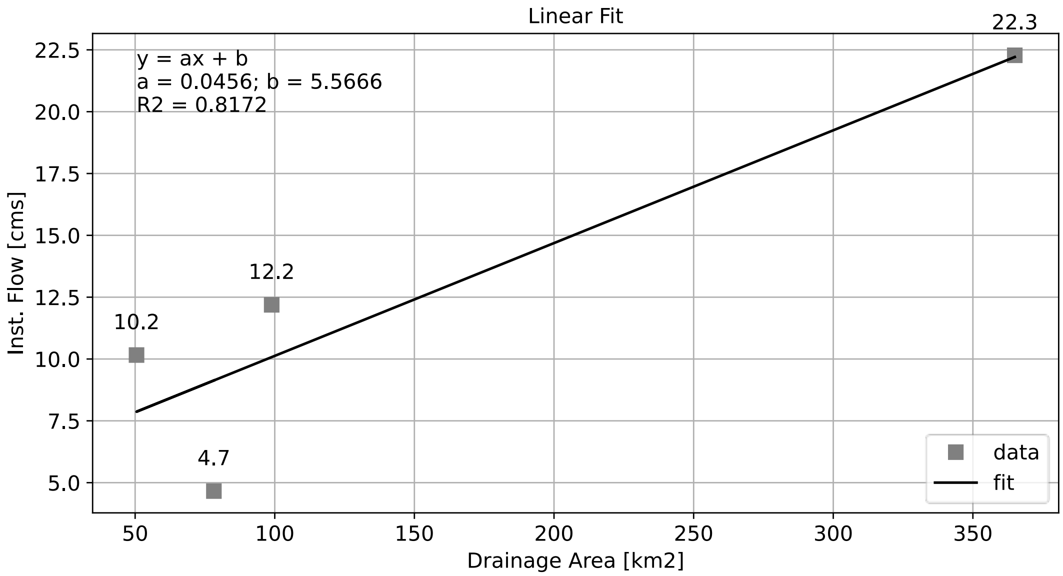


Figure A-13: Regional Curve for 50-yr Flows

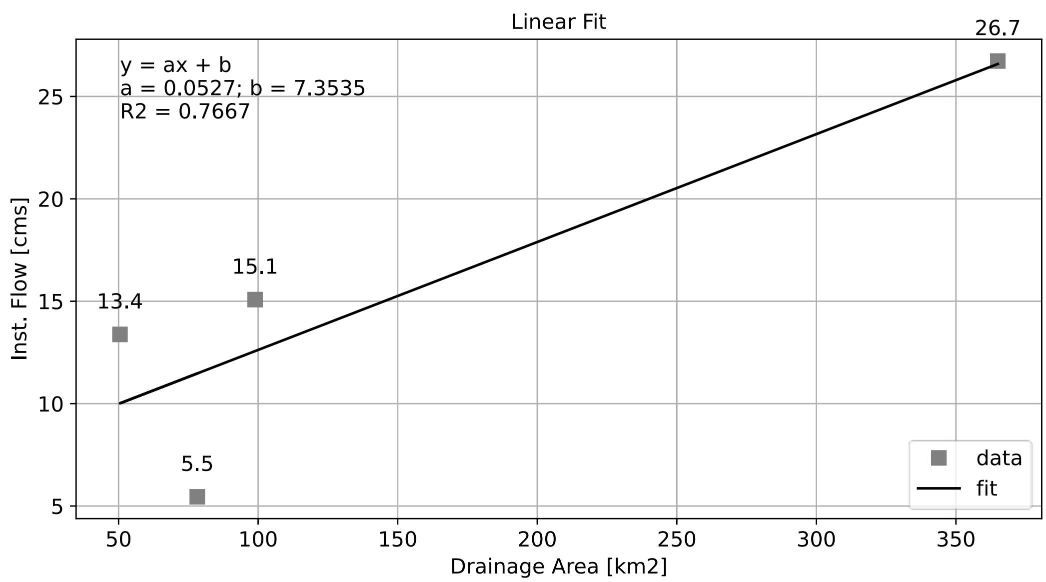


Figure A-14: Regional Curve for 100-yr Flows

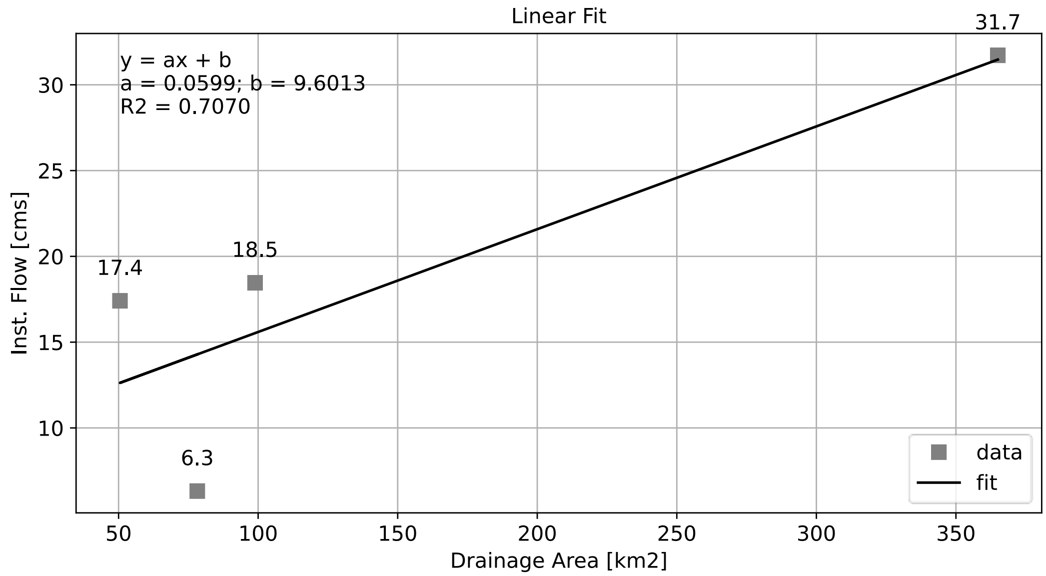


Figure A-15: Regional Curve for 200-yr Flows

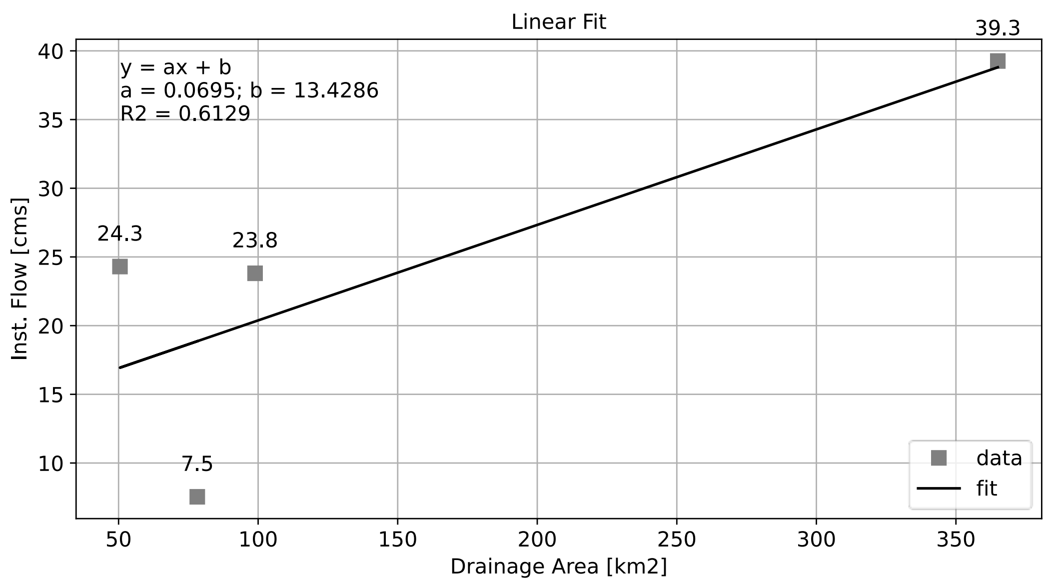


Figure A-16: Regional Curve for 500-yr Flows

Table A-1: Peak Flows at the Village of Clinton (without Climate Change)

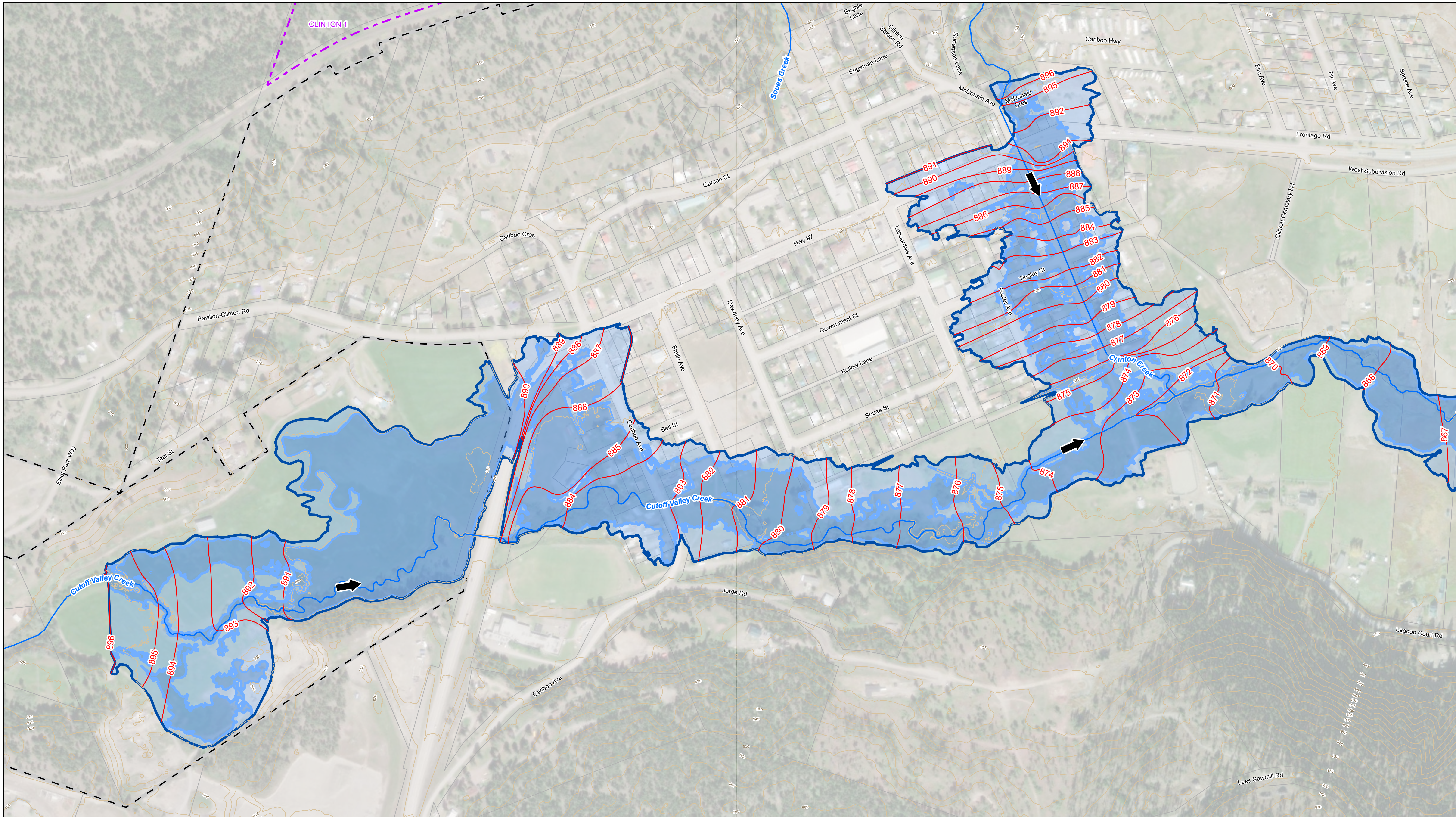
RETURN PERIOD (YRS)	CLINTON CREEK AT CN RAILWAY (M^3/S)	CUTOFF CREEK U/S OF CONFLUENCE (M^3/S)	CLINTON CREEK AT D/S LIMIT OF MUNICIPAL BOUNDARY (M^3/S)
2	1.2	2.9	4.1
5	2.0	4.9	6.9
10	2.6	6.6	9.2
20	3.4	8.3	11.7
50	4.5	11.0	15.5
100	5.4	13.5	18.9
200	6.5	16.2	22.7
500	8..2	20.4	28.6

Table A-2: Peak Flows at the Village of Clinton (with 20% Climate Change)

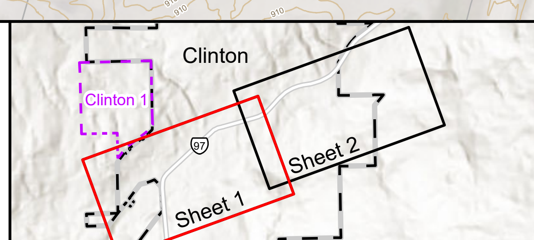
RETURN PERIOD (YRS)	CLINTON CREEK AT CN RAILWAY (M^3/S)	CUTOFF CREEK U/S OF CONFLUENCE (M^3/S)	CLINTON CREEK AT D/S LIMIT OF MUNICIPAL BOUNDARY (M^3/S)
2	1.4	3.5	4.9
5	2.4	5.9	8.3
10	3.2	7.9	11.0
20	4.0	10.0	14.0
50	5.4	13.2	18.6
100	6.5	16.2	22.7
200	7.8	19.4	27.2
500	9.9	24.4	34.3

APPENDIX B

Floodplain Mapping



CLINTON
SINCE 1863



Village of Clinton 200-Year End of Century with Climate Change Flood Inundation Map

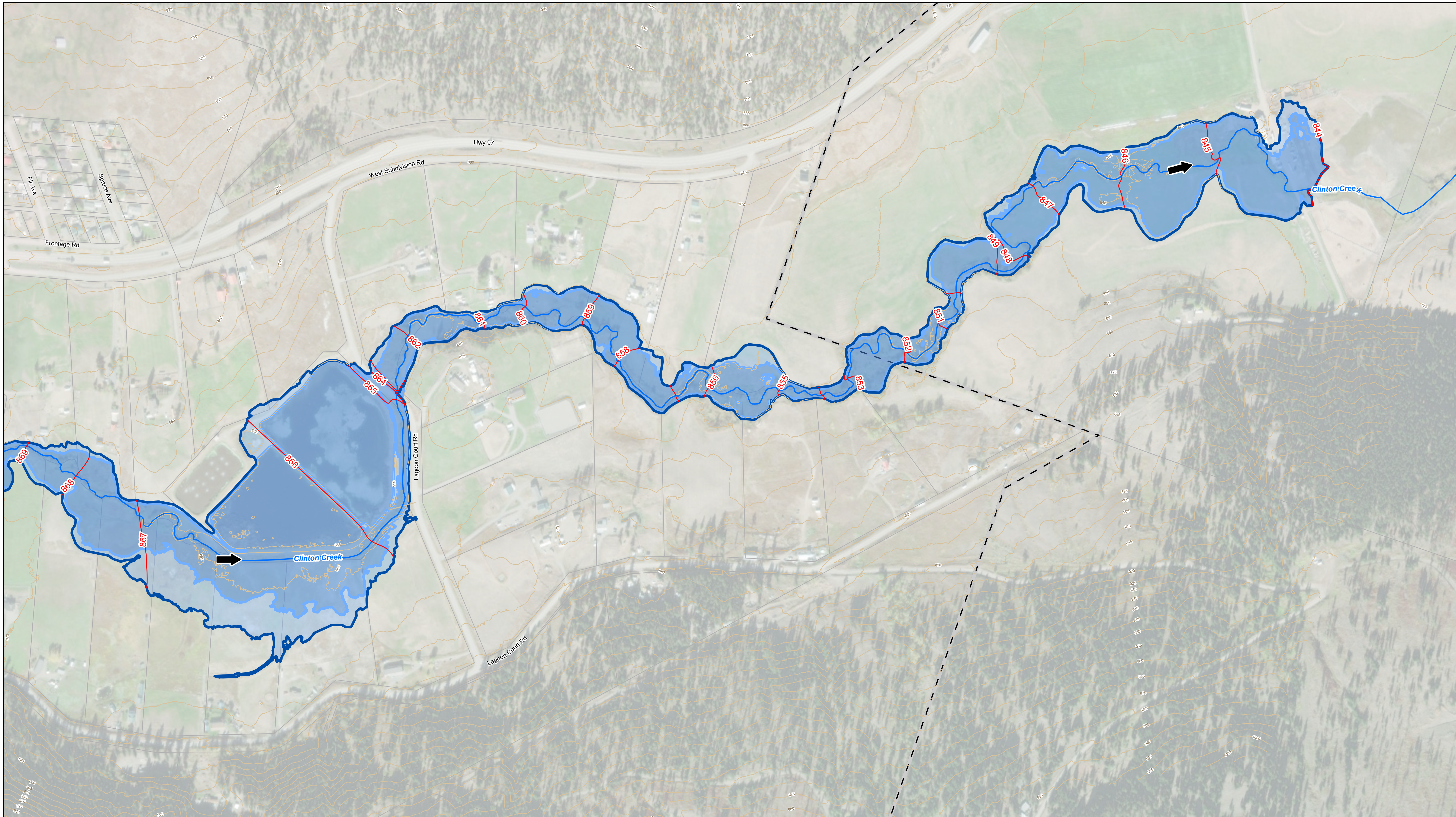
- Flow Direction
- River / Creek
- Flood Construction Level (FCL) River Isoline
- Major Contours at 5m Intervals
- Inundation Extent - Design Without Freeboard
- Inundation Extent With Freeboard (FCL)
- First Nation Reserve Boundary
- Municipal Boundary (Village of Clinton)

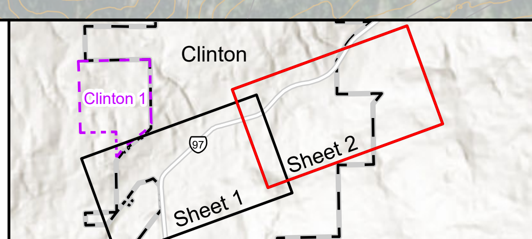
0 50 100 150 200 250 m

N

Reviewed by: PP	Scale: 1:5,000	TRUE
Revision #: 0	Issued for: Review	
Datum: NAD 83 CSRS (Zone 10)	Drawn by: RK	
Vertical Datum: CGVD2013	Date: 4/12/2024	Figure A1
Projection: Transverse Mercator	Project Ref No. 675-541	Sheet 1 of 2

R:\Clients\600-699\675\675-541\03 Drawings\GIS\675-541.aprx





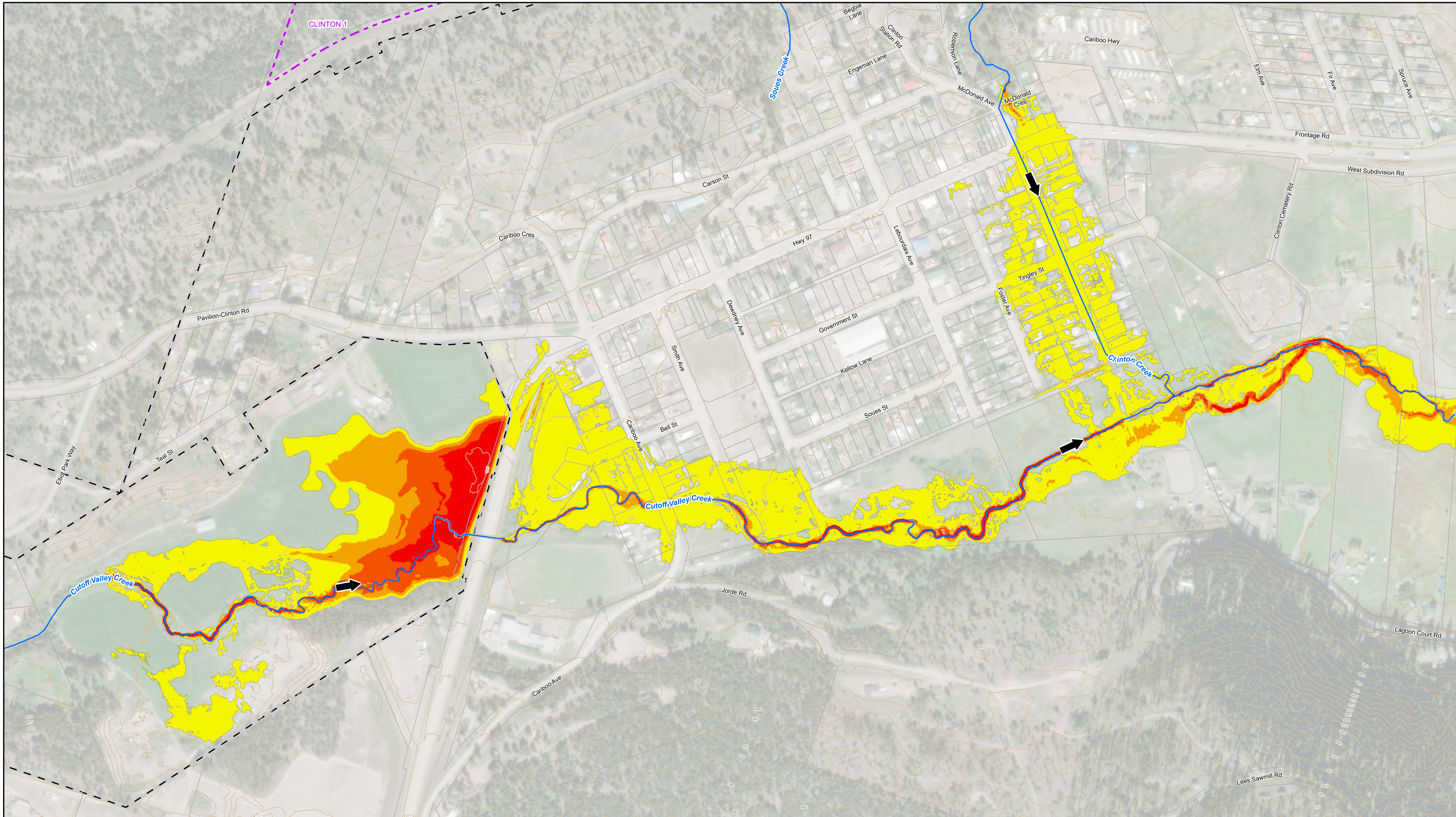
Village of Clinton 200-Year End of Century with Climate Change Flood Inundation Map

- Flow Direction
- River / Creek
- Flood Construction Level (FCL) River Isoline
- Major Contours at 5m Intervals
- Inundation Extent - Design Without Freeboard
- Inundation Extent With Freeboard (FCL)
- First Nation Reserve Boundary
- Municipal Boundary (Village of Clinton)

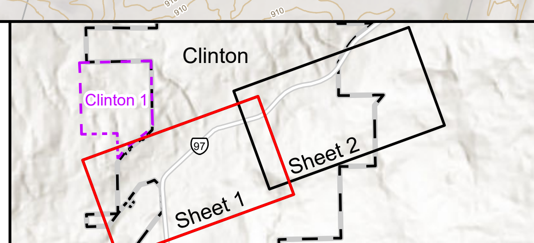
0 50 100 150 200 250 m

Reviewed by: PP	Scale: 1:5,000		
Revision #: 0	Issued for: Review		
Datum: NAD 83 CSRS (Zone 10)	Drawn by: RK		
Vertical Datum: CGVD2013	Date: 4/12/2024	Figure A1	
Projection: Transverse Mercator	Project Ref No. 675-541	Sheet 2 of 2	

R:\Clients\600-699\675\675-541\03 Drawings\GIS\675-541.aprx



CLINTON
SINCE 1863



Village of Clinton
200-Year End of Century with Climate Change Hazard Map

Flood Hazard Classification

- < 0.75 (Low)
- 0.75 - 1.25 (Moderate)
- 1.25 - 2.00 (Significant)
- > 2.00 (Extreme)

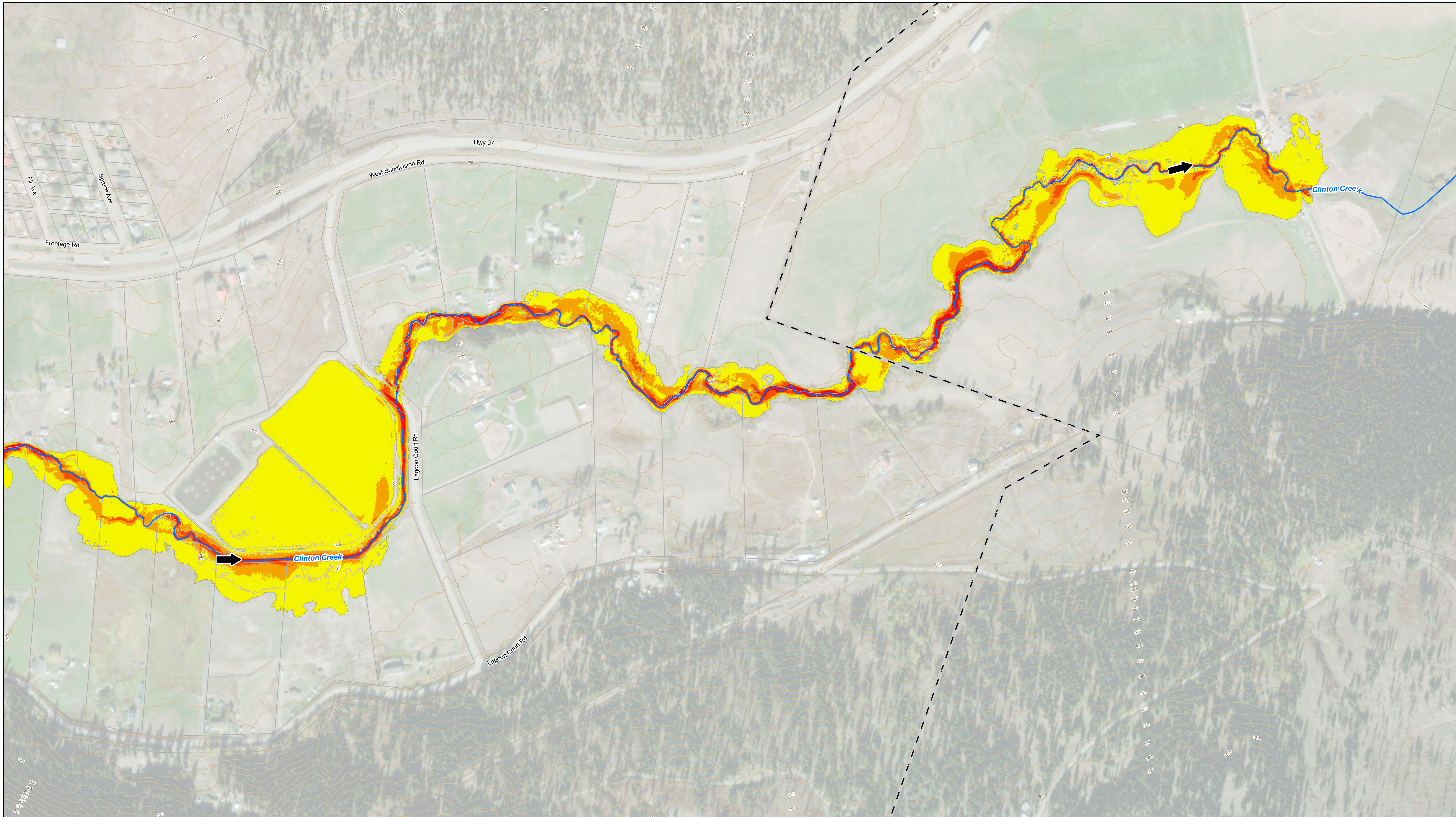
- Flow Direction
- Major Contours at 5m Intervals
- River / Creek
- First Nation Reserve Boundary
- Municipal Boundary (Village of Clinton)

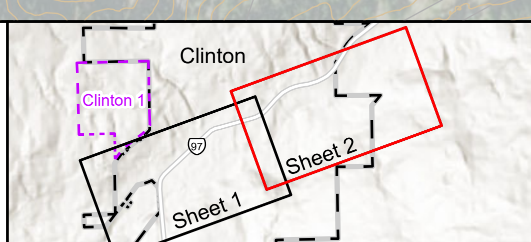
0 50 100 150 200 250 m

N

Reviewed by: PP	Scale: 1:5,000	TRUE	
Revision #: 0	Issued for: Review		
Datum: NAD 83 CSRS (Zone 10)	Drawn by: RK		
Vertical Datum: CGVD2013	Date: 4/15/2024	Figure A2	
Projection: Transverse Mercator	Project Ref No. 675-541	Sheet 1 of 2	

R:\Clients\600-699\675\675-541\03 Drawings\GIS\675-541.aprx





Village of Clinton
200-Year End of Century with Climate Change Hazard Map

Flood Hazard Classification

- < 0.75 (Low)
- 0.75 - 1.25 (Moderate)
- 1.25 - 2.00 (Significant)
- > 2.00 (Extreme)

- Flow Direction
- Major Contours at 5m Intervals
- River / Creek
- First Nation Reserve Boundary
- Municipal Boundary (Village of Clinton)

0 50 100 150 200 250 m

N

Reviewed by:	PP	Scale:	1:5,000	TRUE
Revision #:	0	Issued for:	Review	
Datum:	NAD 83 CSRS (Zone 10)	Drawn by:	RK	
Vertical Datum:	CGVD2013	Date:	4/15/2024	Figure A2
Projection:	Transverse Mercator	Project Ref No.	675-541	Sheet 2 of 2

R:\Clients\600-699\675\675-541\03 Drawings\GIS\675-541.aprx

APPENDIX C

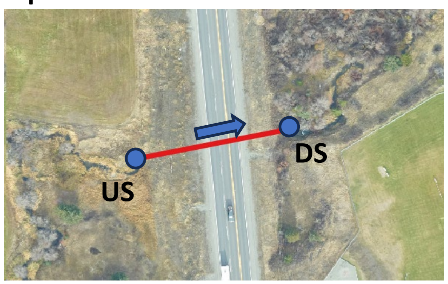
Existing Flood Management Infrastructure

HYDRAULIC INFRASTRUCTURE SHEET

Cutoff Creek

Location: Highway 97 (Cariboo Highway)

Watershed and location Information	Infrastructure Details and Dimensions		Current Flow Information
Date (dd/mm/yyyy): 19/04/2023	**Structure Type (Culvert/Bridge):**	Culvert	**Flow Present (Yes/No):** Yes
Field Crew: TRUE Land Surveying	**Number of Cells:**	1	**Approx. Depth (mm) (U/S):** 250
Watershed Name: Clinton Creek	**Material (Concrete/Steel):**	Corrugated Steel Pipe	**Approx. Depth (mm) (D/S):** 200
Tributary Name: Cutoff Creek	**Geometry**	Circular	**Upstream Erosion (Yes/No):** No
Municipality: Clinton, BC.	**Height (m) x Width (m) (If Applicable):**	N/A	**Downstream Erosion (Yes/No):** No
Key Map:	**Diameter (m) (If Applicable):**	1.5	**Additional Flow Information:**
	Length (m):	52	
	Inlet Type (Projection/Miltered/Headwall):	Projection	
	Upstream Invert (m):	884.36	
	Downstream Invert (m):	883.83	
	Slope (%)	1.02	
	Top of the Road Elevation (m):	894.03	
	Embankment Height (m):	10.2	



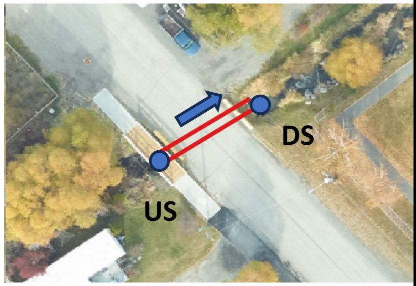
Site Photograph and Additional Field Note

Additional Field Note:	Upstream Photograph (Looking Downstream)	Downstream Photograph (Looking Upstream)

HYDRAULIC INFRASTRUCTURE SHEET

Cutoff Creek

Location: Cariboo Avenue

Watershed and location Information	Infrastructure Details and Dimensions		Current Flow Information
Date (dd/mm/yyyy): 19/04/2023	**Structure Type (Culvert/Bridge):**	Culvert	**Flow Present (Yes/No):** Yes
Field Crew: TRUE Land Surveying	**Number of Cells:**	2	**Approx. Depth (mm) (U/S):** 400
Watershed Name: Clinton Creek	**Material (Concrete/Steel):**	Corrugated Steel Pipe	**Approx. Depth (mm) (D/S):** 250
Tributary Name: Cutoff Creek	**Geometry**	Ellipsoid	**Upstream Erosion (Yes/No):** No
Municipality: Clinton, BC.	**Height (m) x Width (m) (If Applicable):**	Span 1.15m - Rise 0.82m	**Downstream Erosion (Yes/No):** No
Key Map: 	**Diameter (m) (If Applicable):**	N/A	**Additional Flow Information:**
	Length (m):	13.5	
	Inlet Type (Projection/Miltered/Headwall):	Projection	
	Upstream Invert (m):	881.3	
	Downstream Invert (m):	880.9	
	Slope (%)	2.96	
	Top of the Road Elevation (m):	882.8	
	Embankment Height (m):	1.9	

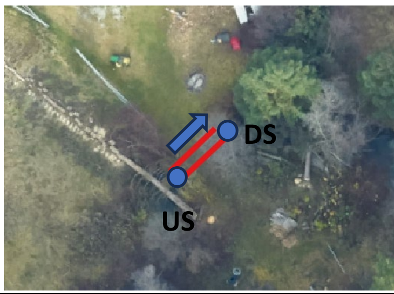
Site Photograph and Additional Field Note

Additional Field Note:	**Upstream Photograph (Looking Downstream)**	**Downstream Photograph (Looking Upstream) (Oct-12,2023)**
CARIBOO STREET 2 CULVERT WITH CROSS SECTION IN ELLIPSOID WITH 1150 mm OF SPAN, RISE 820 mm (VALUES APPROX FROM ARMTEC CATALOG), VALUES MEASURED IN FIELD WERE DIAMETER 1200 mm AND RISE 700-800 mm.		

HYDRAULIC INFRASTRUCTURE SHEET

Cutoff Creek

Location: Dewdney Avenue

Watershed and location Information	Infrastructure Details and Dimensions		Current Flow Information
Date (dd/mm/yyyy): 19/04/2023	**Structure Type (Culvert/Bridge):**	Culvert	**Flow Present (Yes/No):** Yes
Field Crew: TRUE Land Surveying	**Number of Cells:**	2	**Approx. Depth (mm) (U/S):** 300
Watershed Name: Clinton Creek	**Material (Concrete/Steel):**	Corrugated Steel Pipe	**Approx. Depth (mm) (D/S):** 300
Tributary Name: Cutoff Creek	**Geometry**	Circular	**Upstream Erosion (Yes/No):** No
Municipality: Clinton, BC.	**Height (m) x Width (m) (If Applicable):**	N/A	**Downstream Erosion (Yes/No):** No
Key Map: 	**Diameter (m) (If Applicable):**	0.8	**Additional Flow Information:**
	Length (m):	5.2	
	Inlet Type (Projection/Miltered/Headwall):	Projection	
	Upstream Invert (m):	876.8	
	Downstream Invert (m):	876.5	
	Slope (%)	5.77	
	Top of the Road Elevation (m):	877.8	
	Embankment Height (m):	N/A	

Site Photograph and Additional Field Note

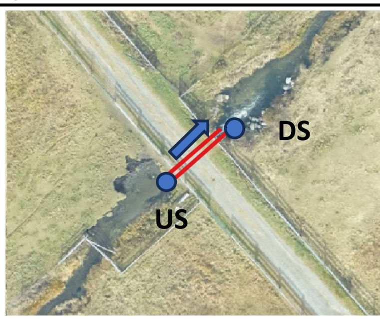
Additional Field Note:	Upstream Photograph (Looking Downstream)	Downstream Photograph (Looking Upstream)
		

HYDRAULIC INFRASTRUCTURE SHEET

Cutoff Creek

Location: McDonald Avenue

Watershed and location Information	Infrastructure Details and Dimensions		Current Flow Information
Date (dd/mm/yyyy): 19/04/2023	**Structure Type (Culvert/Bridge):**	Culvert	**Flow Present (Yes/No):** Yes
Field Crew: TRUE Land Surveying	**Number of Cells:**	2	**Approx. Depth (mm) (U/S):** 300
Watershed Name: Clinton Creek	**Material (Concrete/Steel):**	Corrugated Steel Pipe	**Approx. Depth (mm) (D/S):** 300
Tributary Name: Cutoff Creek	**Geometry**	Circular	**Upstream Erosion (Yes/No):** No
Municipality: Clinton, BC.	**Height (m) x Width (m) (If Applicable):**	N/A	**Downstream Erosion (Yes/No):** No
Key Map:	**Diameter (m) (If Applicable):**	C1=1.2 - C2=0.5	**Additional Flow Information:**
	Length (m):	9	
	Inlet Type (Projection/Miltered/Headwall):	Projection	
	Upstream Invert (m):	870.7	
	Downstream Invert (m):	870.2	
	Slope (%)	5.6%	
	Top of the Road Elevation (m):	872.8	
	Embankment Height (m):	2.6	



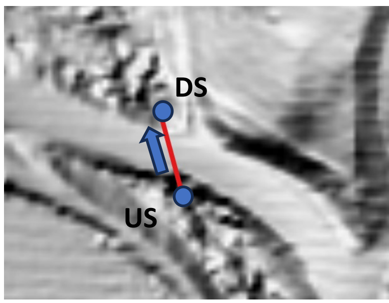
Site Photograph and Additional Field Note

Additional Field Note:	Upstream Photograph (Looking Downstream)	Downstream Photograph (Looking Upstream)
		

HYDRAULIC INFRASTRUCTURE SHEET

Clinton Creek

Location: Lagoon Road

Watershed and location Information	Infrastructure Details and Dimensions		Current Flow Information
Date (dd/mm/yyyy): 19/04/2023	**Structure Type (Culvert/Bridge):**	Culvert	**Flow Present (Yes/No):** Yes
Field Crew: TRUE Land Surveying	**Number of Cells:**	1	**Approx. Depth (mm) (U/S):** 300
Watershed Name: Clinton Creek	**Material (Concrete/Steel):**	Corrugated Steel Pipe	**Approx. Depth (mm) (D/S):** 300
Tributary Name: Clinton Creek	**Geometry**	Circular	**Upstream Erosion (Yes/No):** No
Municipality: Clinton, BC.	**Height (m) x Width (m) (If Applicable):**	N/A	**Downstream Erosion (Yes/No):** No
Key Map: 	**Diameter (m) (If Applicable):**	1.2	**Additional Flow Information:**
	Length (m):	14.4	
	Inlet Type (Projection/Miltered/Headwall):	Projection	
	Upstream Invert (m):	861.3	
	Downstream Invert (m):	860.9	
	Slope (%)	2.78	
	Top of the Road Elevation (m):	864.2	
	Height from Obvert to Top of Road (m):	3.3	

Site Photograph and Additional Field Note

Additional Field Note:	Upstream Photograph (Looking Downstream)	Downstream Photograph (Looking Upstream) (Oct-12,2023)
		

HYDRAULIC INFRASTRUCTURE SHEET

Clinton Creek

Location: Railway Embankment

Watershed and location Information

Date (dd/mm/yyyy): 12/10/2023

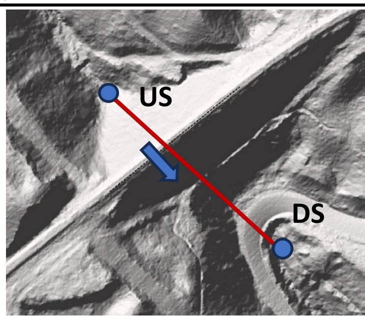
Field Crew: J.W./J.C.M.

Watershed Name: Clinton Creek

Tributary Name: Clinton Creek

Municipality: Clinton, BC.

Key Map:



Infrastructure Details and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Corrugated Steel Pipe
Geometry	Circular
Height (m) x Width (m) (If Applicable):	N/A
Diameter (m) (If Applicable):	0.7
Length (m):	102
Inlet Type (Projection/Miltered/Headwall):	Headwall
Upstream Invert (m):	944.6
Downstream Invert (m):	936.5
Slope (%)	7.94
Top of the Road Elevation (m):	964.6
Height from Obvert to Top of Road (m):	20

Current Flow Information

Flow Present (Yes/No): Yes

Approx. Depth (mm) (U/S): 200

Approx. Depth (mm) (D/S): 150

Upstream Erosion (Yes/No): No

Downstream Erosion (Yes/No): No

Additional Flow Information:

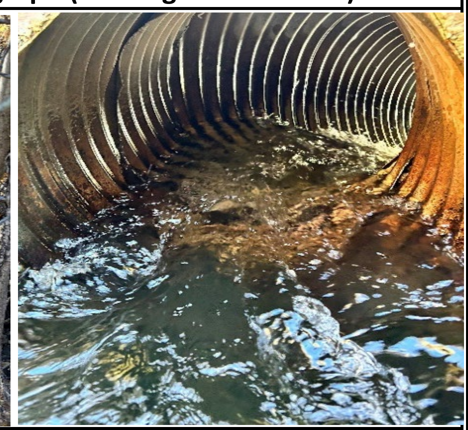
Site Photograph and Additional Field Note

Additional Field Note:

Invert Elevation taken from DEM.

Upstream Photograph (Looking Downstream)

Downstream Photograph (Looking Downstream)



HYDRAULIC INFRASTRUCTURE SHEET

Clinton Creek

Location: Village of Clinton Culvert (Parallel to McDonald Avenue)

Watershed and location Information
Date (dd/mm/yyyy): 12/10/2023
Field Crew: J.W./J.C.M.
Watershed Name: Clinton Creek
Tributary Name: Clinton Creek
Municipality: Clinton, BC.
Key Map:

Infrastructure Details and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Corrugated Steel Pipe
Geometry	Circular
Height (m) x Width (m) (If Applicable):	N/A
Diameter (m) (If Applicable):	1.1
Length (m):	425
Inlet Type (Projection/Miltered/Headwall):	Headwall
Upstream Invert (m):	893.2
Downstream Invert (m):	873.9
Slope (%)	4.54
Top of the Road Elevation (m):	895
Height from Obvert to Top of Road (m):	1.8

Current Flow Information
Flow Present (Yes/No): Yes
Approx. Depth (mm) (U/S): 150
Approx. Depth (mm) (D/S): 250
Upstream Erosion (Yes/No): No
Downstream Erosion (Yes/No): No
Additional Flow Information:

Site Photograph and Additional Field Note

Additional Field Note:

Upstream Photograph (Looking Downstream)

Downstream Photograph (Looking Upstream)

APPENDIX D

Project Sheet and Cost Estimates

Flood Mitigation Projects

Project No.	Project Title	Priority	Type	Cost Estimate
P1	Flood Early Warning System	Very High	Structural	$ 111,000
P2	CN Railway Embankment Hydraulic Upgrades	High	Structural	TBD
P3	Clinton and Cutoff Creeks Hydrometric Stations	High	Structural	$ 154,000
P4	WWTP Floodproofing and Lagoon Road Upgrades	High	Structural	$ 2,300,000
P5	Wastewater Treatment Plant (WWTP) Erosion Protection	Medium	Structural	$ 124,000
P6	Floodplain Land Use Regulation	Medium	Non-Structural	$ 145,000
P7	Flood Response Plan	Medium	Non-Structural	$ 147,000
P8	Clinton Creek Drainage Infrastructure Upgrades - MoTT	Medium	Structural	TBD
P9	Highway 97 Drainage Infrastructure Upgrades - MoTT	Medium	Structural	TBD
P10	Flood Education Program	Medium	Non-Structural	$ 55,000
P11	Cariboo Avenue Capacity Improvements	Low	Structural	$ 890,000
Total				**$ 3,930,000**

P1 – Flood Early Warning System

Priority	Very High	**Type**	Non-structural
Current Flood Vulnerability	Not Applicable	**Design Event**	200yr
Budget	$111,000		

1. Background

The Village of Clinton's water supply system includes two reservoirs located in the upper and lower Clinton Creek watershed (Figure 1). The Upper Clinton Creek Reservoir is classified as a High Consequence structure under BC Dam Safety Regulations.

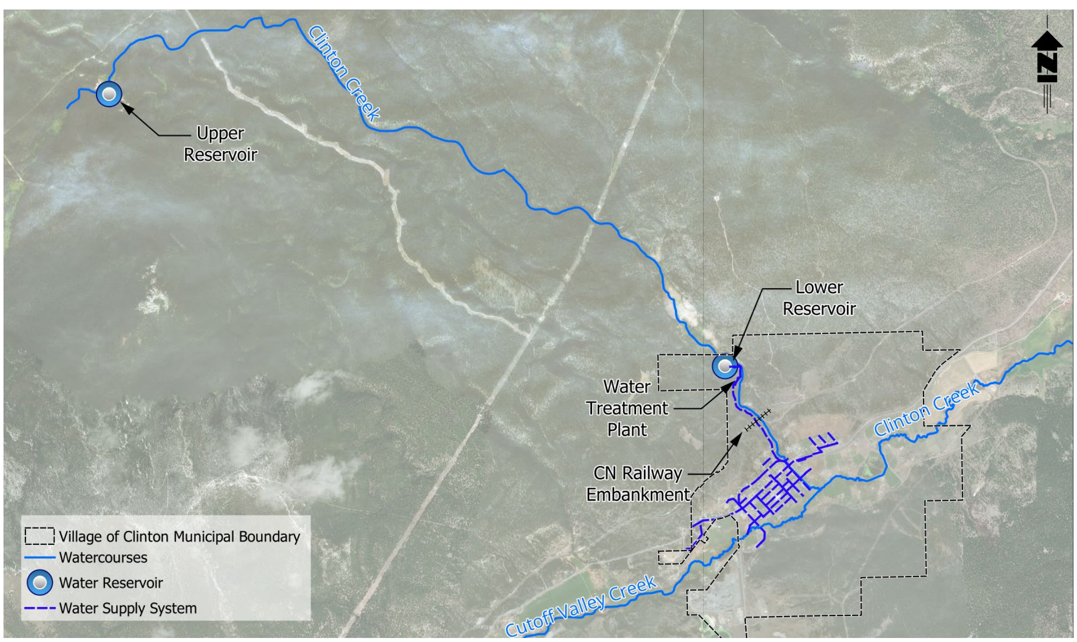


FIGURE 1 UPPER AND LOWER RESERVOIRS

The CN Railway Embankment at Clinton Creek, upstream of the Village urban area, poses a high flood risk. Previous studies identified the existing culvert infrastructure as vulnerable to debris blockage or insufficient hydraulic capacity during high flows. These risks could result in water accumulation and embankment failure, threatening downstream areas.

The figures below illustrate the projected extent and profile of water accumulation behind the existing infrastructure:

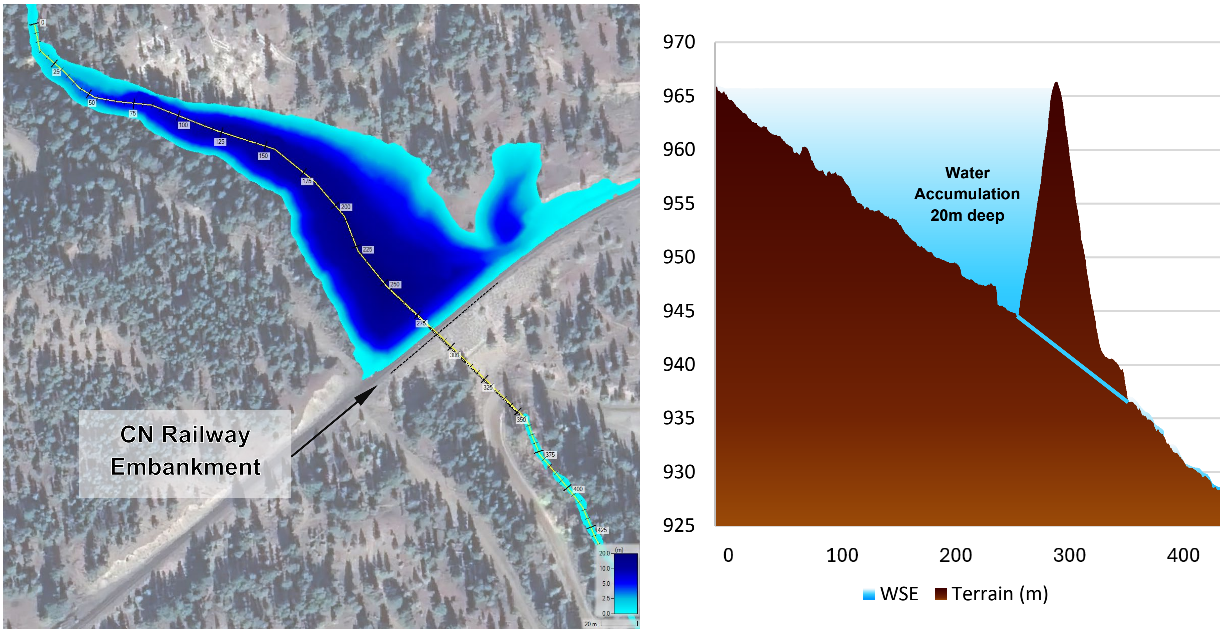


FIGURE 2 RAILWAY EMBANKMENT WATER ACCUMULATION EXTENT (LEFT) - PROFILE (RIGHT)

The 2019 Dam Break Analysis identified key risks related to geomorphology, debris, and potential flood scenarios. However, inaccuracies in the study affected its results and conclusions. Key findings include:

Flood Scenarios:

- <u>Moderate Scenario:</u>
  - Partial flow through the culvert (1.8m diameter), resulting in localized flooding along Robertson Lane, McDonald Crescent, and McDonald Avenue.
  - Assumed emergency personnel would have time to implement evacuation protocols and monitor water buildup.
- <u>Worst-Case Scenario:</u>
  - Blockage of the culvert due to debris and silt.
  - Overtopping of the embankment with peak flow of approximately 200 m^3/s, causing severe flooding.
  - Flood depths in impacted areas (e.g., Robertson Lane, McDonald, Lebourdais Avenue) range from 0.5m to 1.6m.

Incorrect Assumptions:

- <u>Culvert Size:</u> The analysis assumed a 1.8m culvert diameter. The actual culvert diameter is 0.7m, rendering it incapable of accommodating the predicted peak flows.
- <u>Water Depth:</u> The study estimated a water depth of 10m behind the embankment during a blockage. The actual depth would be closer to 20m, significantly increasing inundation extents and depths.

Emergency Plan:

- The study did not specify whether the Village had existing emergency protocols
- It assumed the Village's response capacity without highlighting the need of a Flood Early Warning System to safeguard lives and assets
- While it concluded that fatalities would be minimal due to assumed evacuations, it projected significant damage to homes and infrastructure in central Clinton.

2. Rationale

Flood Early Warning Systems (FEWS) are globally recognized by organizations such as the UN Office for Disaster Risk Reduction and BC's Provincial Government as essential tools for disaster preparedness. In Clinton, implementing a FEWS could provide advanced notice of a potential CN Railway embankment failure, thereby protecting lives and assets.

The 2019 Dam Break Analysis highlighted significant impacts from a potential embankment failure, with projected inundation areas illustrated in Figure 3.

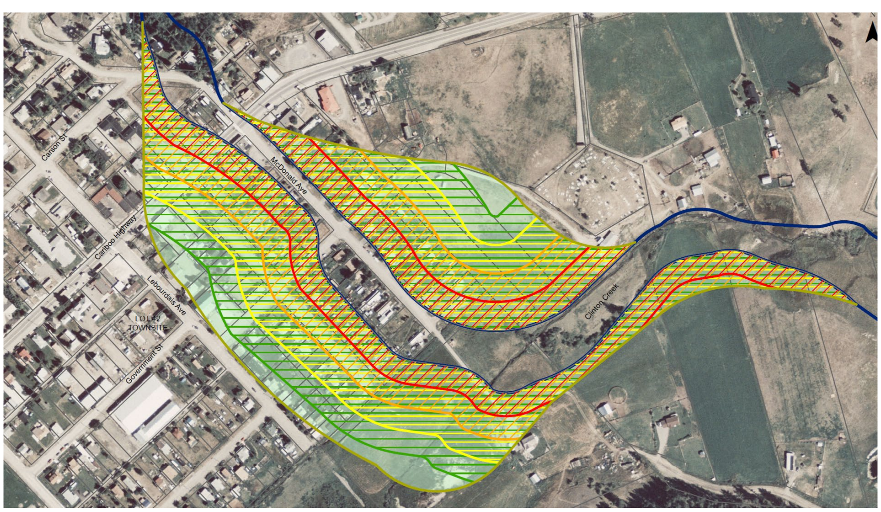


FIGURE 3 INUNDATION AREAS DAM BREAK ANALYSIS 2019

However, the study underestimated the potential impact due to:

- Incorrect assumptions regarding the size of the existing drainage infrastructure.
- An underestimation of the flood wave magnitude and extent.

When combined with findings from Floodplain Mapping and weighted risk assessments, these inaccuracies emphasize the need for a FEWS. Its implementation is critical to ensuring the Village's resilience and the safety of its community.

3. Mitigation Strategy

This project proposes installing a water level sensor and early warning system at the CN Railway embankment. The system will monitor water accumulation behind the embankment, identifying potential flood risks early. If significant water backup is detected, the system will automatically trigger alerts to notify the community and relevant authorities. This immediate notification enables timely actions, such as evacuations and preventive measures, to minimize impacts. By addressing the risks of embankment overtopping and flood wave propagation, the early warning system enhances community safety and resilience against severe flood events.

4. Project Scope

The Flood Early Warning System (FEWS) project aims to enhance community safety and flood risk preparedness for the Village of Clinton. This initiative involves the installation of a water level monitoring sensor and a separate early warning system at the CN Railway embankment to address potential flood risks and enable timely responses during critical events.

Key tasks include:

Water Level Sensor Installation

- Conduct a site assessment to identify the optimal location for the water level sensor.
- Install a high-precision water level sensor to detect potential water accumulation.
- Connect the sensor to a solar-powered data logger with backup batteries.
- Establish protocols for data transmission to ensure accurate, continuous monitoring.

Early Warning System Installation

- Design and install an automated alert system connected to the water level sensor.
- Configure alert thresholds based on flood scenarios identified in previous studies.
- Set up communication channels to send automated alerts to emergency responders and community members via SMS, email, or sirens.
- Develop and test protocols for activating evacuation procedures based on sensor data.

Integration and Testing

- Link the sensor and warning system to the Village's emergency response plans.
- Conduct calibration and pilot testing to verify system functionality and reliability.

Coordination and Training

- Collaborate with CN Railway and relevant authorities to ensure alignment with existing safety protocols.
- Train local staff and responders on system operation, monitoring, and maintenance.

Project Deliverables

- A fully operational water level sensor providing real-time monitoring of water accumulation.
- A robust early warning system delivering automated alerts to designated stakeholders.
- Documentation detailing installation, calibration, and operational protocols.
- Community education materials to inform residents about the system and response actions

Village of Clinton
P1 - Flood Early Warning System
Class 'D' Cost Estimate

ITEM NO.	DESCRIPTION	UNIT OF MEASURE.	EST. QUANT.	UNIT PRICE	TOTAL PRICE
1.0	**Project Management**				
1.1	Start up meeting		1	$3,000	$3,000
1.2	Prepare Awareness and Education Plan (AEP)		1	$4,000	$4,000
1.3	Team meetings (e.g. check-in, updates, next steps)		1	$3,000	$3,000
1.4	Project management & communications		1	$4,000	$4,000
	Subtotal 1.0 Project Management				**$14,000**
2.0	**Water Level Sensor Installation**				
2.1	Site assessment to identify the optimal location		1	$6,000	$6,000
2.2	Water Level sensor at CN Railway Embankment supply and installation		1	$25,000	$25,000
2.3	Integrate the sensor with a real-time data logger		1	$4,000	$4,000
2.4	Establish protocols for data transmission		1	$5,000	$5,000
	Subtotal 2.0 Water Level Sensor Installation				**$40,000**
3.0	**Early Warning System Installation**				
3.1	Design and Installation of automated aler system		1	$12,000	$12,000
3.2	Configurated alert thresholds		1	$3,000	$3,000
3.3	Set up communication channels		1	$5,000	$5,000
3.4	Develop and test protocols for activating evacuation procedures		1	$4,000	$4,000
	Subtotal 3.0 Early Warning System Installation				**$24,000**
3.0	**Integration and Testing**				
3.1	Synchronize the water level sensor and early warning system with the Village's emergency response plans		1	$6,000	$6,000
3.2	System calibration and commissioning		1	$5,000	$5,000
	Subtotal 3.0 Integration and Testing				**$11,000**
4.0	**Coordination and Training**				
4.1	Collaborate with CN Railway and relevant authorities		1	$3,000	$3,000
4.2	Operation and maintenance training		1	$4,000	$4,000
	Subtotal 4.0 Coordination and Training				**$7,000**

<u>Project Summary</u>

Subtotal	**$96,000**
Permitting (5%)	**$4,800**
Contingency (10%)	**$10,000**
Total Project (rounded, not including GST)	**$111,000**

P2 – CN Railway Embankment Hydraulic Capacity Upgrades

Priority	High	**Type**	Structural
Current Flood Vulnerability	Varies	**Design Event**	200yr
Budget	TBD		

1. Background

Clinton's water supply relies on two earthfill reservoirs located in the upper and lower sections of the Clinton Creek watershed. The Upper Clinton Creek Reservoir is classified as a High Consequence structure under BC Government dam safety policies and regulations, mainly due to:

- The creek diversion pond downstream (Lower Clinton Creek Reservoir);
- Potential impacts on water treatment works;
- The creek crossing beneath a high railway embankment upstream of the Village of Clinton; and
- The creek's flow path through the Village itself.

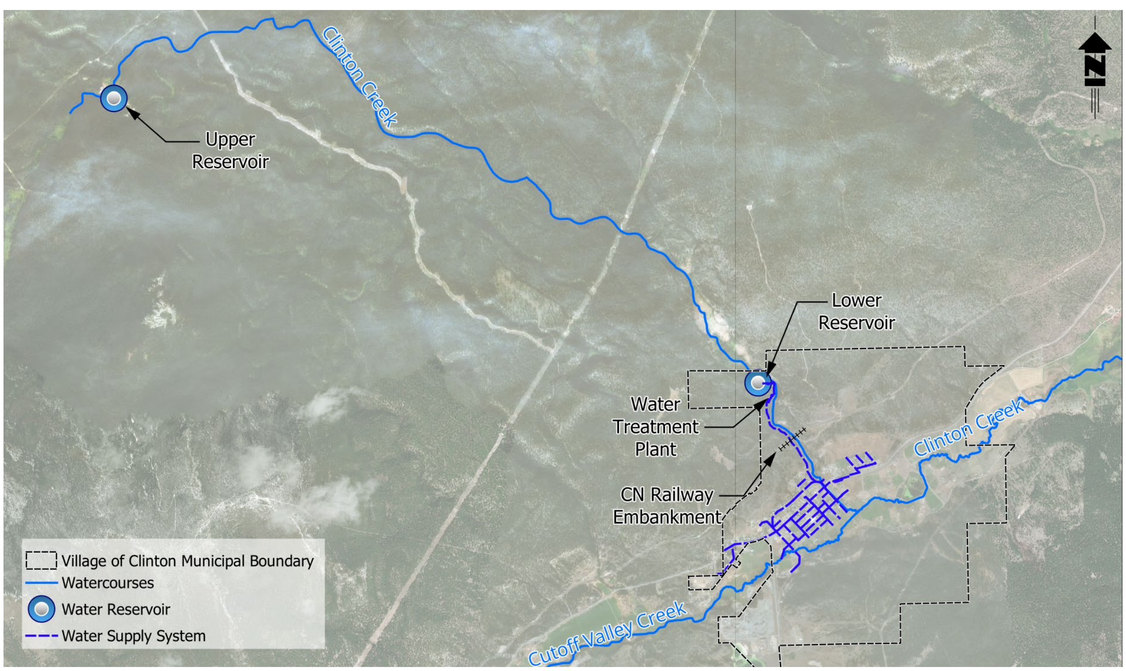


FIGURE 1 UPPER AND LOWER RESERVOIRS

The CN Railway Embankment at Clinton Creek, upstream of the Village urban area, poses a high flood risk. Previous studies identified the existing culvert infrastructure as vulnerable to debris blockage or insufficient hydraulic capacity during high flows. These risks could result in water accumulation and embankment failure, threatening downstream areas.

The figures below illustrate the projected extent and profile of water accumulation behind the existing infrastructure:

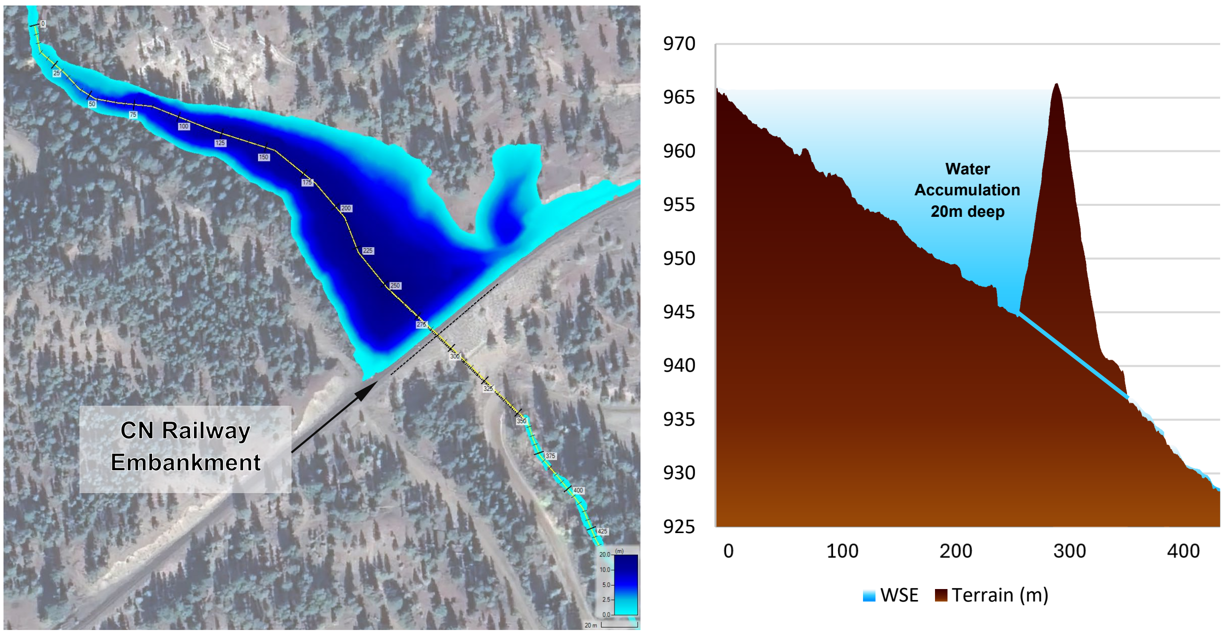


FIGURE 2 RAILWAY EMBANKMENT WATER ACCUMULATION EXTENT (LEFT) - PROFILE (RIGHT)

Key findings from past studies are summarized below:

Clinton Creek Reservoir Dam (D11020-00) Dam Break Analysis (AC Eagle, 2019).

This study analyzed potential dam break scenarios for the Upper and Lower Clinton Creek Reservoirs but contained inaccuracies regarding the CN Railway embankment.

Key observations (adjusted to reflect accurate data):

- **Geomorphological and Debris Considerations**: Natural features, such as gullies along watercourses, could transport silt and woody debris downstream. If a dam break flood wave occurs, this debris could block the culvert under the CN Railway embankment, exacerbating flood risks. The accumulation of water behind the embankment could cause it to overtop, leading to erosion and potentially creating a second flood wave into the Village.

- **Flood Scenarios:** The study incorrectly assumed that the embankment could attenuate peak flows with a 1.8m culvert. In reality, the culvert's diameter is 0.7m, making it incapable of accommodating such flows.
  In the worst-case scenario, the study estimated a water depth of 10m behind the embankment, but the actual depth would be closer to 20m. This increases the inundation extent and associated risks. A blockage could lead to embankment overtopping, with a peak flow of approximately 200 m³/s causing significant flooding in areas such as Robertson Lane, McDonald, and Lebourdais Avenue, with depths greater than previously assumed (0.5 m to 1.6 m).
  These discrepancies highlight the need for updated dam break analysis and refined risk assessments to address the greater hazard posed by the actual conditions

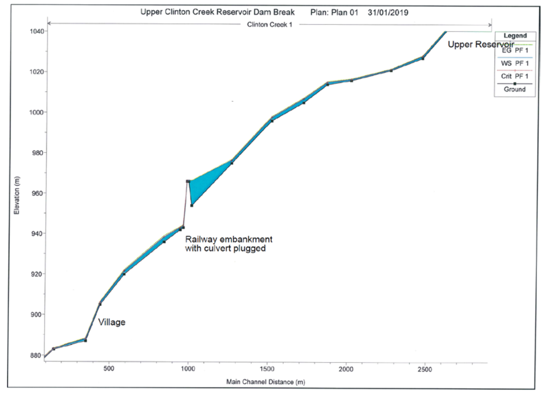


FIGURE 3 CLINTON CREEK PROFILE (AC EAGLE, 2019)

Recommended Actions and Mitigation:

- **Collaboration with CN Rail:** The 2014 Dam Safety Review (DSR) highlighted the “bottleneck” risk at the CN Railway embankment, urging CN Rail to address the potential culvert blockage as a safety priority. The DSR recommended partnering with CN Railway to establish emergency protocols for debris removal, monitoring, and flood response should a blockage occur during a large flood event or dam break.
- **Emergency Protocols:** Suggested actions include creating procedures for debris removal, issuing evacuation notices for downstream areas, and establishing monitoring systems for the embankment to identify potential blockages early. These protocols could be formalized with CN Railway using recent studies as a reference for discussions.

Floodplain Mapping Report (TRUE, 2024)

This project focused on developing floodplain mapping for the Village based on a 200yr design flood event. While it did not update the 2019 dam breach analysis, the report built on previous investigations and provided additional insights:

- The CN Railway embankment, located upstream of the town on the steep portion of Clinton Creek, consists of a 20 m high earthen embankment. LiDAR data updated the previous 2019 study, which had estimated the height at 10 m. Additionally, a field inspection revised the culvert


FIGURE 4 700MM CSP CULVERT

size below the CN Railway embankment to 0.7 m, compared to the 1.8 m referenced in the 2019 study.

- The CN Railway culvert has a high chance of being plugged with debris during a major flood event.
- Clinton Creek upstream of the Village is a steep mountainous watercourse, which does not have a natural floodplain that requires mapping (all flows stay within the main channel and its valley slopes). However, the existing infrastructure along the Clinton Creek upstream of the Village (drinking water reservoirs and the CN Railway embankment) pose serious threat in case if it becomes compromised in the future.

2. Rationale

Findings from referenced studies emphasize the need for the Village to engage with CN Railway regarding potential risks and necessary upgrades to the existing embankment. The scale of downstream impacts justifies a detailed review of the crossing's hydraulic capacity, debris management, and flood early warning systems.

Under Transport Canada's Grade Crossings Regulations, railway companies are obligated to ensure that crossings meet current safety and engineering standards. This includes responsibilities for the design, construction, and maintenance of crossing surfaces within the railway right-of-way, as well as ensuring adequate hydraulic and structural functionality to mitigate risks and maintain safety.

3. Mitigation Strategy

Given the potential flood risks to properties and Village residents downstream, the most effective mitigation solution is likely to combine hydraulic upgrades with a robust monitoring system. This would address both immediate structural vulnerabilities and the need for ongoing oversight of debris accumulation and flow conditions.

Preliminary assessments suggest that a 2.1–2.5 m diameter culvert would be required to manage the projected 200yr flood event, assuming no debris obstruction. This range provides a reference point for further investigation and discussions.

4. Next Steps

- Engaging with CN Railway and other interested parties to discuss the outlined risks, potential consequences, and proposed actions.
- Considering additional strategies the Village could implement to reduce short-term flood risks.
- Educating the community about the risks and available tools to reduce their vulnerability during high-flow scenarios, with a focus on protecting lives and community assets.

P3 – Clinton and Cutoff Creeks Hydrometric Stations

Priority	High	**Type**	Non-structural
Current Flood Vulnerability	Not Applicable	**Design Event**	200yr
Budget	$154,000		

1. Background

Climate change has intensified flood risks across British Columbia, with projections indicating more frequent and less predictable flood events in key watercourses. For the Village of Clinton, the anticipated impacts include:

- **Flood Risks:** Increased variability in freshet seasons and rain-on-snow events contribute to more intense and unpredictable flooding
- **Reduced Water Availability:** Reduced snowpack due to warmer winters, threatening water availability for residential and agricultural activities

Clinton's water supply system depends on a balance between snowmelt and reservoir storage, making it highly sensitive to changes in snow accumulation. Studies such as the Dam Break Analysis (AC Eagle, 2019) and Floodplain Mapping have identified potential dam failure scenarios, with projected inundation threatening the Village's urban area.

The figure below shows the projected 200yr inundation extent based on the Floodplain Mapping:

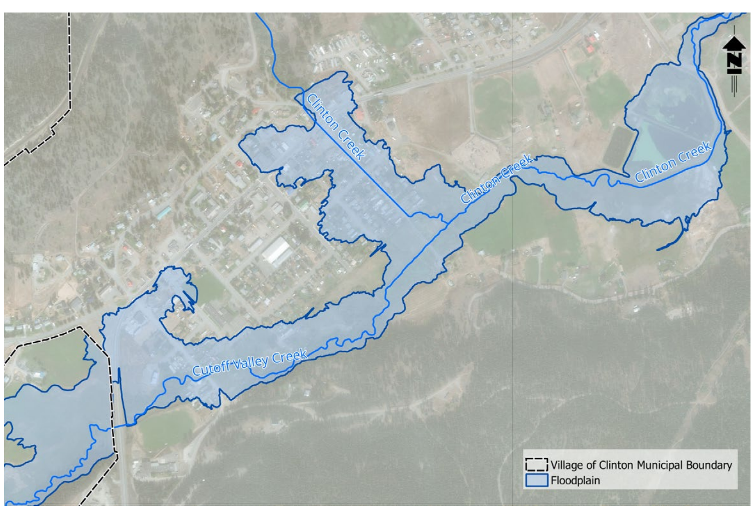


FIGURE 1 200YR FLOODPLAIN

2. Rationale

Floodplain Mapping, the Dam Break Analysis, and complementary studies rely on regional flood frequency analysis and simplified or uncalibrated hydrological models. These methods introduce significant uncertainty in flow estimates. The lack of flow data prevents the verification of hydrological and hydraulic models. Moreover, the absence of hydrometric stations limits the ability to track climate-related trends and quantify impacts under future scenarios.

Projected flows in Clinton and Cutoff Creeks will require mitigation projects with significant capital costs. Installing hydrometric stations will reduce uncertainty in infrastructure design and future climate scenarios, helping optimize resources and provide solutions tailored to watercourse characteristics.

3. Mitigation Strategy

This project proposes installing hydrometric stations at Cutoff Creek, upstream the Cariboo Highway embankment and at Clinton Creek, at the water supply's lower reservoir. These stations will monitor resources and track trends, aiding in preparedness for flooding events, or drought scenarios with water scarcity.

Essential components for the hydrometric station include:

- Flow measurement device: Options include Acoustic Doppler Current Profilers (ADCPs), pressure transducers, or water level/flow gauges
- Data logger: Transmits real-time data to a central control system
- Independent energy source: Powered by solar panels and a backup battery
- Additional equipment: May include desiccating air dryers, PLCs (Programmable Logic Controllers), etc.

FIGURE 2 EXAMPLE OF A HYDROMETRIC STATION: WSC - NORTH THOMPSON AT BIRCH ISLAND

The hydrometric station should feature a robust, automatic data recording system, requiring minimal maintenance and designed for harsh environmental conditions. The final location of the hydrometric stations will be selected based on hydraulic, high and low flow considerations. Figure 3 illustrates the proposed location for the hydrometric stations.

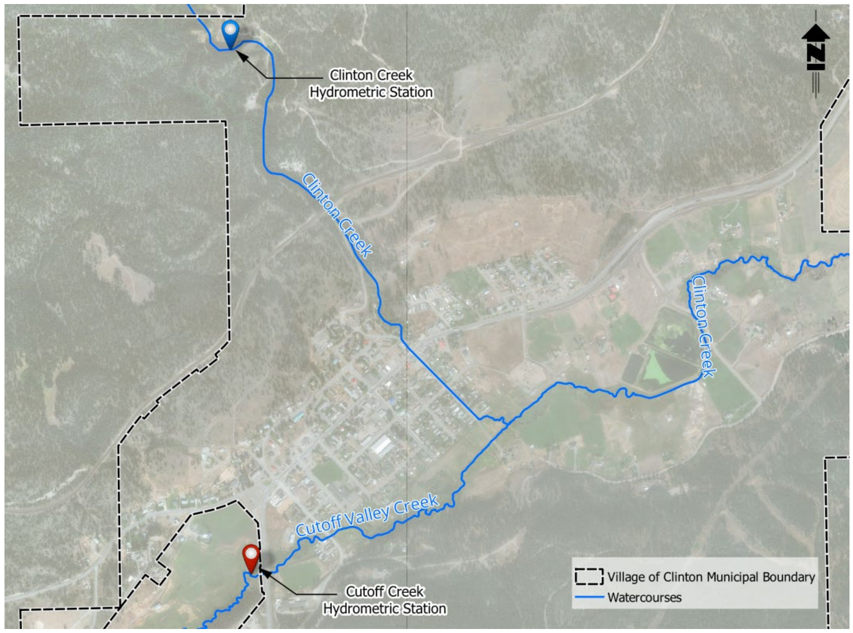


FIGURE 3 PROPOSED HYDROMETRIC STATIONS LOCATION

Key considerations in the installment of the hydrometric stations include:

- **Site Selection:** Ensure accessibility, minimal environmental impact, and hydraulic representativeness.
- **Durability:** Design for harsh conditions, including floods and freezing temperatures.
- **Power and Communication:** Include reliable systems with solar backup and real-time data transmission.
- **Standards Compliance:** Align with provincial and federal regulations.
- **Integration:** Link stations to early warning systems for emergency preparedness.
- **Community Engagement:** Highlight project benefits and gather local input.
- **Cost-Effectiveness:** Focus on practical, efficient designs and explore funding opportunities.

4. Project Scope

The Clinton and Cutoff Creek Hydrometric Stations project aims to enhance water resource monitoring and flood preparedness in the Village of Clinton. This initiative involves installing two hydrometric stations at the specified watercourses to monitor flood events and water availability for drought management.

Key tasks include:

Hydrometric Station Installation

- Assess locations and design the hydrometric stations
- Install flow measurement devices (e.g., Pressure transducers, or Acoustic Doppler Current Profiler)
- Set up solar-powered data loggers for real-time transmission
- Adjust existing hydraulic structures for calibration, if required

Integration and Testing

- Link hydrometric data to flood response plans
- Perform system calibration and pilot testing to ensure reliability

Coordination and Training

- Collaborate with relevant authorities for implementation, apply for water data sharing agreement with the Province.
- Train staff in system operation and maintenance

Project Deliverables

Anticipated deliverables and outcomes include:

- Two fully operational hydrometric stations providing real time water flow and level data
- Data records for future works and better decision making
- Documentation including technical guidelines, calibration records, and operational protocols

Village of Clinton
P3 - Clinton and Cutoff Creeks Hydrometric Stations
Class 'D' Cost Estimate

ITEM NO.	DESCRIPTION	UNIT OF MEASURE.	EST. QUANT.	UNIT PRICE	TOTAL PRICE
1.0	**Project Management**				
1.1	Start up meeting		1	$2,000	$2,000
1.2	Team meetings (e.g. check-in, updates, next steps)		1	$4,000	$4,000
1.3	Project management & communications		1	$4,000	$4,000
	Subtotal 1.0 Project Management				**$10,000**
2.0	**Hydrometric Station Installation**				
2.1	Hydrometric Station Assessment and Design		2	$6,000	$12,000
2.2	Hydrometric Station supply and installation		2	$25,000	$50,000
2.3	Setting up solar-powered data loggers for real-time transmission		2	$8,000	$16,000
2.4	Hydraulic Structure Calibration		2	$15,000	$30,000
	Subtotal 2.0 Hydrometric Station Installation				**$108,000**
3.0	**Integration and Testing**				
3.1	Link hydrometric data to flood response plans		1	$6,000	$6,000
3.2	System calibration and commissioning		1	$3,000	$3,000
	Subtotal 3.0 Integration and Testing				**$9,000**
4.0	**Coordination and Training**				
4.1	Collaborate with relevant authorities for implementation, apply for water data sharing agreement with the Province		1	$3,000	$3,000
4.2	Operation and maintenance training		1	$4,000	$4,000
	Subtotal 4.0 Coordination and Training				**$7,000**

Project Summary

Subtotal	**$134,000**
Permitting (5%)	**$6,700**
Contingency (10%)	**$13,000**
Total Project (rounded, not including GST)	**$154,000**

P4 – WWTP Floodproofing and Lagoon Road Upgrades

Priority	Medium	**Type**	Structural
Current Flood Vulnerability	50yr	**Design Event**	200yr
Budget	Predesign $88,000 Capital $2,212,000 Total $2,300,000		

1. Background

The facultative lagoon cells at the Clinton WWTP play an essential role in reducing organic matter, pathogens, and suspended solids, ensuring effluent quality before discharge into Clinton Creek. Lagoon Road, on the other hand, serves as a secondary transportation link connecting properties south of Clinton Creek with Highway 97 and the Village core. Floodplain mapping has highlighted the vulnerability of these community assets, which are susceptible to overtopping during a 50yr flood event and higher under climate-adjusted scenarios. Such conditions threaten the reliability of the treatment process and community connectivity. Figure 1 illustrates the anticipated water depths during a 200yr flood event.

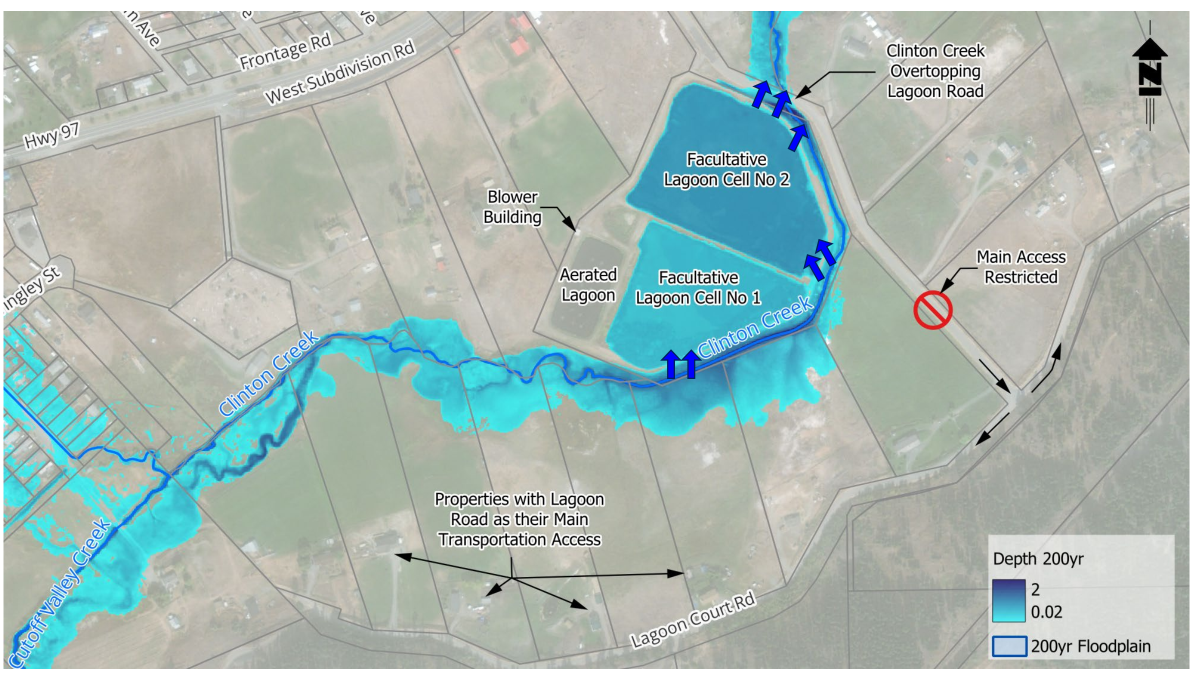


FIGURE 1 WWTP AND LAGOON ROAD 200YR FLOOD EVENT

2. Rationale

Field inspections found the Lagoon Road section near the WWTP in good condition, with Clinton Creek at this location currently drained by a 1200-mm metal culvert (Figure 2). However, projections for a 200yr flood indicate that flows will exceed the culvert's capacity, posing a significant risk of embankment failure. While WWTP access would remain unaffected, Lagoon Road is the primary transportation route for properties south of the plant. Its washout would severely disrupt accessibility and increase the challenges of flood response and recovery.

FIGURE 2 CLINTON CREEK CULVERTS AT LAGOON ROAD

Simultaneously, the berms surrounding WWTP cells No. 1 and No. 2 face a high risk of overtopping during a 50-year flood event. This could lead to inundation of the treatment cells, disrupting the final stage of wastewater treatment. Flooding of the treatment cells could result in environmental contamination, public health concerns, and extended recovery times.

FIGURE 3 WWTP FACULTATIVE CELLS BERMS

The flood mechanisms influencing the WWTP berms and Lagoon Road are interconnected. Upgrades or mitigation measures for one component will directly impact the flood levels and associated risks for the other. Addressing these vulnerabilities holistically is critical to safeguarding the wastewater treatment process, protecting downstream properties, and ensuring reliable transportation access for the community.

3. Mitigation Strategy

To address the identified vulnerabilities, two mitigation alternatives are proposed. The first involves raising the existing berms to accommodate flows associated with a 200yr flood event, with initial assessments recommending height increases ranging from 0.3 to 1.3 meters. The second alternative focuses on creek training works to enhance Clinton Creek's hydraulic capacity. This would involve modifying the creek alignment to an 8m bottom-wide, 2m deep trapezoidal channel, designed to reduce flooding during the simulated 200yr flood scenario. Both alternatives have proven effective in floodproofing the WWTP under these conditions, and the most viable solution will likely combine elements of both approaches.

The optimal balance between these strategies will be determined during the predesign phase, which will include:

- Geotechnical conditions of the existing berms.
- Environmental permitting requirements.
- Detailed survey and design refinements.

Figure 4 illustrates the projected extent of berm raising and creek training works.

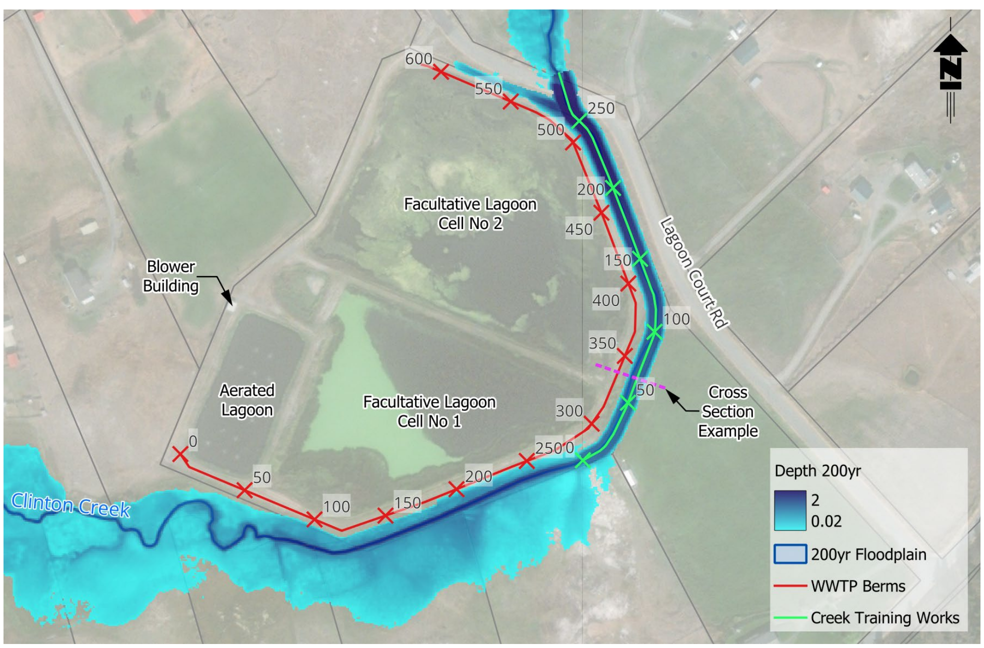


FIGURE 4 PROPOSED BERMS AND CREEK UPGRADES

To demonstrate the effectiveness of these strategies, Figure 5 compares water surface elevation profiles under existing conditions, berm-raising scenarios, and creek training works.

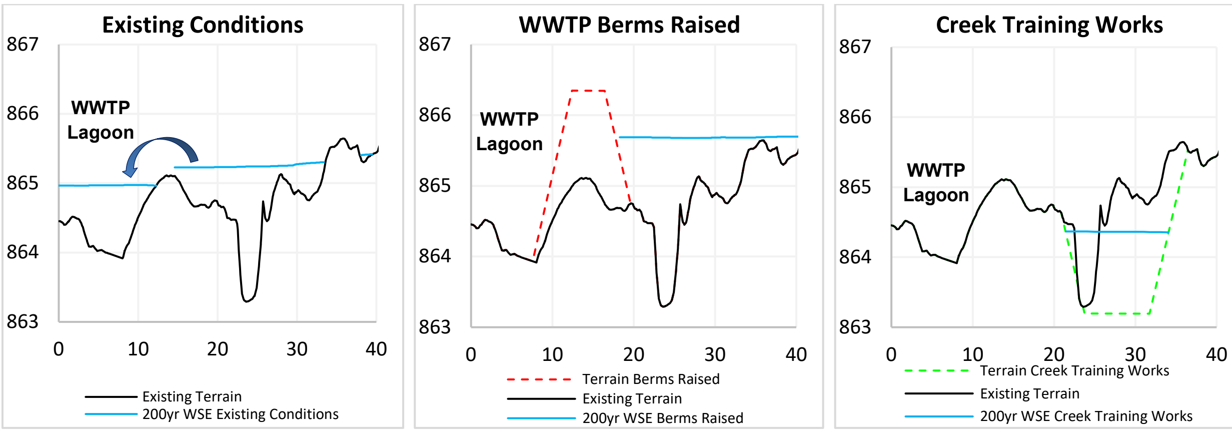


FIGURE 5 BERMS RAISING VS CREEK TRAINING WORKS COMPARISON

Any floodproofing measures implemented for the WWTP will also affect water levels at Lagoon Road. The current drainage infrastructure at Lagoon Road is inadequate for conveying projected 200yr flows. Climate-adapted flow conditions will require a structure approximately 4–5 meters wide and 2.5 meters high. The predesign phase will evaluate optimal solutions, such as bridge plates, arch culverts, or box culverts, and consider raising the road to align with the WWTP flood mitigation measures.

4. Project Scope

The WWTP Floodproofing and Lagoon Road Upgrades project aims to mitigate flood risks to critical infrastructure in Clinton, BC, by addressing vulnerabilities in the wastewater treatment plant (WWTP) and Lagoon Road. The project encompasses strategies to enhance the resilience of the WWTP berms and Lagoon Road drainage infrastructure, ensuring functionality and community connectivity during a 200yr flood event. Recognizing the interconnectivity of flood mechanisms at these locations, the project proposes an integrated approach to safeguard public health, environmental quality, and transportation access.

Predesign Phase

- Conduct detailed topographic survey and geotechnical assessment;
- Perform hydraulic and hydrologic modeling;
- Refine mitigation options; and
- Complete environmental reviews and obtain permits.

Construction Phase

- Creek Preparation: Install temporary barriers to minimize impacts on the stream;

- Earthworks: Excavate, grade, and stabilize the creek bank;
- Lagoon Road Drainage Upgrades: Replace or upgrade the culvert to accommodate 200yr flows;
- Lagoon Road Reconstruction: Elevate and stabilize the road to align with WWTP floodproofing measures; and
- Site Restoration: Implement erosion control measures and restore vegetation post-construction.

Project Deliverables

Anticipated deliverables and outcomes include:

- Topographic and geotechnical survey reports;
- Environmental assessment and permitting documentation;
- Predesign and detailed design packages;
- Comprehensive construction plans;
- Cost estimates for all project phases;
- Completed berm upgrades;
- Clinton Creek training works;
- Lagoon Road drainage upgrades;
- Monitoring and maintenance plans; and
- Final Project Report.

Village of Clinton
P4 - WWTP Floodproofing and Lagoon Road Upgrades
Class 'D' Cost Estimate

ITEM NO.	DESCRIPTION	UNIT OF MEASURE.	EST. QUANT.	UNIT PRICE	TOTAL PRICE
1.0	**General**				
1.1	Site assessment		1	$6,000	$6,000
1.2	Topographic survey		1	$7,000	$7,000
1.3	Geotechnical Assessment		1	$12,000	$12,000
1.4	Structural Assessment		1	$10,000	$10,000
1.5	Mobilization and Demobilization		1	$5,000	$5,000
1.6	WWTP Operation Protocol		1	$8,000	$8,000
	Subtotal 1.0 General				**$48,000**
2.0	**Wastewater Treatment Plant**				
2.1	WWTP Operation Protocol		1	$8,000	$8,000
2.2	Dewater Facultative Lagoon Cells		1	$5,000	$5,000
2.3	Sludge Removal		1	$10,000	$10,000
2.4	Allowance for utilities relocation		1	$25,000	$25,000
	Subtotal 2.0 Wastewater Treatment Plant				**$48,000**
3.0	**Berms Upgrades**				
3.1	Stripping	m^2	5000	$5	$25,000
3.2	Earthworks, including compacting to 95% SPD	m^3	3500	$25	$87,500
3.3	Lagoon berms geosyntetic linning	m^2	2500	$10	$25,000
3.4	Surface restoration	m^2	5000	$10	$50,000
	Subtotal 3.0 Berms Upgrades				**$187,500**
4.0	**Clinton Creek Training Works**				
4.1	Creek Training Works	lm	300	$600	$180,000
4.2	Riverine restoration	lm	300	$120	$36,000
	Subtotal 4.0 Clinton Creek Training Works				**$216,000**
5.0	**Drainage Upgrades**				
5.1	Creek deviation works	L.S.	1	$50,000	$50,000
5.2	Existing culvert removal	L.S.	1	$20,000	$20,000
5.3	Supply and Install 5m wide, 2.5 meters high bridge culvert	L.S.	1	$500,000	$500,000
	Subtotal 5.0 Drainage Upgrades				**$570,000**

6.0	**Lagoon Road Reconstruction**				
6.1	Earthworks, including compacting to 95% SPD	m^3	800	$25	$20,000
6.2	Base, Subbase and Subgrade preparation	m^2	720	$50	$36,000
6.3	Pavement (Cutting, removal and installation)	m^2	720	$60	$43,200
6.4	Traffic Control	L.S.	1	$2,000	$2,000
6.5	Landscape Restoration	m^2	400	$10	$4,000
6.6	Riprap installation 25 Kg	m^2	400	$325	$130,000
	Subtotal 6.0 Lagoon Road Reconstruction				**$235,200**

Fieldworks Summary

Subtotal 1.0 General	$48,000
Subtotal 2.0 Wastewater Treatment Plant	$48,000
Subtotal 3.0 Berms Upgrades	$187,500
Subtotal 4.0 Clinton Creek Training Works	$216,000
Subtotal 5.0 Drainage Upgrades	$570,000
Subtotal 6.0 Lagoon Road Reconstruction	$235,200
Contingency Allowance (35%)	$457,000
Subtotal Field Works	**$1,760,000**

Design and Construction Services

Predesign and Environmental Assessment (5%)	$88,000
Engineering (10%)	$176,000
Permitting (2%)	$35,000
Environmental Management Plan & Monitoring (3%)	$53,000
Construction Inspection (10%)	$176,000
First Nations Engagement	$15,000
Subtotal Design and Construction	**$540,000**

Total Project (rounded, not including GST)	**$2,300,000**
	CAD 2025

P5 – Wastewater Treatment Plant Erosion Protection

Priority	Medium	**Type**	Structural
Current Flood Vulnerability	Varies	**Design Event**	200yr
Budget	$124,000		

1. Background

The Wastewater Treatment Plant (WWTP) in Clinton is a vital facility designed to accommodate a population of up to 3,000 people. Under Effluent Permit No. 170 issued by the Province of British Columbia, the Village is authorized to discharge a maximum flow of 680 m^3/day. The plant operates using tertiary lagoons for sewage treatment, with its critical components, including the aerated lagoon and blower building, depicted in Figure 1.

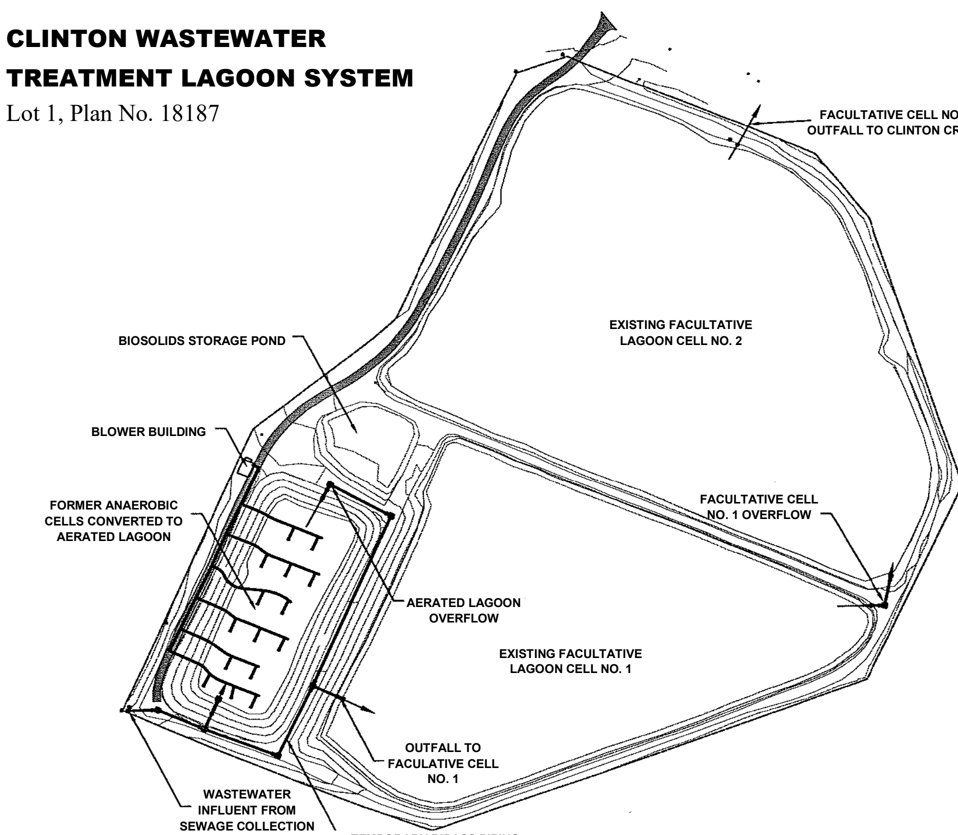


FIGURE 1 WWTP PLAN VIEW (PROVINCE OF BC WEBSITE, 2017)

While the blower building and aerated lagoon are not expected to experience direct flooding under a 200yr flood scenario, the south embankment lacks bank protection and is susceptible to erosion during extreme creek flow events.

2. Rationale

During a 200yr flood event, the creek bend near the aerated lagoon is at risk of significant morphological changes. Presently, shrubs on the external creek bend provide some protection; however, these could erode and collapse into the channel during high flows, increasing pressure on the embankment. Velocity projections and field observations indicate that the unprotected embankment could fail under such conditions, posing risks to the WWTP's operations and surrounding areas. Figure 2 provides images of the creek bank and aerated lagoon under current conditions, and Figure 3 shows the velocities expected during the 200yr event and the proposed erosion protection.

FIGURE 2 CLINTON CREEK BANK (LEFT) AND AERATED LAGOON (RIGHT)

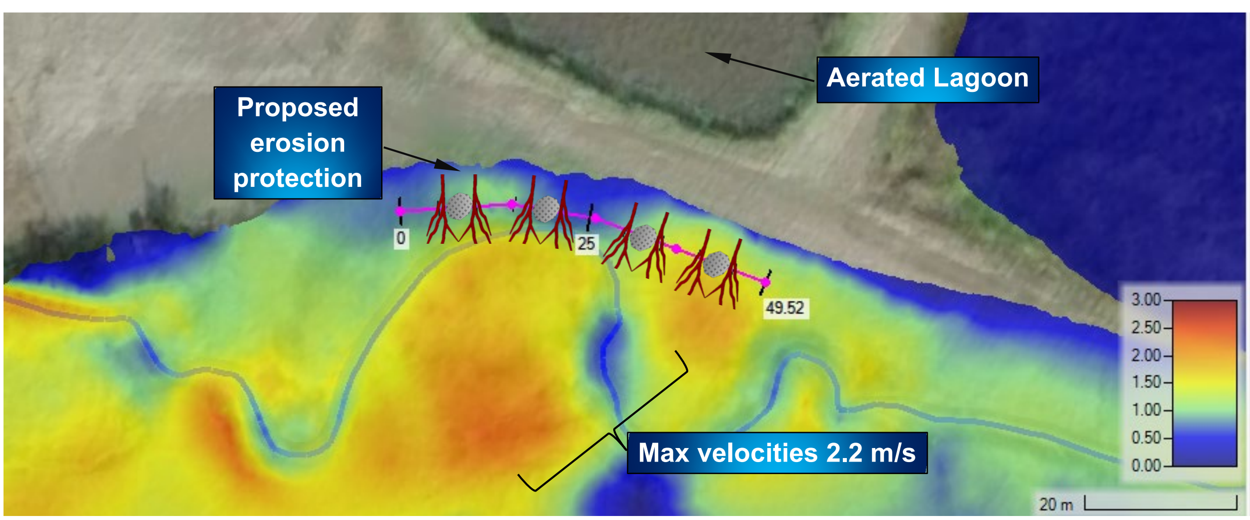


FIGURE 3 PROPOSED EROSION PROTECTION AND 200YR VELOCITIES

3. Mitigation Strategy

To address the mentioned risks, the strategy proposes using bio-engineering methods to reinforce the embankment. The primary solution involves installing live stakes for vegetative stabilization and reinforcing the creek toe with boulders and rocks to resist erosion. These measures are intended to reduce flow impacts on the bank while maintaining ecological sensitivity. A profile example of the proposed strategy is illustrated in Figure 4.

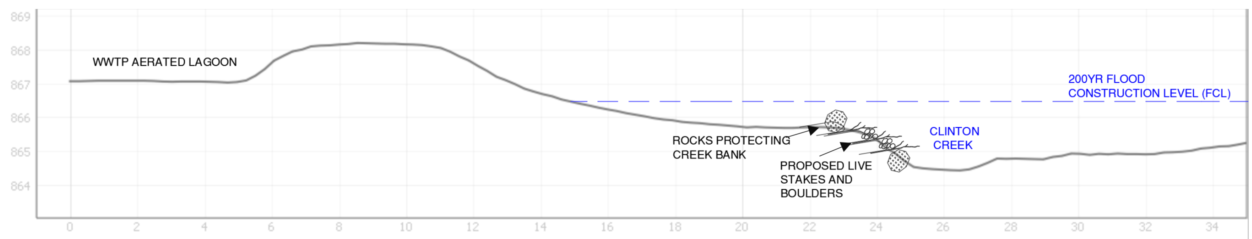


FIGURE 4 EROSION PROTECTION PROFILE EXAMPLE

The final design will be refined during the predesign phase, ensuring the measures align with hydraulic modeling outputs and environmental considerations. This strategy is designed to enhance the WWTP's resilience against erosion while supporting environmentally sustainable flood protection practices.

4. Project Scope

Objective: Design and implement measures to protect the WWTP's aerated lagoon embankment against erosion during a 200yr flood event, key activities include:

- Site Assessment: Evaluate current conditions;
- Design: Develop bio-engineering measures using live stakes, toe reinforcements, and hydraulic modeling;
- Survey and Approvals: Conduct a topographic survey and secure regulatory permits;
- Creek Preparation: Install temporary barriers to minimize stream impacts;
- Earthworks: Excavate, grade, and stabilize the creek bank; and
- Erosion Control: Supply and install geotextile, live stakes, and boulders for creek bank reinforcement.

Project Deliverables

Anticipated deliverables and outcomes include:

- Enhanced erosion protection for Clinton's creek bank to secure the WWTP's aerated lagoon.

Village of Clinton
P5 - Wastewater Treatment Plant Erosion Protection
Class 'D' Cost Estimate

ITEM NO.	DESCRIPTION	UNIT OF MEASURE.	EST. QUANT.	UNIT PRICE	TOTAL PRICE
1.0	**General**				
1.1	Site assessment		1	$6,000	$6,000
1.2	Topographic survey		1	$7,000	$7,000
1.3	Mobilization and Demobilization		1	$5,000	$5,000
	Subtotal 1.0 General				**$18,000**
2.0	**Erosion Protection**				
2.1	Supply and Install erosion protection geotextile	m^2	1000	$20	$20,000
2.2	Supply and Install Live Stakes in the creek bank	m^2	1000	$10	$10,000
2.3	Supply and Install boulders and rocks	lm	50	$330	$16,500
	Subtotal 2.0 Erosion Protection				**$46,500**

Fieldworks Summary

Subtotal 1.0 General	$18,000
Subtotal 2.0 Erosion Protection	$46,500
Contingency Allowance (35%)	$23,000
Subtotal Field Works	**$90,000**

Design and Construction Services

Predesign (5%)	$5,000
Engineering (10%)	$9,000
Permitting (5%)	$5,000
Archaeology Assessment and Monitoring (3%)	$3,000
Environmental Management Plan & Monitoring (3%)	$3,000
Construction Inspection (10%)	$9,000
Subtotal Design and Construction	**$34,000**

Total Project (rounded, not including GST)	**$124,000**
	CAD 2025

P6 – Floodplain Land Use Regulation

Priority	Medium	**Type**	Non-Structural
Current Flood Vulnerability	Varies	**Design Event**	200yr
Budget	$145,000		

1. Background

The Village of Clinton, a community with approximately 570 residents as of the 2021 census, is predominantly centered along the Highway 97 corridor. Based on the 2023 Flood Mapping, portions of the Village core face flood risks from projected high flows in Cutoff and Clinton Creeks under climate change scenarios. The projected 200yr inundation extent is illustrated in the following figure:

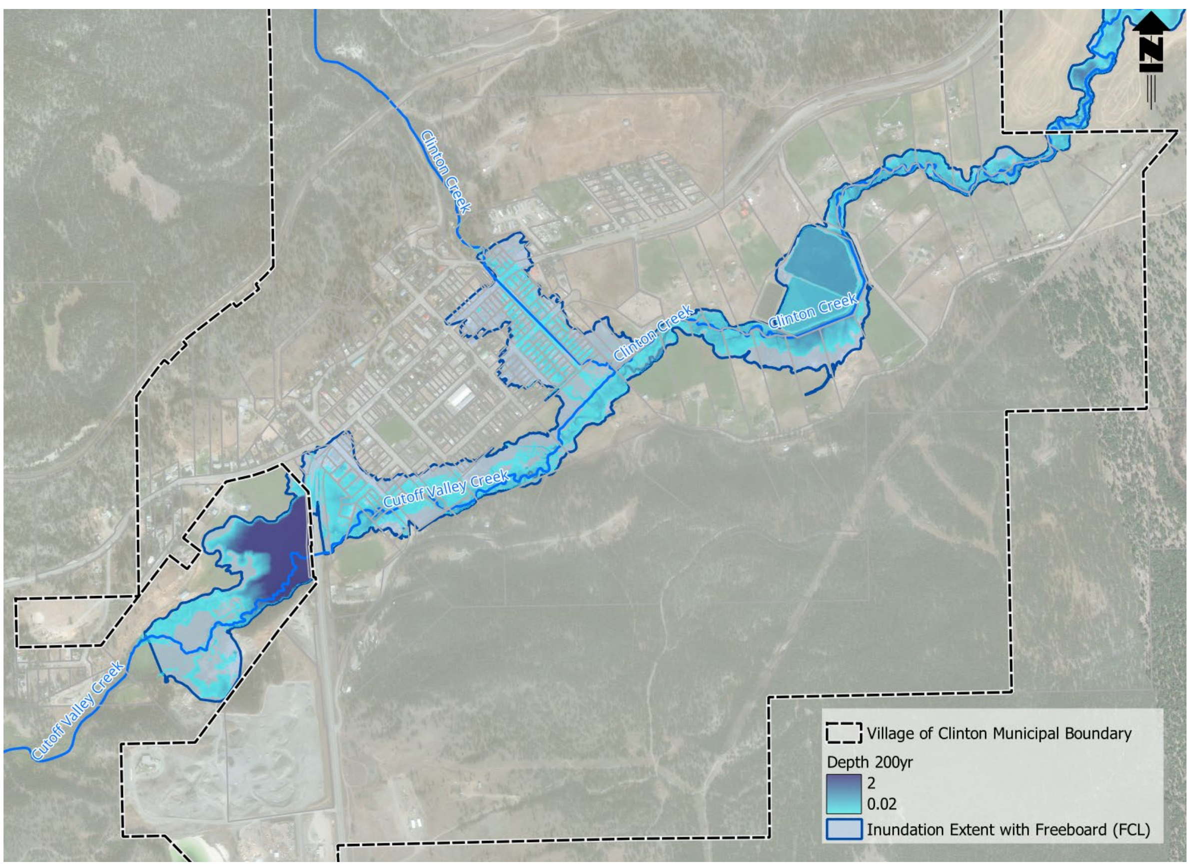


FIGURE 1 200YR INUNDATION EXTENT

This project involves updating the Official Community Plan (OCP) to integrate the 200yr floodplain identified in the mapping and implementing a policy to regulate future development in flood hazard areas. The initiative builds on past regional flood hazard identification efforts, including:

- Thomspon River Watershed Geohazard Risk Prioritization (BGC, 2019);
- Thompson River Watershed Base Level Flood Hazard Mapping (BGC, 2020);
- Housing Needs Report – Village of Clinton (TNRD, 2021); and
- Floodplain Mapping Report – Village of Clinton (TRUE, 2024).

While Clinton has not recently experienced significant flooding compared to neighboring communities like Cache Creek, the findings from the 2023 Flood Mapping highlight risks from infrequent but potentially severe flood events. This project aims to provide residents with clear information on these risks and establish a framework for flood-resilient development in the floodplain.

2. Rationale

The Floodplain Mapping underscores the need for incorporating flood risk into land-use planning. The updated OCP will serve as a foundational document for flood risk mitigation by ensuring that future development aligns with the Village's hazard management goals.

Official Community Plan

The current OCP includes provisions for managing development near watercourses under the B.C. Riparian Areas Regulation (RAR). Specifically, the OCP requires that any proposed development within 30 meters of streams or ditches undergo assessment by a Qualified Environmental Professional (QEP).

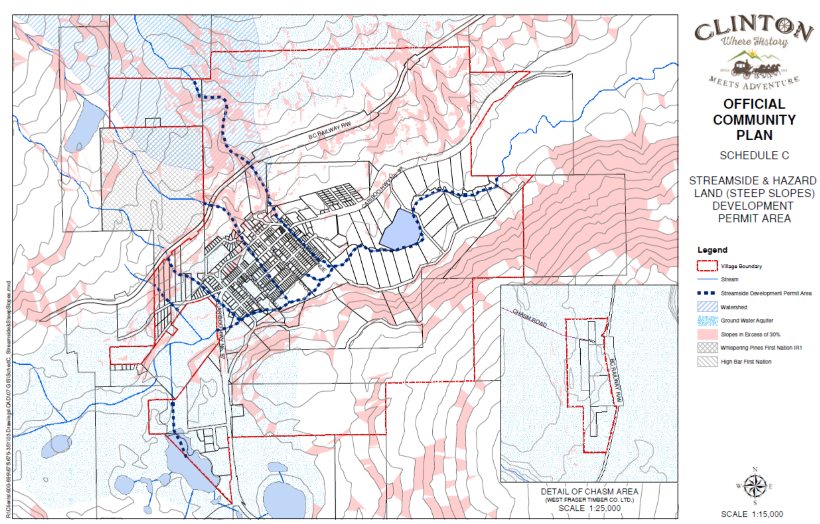


FIGURE 2 OCP SCHEDULE C STREAMSIDE & HAZARD LAND

Schedule C of the OCP maps the streams within the Village's municipal boundary to support compliance with these requirements and other hazard land considerations. Additionally, Section 7.1 of the OCP commits to reducing flood risk, stating:

"Clinton is committed to ensuring the protection of people and property from development in areas where natural hazards could pose a threat... Development should be limited to park, open space, recreation, or agricultural use unless proof of appropriate preventative measures is demonstrated by a registered professional to Council and approved by appropriate government agencies."

3. Mitigation Strategy

Floodplain Land Use Regulation

The project seeks to enhance flood resilience and mitigate the impacts of future flood events in the Village by updating the OCP to reflect the recently completed Floodplain Mapping. This update will form the foundation for developing a flood land use regulation tool. Additional steps include gathering community feedback and promoting flood-resilient construction opportunities for effective flood management.

To regulate land use in the floodplain, the Village can consider the following tools:

- **Zoning Bylaw:** Regulating land use, building elevations, setbacks, and high-risk activities while introducing floodplain covenants.
- **Development Permit Areas (DPAs):** Designate DPAs to manage development in specific areas, including floodplains. Establishing guidelines for floodproofing, maintaining natural water flow, and preserving ecological features.
- **Floodplain Bylaw:** Developing a dedicated policy for flood hazard management.

The Village should assess these regulatory tools to determine the most effective option for its needs. Updating the OCP and implementing the selected policy will help reduce overall community flood risk while raising public awareness of flood risks. Engaging the community in these processes ensures that local knowledge and values are integrated into the floodplain management strategy.

The regulation tool should specify the following aspects:

- Flood Construction Levels (FCLs);
- Standards for flood-resilient constructions inside the floodplain;
- Minimum setbacks for Clinton and Cutoff Creeks, as well as setbacks for other streams;
- Restrictions and conditions for land use inside the floodplain;
- Conditions for renovations or modifications to existing structures and/or properties; and
- Applicable covenants to properties inside the floodplain or in high erosion risk areas.

Additional considerations include:

Flood-Resilient Construction

Implementing flood-resilient construction methods is a viable alternative to mitigate future flood impacts in Clinton. These methods are particularly suitable for areas prone to flooding where water velocities and erosion risks are minimal. Examples of flood-resilient designs, such as elevated structures and water-resistant materials, are illustrated in Figure 3:

Additionally, the Thompson Nicola Regional District in its 2021 study has identified the challenges to find safe, affordable and inclusive housing in the Village. The implementation of this floodplain land use regulation and flood-resilient is intended to increase flood resilience and safety of housing opportunities in Clinton. For reference, the *Guide for design of flood-resistant buildings (NRC-CNRC, 2021)* provides insights of flood-resilient buildings. This guidance document is proposed as a complement to the *National Building Code (NBC)*.

FIGURE 3 EXAMPLE OF FLOOD-RESILIENT CONSTRUCTION

Impact of Flood Mitigation Projects on Flood Construction Levels (FCL)

As flood mitigation projects are implemented in the Village of Clinton, they are expected to influence flood levels by changing the extent and depth of flooding. These projects will likely result in modifications to the Flood Construction Levels (FCL), aimed at increasing the safety of new developments and potentially reducing building costs. As part of the Land Use Regulation Tool, the future impact of these projects should be incorporated to ensure that FCL adjustments are reflected accurately in the OCP, zoning bylaws and development requirements, aligning future construction with improved flood resilience.

Engagement with First Nations

One of the anticipated co-benefits of the project is the opportunity to engage First Nations to share their ancestral and cultural knowledge and provide an opportunity for them to share input and advice based on their history and experience in flood and environmental management. The budget also includes honoraria as well as compensation to First Nations members for their time.

Special Considerations for Specific Areas

Different areas within Clinton face unique flood risks that must be addressed in the Land Use Regulation Framework. For example, the McDonald Avenue area is vulnerable to shallow flooding due to the limited capacity of the Clinton Creek drainage system. In rare, higher-intensity flood events, the failure of upstream embankments could result in significant wave heights with potentially damaging effects. Addressing these localized risks is critical to ensuring that land use regulations are tailored to the diverse flooding mechanisms within the Village.

4. Project Scope

Updating of the OCP: Update the Village's OCP land use policy statements and maps defining the 200yr active floodplain and Flood Construction Levels. The overall updates to the OCP should include:

- 200yr Floodplain map and Flood Construction Levels (FCL's) map within OCP;
- Restrictions on the use of land subject to hazardous conditions whether it is flooding, erosion, or both;
- Define the land within the floodplain map as a "designated development permit area" for the purpose of protecting the natural environment, it's ecosystems and biological diversity, and protection of development from hazardous conditions;
- Description of special conditions and/or objectives that justify the development permit area justification and specifies how the special conditions and/or objectives will be addressed;
- Adjustment to existing zoning bylaws to align with OCP changes as necessary; and
- Presentation to council for adoption of revised OCP.

Floodplain Land Use Regulation: Update and/or implement floodplain regulation that applies to the OCP-defined floodplain area that will subsequently be adopted by council. The local government floodplain regulations should include the following elements at a minimum:

- Selection of the preferred regulatory tool;
- Flood Construction Levels;
- Building Setbacks (largely covered riparian regulations);
- Restricted and/or Conditional land uses;
- Modification to existing structure and/or properties; and
- Application of Covenants.

5. Project Deliverables

This project is centered around updating the OCP and creating a floodplain bylaw. Throughout the updating and creating process stakeholder engagement and public workshops/ consultation will occur; thus, providing an opportunity for public awareness and education. Anticipated deliverables and outcomes include:

- Updated OCP & Mapping;
- Community Engagement; and
- Floodplain Land Use Regulation.

Village of Clinton
P6 - Floodplain Land Use Regulation
Class 'D' Cost Estimate

ITEM NO.	DESCRIPTION	UNIT OF MEASURE.	EST. QUANT.	UNIT PRICE	TOTAL PRICE
1.0	**Community Engagement**				
1.1	Develop Community Engagement Strategy (CES)	L.S.	1	$6,000	$6,000
1.2	Develop materials, workshop information/materials and templates	L.S.	1	$6,000	$6,000
1.3	First Nations consultation (including capacity funding)	L.S.	1	$12,000	$12,000
1.4	Education Campaign	L.S.	1	$10,000	$10,000
1.5	Public Consultation	L.S.	1	$15,000	$15,000
1.6	Prepare a 'What We Heard' report for Council and staff	L.S.	1	$8,000	$8,000
	Subtotal 1.0 Community Engagement				**$57,000**
2.0	**Update the Village of Clinton Official Community Plan (OCP)**				
2.1	Detailed review of background documents (e.g. OCP, Zoning Bylaw, Flood Mitigation Plan)	L.S.	1	$3,000	$3,000
2.2	Update OCP Hazard Map	L.S.	1	$3,000	$3,000
2.3	Develop draft OCP amendments	L.S.	1	$8,000	$8,000
2.4	Finalize OCP Amendments	L.S.	1	$5,000	$5,000
2.5	OCP Amendments adoption (Council meetings, public meeting, etc.)	L.S.	1	$12,000	$12,000
	Subtotal 2.0 Update the Village of Clinton Official Community Plan (OCP)				**$31,000**
3.0	**Implement Land Use Regulation**				
3.1	Background research and staff consolation on preferred regulatory tool (e.g. DPAs, zoning, standalone bylaw)	L.S.	1	$3,000	$3,000
3.2	Briefing report summarizing recommended elements for floodplain regulation	L.S.	1	$8,000	$8,000
3.3	Prepare draft floodplain regulation	L.S.	1	$15,000	$15,000
3.4	Finalize floodplain regulation (based on engagement)	L.S.	1	$6,000	$6,000
3.5	Floodplain regulation adoption (Council meetings, public meetings, etc.)	L.S.	1	$12,000	$12,000
	Subtotal 3.0 Implement Land Use Regulation				**$44,000**

Project Summary

Subtotal	**$132,000**
Contingency (10%)	**$13,000**
Total Project (rounded, not including GST)	**$145,000**

P7 – Flood Response Plan

Priority	Medium	**Type**	Non-Structural
Current Flood Vulnerability	Varies	**Design Event**	200yr
Budget	$147,000		

1. Background

The Village of Clinton has not experienced significant flood events in recent years. Emergency alerts and evacuation orders have predominantly addressed wildfire risks, such as the 2017 Elephant Hill wildfire. However, the potential risks associated with embankment failures at water reservoirs or the CN Railway, combined with the projected inundation extents from the Flood Mapping, underscore the need for a Flood Response Plan to address infrequent yet potentially severe flood events.

2. Mitigation Strategy

A flood response plan is a comprehensive strategy developed by a local government to prepare for, respond to, and recover from flood events. It would be a subset of the overall emergency response plan for the community. This plan outlines the roles, responsibilities, procedures, and resources required to manage flood emergencies effectively. Here are the key reasons why a municipality would develop a flood response plan:

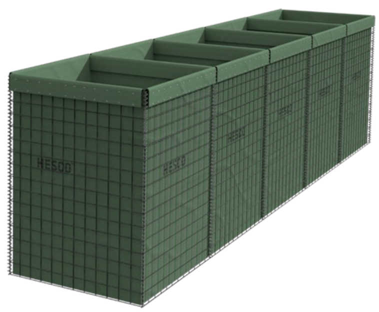
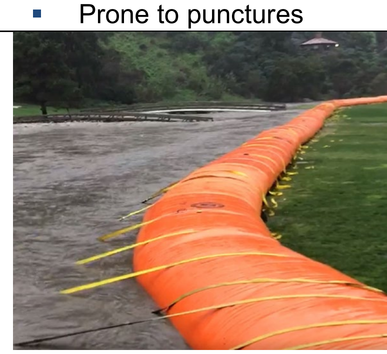
- **Coordination:** Streamlining the response process by clearly defining roles, responsibilities, and implementation triggers.
- **Resource Management:** Identifying and efficiently allocating resources/equipment during a flood emergency.
- **Public Awareness and Preparedness:** Building a culture of preparedness within the community.
- **Long-Term Recovery**: Facilitating a quicker and more efficient recovery process to restore normalcy.
- **Liability Reduction:** Reducing the municipality's liability by demonstrating due diligence in flood preparedness and response.
- **Business Continuity:** Supporting community in maintaining operations and/or recovering quickly after a flood.
- **Infrastructure Protection:** Protecting critical infrastructure to ensure continuity of services.

Key considerations for the Flood Response Plan include:

Temporary Flood Protection

Clinton and Cutoff Creeks are freshet-dominated streams, where peak runoff from snowmelt occurs between late May and early June annually. This predictable regime allows for temporary flood protection measures. Available options include:

TABLE 1 TEMPORARY FLOOD PROTECTION ALTERNATIVES

SANDBAGS	GABION BASKET	BLADDER DAMS
Advantages ▪ Low cost ▪ Flexible for small areas ▪ Readily available **Disadvantages** ▪ Labor-intensive ▪ Non-reusable ▪ Limited durability	**Advantages** ▪ Durable and stable ▪ Reusable ▪ Fast Installation **Disadvantages** ▪ High initial cost ▪ Requires machinery ▪ Heavier logistics	**Advantages** ▪ Quick deployment ▪ Reusable ▪ Minimal labor required **Disadvantages** ▪ Expensive ▪ Needs flat terrain ▪ Prone to punctures
 (Zurich, 2020)	 (Hesco, 2024)	 (U.S. Flood Control, 2024)

Potential deployment locations for temporary measures include:

a) Highway 97 Cutoff Creek overflow path;
b) McDonald Avenue; and
c) Wastewater Treatment Plant lagoon berms.

The freshet-dominated nature of Clinton's flood regime allows for structured response planning compared to the more abrupt challenges posed by winter rainfall-induced events.

Early warning system alert

An early warning system is proposed to monitor water levels at critical embankments, such as the CN Railway and Highway 97. This system would support phased activation of the Flood Response Plan by:

- Allowing sufficient time for deploying temporary flood protection measures.
- Prioritizing activities and allocating resources effectively.

The failure of critical infrastructure, such as the CN or Highway 97 embankments, poses a significant threat, necessitating an integrated approach. The system would provide real-time alerts on water accumulation behind embankments, facilitating appropriate response actions. These may range from blockage removal using heavy machinery to issuing evacuation alerts in case of a potential dam break.

Web Mapping Integration

The plan will incorporate web mapping tools to simulate flood scenarios for various return periods. This platform will support local staff and the community by illustrating potential flood impacts, mitigation strategies, and affected areas. It will also provide essential insights into critical infrastructure, evacuation routes, and vulnerable zones, helping to build resilience and improve emergency response coordination.

3. Project Scope

Pre-planning response activities for various flood events can help to ensure a safe, effective, and efficient response. This flood response plan should include an outline of activities to be taken at different stages (water levels at Clinton and Cutoff Creeks) of a flooding event.

The staged flood response plan would include, but not be limited to:

- Freshet planning activities (monitoring snowpacks, river forecasts, etc.);
- Preplanning trigger(s) to declare a Local State of Emergency, Evacuation Alerts, Evacuation Orders;
- Planning Temporary Flood Protection measures to be deployed (type, location, quantity);
- Protocols for transitions from response to recovery;
- Disposal plans for flood debris; and
- Pre-Identification of required/preferred outside resources (e.g. contractors, engineering, agencies, etc.)

Most flooding events allow an adequate warning period to implement an effective emergency flood response plan. This warning period is an important factor in developing the Flood Response Plan and will be explored and discussed in detail within this plan utilizing data and resources from the BC River Forecast Centre.

By developing a flood response plan, municipalities can significantly enhance their ability to manage flood risks, protect their communities, and ensure a structured and effective response to flood emergencies.

4. Project Deliverables

The staged Flood Response Plan will include:

- A detailed freshet activities protocol;
- Critical infrastructure and temporary flood protection mapping;
- GIS-based water level mapping, identifying emergency and evacuation trigger levels;
- Community workshop; and
- Flood response Plan Report.

Village of Clinton
P7 - Flood Response Plan
Class 'D' Cost Estimate

ITEM NO.	DESCRIPTION	UNIT OF MEASURE.	EST. QUANT.	UNIT PRICE	TOTAL PRICE CAD 2024
1.0	**Project Management & Engagement**				
1.1	Background Review (e.g. Flood Response History, Flood Mitigation Plan, Emergency Response Documentation, Record Drawings)	L.S.	1	$5,000	$5,000
1.2	Community Consultation	L.S.	1	$7,000	$7,000
1.3	First Nations Consultation, Honoraria, & Costs	L.S.	1	$8,000	$8,000
1.4	Project management & communications	L.S.	1	$10,000	$10,000
	Subtotal 1.0 Project Management & Engagement				**$30,000**
2.0	**Flood Response Tools**				
2.1	Develop Flood Response Map (digital and mobile)	L.S.	1	$14,000	$14,000
2.2	Mapping of critical infrastructure, hazard and vulnerability	L.S.	1	$8,000	$8,000
2.3	Development of Project Sheets	L.S.	1	$20,000	$20,000
2.4	Coordination with Operations Staff	L.S.	1	$12,000	$12,000
2.5	Determine inspection, maintenance, and repair protocols of equipment	L.S.	1	$10,000	$10,000
	Subtotal 2.0 Flood Response Tools				**$64,000**
3.0	**Emergency Response**				
3.1	Freshet planning activities (monitoring rainfall, river forecast, and flood scenarios).	L.S.	1	$6,000	$6,000
3.2	Trigger(s) to declare a Local State of Emergency, Evacuation Alert and Evacuation Order	L.S.	1	$5,000	$5,000
3.3	Determine communication protocols and transitions from response to recovery	L.S.	1	$4,000	$4,000
	Subtotal 3.0 Emergency Response				**$15,000**
4.0	**Reporting and Presentation to Council**				
4.1	Draft Document	L.S.	1	$12,000	$12,000
4.2	Final Document	L.S.	1	$8,000	$8,000
4.3	Council Meeting Materials and Presentation	L.S.	1	$5,000	$5,000
	Subtotal 4.0 Reporting and Presentation to Council				**$25,000**

Project Summary

Subtotal	**$134,000**
Contingency (10%)	**$13,000**
Total Project (rounded, not including GST)	**$147,000**
	CAD 2024

P8 – Clinton Creek Drainage Infrastructure Upgrades - MoTT

Priority	Medium	**Type**	Structural
Current Flood Vulnerability	Varies	**Design Event**	200yr
Budget	TBD		

1. Background

The diversion of Clinton Creek was initiated by the Ministry of Transportation and Highways and subsequently approved by the Department of Lands, Forests, and Water Resources under Conditional Water License No. 23155, as documented in the 1957 and 1967 license files. The license permitted the realignment of Clinton Creek for land improvement purposes.

In 1982, the Ministry of Transportation and Highways proposed transferring the water license to the Village of Clinton. However, this transfer was declined in 1983, with support from the Ministry of Environment. The refusal was based on the Village's concerns about assuming responsibility for the maintenance, repair, and eventual replacement of the infrastructure.

The Clinton Creek realignment consists of a 1200mm-diameter corrugated steel pipe (CSP) storm system with its inlet located north of McDonald Cres Road. This storm system follows McDonald Avenue to Tingley Street, where it reduces to a 900mm-diameter CSP before discharging approximately 100 meters upstream of its confluence with Cutoff Creek, as shown in Figure 1.

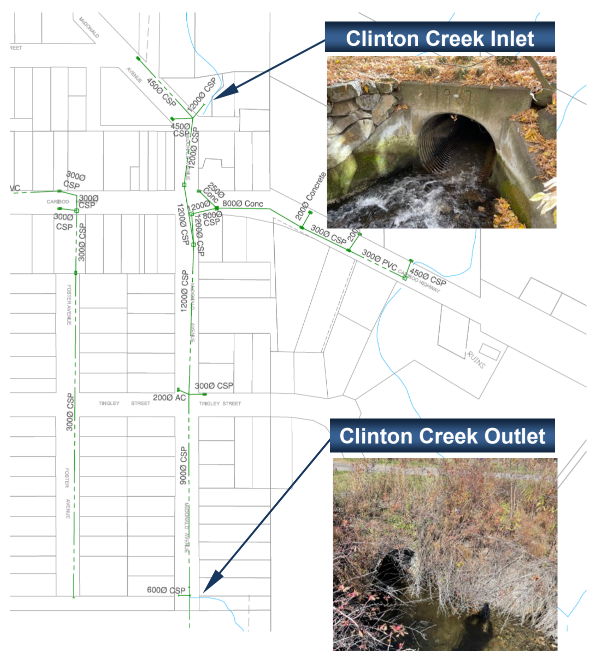


FIGURE 1 CLINTON CREEK INFRASTRUCTURE

It is important to note that the creek's realignment facilitated the urbanization of a significant area in Clinton. However, the projected 200yr design flows present a flood risk to the Village's urban area. As the infrastructure owner, the Ministry of Transportation and Transit (MoTT) should conduct a comprehensive review and assessment of the system to address these vulnerabilities.

2. Rationale

The floodplain mapping highlights the importance of the Village engaging with the Ministry of Transportation and Transit (MoTT) to address potential risks and necessary upgrades to the Clinton Creek infrastructure. Based on climate-adapted flow projections, the Village faces vulnerability beginning with the 10yr flood event. For the 200yr flood event, significant flooding is anticipated northeast of Foster Avenue, with over five hectares of the Village projected to experience water depths between 5 cm and 20 cm. The figure below illustrates the projected water depth and inundation extent, including freeboard.

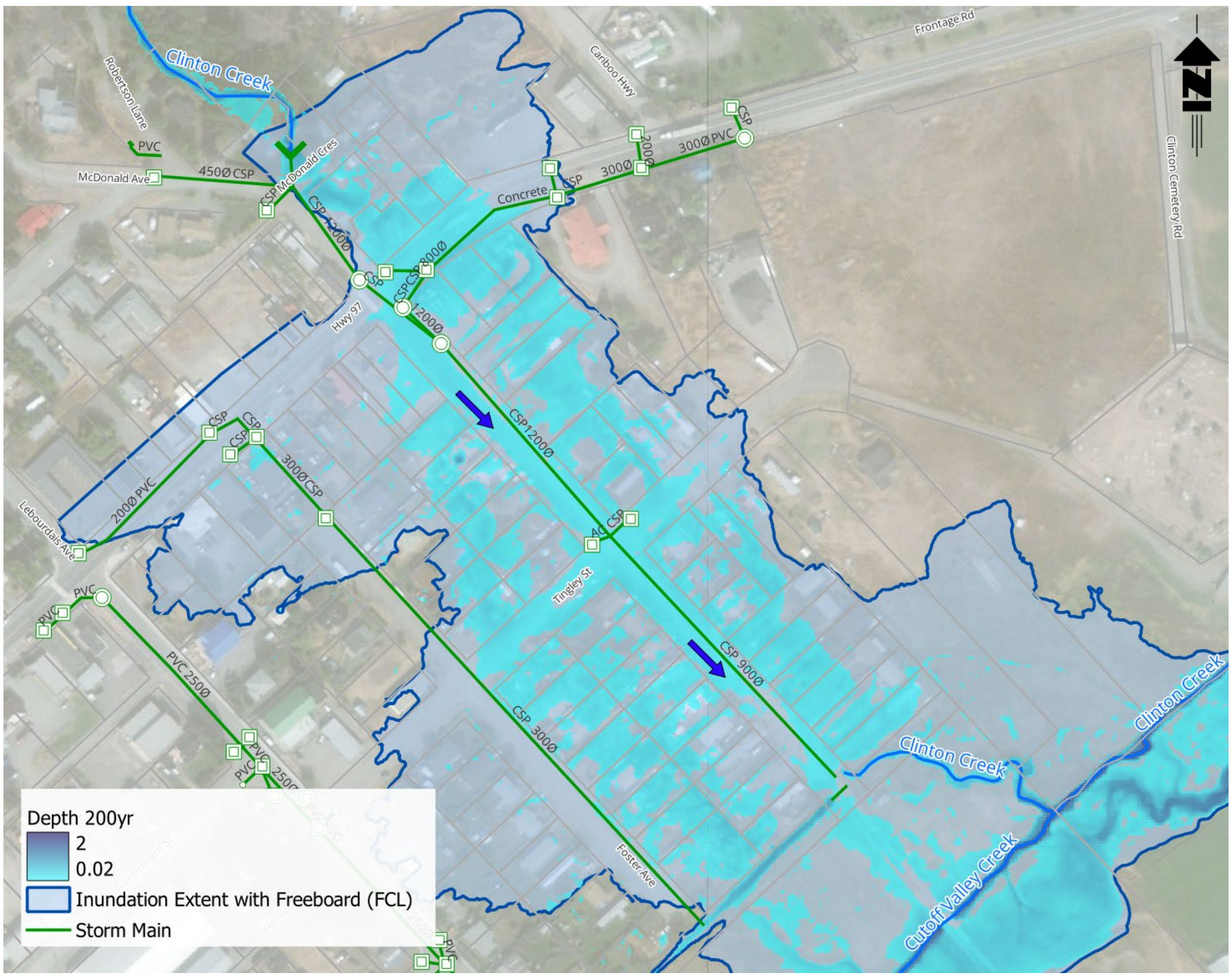


FIGURE 2 CLINTON CREEK 200YR FLOOD DEPTH

Key considerations for flood mitigation strategy development include:

Design Flows and Climate Change Assessment

A Regional Flow Frequency Analysis was conducted to estimate the design flow for the Clinton Creek watershed. Traditional Flood Frequency Analysis methods were not used due to the lack of streamflow gauges with adequate data records for direct flow estimates. Instead:

- Relationships between instantaneous and daily flows were analyzed at neighboring flow stations to create a Regional Curve, enabling interpolation of peak instantaneous flows for Clinton Creek downstream of the Village boundary; and
- Inflows at Clinton Creek (CN Railway Embankment) and Cutoff Creek (upstream of the Village) were scaled using drainage area proportioning.

Climate change impacts were considered using a 20% adjustment factor for peak flow increases, aligned with EGBC (2018) guidelines for small watersheds with limited future local data. This factor is consistent with prior floodplain mapping efforts in the region, including Cache Creek (TRUE, 2021). Additionally, the Pacific Climate Impacts Consortium's (PCIC) large-scale hydrologic modeling and its Climate Explorer (PCEX) tool were consulted. The PCEX tool, while limited by coarse grid resolution for smaller catchments, provided useful mean change factors under the RCP8.5 scenario, ranging from 1.05 (2020s) to 1.25 (2050s). These outputs supported the decision to apply the 20% increase in peak flow for Clinton Creek, ensuring consistency with regional analyses and established practices.

Peak flow estimates for Clinton Creek at the CN Railway Embankment, with and without the climate change factor, are summarized in Table 1.

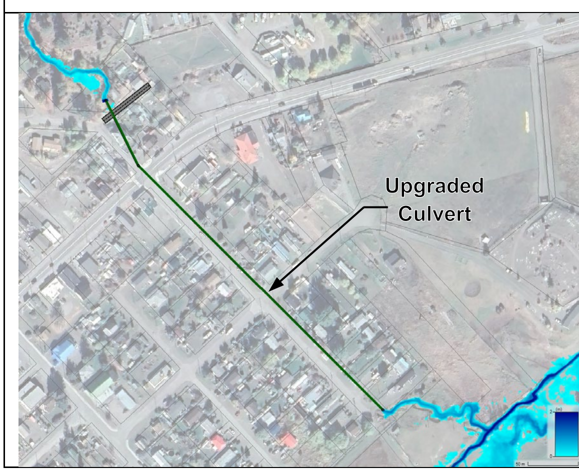
TABLE 1 PEAK FLOWS CLINTON CREEK AT CN RAILWAY

RETURN PERIOD	CLINTON CREEK AT CN RAILWAY (M^3/S)	
	WITHOUT CC FACTOR	WITH CC FACTOR (+20%)
2yr	1.2	1.4
5yr	2.0	2.4
10yr	2.6	3.2
20yr	3.4	4.0
50yr	4.5	5.4
100yr	5.4	6.5
200yr	6.5	7.8
500yr	8.2	9.9

3. Mitigation Strategy

To mitigate the projected impacts of 200yr flows, two conceptual-level options are proposed as follows. These options provide a foundation for discussions between MoTT, the Village of Clinton, First Nations and other interested parties. A detailed evaluation of the preferred alternative, including technical aspects and further refinements, will follow these discussions.

TABLE 2 POTENTIAL FLOOD MITIGATION OPTIONS CLINTON CREEK

OPTION A. UPGRADES TO EXISTING ALIGNMENT	OPTION B. DIVERSION TO A NEW ALIGNMENT
Description: Upgrade the existing infrastructure to convey 200yr flood flows. Preliminary assessments indicate that a culvert-size between 2.1 and 2.4 meters in diameter will be required. **Advantages** ▪ No property acquisition required ▪ Aligns with overflow path ▪ Replaces aging infrastructure **Disadvantages** ▪ Potential utility conflicts ▪ Traffic disruptions during repairs ▪ Blockage risk ▪ Less flexibility for future upgrades if climate change impacts intensify	**Description:** Divert Clinton Creek to an alternative alignment that avoids the Village's denser area. Preliminary designs include a trapezoidal channel with a 3-meter bottom width, 2:1 side slope, and a depth of 1.2 meters. **Advantages** ▪ Habitat/Creek restoration ▪ Promotes natural systems ▪ Lower risk of blockages ▪ Resilient design, flexible for future upgrades ▪ Existing culvert could act as overflow ▪ Less utility conflicts ▪ Freeboard **Disadvantages** ▪ Requires property acquisition ▪ Longer flow path compared with option A ▪ Possible need for new water license
	

The existing road network was evaluated as a potential overflow path but was discarded due to the magnitude of the flows and its limited capacity to effectively channel the water. The optimal option will be determined through an engagement process with the community; however, the final decision will rest with the responsible authorities and will adhere to provincial guidelines.

4. Recommended actions

Collaboration between the Ministry of Transportation and Infrastructure (MoTT) and the Village of Clinton is essential for implementing effective mitigation measures. The Village should use this Flood Mitigation Plan as a basis for engaging with the Ministry to address risks and potential flood impacts in urban areas.

Key recommendations:

- Hydrometric Station Integration: Implement hydrometric stations in Clinton Creek (proposed in other projects) to improve design flow estimates. While these stations will reduce uncertainty, the balance between uncertainty and risk should be collaboratively determined by MoTT and the Village.
- Adaptive Risk Approach: Some alternatives, such as the diversion channel, could follow an adaptive risk approach, allowing incremental upgrades if future conditions necessitate further action.

Clinton Creek Drainage Infrastructure Upgrades

The proposed upgrades aim to:

- Reduce MoTT's liability and address vulnerabilities associated with aging stormwater infrastructure.
- Accommodate 200yr flood events by upgrading or diverting the existing system, mitigating risks in urban areas.
- Minimize potential damages to property and infrastructure, enhancing community safety.

By addressing flood risks proactively, MoTT and the Village demonstrate due diligence, reduce legal exposure, and protect both residents and critical infrastructure from future liabilities.

P9 – Highway 97 Drainage Infrastructure Upgrades - MoTT

Priority	Medium	**Type**	Structural
Current Flood Vulnerability	Varies	**Design Event**	200yr
Budget	TBD		

1. Background

Highway 97, serves as a primary north-south route in British Columbia, connecting the Canada-US border to the BC-Yukon boundary. The 441 km Cariboo Highway segment between Cache Creek and Prince George largely follows the historic Cariboo Wagon Road, constructed during the Cariboo Gold Rush to facilitate settlement. The Village of Clinton originated as one such settlement, evolving from gold mining in the mid-1800s to forestry in the 1950s, and now relies on tourism as a key economic activity.

Floodplain mapping highlighted significant flood and erosion risks to this transportation link under projected climate change scenarios. Figure 1 depicts the projected inundation extent and overflow route for Cutoff Creek.

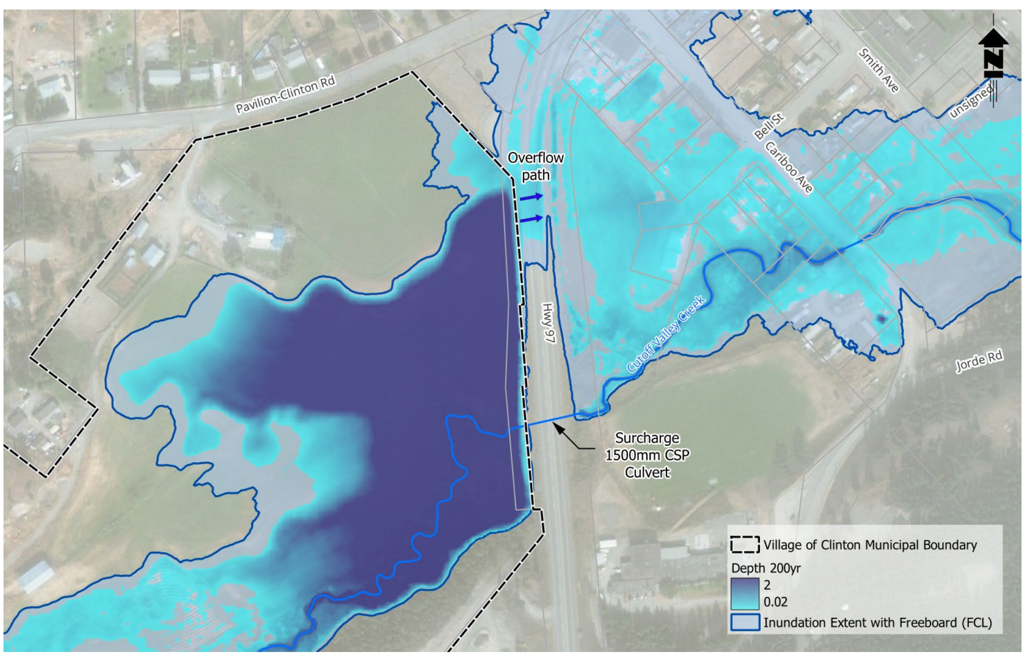


FIGURE 1 HIGHWAY 97 200YR FLOOD DEPTH

2. Rationale

The existing 1500 mm-diameter corrugated steel pipe (CSP) at Cutoff Creek & Highway 97 is insufficient to handle the projected 200yr flood flows. In such an event, water would accumulate behind the embankment, leading to overtopping and potential washout of the highway. This could result in widespread flooding in Clinton's residential and commercial areas. Figure 2 provides images of the upstream, interior, and downstream sections of the CSP culvert.

FIGURE 2 HWY 97 CULVERT UPSTREAM (LEFT) - INTERIOR (CENTER) - DOWNSTREAM (RIGHT)

Key considerations for flood mitigation strategy development include:

Design Flows and Climate Change Assessment

A Regional Flow Frequency Analysis was conducted to estimate the design flow for the Clinton Creek watershed. Traditional Flood Frequency Analysis methods were not used due to the lack of streamflow gauges with adequate data records for direct flow estimates. Instead:

- Relationships between instantaneous and daily flows were analyzed at neighboring flow stations to create a Regional Curve, enabling interpolation of peak instantaneous flows for Clinton Creek downstream of the Village boundary; and
- Inflows at Clinton Creek (CN Railway Embankment) and Cutoff Creek (upstream of the Village) were scaled using drainage area proportioning.

Climate change impacts were considered using a 20% adjustment factor for peak flow increases, aligned with EGBC (2018) guidelines for small watersheds with limited future local data. This factor is consistent with prior floodplain mapping efforts in the region, including Cache Creek (TRUE, 2021). Additionally, the Pacific Climate Impacts Consortium's (PCIC) large-scale hydrologic modeling and its Climate Explorer (PCEX) tool were consulted. The PCEX tool, while limited by coarse grid resolution for smaller catchments, provided useful mean change factors under the RCP8.5 scenario, ranging from 1.05 (2020s) to 1.25 (2050s). These outputs supported the decision to apply the 20% increase in peak flow for Cutoff Creek, ensuring consistency with regional analyses and established practices.

Peak flow estimates for Cutoff Creek at the Village's Boundary, with and without the climate change factor, are summarized in Table 1.

TABLE 1 PEAK FLOWS CUTOFF CREEK AT VILLAGE BOUNDARY

RETURN PERIOD	CUTOFF CREEK AT VILLAGE'S BOUNDARY (M^3/S)	
	WITHOUT CC FACTOR	WITH CC FACTOR (+20%)
2yr	2.9	3.5
5yr	4.9	5.9
10yr	6.6	7.9
20yr	8.3	10.0
50yr	11.0	13.2
100yr	13.5	16.2
200yr	16.2	19.4
500yr	20.4	24.4

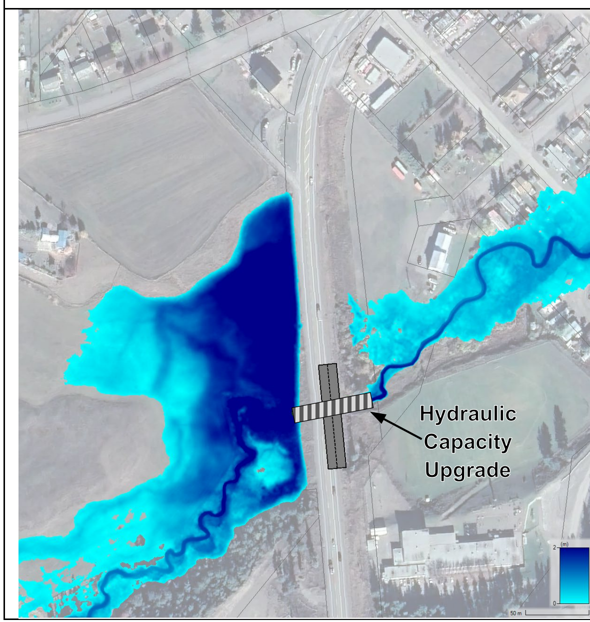
3. Mitigation Strategy

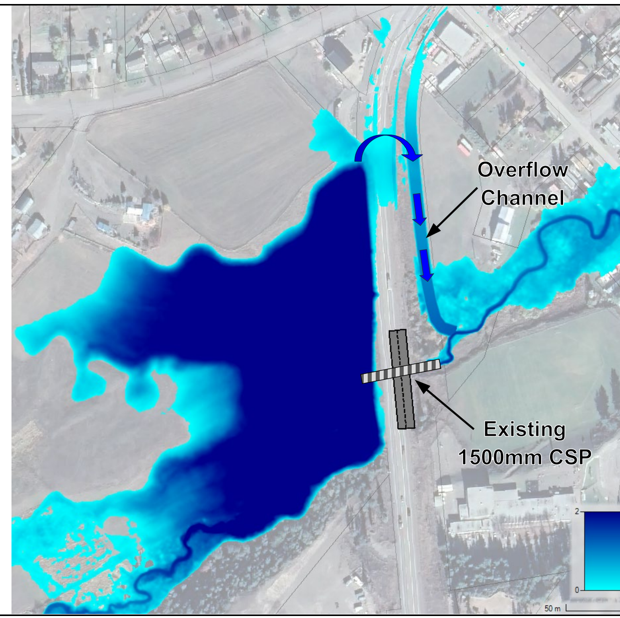
Two complementary options are proposed to address the projected 200yr flood impacts. These options serve as the foundation for discussions with MoTT, the Village of Clinton, First Nations, and other interested parties. A detailed evaluation of the preferred alternative, including technical aspects and further refinements, will follow these discussions.

TABLE 2 FLOOD MITIGATION OPTIONS CUTOFF CREEK

OPTION A1. HYDRAULIC CAPACITY IMPROVEMENT	OPTION A2. INTERIM / TEMPORARY OPTION
Description: Improve the drainage capacity at Highway 97 to convey the 200yr flood event. Alternatives include upgrading the existing culvert or replacing it with a bridge opening for Cutoff Creek. Preliminary assessments indicate that a 2.7-3.0-meter-diameter culvert or box culvert would be required.	**Description:** This project focuses on reducing impacts to properties during a flood scenario. The strategy involves developing an overflow channel to redirect water overtopping Highway 97 as quickly as possible to the main Cutoff Creek channel. Preliminary assessments suggest an 8-meter-wide channel with 1.5:1 side slope and a depth of 1.2 meters would be necessary.

OPTION A1. HYDRAULIC CAPACITY IMPROVEMENT	OPTION A2. INTERIM / TEMPORARY OPTION
Advantages ▪ Protects Hwy 97 integrity during floods ▪ Reduces residential property impacts ▪ Aligns with natural flow path ▪ Replaces aging infrastructure ▪ Lower blockage risk ▪ Permanent measure **Disadvantages** ▪ Traffic disruptions during repairs ▪ Higher cost	**Advantages** ▪ Reduces flooding impact on properties ▪ Cost-effective ▪ Enables floodplain restoration in the overflow area **Disadvantages** ▪ Does not protect Highway 97 from washouts ▪ Impact to Hwy 97 as emergency corridor





The optimal option will be discussed through an engagement process with the community; however, the final decision will rest with the responsible authorities and will adhere to provincial guidelines.

Downstream Impacts

In a major flood event, the Highway 97 embankment functions as a reservoir, attenuating Cutoff Creek flows based on the capacity of the existing infrastructure. This attenuation effect is less pronounced during freshet seasons when peak flows can persist for several days.

It is essential to recognize that any upgrades to the Highway 97 drainage system may influence downstream conditions. These potential downstream impacts must be carefully assessed and balanced with appropriate hydraulic improvements to the downstream sections of Cutoff Creek to avoid unintended consequences.

4. Recommended actions

Collaboration between the Ministry of Transportation and Infrastructure (MoTT) and the Village of Clinton is essential for implementing effective mitigation measures. The Village should use this Flood Mitigation Plan as a basis for engaging with the Ministry to address risks and potential flood impacts in urban areas.

Key recommendations:

- Hydrometric Station Integration: Implement hydrometric stations in Cutoff Creek (proposed in other projects) to improve design flow estimates. While these stations will reduce uncertainty, the balance between uncertainty and risk should be collaboratively determined by MoTT and the Village.
- Adaptive Risk Approach: Some alternatives, such as the overflow channel, could follow an adaptive risk approach, allowing incremental upgrades if future conditions necessitate further action.

Cutoff Creek Drainage Infrastructure Upgrades

The proposed upgrades aim to:

- Reduce MoTT's liability and address vulnerabilities associated with aging stormwater infrastructure.
- Accommodate 200yr flood events by upgrading or diverting the existing system, mitigating risks in urban areas.
- Minimize potential damages to property and infrastructure, enhancing community safety.

By addressing flood risks proactively, MoTT and the Village demonstrate due diligence, reduce legal exposure, and protect both residents and critical infrastructure from future liabilities.

P10 – Flood Education Program

Priority	Medium	**Type**	Non-Structural
Current Flood Vulnerability	Not Applicable	**Design Event**	200yr
Budget	$55,000		

1. Background

The government of British Columbia is committed to increasing flood resilience across the province, as outlined in its *B.C. Flood Strategy 2035*. Developed in collaboration with First Nations, local governments, and community, this strategy serves as a phased roadmap for significant improvements in integrated flood hazard management.

FIGURE 1 B.C. FLOOD STRATEGY

Specifically, *Action 1.3: Raise Awareness of Flood Risk with a Human-Centred Approach*, focuses on building public flood awareness through:

- Producing educational content about flood risks.
- Sharing innovative flood mitigation strategies (e.g., Floodplains by Design).
- Promoting flood outreach tools such as the federal Flood Ready website, the provincial *ClimateReadyBC* website, the Flood Preparedness Guide, the Storm Ready social media package, and other academic and public resources like the Fraser Basin Council's *FloodWise* website, the University of Waterloo's Intact Centre on Climate Adaptation, and Partners for Action's Flood Smart Canada website.

Although the Village of Clinton has not experienced significant flood events in recent years, the proposed strategy aligns with the BC Flood Strategy by addressing projected flood risk impacts identified in the Dam Break Analysis and the Floodplain Mapping. This initiative includes the creation of an Online Flood Hub and pamphlets to improve communication with the community on these critical issues. These tools will provide information about recently completed floodplain mapping, available mitigation options, and additional resources to support emergency preparedness.

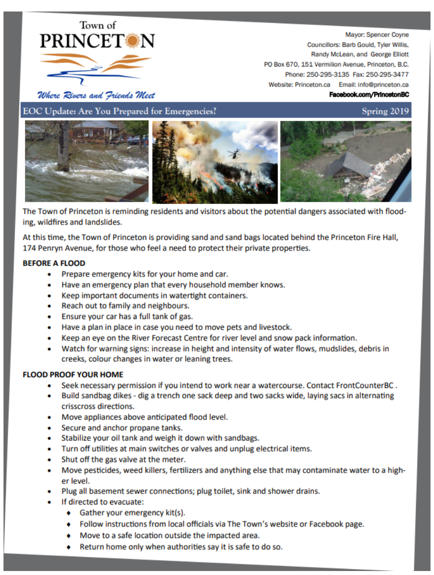
2. Mitigation Strategy

The Flood Education Program aims to equip the community with knowledge and tools to understand flood risks, adopt effective mitigation strategies, and respond efficiently during emergencies. Well-informed communities are more resilient and capable of recovering from flood-related events.

Raising awareness among individuals and businesses empowers them to prepare for potential flooding. Online tools such as story maps and flood hubs have proven effective in sharing flood hazard information across various communities in British Columbia. These tools should be complemented with traditional outreach methods like printed materials, and seasonal reminders.

Key messages to communicate include:

- Identifying areas at risk of flooding;
- What aspects of flood risk reduction are an individual's responsibility and/or governmental responsibility;
- What individuals can do to reduce flood risk, such as flood proofing or raising homes;
- Offer guidelines for managing erosion along Cutoff and Clinton Creeks. Emphasize solutions that do not alter watercourses, promoting sustainable practices;
- Publicly accessible flood forecasting information sources for Clinton;
- What individuals can do to prepare for imminent floods, including sand bagging and preparing for potential evacuation; and
- Supports available after flood event (eg Disaster Financial Assistance).



Town of PRINCETON

Where Rivers and Friends Meet

Mayor: Spencer Coyne
Councillors: Barb Gould, Tyler Willis, Randy McLean, and George Elliott
PO Box 670, 151 Vermilion Avenue, Princeton, B.C.
Phone: 250-295-3135 Fax: 250-295-3477
Website: Princeton.ca Email: info@princeton.ca
Facebook.com/PrincetonBC

EOC Update: Are You Prepared for Emergencies? Spring 2019

The Town of Princeton is reminding residents and visitors about the potential dangers associated with flooding, wildfires and landslides.

At this time, the Town of Princeton is providing sand and sand bags located behind the Princeton Fire Hall, 174 Penryn Avenue, for those who feel a need to protect their private properties.

BEFORE A FLOOD

- Prepare emergency kits for your home and car.
- Have an emergency plan that every household member knows.
- Keep important documents in watertight containers.
- Reach out to family and neighbours.
- Ensure your car has a full tank of gas.
- Have a plan in place in case you need to move pets and livestock.
- Keep an eye on the River Forecast Centre for river level and snow pack information.
- Watch for warning signs: increase in height and intensity of water flows, mudslides, debris in creeks, colour changes in water or leaning trees.

FLOOD PROOF YOUR HOME

- Seek necessary permission if you intend to work near a watercourse. Contact FrontCounterBC .
- Build sandbag dikes - dig a trench one sack deep and two sacks wide, laying sacs in alternating crisscross directions.
- Move appliances above anticipated flood level.
- Secure and anchor propane tanks.
- Stabilize your oil tank and weigh it down with sandbags.
- Turn off utilities at main switches or valves and unplug electrical items.
- Shut off the gas valve at the meter.
- Move pesticides, weed killers, fertilizers and anything else that may contaminate water to a higher level.
- Plug all basement sewer connections; plug toilet, sink and shower drains.
- If directed to evacuate:
  - Gather your emergency kit(s).
  - Follow instructions from local officials via The Town's website or Facebook page.
  - Move to a safe location outside the impacted area.
  - Return home only when authorities say it is safe to do so.

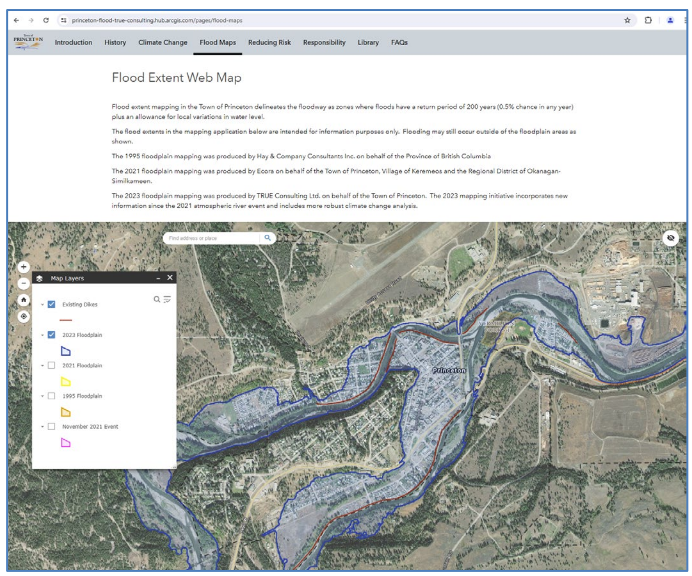


FIGURE 2 EXAMPLES OF AN EMERGENCY AWARENESS NEWSLETTER (LEFT), AND AN ONLINE FLOOD HUB (RIGHT)

3. Project Scope

Recent flood events in British Columbia have highlighted the importance of public education, as many residents remain unaware of local flood mitigation efforts. This project aims to inform the community about flood risks and the Village's initiatives, while increasing awareness among local First Nations.

The Flood Education Program will use online tools, newsletters, and targeted engagement sessions to foster collaboration and community involvement, scope of work include:

Project Management

- Startup meeting(s)
- Identify impacted & affected parties
- Prepare Awareness and Education Plan (AEP)
- Team meetings (e.g. check-in, updates, next steps)
- Project management & communications

Community Group Meetings and Communication

- Develop Flood Mapping and Mitigation webpage
- Develop awareness materials and communication templates (e.g. fact sheets, posterboards, pamphlets, etc.)
- First Nations Engagement

Final Reporting

- Prepare a draft Summary Report for Council consideration
- Review Summary Report with staff
- Presentation of final Summary Report to Council
- Update Flood Mitigation webpage following conclusion of project

4. Project Deliverables

Specific deliverables from this project include:

- Awareness materials and communication templates (pamphlets, posterboards, etc.)
- Flood Mapping and Mitigation webpage
- Final Summary Report
- Presentation to Council

Village of Clinton
P10 - Flood Education Program
Class 'D' Cost Estimate

ITEM NO.	DESCRIPTION	UNIT OF MEASURE.	EST. QUANT.	UNIT PRICE	TOTAL PRICE
1.0	**Project Management**				
1.1	Start up meeting		1	$3,000	$3,000
1.2	Prepare Awareness and Education Plan (AEP)		1	$4,000	$4,000
1.3	Team meetings (e.g. check-in, updates, next steps)		1	$3,000	$3,000
1.4	Project management & communications		1	$4,000	$4,000
	Subtotal 1.0 Project Management				**$14,000**
2.0	**Community Group Meetings and Communication**				
2.1	Develop content for Flood Mapping and Mitigation webpage		1	$10,000	$10,000
2.2	Develop consultation materials and communication templates		1	$5,000	$5,000
2.3	First Nation Engagement		1	$10,000	$10,000
	Subtotal 2.0 Community Group Meetings and Communication				**$25,000**
3.0	**Final Reporting**				
3.1	Prepare a Summary Report		1	$6,000	$6,000
3.2	Presentation of final Summary Report to Council		1	$3,000	$3,000
3.3	Update Flood Mapping and Mitigation webpage following conclusion of project		1	$2,000	$2,000
	Subtotal 3.0 Final Reporting				**$11,000**

Project Summary

Subtotal	**$50,000**
Contingency (10%)	**$5,000**
Total Project (rounded, not including GST)	**$55,000**

P11 – Cariboo Avenue Capacity Improvements

Priority	Low	**Type**	Structural
Current Flood Vulnerability	5yr	**Design Event**	20yr
Budget	$890,000		

1. Background

Floodplain mapping has identified the limited capacity of the Cutoff Creek main channel to accommodate projected climate-adapted flows. Additional projects have been proposed to mitigate the impacts of potential overflow scenarios at Highway 97; however, even with these upgrades, some properties adjacent to Cutoff Creek and Cariboo Avenue are expected to be affected. Figure 1 illustrates the projected inundation extent for a 200yr flood event, assuming Highway 97 drainage upgrades are implemented.

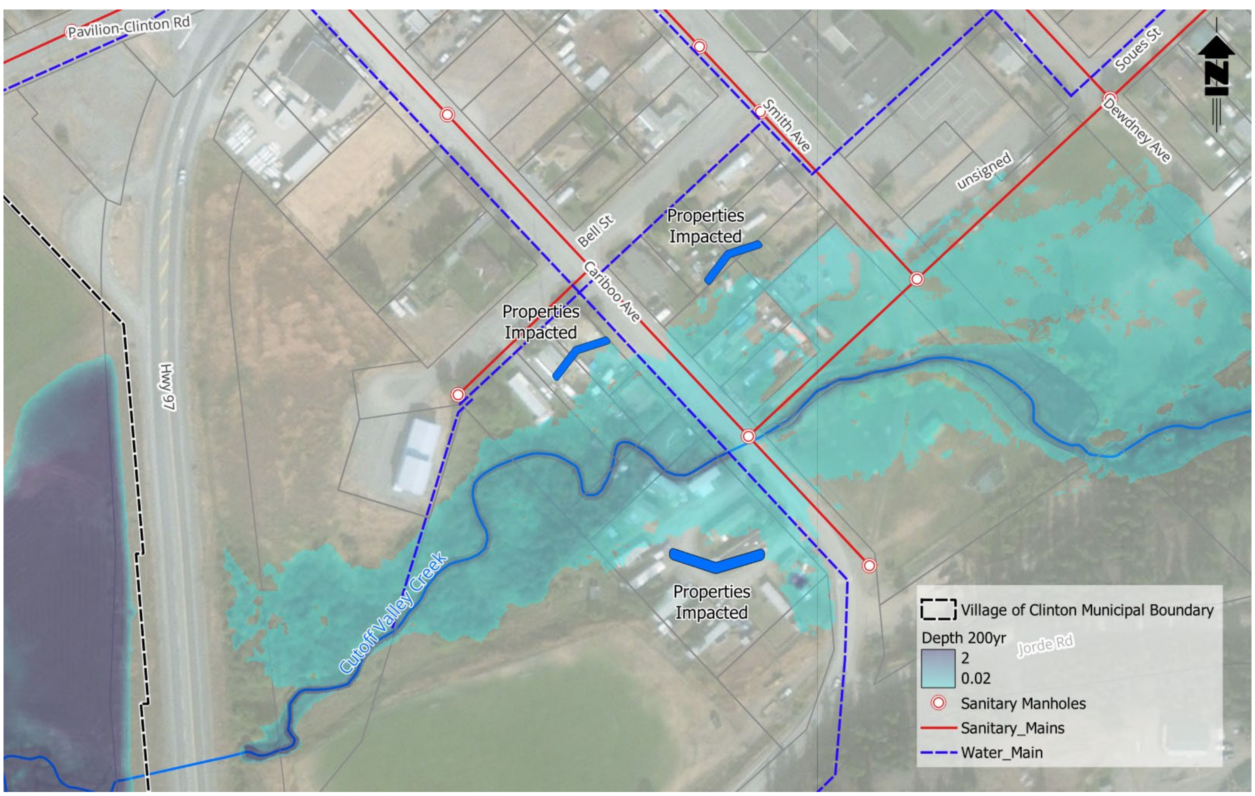


FIGURE 1 200YR FLOOD EXTENT AT CARIBOO AVENUE WITH HWY 97 DRAINAGE UPGRADES

The Cariboo Avenue & Cutoff Creek crossing consists of two ellipsoid culverts, each with an approximate span of 1150 mm and a rise of 820 mm. Figure 2 provides images of the upstream and downstream sections of the culverts.

FIGURE 2 CARIBOO AVENUE CULVERTS: UPSTREAM (LEFT), AND DOWNSTREAM (RIGHT)

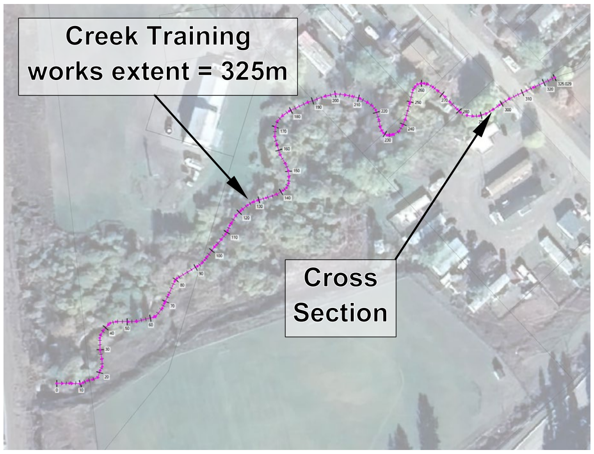
2. Mitigation Strategy

Cariboo Avenue crossing represents a constriction for Cutoff creek main channel. Furthermore, residential properties at this location have minimal setbacks from the watercourse, making them particularly vulnerable during major flow events. To mitigate these impacts, the project proposes the following hydraulic capacity improvements:

- **Replace Existing Culverts:** Remove the current culverts at Cariboo Avenue and replace them with a concrete box girder. Preliminary assessments estimate a span of approximately 6 meters and a depth of 1.5 meters.
- **Deepen the Creek Bed:** Excavate approximately 0.6 meters deeper into the creek bed to enhance flow capacity for a creek extent of 325 meters.
- **Expand Creek Banks:** Widen the creek by 1 meter on each side of the watercourse.

These enhancements are projected to reduce water depth by approximately 0.4 meters, effectively avoiding private property impacts for flood events up to the 20yr return period. While the 200yr inundation extent will still affect some properties, it will reduce the inundation extent compared to the base scenario. Due to existing utilities and the characteristics of the watercourse, designing for the 200yr event is deemed impractical.

The figures below present a plan view of the projected extent of the proposed upgrade and a cross section of the required creek training works.



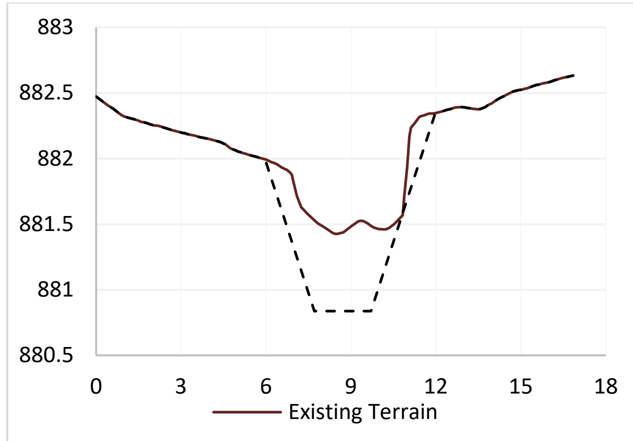


FIGURE 3 PLAN VIEW (RIGHT) AND CROSS SECTION (RIGHT) OF THE PROPOSED WORKS

Key considerations for flood mitigation strategy development include:

Utility Conflicts

The existing Cariboo Avenue crossing includes water and sanitary network components that must be taken into account. In a flood scenario, these elements could be at risk of being washed out, potentially leaving some residential properties and the David Stoddart School without water and sanitary services. If the proposed project is implemented, the existing utilities will need to be replaced or rerouted.

These considerations should be addressed during the predesign stage to evaluate potential routes, restrictions, and system constraints effectively. Figure 4 illustrates the utilities at the Cariboo Avenue crossing.

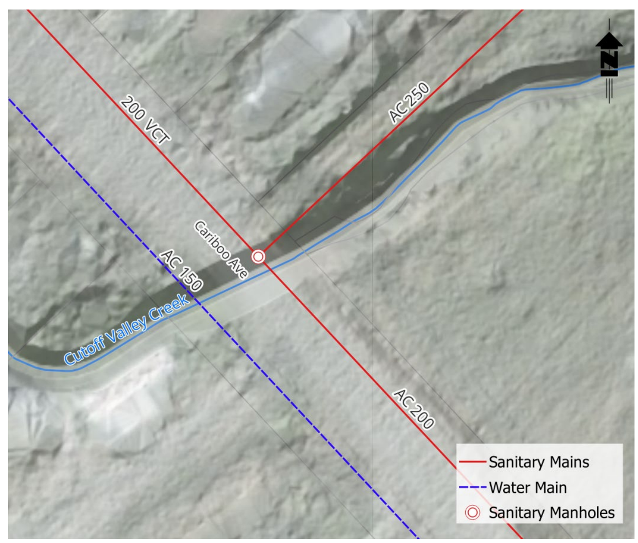


FIGURE 4 WATER AND SANITARY UTILITY NETWORK AT CARIBOO AVENUE CROSSING

3. Project Scope

The Cariboo Avenue Capacity Improvements project aims to address the limited channel capacity and mitigate flood impacts in the vicinity of Cutoff Creek. The scope includes the following key components:

Predesign Phase

- Detailed Topographic survey
- Box culvert or hydraulic capacity improvement at Cariboo Avenue crossing predesign
- Creek Training Works predesign
- Perform environmental assessments and comply with regulatory requirements

Cariboo Avenue Crossing Hydraulic Improvement Culvert

- Remove the existing arch culverts at Cariboo Avenue, which currently restrict flow
- Install a new concrete box girder structure with a span of approximately 6 meters and a depth of 1.5 meters to improve hydraulic performance

Creek Hydraulic Improvements

- Excavate the creek bed to a depth of approximately 0.6 meters to increase channel capacity and reduce water levels during flood events
- Widen the creek banks by 1 meter on each side to accommodate larger flows and reduce the risk of overtopping

Utility Relocation

- Relocate or reroute water and sanitary network components crossing Cariboo Avenue to ensure infrastructure resilience in flood conditions

Community Engagement and Traffic Control

- Engage with residents, municipal authorities, and other interested parties to address concerns and integrate feedback into the final design
- Establish a traffic control strategy

Project Deliverables

Anticipated deliverables and outcomes include:

- Renewed drainage infrastructure at Cariboo Avenue crossing
- Creek training works to enhanced hydraulic capacity at Cutoff Creek
- Rerouted or replace water and sanitary infrastructure at Cariboo Avenue

Village of Clinton
P11 - Cariboo Avenue Capacity Improvements
Class 'D' Cost Estimate

ITEM NO.	DESCRIPTION	UNIT OF MEASURE.	EST. QUANT.	UNIT PRICE	TOTAL PRICE
1.0	**General**				
1.1	Site assessment		1	$6,000	$6,000
1.2	Tophographic Survey		1	$8,000	$8,000
1.3	Mobilization and demobilization		1	$10,000	$10,000
1.4	Traffic Control, Vehicle Access and Parking		1	$10,000	$10,000
	Subtotal 1.0 General				**$34,000**
2.0	**Cariboo Avenue Crossing Hydraulic Improvement**				
2.1	Supply and Install 9m long concrete box girder bridge	lm	6	$60,000	$360,000
2.2	CIP Sidewalk approximately 1.5m wide	lm	6	$200	$1,200
2.3	CIP Parapets on both sides of the bridge	lm	12	$500	$6,000
2.4	Pavement cutting and removal	m^2	60	$80	$4,800
	Subtotal 2.0 Cariboo Avenue Crossing Hydraulic Improvement				**$372,000**
3.0	**Cutoff Creek Hydraulic Improvements**				
3.1	Excavate the creek bed to a depth of approximately 0.6 meters	lm	325	$45	$14,625
3.2	Widen the creek banks by 1 meter on each side	lm	325	$50	$16,250
3.3	Riverine restoration	lm	325	$80	$26,000
	Subtotal 3.0 Cutoff Creek Hydraulic Improvements				**$56,875**
4.0	**Utility Conflicts**				
4.1	Allowance for sanitary network conflicts	allow		$15,000	$15,000
4.2	Allowance for water network conflicts	allow		$10,000	$10,000
	Subtotal 4.0 Utility Conflicts				**$25,000**

Fieldworks Summary

Subtotal 1.0 General	$34,000
Subtotal 2.0 Cariboo Avenue Crossing Hydraulic Improvement	$372,000
Subtotal 3.0 Cutoff Creek Hydraulic Improvements	$56,875
Subtotal 4.0 Utility Conflicts	$25,000
Contingency Allowance (35%)	$171,000
Subtotal Field Works	**$660,000**

Design and Construction Services

Predesign (3%)	$20,000
Engineering (10%)	$66,000
Permitting (3%)	$20,000
Archaeology Assessment and Monitoring (3%)	$20,000
First Nations Consultation (LS)	$15,000
Environmental Management Plan & Monitoring (3%)	$20,000
Construction Inspection (10%)	$66,000
Subtotal Design and Construction	**$230,000**

Total Project (rounded, not including GST)	**$890,000**
	CAD 2024