Appendix D Tagish Conceptual Flood Mitigation Design Options

The contents of this appendix are subject to the project objectives, methods, assumptions, and limitations outlined in the main body of the Yukon Territory Flood Mitigation Conceptual Design Options report and in Appendix T.

D.1 Existing Conditions

The existing conditions presented in this section provide a brief summary of characteristics of the Study Area that are pertinent to the development of mitigation options and their evaluation. The contents of this section are not a comprehensive review of all existing conditions for Tagish.

D.1.1 POPULATION

Tagish has a population of 311 with 413 private dwellings according to 2021 census data (Statistics Canada 2023c). The population has increased by approximately 25% from 2016 when the population was 249 (Statistics Canada 2023c).

D.1.2 STUDY AREA

The Study Area in Figure D2 outlines the areas that are considered in this Project at Tagish. The boundaries of the Study Area are based on Stantec's understanding that the flood mitigations are to be designed for communities, and that individual properties outside of the main community consolidation are not included.

D.1.3 FIRST NATIONS

The Tagish Study Area is within the Traditional Territories of the Carcross / Tagish First Nation (C/TFN). C/TFN has parcels of Category B Settlement Lands and Fee Simple Lands around Tagish, along Tagish River. The land claim selections are R-16B, R-40B, C-41B, C-56B and C-60FS.This means that C/TFN has surface and private property ownership of these parcel of land (Government of Yukon 2022). Figure D2 illustrates the C/TFN settlement lands within the Study Area.

D.1.4 BATHYMETRY AND TOPOGRAPHY

Bathymetry data for Tagish Lake, Tagish River and Marsh Lake near Tagish were not provided to Stantec.

The following data sources were provided to or obtained by Stantec:

- 2022 LiDAR LAS Dataset and LAS files UTM Zone 8 CSRS NAD1983 (GeoYukon 2023) and interpolated into a derivative 1m horizontal resolution Digital Elevation Model (DEM) (Government of Yukon 2022e).

All elevations are reported in CGVD2013. The LiDAR accuracy is assumed to be sufficient for the preliminary flood inundation analysis and conceptual design presented in this Report. There is insufficient metadata to determine whether the LiDAR meets the base requirement in terms of accuracy or precision for flood mapping per NRCan (2022b).

D.1.5 GEOLOGY

Based on the surficial geology mapping (Yukon Geological Survey, 2020), the Study Area consists of Eolian sand along the southwest portion of the site and Glaciolacustrine materials consisting of silt, clay,

sand and gravel along the northwest and east portions of the site. The Eolian sand was deposited in forms of veneers in thicknesses ranging between 0.1 m and 1 m. The Glaciolacustrine materials were deposited in forms of plains, thicknesses unknown.

Based on testpit data provided in the Yukon Permafrost Database (Government of Yukon, 2022b), the soil conditions in the southwest portion of the flooding areas within the Tagish area are likely to consist of sand and silt up to explored depths of 3 m. Based on the testpit data reviewed from the Yukon Permafrost Database (Government of Yukon, 2022b) permafrost was not encountered, however permafrost may be present in the Tagish area based on the Permafrost Probability Model (Yukon Geological Survey, 2020) and the Canada Permafrost Map (The National Atlas of Canada, 1995). The Permafrost Probability Model suggests the Study Area is located within a region of sporadic discontinuous permafrost (10–20% of land underlain by permafrost). The Canada Permafrost Map also indicates the Study Area is in a region of sporadic discontinuous permafrost (10–50% of land underlain by permafrost) with a low (<10% by volume of visible ice) ground ice content in the upper 10–20 m of the ground. If permafrost is present at this site within the limits of the flood mitigation options, differential settlements of the proposed flood mitigation options may occur and should be further investigated and evaluated in preliminary and detailed designs.

D.1.6 HYDROGEOLOGY

The sand material in the southwest area of the Study Area is likely to result in relatively fast rates of groundwater flow. The Glaciolacustrine materials in the northwest and east portions of the Study Area are likely to result in relatively slow rates of groundwater flow. The groundwater would likely be impacted by the Tagish River levels with the areas consisting of Glaciolacustrine materials to be impacted slower than the areas consisting of sand. If river and lake levels are high for a prolonged period of time, the areas consisting of Glaciolacustrine materials would likely become saturated and would take longer to dissipate and lower when river and lake levels decrease.

Based on the anticipated soils at Tagish, the need for seepage control measures (i.e. seepage cut-off below flood mitigation option, toe drains, sump pits and pumping, etc.) may be required for the proposed flood mitigation options and should be further evaluated in preliminary and detailed designs.

D.1.7 PAST FLOODING EVENTS AND RESPONSE

A summary of documented flood events is provided below. The flood events summarized below do not represent a comprehensive review of flooding history in the Study Area; rather, they are a summary of the flooding documentation provided to Stantec at the time of writing.

2007 Flood Event

The Southern Lakes region—including Tagish—experienced flooding during the summer of 2007 due to a "perfect storm" of heavy snowpack, warm temperatures resulting in substantial snow and glacier melt, and record rainfall (Sierra 2008). Documentation of the flood response in 2007 has not been provided to Stantec. WSC Station 09AA017 (Tagish Lake at 10 Mile Bridge) reported a peak instantaneous WSE of 647.95 m (at the WSC station) on August 12, 2007 during the 2007 flood event (GoC 2023).

2021 Flood Event

The Southern Lakes region—including Tagish—experienced flooding during the summer of 2021. The flooding was largely due to record snowpack in the winter of 2020-2021 and warm temperatures in late June of 2021. Emergency flood response actions were undertaken within Tagish in 2021. The actions included a superbag dike on Tagish Road on the east side of the bridge, temporary earthen fill dikes around the private properties in the McGrath Lane development, and property-owner constructed superbag dikes at the private properties along the west shoreline of Tagish River both north and south of the Tagish River bridge. The peak WSE during the 2021 flood event at Tagish was noted to be 658.06 m on July 12, 2021 (MH 2022).

D.1.8 EXISTING FLOOD MITIGATION INFRASTRUCTURE

Tagish currently has no existing permanent flood mitigation infrastructure documented within the Study Area.

D.1.9 WIND, WAVES, AND EROSION

Flow velocities through the Tagish River are likely to be low during flood stages because during flood conditions, water in the Southern Lakes is backwatered outflow restrictions (control structures, Miles Canyon) such that the Southern Lakes trend towards a single WSE and behave as a single large basin. Erosion protection from riverine flow velocities is not anticipated to be required at Tagish flood mitigations.

California Beach, located at the south end of the Tagish Study Area, is affected by beach processes and erosion due to wind and waves. If flood mitigations are required at California Beach, they would need to be capable of withstanding not only the erosion potential from wind and waves, but higher WSEs due to wave runup and potential lake seiche. Natural beach processes and morphodynamics should be studied and considered in preliminary and detailed design phases of flood mitigations.

D.1.10 HYDROLOGY

Tagish Lake is part of the Southern Lakes system (Tutshi Lake, Bennett Lake, Windy Arm, Nares Lake, Tagish Lake, Marsh Lake). Water supply to the Southern Lakes consists of snowmelt, runoff from precipitation events, and glacier melt. The Southern Lakes drain north, eventually conveying flow out of Marsh Lake and into the Yukon River. Water levels in the Southern Lakes are regulated by two control structures maintained by the Yukon Energy Corporation (YEC): the Marsh Lake/Lewes controls structure and the Whitehorse dam. A natural hydraulic constriction (Miles Canyon) on the Yukon River is located between the Marsh Lake/Lewes control structure and the Whitehorse dam. During high water conditions and when the YEC control structures are fully open, Miles Canyon is the feature that limits flow exiting the Southern Lakes and therefore controls the flood-stage WSEs in the Southern Lakes. During these flood conditions, the Miles Canyon flow restriction produces a backwater effect such that the Southern Lakes trend towards acting as a single large basin with a common WSE.

Water flows from Tagish Lake to Marsh Lake in a narrows through Tagish (the Tagish River). WSC Station 09AA017 (Tagish Lake at 10 Mile Road) is located approximately 12 km southwest of California Beach (Figure D2). Gross drainage area to the WSC station is not reported by GoC (2023). Flood frequency analysis was performed by Morrison Hershfield (2022) at WSC Station 09AA017, however this WSC station has been noted by YG Water Resources Branch and Yukon University to have datum correction uncertainties. For that reason, Yukon University (2022) performed flood frequency analysis for WSC Station 09AB004 (Marsh Lake near Whitehorse, located farther downstream) with moderate and storage peaks related to control structure gate closure (i.e., “non-natural” peaks) excluded from the analysis. Yukon University (2022) then added 0.2 m to Marsh Lake flood frequency WSEs (based on observed difference in peak event WSEs between the two locations; B. Turcotte, personal communication, 11 November 2022) to produce estimates of flood frequency WSEs at Tagish. Table D1 summarizes the frequency results of these two studies.

Table D1 Flood Frequency Analyses at WSC Station 09AA017 (Morrison Hershfield 2022) and WSC Station 09AB004 (Yukon University 2022) for Tagish

	Morrison Hershfield (2022)	**Yukon University (2022)**
Years Included in Analysis	1996-2022	1970-2022
Number of Years	27	53
Selected Distribution	GEV	Gumbel
Water Surface Elevation (m) [1]		
1:2-year Event (50% AEP)	657.00	656.90
1:20-year Event (5% AEP)	657.78	657.80
1:100-year Event (1% AEP)	658.07	not provided
1:200-year Event (0.5% AEP)	658.15	658.50
[1] Elevations provided in CGVD2013 for WSC Station 09AA017 (by Morrison Hershfield 2022) and Station 09AB004+0.2m (by Yukon University 2022)		

The Yukon University (2022) flood frequency analysis results were adopted for the Project because there is greater certainty in the reliability of the datum used for their analysis and the 1:200-year event WSE was higher (which would result in a more conservative conceptual design).

Figure D1 illustrates the on-record daily minimum, mean, and maximum WSEs, the WSE during the highest year on record (2021), and the WSEs for the 1:2-year and 1:200-year event at Tagish from Yukon University (2022). Past high-water events at Tagish (2007, 2022, 2004) have all occurred during open water conditions, and are likely to be correlated to high snowpack conditions in the preceding winter. The 2022 event was associated with high snowpack and saturated ground conditions. Figure D1 shows that water levels at Tagish typically begin to rise in mid-May with the onset of freshet and increase through June. Water levels typically reach a prolonged peak through the months of July and August, before decreasing in September and October. The pattern of several week-long flood conditions at Tagish are typical in the Southern Lakes region, as outflows from the large lakes are restricted by Miles Canyon. Flood conditions at Tagish may generally be expected to persist for several weeks in July and August.

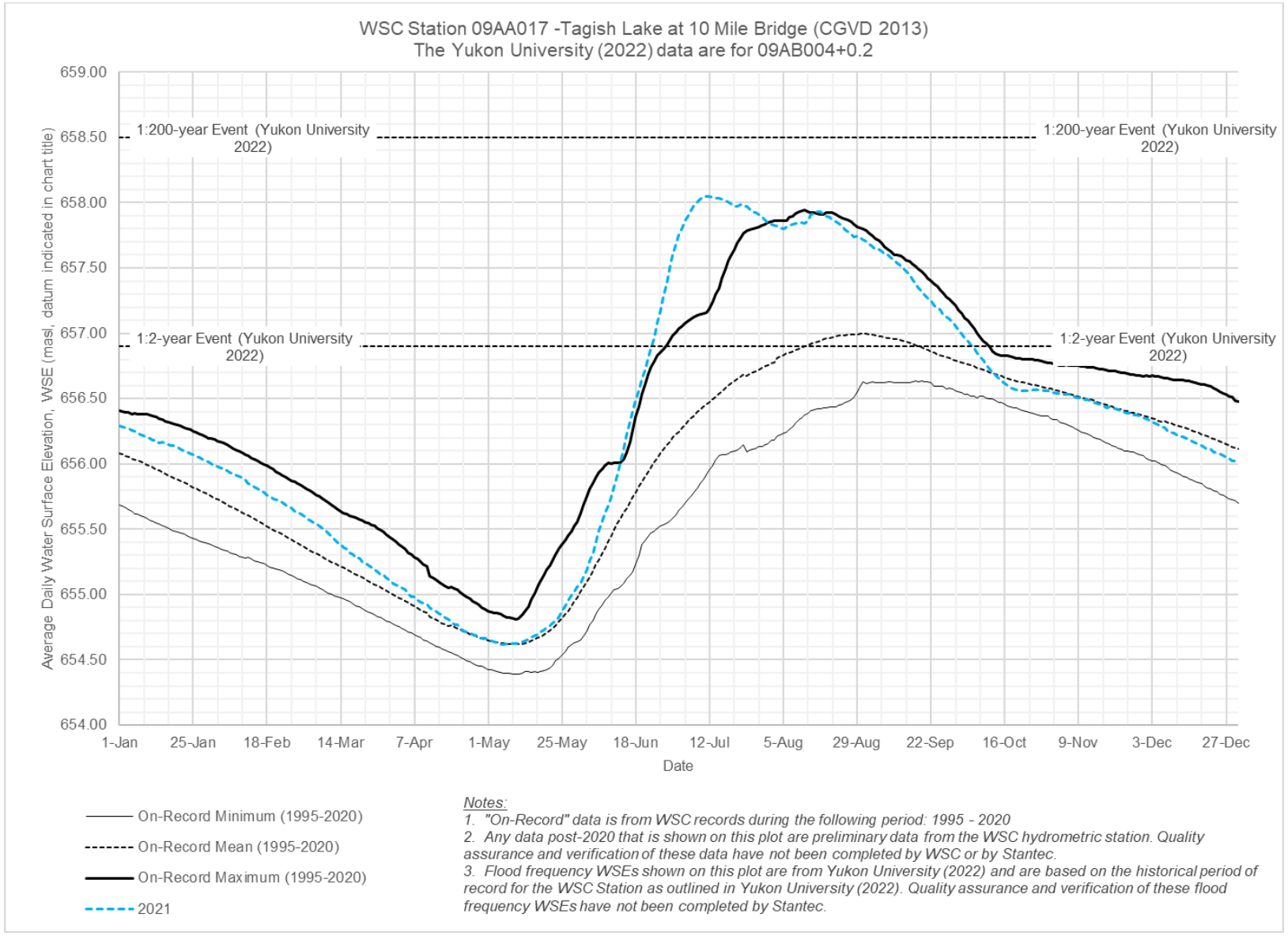


Figure D1 Historical Water Surface Elevations at WSC 03AA017 (Tagish Lake at 10 Mile Road)

The contents of this appendix are subject to the project objectives, methods, assumptions, and limitations outlined in the main body of the Yukon Territory Flood Mitigation Conceptual Design Options report and in Appendix T.

D.1.11 PRELIMINARY INUNDATION MAPPING

Floodplain mapping and the associated flood policy is ultimately what is required for design and implementation of flood mitigations at communities. Wind/wave analysis and floodplain mapping have not been completed to date at Tagish and is not within the scope of this Project. However, an understanding of inundation extents under 1:200-year event is required for conceptual design of flood mitigations.

In lieu of floodplain mapping, Stantec performed preliminary existing conditions (no mitigation) inundation analysis for Tagish using WSEs. This analysis considered the 1:200-year event WSE (658.50 m) developed by Yukon University (2022) in a flat water inundation scenario. The preliminary inundation analysis does not take into account flow pathways and blockages. That is, if the land in a given location is below the 1:200 WSE surface, it presents as inundated whether or not there is an overland flow path for the water to arrive there. The resulting water surface was overlain on the existing conditions topographic elevation data (GeoYukon 2023) and the limits of inundation were mapped (Figure D2). The inundation analysis performed herein is provided for information only and is considered a high-level estimate of the flood inundation under the 1:200-year WSE from Yukon University (2022). As stated in Section 3.6, the inundation/flood vulnerability of the Tagish River bridge is not in the scope of work of this Project.

Inundated areas in the preliminary inundation analysis occur at three main locations in Tagish. On the west side of Tagish River, on both the north and south sides of Tagish Road, the preliminary inundation encroaches onto private properties and community infrastructure located along the west bank of the Tagish River and along the mouth of Tagish Creek. On the east side of the community, the inundation extends to infrastructure on both sides of Tagish Road, including private properties in the McGrath Lane development (north of Tagish Road) and the community campground and local water treatment plant (south of Tagish Road). At California Beach (south end of Study Area, north end of Tagish lake) the inundation extends onto private properties.

The preliminary inundation analysis indicated that an estimated 39 private residence properties and 3 major community features/properties (portion of Sidney Street, boat launch and driveway access west of Tagish River and north of Tagish Road, Tagish Road west of bridge) would have at least 25% of their area inundated (inundated properties). The campground south of the Tagish Road bridge and on the west side of Tagish River would be inundated but is not considered to be a community feature requiring flood mitigation.

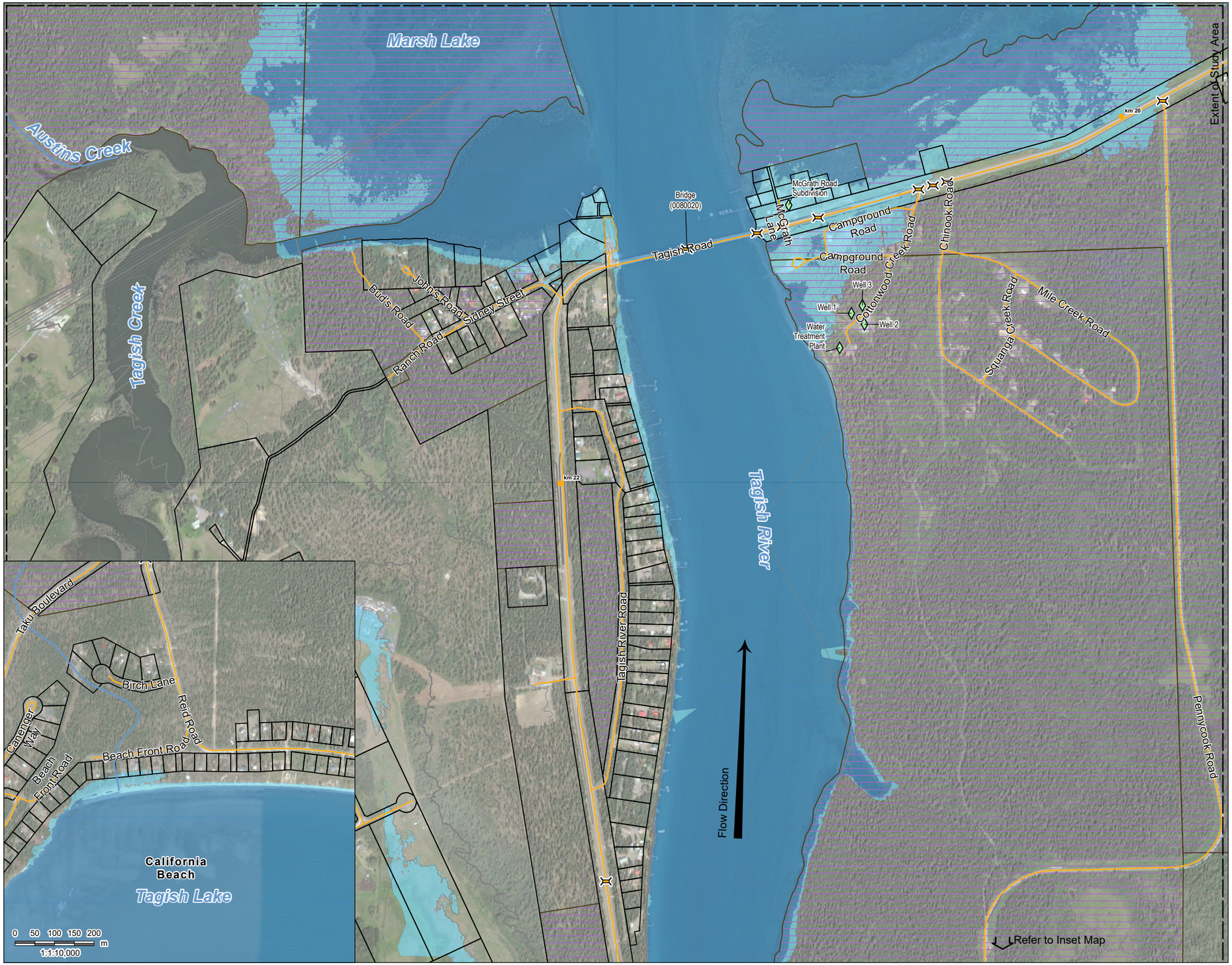


Figure No.

D2

Title

Existing Conditions and Preliminary Flood Inundation at Tagish

Client/Project 144903232

Government of Yukon
Community Services | Infrastructure Development Branch
Yukon Territory Flood Mitigation Conceptual Design Options

Project Location
Tagish, Yukon

Prepared by LLT on 2023-05-08
TR by JM on 2023-05-08

N

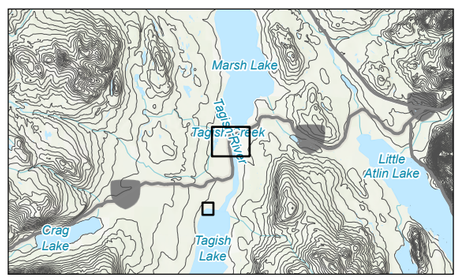
0 50 100 150 200 m
(At original document size of 11x17)
1:10,000

- Culvert/ Bridge
- Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- Parks Campgrounds Surveyed
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed

Water Depth at 1:200 WSE Inundation (m)

- 0 - 1
- 1 - 2
- > 2

The preliminary inundation analysis does not take into account flow pathways and blockages. That is, if the land in a given location is below the 1:200 WSE surface, it presents as inundated whether or not there is an overland flow path for the water to arrive there.



Notes

1. Coordinate System: NAD 1983 Yukon Albers
2. Data Sources: Government of Yukon; Government of Canada
3. Imagery Government of Yukon Geomatics Yukon; ESRI World Imagery

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D.2 Mitigation Options and Evaluation

The scope of this Project is to develop conceptual engineered flood mitigation options; these options for Tagish are presented in this section. Non-engineered options presented in Section 3.3.1 of the main body of this Report (emergency response-based, mitigation funding to property owners, land purchase/exchange, regulation of flow, management of ice, nature-based approaches) should be considered as part of a comprehensive approach to flood mitigation in the Yukon.

Based on the objectives and assumptions presented in the main body of this Report, three flood mitigation options were developed for Tagish (Table D2) using combinations of the typical engineered flood mitigation designs from Section 3.3.2. Flood mitigations in the two options are provided for areas which are inundated under the 1:200-year WSE (658.50 m) in the preliminary inundation mapping (Figure D2). The top elevation of the flood mitigations is designed to reach the DFSL which in the case of Tagish (lake site) is assumed to be 660.50 m (i.e., 2 m above the 1:200-year WSE as outlined for lake sites in Section 3.2).

Areas which are above the 1:200-year WSE in the preliminary inundation analysis but below the DFSL are not included in this Project. These areas may need to be included in future design advancements depending on the requirements of future territorial flood policy.

Table D2 Summary of Conceptual Design Options

Location	Option 1	Option 2
	lower capital costs, higher response/maintenance	*higher capital costs, lower response/maintenance*
West Side of Tagish River	Platform with Temporary Superbag Dike	Structural Dike
Tagish Road	Road as Platform with Temporary Superbag Dike	Road Raising
McGrath Road Subdivision	Platform with Temporary Superbag Dike	Along Tagish River: Structural Dike
		Northern boundary: Earthen Dike
Private Properties on California Beach	Temporary Sandbag Dikes	

Section D2.1 and D2.2 provide a description, Class D cost estimate, and qualitative evaluation of the above listed options.

D.2.1 OPTION 1

Description

The conceptual flood mitigations for Option 1 are illustrated in Figure D3. Option 1 consists of the construction of platforms for temporary superbag dikes during a flood event, in addition to temporary sandbag dikes around individual private properties.

Approximately 400 m of Tagish Road on the east approach to the Tagish River bridge would be treated as a platform during flood conditions and have temporary sandbag dikes on both sides of the road in order to allow for vehicles to continue travelling on the road. The temporary superbag dikes on either side

of the road (400 m x 2 = 800 m of temporary superbag dike) and would likely restrict the number of traffic lanes, meaning traffic control would likely be required during flood conditions.

On the east side of the Tagish River and north of Tagish Road, the McGrath Lane subdivision would have an approximately 500 m long platform constructed around the properties. The platform would be approximately 1.5 m higher than the existing ground. A double superbag dike would need to be placed on the platform to reach the DFSL during flood events. Space is limited for the 150 m along the Tagish River; for this length, a structural element on the lake side (i.e., sheet pile instead of 3H:1V side slopes) would be required. Allowances/modifications to platform design may be required to maintain the boat launch in this section. The section of the proposed platform along the Tagish River (approximately 150 m) may require slope stabilization measures due to the added weight from the new fill for the platform along the top of bank.

On the east side of the Tagish River and the south side of Tagish Road, approximately 500 m of Cottonwood Road would be established as a platform for temporary superbag dike deployment to act as a flood barrier and maintain the travel corridor from Tagish Road to the water treatment plant. Minimal road raising would be required (0–0.5 m above existing). In the event of a flood, a double superbag dike would be required to reach the DFSL.

On the west side of the Tagish River, two platform segments with a total length of 1,600 m would be constructed to provide flood mitigation for private properties on both the north and south sides of the Tagish River bridge. The platform would be approximately 0.5–1.5 m above the existing ground and would require a double superbag dike to reach the DFSL in the event of a flood. The lake side of the platform would be lined with rip rap to mitigate erosion risk from waves (both boat and wind induced) and may require slope stabilization measures due to the added weight from the new fill for the proposed platform along the top of bank.

A total of 4 properties in the community are proposed to be protected by temporary sandbag dikes: 1 individual property at the end of John’s Road and 3 individual properties on California Beach. Temporary sandbag dike height at all locations is estimated to be up to 2.5 m.

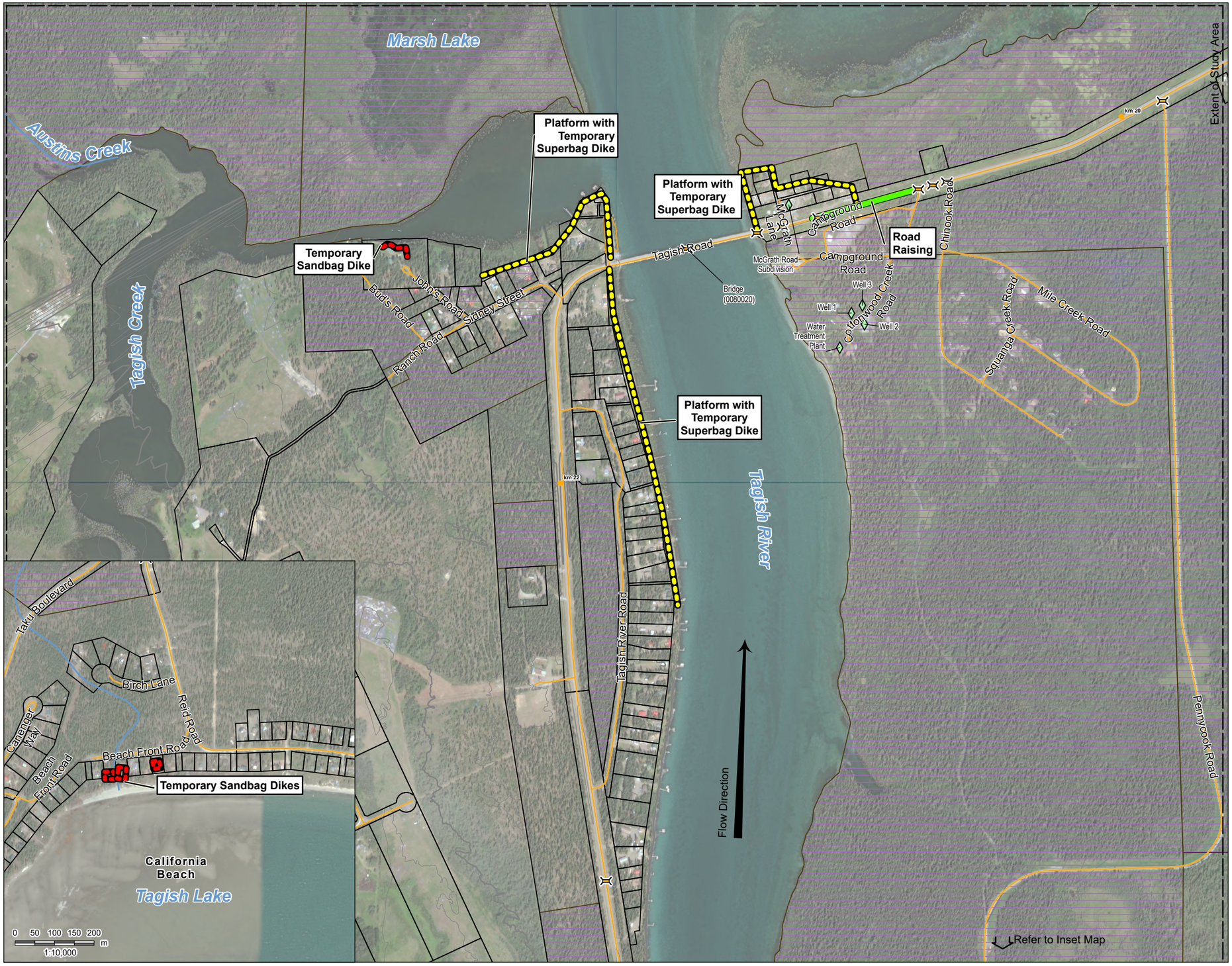


Figure No.

D3

Title

Tagish Conceptual Flood Mitigation Design - Option 1

Client/Project 144903232

Government of Yukon
Community Services | Infrastructure Development Branch
Yukon Territory Flood Mitigation Conceptual Design Options

Project Location
Tagish, Yukon

Prepared by LLT on 2023-04-11
TR by JM on 2023-04-11

N

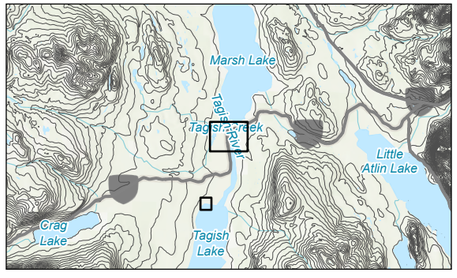
0 50 100 150 200 m
(At original document size of 11x17)
1:10,000

- Culvert/ Bridge
- Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- Parks Campgrounds Surveyed
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed

Proposed Mitigation Feature

- Earthen Dike
- Platform with Temporary Superbag Dike
- Road Raising
- Structural Dike
- Temporary Sandbag Dike

CONCEPTUAL DESIGN
This document is for general information only and is not for permits, tendering, or construction.



Notes
1. Coordinate System: NAD 1983 Yukon Albers
2. Data Sources: Government of Yukon; Government of Canada
3. Imagery Government of Yukon Geomatics Yukon; ESRI World Imagery

Stantec Yukon

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Class D OPC

The Class D OPC's for capital and annual costs are summarized in Table D3, considering the Class D level of accuracy (+/-50%). Table D3 also provides the Class D OPCs on a per inundated property basis (from Section D.1.11).

Table D3 Option 1 Capital Costs Class D OPCs

	Class D OPC	Number of Inundated Properties (Section D.1.11)[1]	Class D OPC per Inundated Property
Capital Cost	$ 22,829,900 - $ 34,244,850	42	$ 543,570 - $ 815,354
Annual Cost (Flood Year)	$ 3,324,000 - $ 4,986,000		$ 79,143 - $ 118,715
Annual Cost (Non-Flood Year)	$ 24,900 - $ 37,350		$ 593 - $ 890
[1]As described in Section D.1.11, the inundated properties from the preliminary inundation analysis consists of 39 private residence properties and 3 major community features/ properties.			

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table D4 (capital costs), Table D5 (annual cost, flood year), and Table D6 (annual cost, non-flood year).

Table D4 Option 1 Capital Costs Class D OPC

Item No.		Description of Work	Units	Qty.	Unit Price	Amount
Section 1A		**Option 1: General Conditions**				
	a)	Mobilization/Demobilization	LS	1	$1,267,650.00	$1,267,650.00
	b)	Site Preparation/Restoration	LS	1	$253,600.00	$253,600.00
					Total 1A	$1,521,250.00
Section 1B		**Option 1: Earthworks & Landscaping, Platform**				
	a)	Clearing and Grubbing	M2	22300	$10.00	$223,000.00
	b)	Topsoil Stripping and Stockpiling, 300mm Depth	M3	6690	$25.00	$167,250.00
	c)	Platform Topsoil	M2	17500	$20.00	$350,000.00
	d)	Platform Seeding	M2	17500	$5.00	$87,500.00
	e)	Geotextile Fabric	M2	5400	$10.00	$54,000.00
	f)	Platform Fill	M3	16150	$100.00	$1,615,000.00
	g)	Riprap	MT	6310	$141.00	$889,710.00
	h)	Seepage Cutoff Wall-Clay, 1m Width	M3	5400	$100.00	$540,000.00
	i)	Toe Drain: Perforated Pipe, Geotextile and Drain Rock	M	800	$300.00	$240,000.00
	j)	Slope Stabilization	M	2750	$3,000.00	$8,250,000.00
					Total 1B	$12,416,460.00
Section 1C		**Option 1: Floodboxes, Platform**				
	a)	600mm Dia. Concrete Culvert	M	200	$750.00	$150,000.00
	b)	Flatback Drainage Gate, 600mm Dia.	EA	10	$3,000.00	$30,000.00
	c)	Type II Concrete Headwall, 600mm Dia.	EA	10	$5,000.00	$50,000.00
	d)	Canal Gate, 600mm Dia.	EA	10	$3,000.00	$30,000.00
					Total 1C	$260,000.00
					Contingency (20%)	$2,839,542.00
					Subtotal	$17,037,252.00
					Location Adjustment Factor (LCAF)	1.34
					Capital Costs Base Price	$22,829,900.00
					Capital Costs Upper Bound	$34,244,850.00

The contents of this appendix are subject to the project objectives, methods, assumptions, and limitations outlined in the main body of the Yukon Territory Flood Mitigation Conceptual Design Options report and in Appendix T.

Table D5 Option 1 Annual Costs During a Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 1D	**Option 1: Annual Costs, Flood Year**				
a)	Inspections	LS	1	$100,000.00	$100,000.00
b)	Minor Repairs & Vegetation Management	LS	1	$10,000.00	$10,000.00
c)	Storage of Superbags and Sandbags	LS	1	$500.00	$500.00
d)	Superbags c/w Sandfill (2.0m)	M	3470	$500.00	$1,735,000.00
e)	Sandbags c/w Sandfill (2.0m)	M	260	$564.00	$146,640.00
f)	Traffic Control	LS	1	$75,000.00	$75,000.00
				Total 1D	$2,067,140.00
				Contingency (20%)	$413,428.00
				Subtotal	$2,480,568.00
				Location Adjustment Factor (LCAF)	1.34
				Annual Cost, Flood Year Base Price	$3,324,000.00
				Annual Cost, Flood Year Upper Bound	$4,986,000.00

Table D6 Option 1 Annual Costs During a Non-Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 1E	**Option 1: Annual Costs, Non-Flood Year**				
a)	Inspections	LS	1	$5,000.00	$5,000.00
b)	Minor Repairs & Vegetation Management	LS	1	$10,000.00	$10,000.00
c)	Storage of Superbags and Sandbags	LS	1	$500.00	$500.00
				Total 1E	$15,500.00
				Contingency (20%)	$3,100.00
				Subtotal	$18,600.00
				Location Adjustment Factor (LCAF)	1.34
				Annual Cost, Non-Flood Year Base Price	$24,900.00
				Annual Cost, Non-Flood Year Upper Bound	$37,350.00

The contents of this appendix are subject to the project objectives, methods, assumptions, and limitations outlined in the main body of the Yukon Territory Flood Mitigation Conceptual Design Options report and in Appendix T.

Qualitative Evaluation

Table D7 summarizes the performance of Option 1 with respect to the evaluation criteria which was previously outlined in the main body of this Report.

Table D7 Option 1 Qualitative Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating
1	Viability and Reliability under Extreme Conditions	temporary dikes may degrade under long duration of flooding (several weeks or months); wind/wave impacts would be mitigated by elevated DFSL and erosion mitigation measures however ice/debris damage from wave action is a risk for temporary superbag dikes; risk of vandalism and degradation risk increases with duration that the temporary dikes are deployed; seepage control measures likely required given underlying soils and long duration of flooding	Low Performance
2	Time to Implementation	geotechnical investigations required including borehole drilling to address bank stability and construction requirements for platforms; hydraulic modelling, wind/wave analysis, and erosion mitigation design required; medium regulatory risk; moderate anticipated design effort; property owner agreements required; moderate anticipated construction effort	Medium Performance
3	Capital Cost Per Inundated Property	reduced capital costs in exchange for increased operational and maintenance costs when compared to permanent flood mitigation infrastructure (Option 2); per-inundated-property capital cost is $543,570/property	Medium Performance
4	Maintenance and Storage	storage required for substantial number of superbags and sandbags; stockpiling of material required for superbags/sandbags; numerous platforms will require inspections, maintenance, and vegetation clearing; floodbox maintenance will be required	Low Performance
5	Response and Activation	numerous temporary superbag dikes require training, labour, and a timely response in a flood scenario to be effective; property-owner deployed temporary sandbag dikes; ; floodbox slide gates would need to be manually closed prior to arrival of flood and opened following abatement of the flood	Low Performance
6	Aesthetics and Community Function	alterations to existing landscape (platforms up to 1.5 m high) during non-flood conditions in front of private properties; the platforms may be used as a community feature (e.g., walking path) if the community members are supportive; temporary alteration of private/community function and view during flood conditions from temporary superbag and sandbag dikes	Low Performance
7	Future Adaptability	three-high temporary superbag dikes or additional raising of road may be completed in future for enhanced flood mitigation; additional sandbags may be provided for raising temporary sandbag dikes; permanent increases in height to platform structure are likely possible without additional widening of structure but will require engineering study	High Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	intrusions into Tagish Lake, Marsh Lake, and Tagish River; portions of mitigations on beach areas may impact natural beach processes and morphodynamics but are not anticipated to substantially disrupt existing lake and river processes; minor reduction to floodplain conveyance is possible across Tagish Road east of bridge from superbag dike; slope stabilization measures may be required over an approximate length of 1.7 km	Medium Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	medium to high return on investment (ROI) for Option 1 given the included mitigations for crucial transportation route	High Performance

The contents of this appendix are subject to the project objectives, methods, assumptions, and limitations outlined in the main body of the Yukon Territory Flood Mitigation Conceptual Design Options report and in Appendix T.

D.2.2 OPTION 2

Description

The conceptual flood mitigations for Option 2 are illustrated in Figure D4. The main difference between Option 1 and Option 2 is that Option 2 includes permanent flood mitigation features instead of platforms requiring temporary deployment of superbag dikes.

Approximately 400 m of Tagish Road on the east approach to the Tagish River bridge would be raised by approximately 2.0 – 2.5 m to reach the DFSL. Floodplain culverts may be required to maintain floodplain conveyance after the road is raised.

On the east side of the Tagish River and north of Tagish Road, the McGrath Lane subdivision would be enclosed by approximately 500 m of dikes that are 3.5 m higher than existing ground. Along the Tagish River (150 m), space is limited and a structural dike would be constructed.

Allowances/modifications to dike design may be required to maintain the boat launch in this section. Along the north and east extents of the McGrath Lane subdivision (350 m), an earthen dike would be constructed. The section of the proposed dike along the Tagish River (approximately 150 m) may require slope stabilization measures due to the added weight from the new fill for the platform along the top of bank.

On the west side of the Tagish River, two structural dike segments with a total length of 1600 m would be constructed to provide flood mitigation for private properties on both the north and south sides of the Tagish River bridge. The structural dike crest would be approximately 2.5–3.5 m above the existing ground. Slope stabilization measures may be required along the riverbank due to the added weight from the new fill for the proposed dike along the top of bank. Allowances/modifications to dike design may be required to maintain the boat launch north of the Tagish River bridge, on the west side of the Tagish River.

As in Option 1, 4 properties in the community are proposed to be protected by temporary sandbag dikes: 1 individual property at the end of John’s Road, and 3 individual properties on California Beach. Temporary sandbag dike height at all locations is estimated to be up to 2.5 m.

Figure No.

D4

Title

Tagish Conceptual Flood Mitigation Design - Option 2

Client/Project 144903232

Government of Yukon
Community Services | Infrastructure Development Branch
Yukon Territory Flood Mitigation Conceptual Design Options

Project Location
Tagish, Yukon

Prepared by LLT on 2023-04-11
TR by JM on 2023-04-11

N

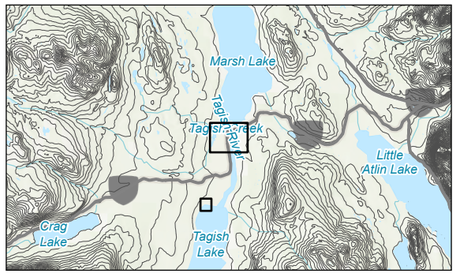
0 50 100 150 200 m
(At original document size of 11x17)
1:10,000

- Culvert/ Bridge
- Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- Parks Campgrounds Surveyed
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed

Proposed Mitigation Feature

- Earthen Dike
- Platform with Temporary Superbag Dike
- Road Raising
- Structural Dike
- Temporary Sandbag Dike

CONCEPTUAL DESIGN
This document is for general information only
and is not for permits, tendering, or construction.



Notes
1. Coordinate System: NAD 1983 Yukon Albers
2. Data Sources: Government of Yukon; Government of Canada
3. Imagery Government of Yukon Geomatics Yukon; ESRI World Imagery

Stantec Yukon

Class D OPC

The Class D OPC's for capital and annual costs are summarized in Table D8, considering the Class D level of accuracy (+/-50%). Table D8 also provides the Class D OPCs on a per inundated property basis (from Section D.1.11).

Table D8 Option 2 Summary of Class D OPCs

	Class D OPC	Number of Inundated Properties (Section D.1.11)[1]	Class D OPC per Inundated Property
Capital Cost	$ 60,092,300 - $ 90,138,450	42	$ 1,430,770 - $ 2,146,154
Annual Cost (Flood Year)	$ 121,404 - $ 182,106		$ 2,891 - $ 4,336
Annual Cost (Non-Flood Year)	$ 97,284 - $ 145,926		$ 2,317 - $ 3,475
[1]As described in Section D.1.11, the inundated properties from the preliminary inundation analysis consists of 39 private residence properties and 3 major community features/ properties.			

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table D9 (capital costs), Table D10 (annual cost, flood year), and Table D11 (annual cost, non-flood year).

Table D9 Option 2 Capital Costs Class D OPC

Item No.		Description of Work	Units	Qty.	Unit Price	Amount
Section 2A		**Option 2: General Conditions**				
	a)	Mobilization/Demobilization	LS	1	$3,738,920.00	$3,738,920.00
	b)	Site Preparation/Restoration	LS	1	$747,800.00	$747,800.00
					Total 2A	$4,486,720.00
Section2B		**Option 2: Earthworks & Landscaping, Earthen Dike**				
	a)	Clearing and Grubbing	M2	9930	$10.00	$99,300.00
	b)	Cut and Re-use Onsite - Native Material	M3	250	$15.00	$3,750.00
	c)	Cut and Dispose Offsite - Native Material	M3	4330	$30.00	$129,900.00
	d)	Import and Place Fill - Native Material	M3	250	$15.00	$3,750.00
	e)	Import and Place Engineered Fill	M3	20040	$100.00	$2,004,000.00
	f)	Topsoil Stripping and Stockpiling, 300mm Depth	M3	2980	$25.00	$74,500.00
	g)	Riprap	MT	5470	$141.00	$771,270.00
	h)	Geotextile Fabric	M2	4680	$10.00	$46,800.00
	i)	Embankment Seeding	M2	4710	$5.00	$23,550.00
	j)	Embankment Topsoil	M2	4710	$20.00	$94,200.00
	k)	Toe Drain: Perforated Pipe, Geotextile and Drain Rock	M	380	$300.00	$114,000.00
	l)	Slope Stabilization	M	380	$3,000.00	$1,140,000.00
					Total 2B	$4,505,020.00
Section2C		**Option 2: Earthworks & Landscaping, Structural Dike (Tagish River East and West, Tagish Creek)**				
	a)	Clearing and Grubbing	M2	7690	$10.00	$76,900.00
	b)	Topsoil Stripping and Stockpiling, 300mm Depth	M3	2310	$25.00	$57,750.00
	c)	Dike Topsoil	M2	5160	$20.00	$103,200.00
	d)	Dike Seeding	M2	5160	$5.00	$25,800.00
	e)	Dike Fill	M3	12300	$100.00	$1,230,000.00
	f)	Sheet Pile Wall	M2	10630	$1,700.00	$18,071,000.00
	g)	Modular Block Wall	M2	5320	$900.00	$4,788,000.00
	h)	Handrails	M	3440	$140.00	$481,600.00
	i)	Toe Drain: Perforated Pipe, Geotextile and Drain Rock	M	1720	$300.00	$516,000.00
	j)	Slope Stabilization	M	1720	$3,000.00	$5,160,000.00
					Total 2C	$30,510,250.00
Section 2D		**Option 2: Floodboxes, Structural Dike & Earthen Dike**				
	a)	600mm Dia. Concrete Culvert	M	360	$750.00	$270,000.00
	b)	Flatback Drainage Gate, 600mm Dia.	EA	18	$3,000.00	$54,000.00

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	c)	Type II Concrete Headwall, 600mm Dia.	EA	18	$5,000.00	$90,000.00
	d)	Canal Gate, 600mm Dia.	EA	18	$3,000.00	$54,000.00
					Total 2D	$468,000.00
Section 2E		**Option 2: Road Raising, Platform (Tagish Rd.)**				
	a)	Rough Grading	M2	10070	$5.00	$50,350.00
	b)	Subgrade Preparation	M2	10070	$5.00	$50,350.00
	c)	80mm Minus Granular Subbase, Variable Depth	M3	15790	$40.00	$631,600.00
	d)	100mm Minus Granular Base, 100mm Depth	M3	380	$50.00	$19,000.00
	e)	BST Surfacing	M2	2730	$50.00	$136,500.00
	f)	Riprap	MT	4450	$141.00	$627,450.00
	g)	Floodplain Culverts	LS	1	$270,000.00	$270,000.00
					Total 2E	$1,785,250.00
Section 2F		**Option 2: Auxiliary Protection**				
	a)	Sandbags c/w Sandfill (2.0m)	M	260	$464.00	$120,640.00
					Total 2F	$120,640.00

Contingency (20%)	$7,474,172.00
Subtotal	$44,845,032.00
Location Adjustment Factor (LCAF)	1.34
Capital Costs Base Price	$60,092,300.00
Capital Costs Upper Bound	$90,138,450.00

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Table D10 Option 2 Annual Costs During a Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 2G	**Option 2: Annual Costs, Flood Year**				
a)	Inspections	LS	1	$25,000.00	$25,000.00
b)	Minor Repairs & Vegetation Management	LS	1	$50,000.00	$50,000.00
c)	Storage of Sandbags	LS	1	$500.00	$500.00
				Total 2G	$75,500.00
				Contingency (20%)	$15,100.00
				Subtotal	$90,600.00
				Location Adjustment Factor (LCAF)	1.34
				Annual Cost Flood Year Base Price	$121,404.00
				Annual Cost, Flood Year Upper Bound	$182,106.00

Table D11 Option 2 Annual Costs During a Non-Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 2H	**Option 2: Annual Costs, Non-Flood Year**				
a)	Inspections	LS	1	$10,000.00	$10,000.00
b)	Minor Repairs & Vegetation Management	LS	1	$50,000.00	$50,000.00
c)	Storage of Sandbags	LS	1	$500.00	$500.00
				Total 2H	$60,500.00
				Contingency (20%)	$12,100.00
				Subtotal	$72,600.00
				Location Adjustment Factor (LCAF)	1.34
				Annual Cost, Non-Flood Year Base Price	$97,284.00
				Annual Cost, Non-Flood Year Upper Bound	$145,926.00

The contents of this appendix are subject to the project objectives, methods, assumptions, and limitations outlined in the main body of the Yukon Territory Flood Mitigation Conceptual Design Options report and in Appendix T.

Qualitative Evaluation

Table D12 summarizes the performance of Option 2 with respect to the evaluation criteria which was previously outlined in the main body of this Report.

Table D12 Option 2 Qualitative Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating
1	Viability and Reliability under Extreme Conditions	permanent structures would withstand long duration of flooding (several weeks or months); wind/wave impacts and damage risks from ice/debris would be mitigated by elevated DFSL and structural elements on lake/river side of dikes; small number of temporary sandbag dikes vulnerable to damage from ice/debris and waves; seepage control measures likely required given underlying soils and long duration of flooding	High Performance
2	Time to Implementation	geotechnical investigations required including borehole drilling to address bank stability and construction requirements for dikes; hydraulic modelling, wind/wave analysis, and erosion mitigation design required; high regulatory risk; high anticipated design effort; property owner agreements required; substantial anticipated construction effort	Low Performance
3	Capital Cost Per Inundated Property	increased capital costs in exchange for decreased operational and maintenance costs when compared to options requiring substantial temporary deployments (Option 1); per-inundated-property capital cost is $1,430,770/property	Low Performance
4	Maintenance and Storage	moderate storage requirements (sandbags for temporary sandbag dikes at 7 properties); numerous large dikes will require inspections, maintenance, and vegetation clearing; floodbox maintenance will be required	Medium Performance
5	Response and Activation	7 property-owner deployed temporary sandbag dike; floodbox slide gates would need to be manually closed prior to arrival of flood and opened following abatement of the flood	High Performance
6	Aesthetics and Community Function	substantial permanent alteration of existing landscape and lake views by structural dike (2.5 - 4.0 m in height); dike crests may be established as community features (e.g., walking paths) if the community members are supportive; temporary alteration of private property function during flood conditions from temporary sandbag dikes	Low Performance
7	Future Adaptability	temporary superbag dike may be deployed on earthen and structural dike crest and raised roads in future for enhanced flood mitigation; additional sandbags may be provided for raising temporary sandbag dikes; permanent increases in height to structural dike are difficult; permanent future raising of earthen dikes and road is possible but will require engineering study and are likely to require widening of structure	Low Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	intrusions into Tagish Lake, Marsh Lake, and Tagish River; portions of mitigations on beach areas may impact natural beach processes and morphodynamics but are not anticipated to substantially disrupt existing lake and river processes; floodplain culverts should maintain floodplain conveyance; slope stabilization measures may be required over an approximate length of 1.7 km	Medium Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	costly overall investment (Option 2) when compared to alternatives proposed for DMAF funding; lower overall return on investment (ROI) than Option 1 however the mitigation for the crucial transportation route alone would have high ROI	Medium Performance

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D.2.3 SUMMARY TABLES

Table D13 summarizes the Class D cost estimates for each of the conceptual design options.

Table D13 Summary of Class D OPCs

	Option 1 Class D OPCs	Option 2 Class D OPCs
Capital Cost	$22,829,900 - $34,244,850	$60,092,300 - $90,138,450
Annual Cost (Flood Year)	$ 3,324,000 - $ 4,986,000	$ 121,404 - $ 182,106
Annual Cost (Non-Flood Year)	$ 24,900 - $ 37,350	$ 97,284 - $ 145,926

Table D14 provides a summary of the evaluation of each of the conceptual design options.

Table D14 Summary of Qualitative Evaluation of Conceptual Options

Criteria No.	Criteria Title	Option 1	Option 2
1	Viability and Reliability under Extreme Conditions	Low Performance	High Performance
2	Time to Implementation	Medium Performance	Low Performance
3	Capital Cost Per Inundated Property	Medium Performance	Low Performance
4	Maintenance and Storage	Low Performance	Medium Performance
5	Response and Activation	Low Performance	High Performance
6	Aesthetics and Community Function	Low Performance	Low Performance
7	Future Adaptability	High Performance	Low Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	Medium Performance	Medium Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	High Performance	Medium Performance