Stantec

Marsh Lake Flood Mitigation Options

March 22, 2022

Prepared for:

Government of Yukon
Community Services | Infrastructure
Development Branch
2121 2nd Avenue
Whitehorse, YT
Y1A 1C2

Prepared by:

Stantec Consulting Ltd.
202-107 Main St.
Whitehorse, YT
Y1A 2A7

Stantec Project Number: 144903232

Revision: 1

Prepared by ______________________________
(seal/signature to the right)

Jeff Muirhead, M.ASc., P.Eng.
Hydrotechnical Engineer

Prepared by ______________________________
(seal/signature to the right)

Justin Saj, M.Eng., P.Eng.
Associate, Geotechnical Engineer

Digitally signed by Davignon, Jamie
Date: 2022.03.22 14:17:15 -07'00'

Reviewed by ______________________________
(signature)

Jamie Davignon, P.Eng.
Civil Engineer

Reviewed by ______________________________
(signature)

Tom Crilly, M.Sc., P.Eng. (MB, BC, NWT/NU)
Principal, Senior Geotechnical Engineer

Matt Wood
2022.03.22
14:43:00-06'00'

Approved by ______________________________
(signature)

Matt Wood, P.Eng. (BC, AB, SK, NWT/NU)
Senior Hydrotechnical Engineer, Canada West Water Resources Sector Lead

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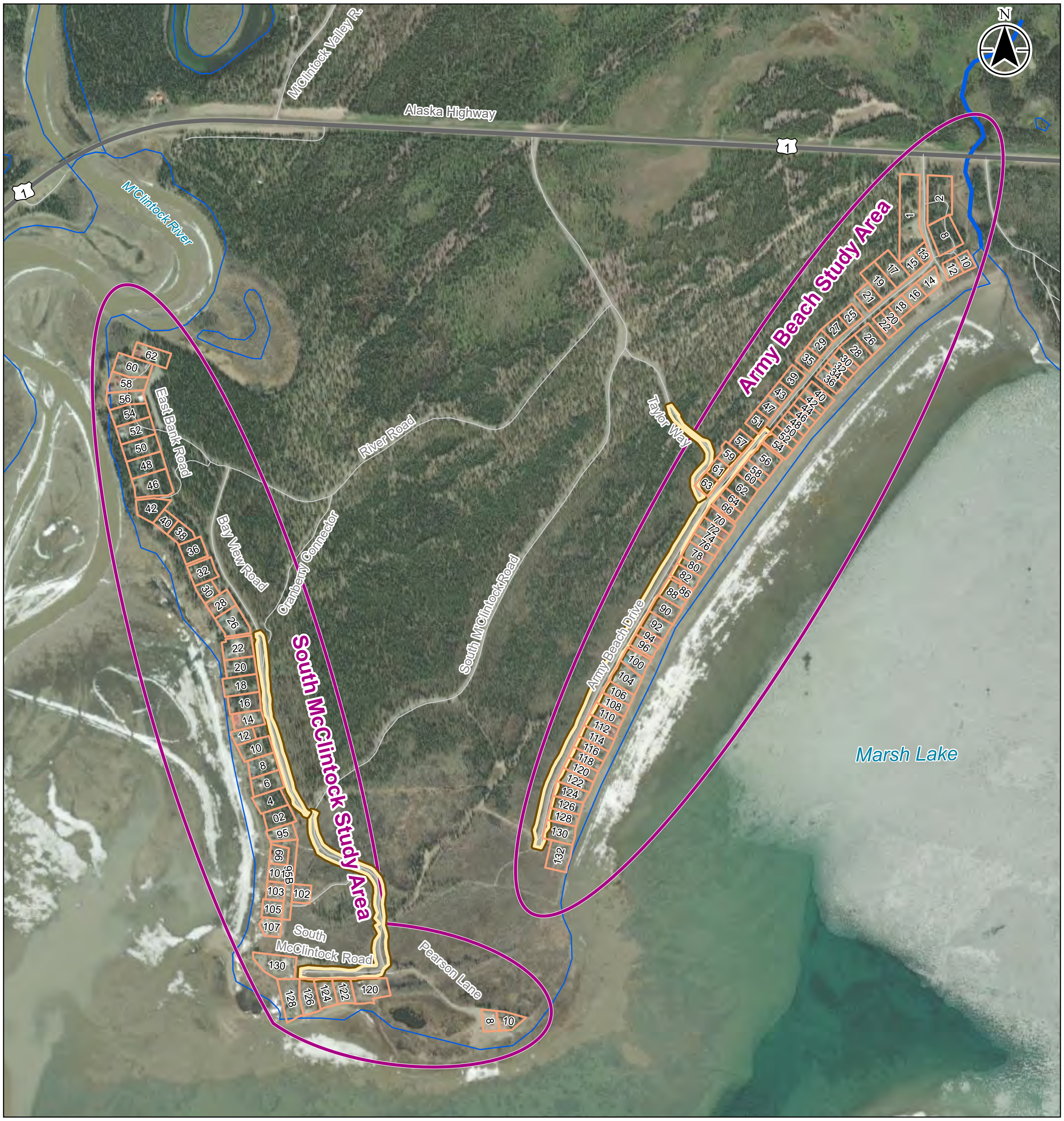
1.0 INTRODUCTION

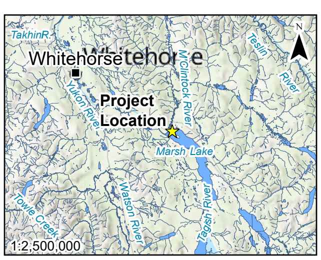
The southern region of the Yukon experienced severe flooding in the spring and summer of 2021. The flooding was largely attributed to high snowpack accumulation in south/central Yukon over the winter of 2020/2021. The first phase of flooding ("phase 1") consisted of local snowmelt and site drainage flooding and occurred in May/June. The second phase of flooding ("phase 2"), which occurred in July/August, consisted of elevated water levels in the larger waterbodies/watercourses – specifically, in the reservoir lakes south of Whitehorse (Southern Lakes) and the downstream Yukon River.

Construction of temporary flood defense berms by individual property owners began in late June of 2021 and generally consisted of earthfill berms and sandbag dikes. On July 9, 2021, a State of Emergency was declared for the Southern Lakes region and significant increases to resources and labour were allocated to the Southern Lakes Flooding Incident (Incident 21-10-21-I, henceforth referred to as the Incident) and the associated Incident Management Team (IMT). Temporary berm building efforts accelerated significantly through July 2021, with berm construction being performed by the Canadian Armed Forces (CAF), Wildland Fire, and other Government of Yukon (YG) staff. By early August 2021, the majority of the defense berm had been constructed and the focus of the IMT shifted towards maintenance, repairs, and ongoing spot upgrades. The maintenance, repair, and spot upgrades continued until the end of the State of Emergency on September 14, 2021.

Throughout the Incident, Stantec Consulting Ltd.'s (Stantec's) Whitehorse-based staff provided ongoing hydrotechnical/water resources, civil, structural, and survey support for the IMT. Based on the data collected during this involvement, Stantec developed a detailed inventory of the temporary defense berms, including berm type and quantity estimates on a lot-by-lot basis for the River Road, Bayview, South McClintock, and Army Beach areas at Marsh Lake (Stantec 2021a). On November 30, 2021, the Infrastructure Branch of YG's Community Services requested that Stantec develop high-level options for more permanent, large-scale flood defense/mitigation measures, with some potential for additional temporary measures, to mitigate flooding on the lakeside areas along Army Beach and South McClintock for varying levels of flood frequencies (e.g., 20-year, 50-year, 200-year).

This report contains the flood mitigation options for the Army Beach and South McClintock areas at Marsh Lake (Study Areas, Figure 1.1), as requested by the Community Services Infrastructure Branch. The objective of this report is to provide YG with high-level description, costing, and evaluation of technically feasible flood mitigation options for potential further exploration. We understand that the list of options can include both engineered and non-engineered options. Costing has been completed for the engineered options.





Highway
Local Street
Topographic Contour
Watercourse
Waterbody
Study Area
Property Boundary
Road Boundary

0 100 200 300 400 500 m

1:15,000 (at original document size of 8.5x11)

Notes
1. Coordinate System: NAD 1983 UTM Zone 8N
2. Data Sources: GeoYukon Open Data; Natural Resources Canada
3. Imagery Source: ESRI World Imagery

Stantec

Project Location:
Marsh Lake,
Yukon

Project Number: 144903232
Prepared by LTRUDELL on 20220125
Requested by JMUIRHEAD on 20220125
Checked by CDEAN on 20220125

Client/Project/Report
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Figure No.
1.1

Title
Army Beach and South McClintock Study Area

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2.0 EXISTING CONDITIONS

The existing conditions presented in this section provide a brief summary of characteristics of Marsh Lake and the Study Area that are pertinent to the development of Mitigation options and their evaluation. This study is not a comprehensive review of all existing conditions for Marsh Lake and the Study Area.

2.1 FIRST NATIONS

The Marsh Lake area is within the Traditional Territories of the Kwanlin Dün First Nation (KDFN) and the Carcross Tagish First Nation (CTFN). The KDFN have a parcel of Category B Settlement Lands on the Northwest corner of the Marsh Lake area, along McClintock River. The land claim selection is R-77B. This means that KDFN has surface ownership of this parcel of land (Government of Yukon 2022). Other First Nation's with Traditional Territories near the Study Area, such as the Ta'an Kwäch'än Council (TKC), should also be considered when engaging with local stakeholders.

2.2 PAST EVENTS

2.2.1 2007 Flood Event

Through July of 2007, high water conditions in the Southern Lakes occurred due to a high snowpack, fast snowpack melt, and higher than average precipitation in the area. Water surface elevations (WSE) peaked on August 14, 2007 at 657.66 m (CGVD2013). Flood defense measures included concrete blocks, concrete barriers, superbags and sandbags. An estimated 40 properties at Marsh Lake were directly impacted by these floods (Government of Yukon 2007a). Discussions with property owners and YG officials throughout the 2021 flood indicated that during the 2007 flood, flood defenses were focused on the lake side of the properties however high water entered the interior of the Marsh Lake peninsula (between Army Beach and South McClintock) and flooded properties from the non-lake side.

After the water levels receded in 2007, YG developed objectives for various branches of government for moving forward, including Wildland Fire Management, Community Development, Community Services Communications, and Yukon Housing Corporation (YHC). Wildland Fire Management was responsible for the removal and cleanup of the flood defense measures and damage on public lands (sandbags, concrete blocks, Jersey Barriers); Community Development was responsible for reclaiming the Army Beach dyke, borrow pits and areas for the dyke, and access trail; the YHC was responsible for developing a purchase process for private property owners to purchase the existing concrete blocks and barriers; Community Services Communications was responsible for developing a communications strategy for private property owner responsibilities and the process for private property owners to purchase concrete blocks (Government of Yukon 2007b). The YHC also developed a Flood Relief Initiative which provided financial grants to homeowners to repair their flood-damaged residences (Government of Yukon 2007c).

Many of the affected homeowners purchased concrete blocks from YG after the 2007 flood and applied for the YHC grants to repair their primary residences (no financing limit, based on the damages done by the flood) and up to $35,000 in loans to repair secondary residences and/or outbuildings and install flood mitigation measures at their properties (YG 2007). A post-flood options analysis was completed by Tetra Tech (formerly EBA Consulting) in 2008 (EBA 2008).

2.2.2 2021 Flood Event

Severe flooding occurred in the Southern Lakes of the Yukon in the spring and summer of 2021, which was largely attributed to high snowpack accumulation in south/central Yukon over the winter of 2020/2021, combined with a cool and wet spring that delayed snowmelt, and a heat wave in late June that resulted in rapid melting of the snowpack and record inflows to the Southern Lakes. A State of Emergency was declared for the Southern Lakes region on July 9, 2021 and significant increases to resources and labour were allocated to the Southern Lakes Flooding Incident. The water levels in Marsh Lake peaked on July 10, 2021, at an elevation of 657.88 m (CGVD2013). Flood defense construction was ongoing from late June through to early/mid-August, and included temporary superbag and sandbag dikes, earthfill berms, concrete blocks, and occasional water bag systems used by private property owners. Berms constructed by YG and CAF were initially built to an elevation of 658.90 m. Once this elevation was achieved for the majority of the defense structure, the target elevation for the defenses was raised by 0.30 m to 659.20 m (CGVD2013) to enhance protection level. The defense structure target elevations were not considered to be flood protection design elevations. The constructed defense structures were not considered to be permanent flood defenses and are not engineered structures.

The State of Emergency was ended on September 14, 2021. The defense structure was not decommissioned or removed by YG personnel before or after the State of Emergency ended as available data in the late summer of 2021 indicated the risk of another flood event in the spring/summer of 2022. At the time of writing, the defense structures presumably remain in place. It is possible that property owners have made alteration to the structures since their deployment.

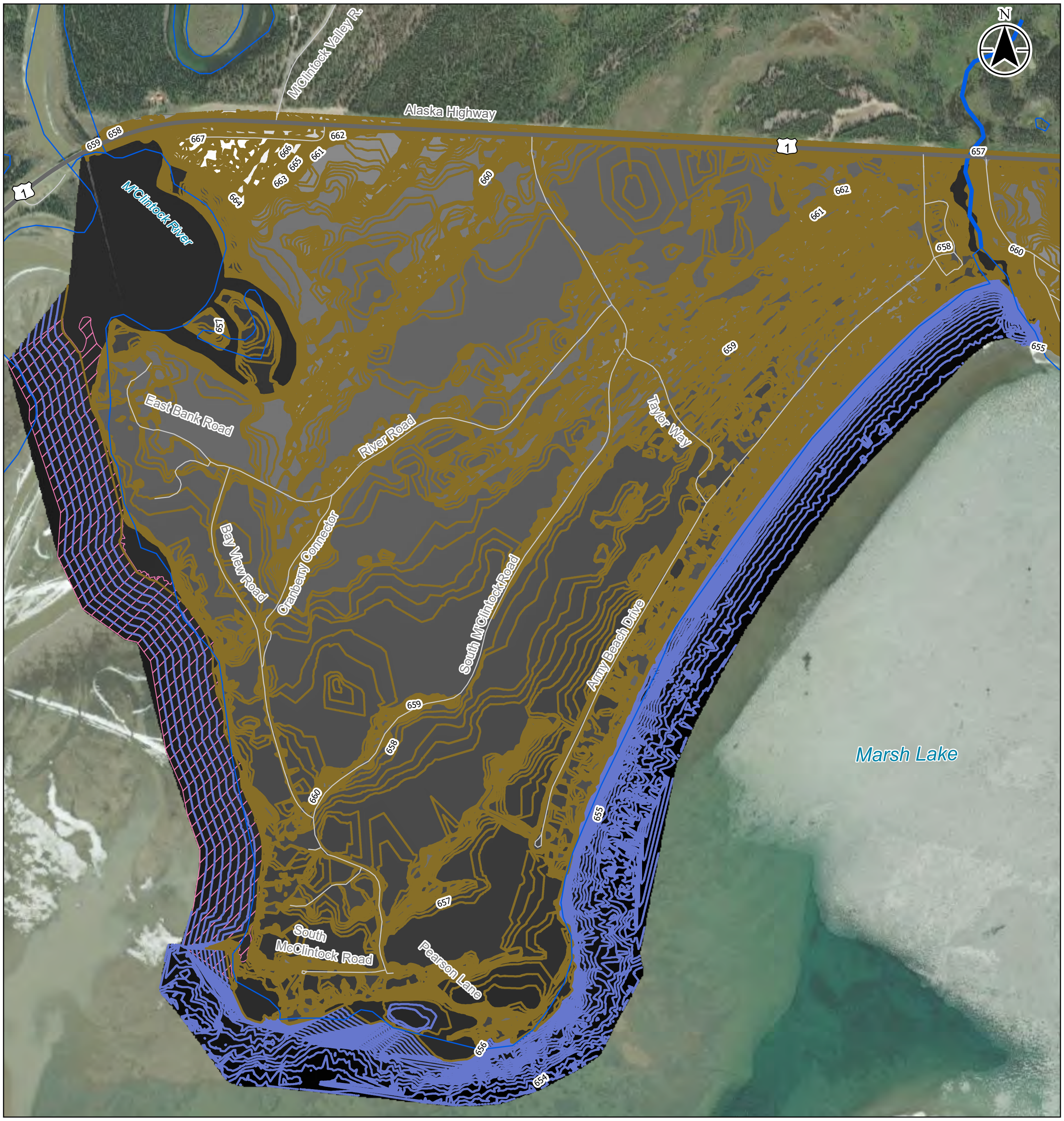
Based on our technical support and response role through the 2021 flood, Stantec produced a detailed berm inventory in October of 2021 for YG (Stantec 2021a). The detailed berm inventory documented, on a lot-by-lot basis, the berm materials, geometry, shoreline protection, and first floor elevations of the structures.

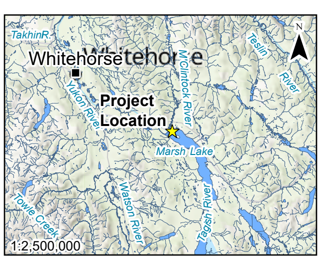
2.3 BATHYMETRY AND TOPOGRAPHY

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

- Land contours and imagery from 1:2500 scale mapping in 2011 (Underhill Geomatics 2021)
- Bathymetry collected in November 2021 (Underhill Geomatics 2021)
- Road crest profiles collected in July-August 2021 (Stantec 2021a)

The existing conditions topography and bathymetry is illustrated in Figure 2.1. Figure 2.1 identifies a zone where bathymetry data was not collected by Underhill (2021) due to ice cover during the survey. In this zone, Stantec created an interpolated surface based on typical bathymetry and shoreline topography collected in adjacent areas. All elevations are reported in CGVD2013.





- Highway
- Local Street
- Topographic Contour
- Watercourse
- Waterbody
- Topographic Contour (0.1 m)
- Bathymetric Contour (0.1 m)
- Assumed Surface Information

Elevation (m)
667.815
653.751

0 100 200 300 400 500 m
1:15,000 (at original document size of 8.5x11)

Notes
1. Coordinate System: NAD 1983 UTM Zone 8N
2. Data Sources: GeoYukon Open Data; Natural Resources Canada
3. Imagery Source: ESRI World Imagery

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Figure No.
2.1

Title
Existing Bathymetry and Topography

2.4 GEOLOGY

The geology in the project area has been briefly reviewed using the following sources:

- The Surficial Geology data set (Yukon Geological Survey, 2020)
- Permafrost Probability Model (Bonnaventure et al., 2012)
- Canada Permafrost Map (Natural Resources Canada, 1995)
- Discussions with local geotechnical engineers (C. Cowan and I. MacIntye 2021, personal communication, 22 December, 2021)

The following points summarize the results of the geology review of the project site.

- Based on the surficial geology mapping, the project site consists of Eolian sand and Glaciolacustrine mud (mix of silt and clay), sand and gravel. The Eolian sand was deposited in forms of veneers and blankets ranging in thickness between 0.1 m and greater than 1 m. The Glaciolacustrine mud, sand and gravel was deposited in form of a plain, thickness unknown. Based on the surficial geology mapping, the Eolian sand is more extensive than the Glaciolacustrine mud, sand and gravel and the surficial material is from the McConnell age.
- The surficial geology mapping aligns with discussions with local geotechnical engineers (C. Cowan and I. MacIntyre 2021, personal communication, 22 December, 2021) who indicated that the area generally consists of silts and fine grained sands. The thickness of the deposit of silts and fine grained sands is unknown. Based on the Canadian Foundation Engineering Manual (CFEM, 2006), silts and fine grained sands are under Frost Group F4 which classifies the material as very high to frost susceptibility.
- From the local discussions, permafrost conditions were considered to be unlikely at the project site. This varies however based on the Permafrost Probability Model, the project site is located within a region of sporadic discontinuous permafrost (10-20%), as well as from the Canada Permafrost Map which shows the project site is located in a region of sporadic discontinuous permafrost (10-50%) with a low (<10%) ground ice content in the upper 10-20 m of the ground.

2.5 HYDROGEOLOGY

The fine-grained sands and silts at Marsh Lake are likely to result in relatively slow rates of groundwater flow. This hypothesis is supported by anecdotal findings from Stantec (2021b), where groundwater in a property owner's basement in October 2021 was 0.644 m higher than Marsh Lake WSE. This is thought to be due to slow dewatering of the ground following the extended period of high water in Marsh Lake through the summer of 2021.

Yukon Energy Corporation completed groundwater modeling at Army Beach and South McClintock to identify properties where the groundwater level may be affected by increasing the full supply level at Marsh Lake (further details in section 2.6.4). The modeling showed that the majority of properties on Army Beach Drive from the loop to Taylor Way and approximately 50% of properties on South McClintock

Road and Bayview Road would be affected by groundwater rise as a result of increasing the full supply level (Hemmera 2019a; Hemmera 2019b).

2.6 HYDROLOGY AND WATER MANAGEMENT

2.6.1 Flood Frequency Analysis

Morrison Hershfield (2022) updated the flood frequency analysis (FAA) for Marsh Lake using water level data from 1985 to 2021 (36 years) from Water Survey of Canada station 09AB004 (Marsh Lake Near Whitehorse) (Table 2.1). Based on the updated FAA, the 2021 flood is considered a 1 in 160-year event, and the 2007 flood corresponds to a 1 in 50-year event (Morrison Hershfield 2022).

Table 2.1 Return Period Water Surface Elevations at Marsh Lake Near Whitehorse (WSC 09AB004) (Morrison Hershfield 2022)

Return Period (years)	Water Surface Elevation, WSE (m)[1]
2	656.69
5	657.05
10	657.26
20	657.44
50	657.66
100	657.80
200	657.94

NOTE:
[1] Referenced to Canadian Geodetic Vertical Datum 2013 (CGVD2013)

The following items should be acknowledged when interpreting the WSEs in Table 2.1:

- The statistical analysis is based on historical WSEs and does not reflect potential implications of climate change on Marsh Lake WSEs.
- Higher levels of uncertainty in the WSEs of the higher magnitude events (e.g., 100-year, 200-year) are likely given the comparatively small source dataset (36 years).
- Return periods provide an estimate of the likelihood of any event occurring in one year. For example, the 100-year return period event has a 1 in 100, or 1%, chance of occurring in a given year. If a 100-year event occurs in a given year, it does not mean that an event of that magnitude will not occur in the next 100 years.

For the above reasons, future projection of flood response requirements was not completed in this report.

2.6.2 Flow Regulation

The Southern Lakes are naturally occurring, but currently regulated, reservoir lakes for the Whitehorse Rapids Generating Station, operated by the Yukon Energy Corporation (YEC). Water levels in the Southern Lakes are regulated by the Lewes Dam which is approximately 30 km upstream of the

Whitehorse Rapids Generating Station and 12 km downstream of the northwest end (outflow) of Marsh Lake.

Operation of the Whitehorse Rapids Generating Station and the Lewes dam is subject to the restrictions and conditions in a class A water license (HY99-010, Amendment 1) held by YEC (Yukon Water Board 2021). HY99-010 was effective February 14, 2000, was amended April 28, 2021, and expires on May 31, 2025.

Operating conditions are specified in Part B of HY99-010. Of particular interest for the Marsh Lake water management are Clauses 19 and 19.1, provided below per Yukon Water Board (2021). YEC is referred to as the Licensee in HY99-010.

> *19. Subject to 19.1, the Licensee must maintain a mean daily water surface elevation on Marsh Lake between a controlled minimum of 653.796 metres* (Stantec note: 654.111 m in CGVD2013) *and a controlled maximum of 656.234* (Stantec note: 656.549 m in CGVD2013) *as measured from Water Survey of Canada Gauge 9AB004.*
>
> *19.1 From the effective date of this Amendment to June 30, 2021, the Licensee must maintain a mean daily water surface elevation on Marsh Lake between a controlled minimum of 653.696 metres* (Stantec note: 654.011 in CGVD2013) *and a controlled maximum of 656.234 metres* (Stantec note: 656.549 m in CGVD2013) *as measured from Water Survey of Canada gauge 9AB004.*

Clause 19 has been in HY99-010 since the effective date of the license. Clause 19.1 was the only amendment made to the original license on April 28, 2021 and functionally represented a temporary (April 28 – June 30, 2021) allowance for lowered minimum Marsh Lake WSE, in an effort to increase storage capacity in the Southern Lakes in an effort to reduce the risk of flooding to infrastructure and property. Clause 19.1 expired on June 30, 2021 and WSE regulation has returned to the conditions in Clause 19.

HY99-010 includes the following extreme low flow thresholds and protocols, under Clause 20:

> *20. With respect to the Lewes Dam, the Licensee must comply with the following:*
>
> *a) Except as permitted by sub-condition b) of this License, or as required for repairs and maintenance, all gates must remain open from May 15 to August 15 of each year.*
>
> *b) The following exceptions shall be permitted to the requirements of sub-condition a) of this License:*
>
> *i) If, on July 7 of any year, the water surface elevation of Marsh lake is less than 654.82 metres* (Stantec note: 655.14 m in CGVD2013)*, then up to twenty gates may be closed and at least ten gates must remain open. If the water surface elevation equals or exceeds 654.82 metres* (Stantec note: 655.14 m in CGVD2013)*, then all gates must remain open.*

ii) If, on July 21 of any year, the water surface elvation of Marsh Lake is less than 655.15 metres (Stantec note: 655.46 m in CGVD2013)*, then up to twenty gates may be closed atn at least ten gates must remain open. If the water surface elevation equals or exceeds 655.15 metres* (Stantec note: 655.46 m in CGVD2013)*, then all gates must remain open.*

iii) if, on August 10 of any year, the water surface elevation of Marsh Lake is less than 655.65 metres (Stantec note: 655.96 m in CGVD2013)*, then up to twenty gates may be closed and at least ten gates must remain open. If the water surface elevation equals or exceeds 655.65 metres* (Stantec note: 655.96 m in CGVD2013)*, then all gates must remain open.*

Aside from the temporary allowance for lowered minimum Marsh Lake WSE in 2021 (Clause 19.1, since expired), there are no high flow or flood thresholds and protocols in HY99-010.

2.6.3 Miles Canyon

Between the Lewes dam and the Whitehorse Rapids Generating Station is a naturally occurring hydraulic constriction called Miles Canyon. YEC has communicated that under flood conditions and when gates are open at the Lewes Dam structure, Miles Canyon is the feature which limits Yukon River discharge (and therefore, outflows from the Southern Lakes). The discharge through Miles Canyon is restricted by the canyon geometry, and by the hydraulic head differential between the upstream and downstream sides. Miles Canyon is a culturally and recreationally important site in Whitehorse, and Canyon City, at the south end of Miles Canyon, is a Heritage site. Therefore, any alterations to improve the discharge constriction of Miles Canyon are not being considered as an option for flood mitigation.

The presence of Miles Canyon has historically meant that there are limitations, outside of the control of water managers at YEC, to the Southern Lakes outflow rates. As a result of both the outflow limitations and size of the lakes and their drainage basins, flooding in the Southern Lakes is longer lasting than a more typical flood; water can only empty from the lake so fast and elevated WSE's can persist in the lakes for multiple weeks or even months. Outflow limitations and lake/basin size also mean that water management actions are generally slow to have the desired effect on Marsh Lake WSEs, therefore highlighting the importance of monitoring basin snowpack, precipitation, and tributary flows in advance of peak flood conditions as to inform flood forecasting efforts.

2.6.4 Southern Lakes Enhanced Storage Concept (SLESC) Initiative

Yukon Energy Corporation (YEC) has been working on the Southern Lakes Enhanced Storage Concept (SLESC) since 2009. If implemented, this project would mean storing more water in Marsh, Tagish, and Bennett Lakes in the fall and early winter to increase hydropower generation during the winter at the Whitehorse power plant. To do this, a revision of the water license would be needed to increase the Full Supply Level (FSL) (i.e. the controlled maximum lake level stipulated in YEC's water use license) by 0.30 m for a limited period in the late fall, and a decrease of 0.1 m to the Low Supply Level during the spring (YEC 2022; Stantec 2020). The SLESC's FSL increase of 0.30 m would equate to a maximum

WSE of 656.534 m (CGVD2013), which is well below the peak WSE's from the 2007 (657.66 m, CGVD2013) and 2021 (657.88 m, CGVD2013) flood events.

YEC has completed planning, research, and engagement for this project since 2009. Submission of the project proposal to the Yukon Environmental and Socio-Economic Board was delayed due to the flooding incident of 2021 (YEC 2022). Although a decision on this project has not been made, some of the information collected for the SLESC can be used as relevant background information for developing flood mitigation options at Army Beach and South McClintock. Of note, one of the main points of discussion regarding the SLESC for property owners at Marsh Lake was enhanced erosion protection for shoreline areas susceptible to wave erosion (discussed further in Section 2.7).

On behalf of YEC for the SLESC, Stantec completed community engagement between September 2019 and January 2020. Through this process, Stantec was able to identify common values and themes that were important to Yukoners (Stantec 2020). These values and themes included the environment, use of renewable energy, financial responsibility, and property rights, including preventing or mitigating any negative impacts to private properties or First Nation lands. Additional concerns identified during engagement with residents from Marsh Lake communities included how the project would affect property values, house insurance rates, and increased erosion and groundwater levels. These same general concerns are anticipated to be important to the local community regarding any proposed flood mitigation works at Marsh Lake.

2.7 WIND, WAVES, AND SHORELINE PROTECTION

Stantec has been made aware of the following wind and wave studies for Marsh Lake completed to date.

- Flood Assessment and Abatement Options Study Marsh Lake and Upper Liard (EBA 2008): A wind analysis was completed in 2008 for Marsh Lake using historical data form the Whitehorse Airport Canadian Atmosphere and Environment Services (AES) climate station. The analysis was to be an accurate representation of Marsh Lake conditions when compared to local data provided by YEC. Winds primarily originate from the south and southeast, with approximately 79% of wind speeds ranging from 1 to 9 m/s (EBA, 2008).
- Flood Assessment and Abatement Options Study Marsh Lake and Upper Liard (EBA 2008): A wave analysis was completed in 2008 for Marsh Lake which included a nearshore wave transformation analysis and a wave run up analysis. The wave run up analysis showed that for a 200-year water level, the wave run up height ranged from 1.24 m to 1.46 m for a 10-year and 100-year return period, respectively.
- SLESC Wind Data Analysis (NHC 2014): A wind analysis was completed in 2014 with data collected from August 2000 to July 2021 comparing wind speeds and directions at Army Beach and Whitehorse. The results showed that wind direction in the spring and summer were from the southeast to the northwest, with relatively calm speeds (43% less than 1 m/s). Wind speeds at Army Beach were typically lower than those measured in Whitehorse.

Based on the detailed berm inventory report for Marsh Lake (Stantec 2021a), 1.2 km of shoreline has existing erosion protection in the form of rip rap, gabion baskets, or concrete blocks, while 3.4 km of the shoreline is unprotected (e.g., vegetated, bare soil). Most of the shoreline protection documented was along Army Beach, where approximately 1.0 km of the 1.6 km (63%) of the shoreline had some form of shoreline protection.

YEC assessed impacts to shoreline erosion at Army Beach and South McClintock as part of the SLESC project. They found that raising the FSL by 0.30 m would increase shoreline erosion at Army Beach and that 507 m of shoreline would require erosion mitigation (NHC, 2015). No erosion impacts were anticipated for properties along South McClintock (NHC, 2015).

YEC assessed different types of shoreline protection through landowner engagement and functionality of the options (Compass Resources Ltd., and NHC 2015). Of the types of shoreline protection assessed (rip rap, gabion baskets, groynes, perched beaches, cribwalls, large woody debris structures, live staking, brush layering, and brush matting), rip rap was determined to be the best option due to wave conditions, existing and potential erosion, durability and feasibility for construction. Through engagement, rip rap was acceptable to most landowners from Judas Creek North McClintock, Tagish Lake Outlet, and Taku Subdivision North. Stantec notes that the existing erosion protection at Army Beach meant only one landowner from Army Beach was engaged in this process, and their property was assessed to not require shoreline protection. In a meeting between YEC (Travis Ritchie), YG (Ben Hancock), and Stantec (Jeff Muirhead and Jamie Davignon) on January 18, 2021, YEC confirmed that rip rap was still considered the main option for erosion protection for the SLESC based on a balanced consideration of the performance, functional, and aesthetic criteria identified by YEC planning engineers in collaboration with property owners (T. Ritchie 2022, personal communication, 18 January).

2.8 FLOOD DESIGN STANDARD

To date, it is Stantec’s understanding that YG has not established a flood design standard or performed formal floodplain mapping for regulatory/planning purposes in the Yukon. In addition, we are not aware of guidance or official policy for building in a flood-affected area.

Flood standards, policy, mapping are important components in assessing and mitigating risks to properties from flooding, as well as determining responsible parties for mitigating flood risks.

To provide context for flood design standard considerations, Figure 2.2 illustrates the historical annual daily maximum WSEs from the Water Survey of Canada Station 09AB004 (Marsh Lake Near Whitehorse), as well as the Marsh Lake return period WSEs from the flood frequency analysis performed by Morrison Hershfield (2022) (Section 2.6.1). Freeboard of 1 m and 2 m above the 200-year WSE is also illustrated in Figure 2.2.

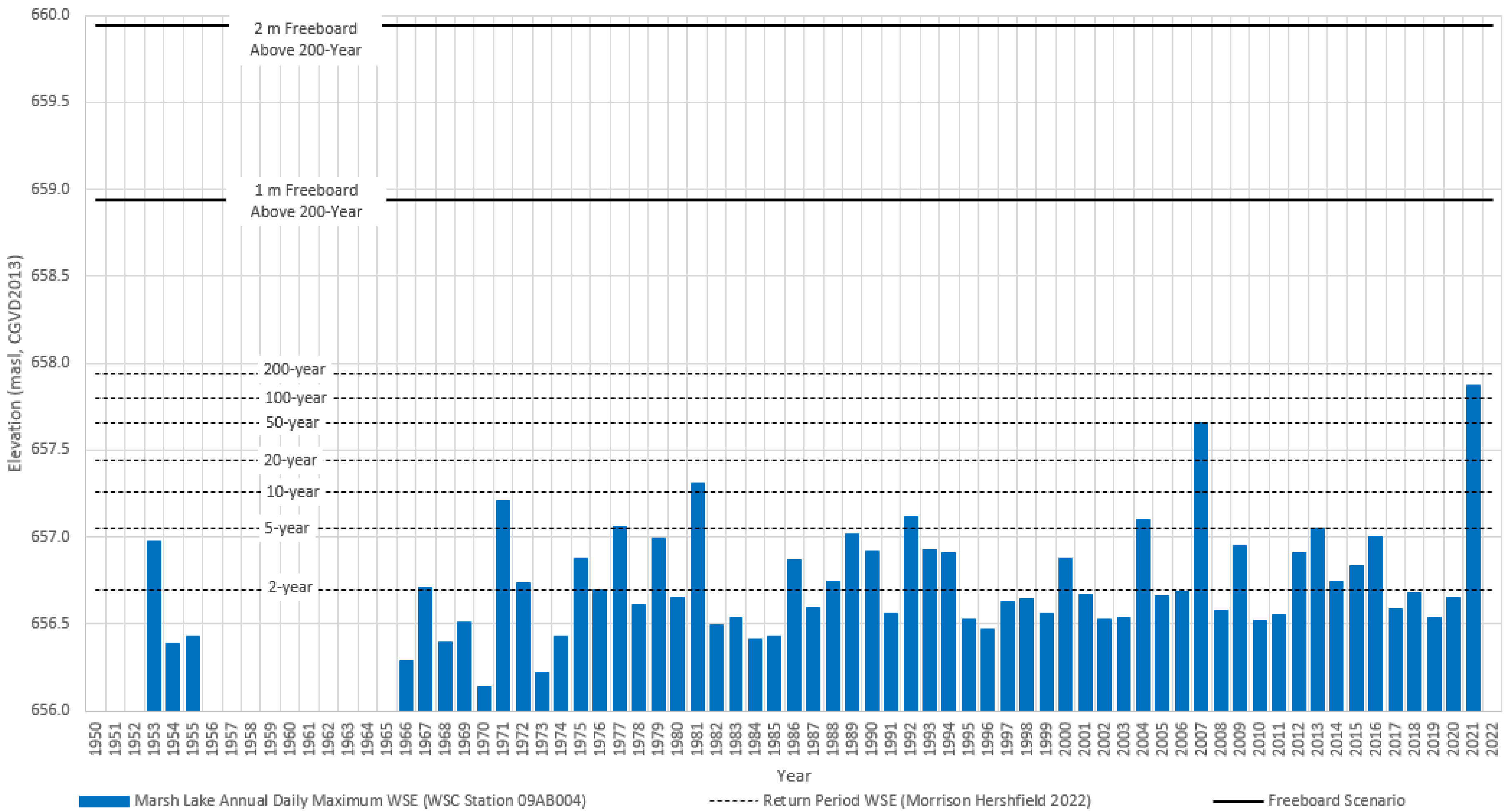


Figure 2.2 **Marsh Lake Annual Daily Maximum Water Surface Elevations (WSC Station 09AB004) Compared to the Return Periods WSEs for Marsh Lake (Morrison Hershfield 2022)**

2.9 RETURN PERIOD INUNDATION

To understand the relative vulnerability of Marsh Lake properties during different flood levels, Stantec performed a preliminary existing conditions (no mitigation) inundation analysis for the properties at Marsh Lake. The analysis used the existing conditions bathymetry and topography (Section 2.3), the return period WSEs provided by Morrison Hershfield (2022) and summarized in Section 2.6.1, the first floor elevations (FFEs) surveyed by Stantec (2021a), and the assessed value of each lot (V. Lloyd 2022, email communication titled "Re: Marsh Lake Property Assessment Values", 20 January). The inundation analysis performed herein is provided for information only and is considered a high-level estimate of the relative vulnerability of properties at different return period WSEs.

Results of the preliminary inundation analysis are summarized in Figure 2.3 and Table 2.2. WSEs for the 20-, 50-, 100-, and 200-year events as well as a WSE of 0.5 m above the 200-year event were considered in the analysis (Morrison Hershfield 2022). A lot was classified as inundated if 25% or more of its area was inundated by water during an event. The assessed value of lots which were inundated and had their FFE inundated were totaled for each event. We highlight that the values provided here are the assessed values of the property (land and improvement value) for tax purposes, and that the market value of the properties are likely markedly higher.

Table 2.2 Assessed Value of Inundated Marsh Lake Properties During Return Period Events

Event	Elevation (masl)[1]	Number of Inundated Lots[2,3]	Assessed Value of Properties[5]	
			Inundated Lots[2,3]	First Floor Elevation (FFE) Inundated[4]
200 yr + 0.5m	658.44	79 / 117 (67%)	$16,536,640.00	$2,876,950.00
200 yr	657.94	61 / 117 (52%)	$12,600,410.00	$1,033,150.00
100 yr	657.80	52 / 117 (44%)	$10,298,610.00	$549,800.00
50 yr	657.66	50 / 117 (43%)	$9,779,760.00	$274,520.00
20 yr	657.44	34 / 117 (29%)	$7,158,120.00	$274,520.00

NOTES:

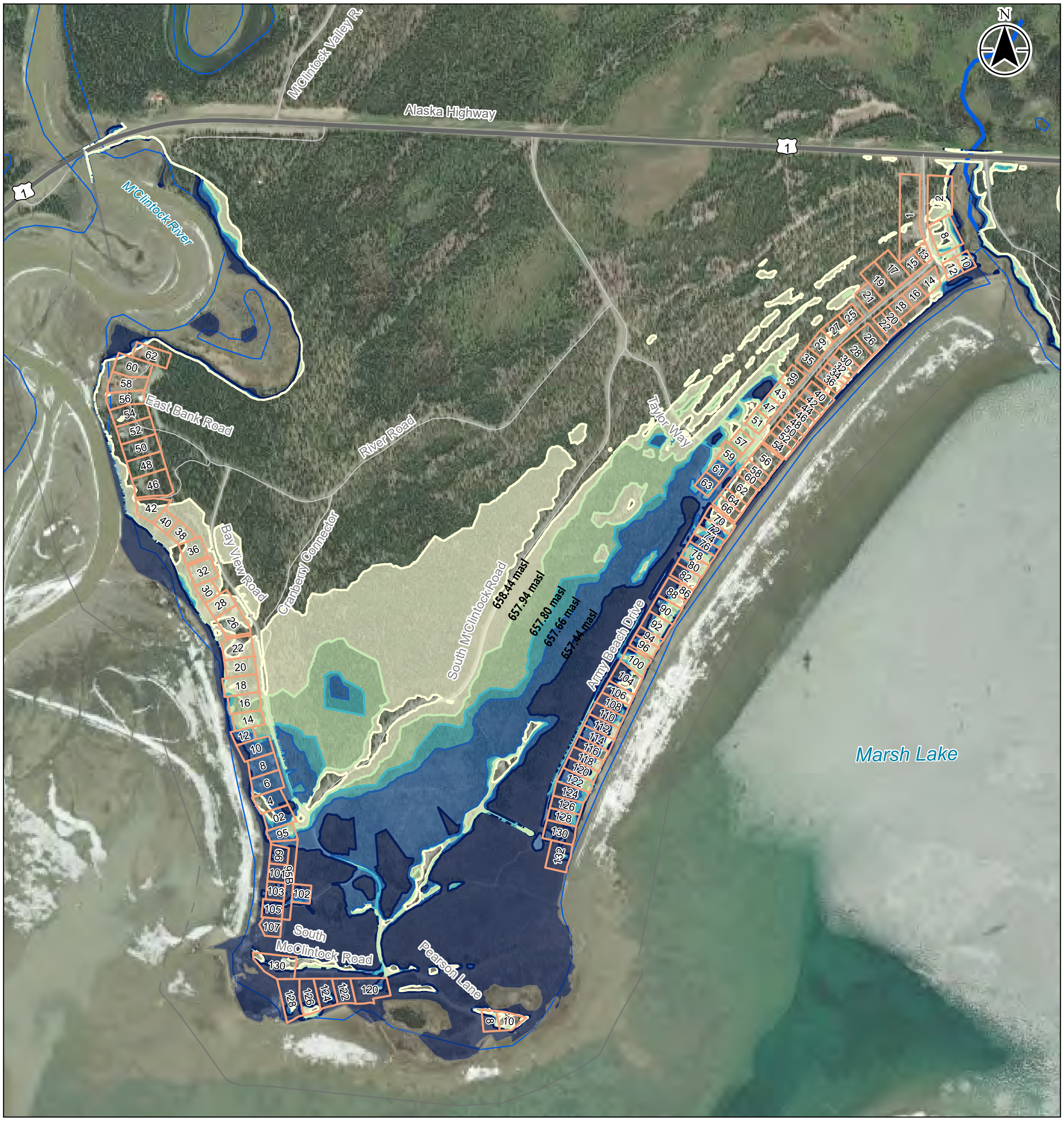
1 From Morrison Hershfield (2022); referenced to CGVD2013

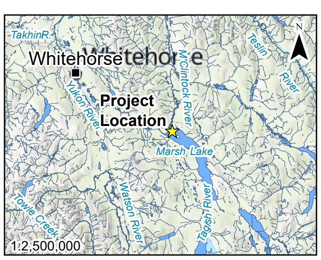
2 Threshold for classification as "inundated" was that a minimum of 25% of the total lot area was inundated with water using available topographic data (Section 2.4)

3 Total number of lots on Marsh Lake was 117 according to the Marsh Lake tax roll numbers (V. Lloyd 2022, email communication titled "Re: Marsh Lake Property Assessment Values", 20 January)

4 The FFE's for 58 Marsh Lake properties obtained by Stantec (2021a) were considered in analysis; it is possible that additional properties (FFEs not surveyed by Stantec 2021a) may have inundated FFE's

5 Total assessed value of all 117 properties in Marsh Lake (V. Lloyd 2022, email communication titled "Re: Marsh Lake Property Assessment Values", 20 January) is $25,282,650





- Highway
- Local Street
- Watercourse
- Waterbody
- Property Boundary

Elevation (masl) [Inundation Event]
- 658.44 [200 yr + 0.5 m] (MH 2022)
- 657.94 [200 yr] (MH 2022)
- 657.80 [100 yr] (MH 2022)
- 657.66 [50 yr] (MH 2022)
- 657.44 [20 yr] (MH 2022)

0 100 200 300 400 500 m

1:15,000 (at original document size of 8.5x11)

Stantec

Project Location:
Marsh Lake,
Yukon

Project Number: 144903232
Prepared by LTRUDELL on 20220125
Requested by JMUIRHEAD on 20220125
Checked by CDEAN on 20220125

Client/Project/Report
Government of Yukon
Community Services | Infrastructure
Marsh Lake Flood Mitigation Options

Figure No.
2.3

Title
Preliminary Flood Inundation Analysis

Notes
1. Coordinate System: NAD 1983 UTM Zone 8N
2. Data Sources: GeoYukon Open Data; Natural Resources Canada
3. Imagery Source: ESRI World Imagery4. This figure does not represent floodplain mapping for the Marsh Lake area. The results of this analysis are provided for information only and is considered a high-level estimate of the relative vulnerability of properties at different return period WSEs provided by Morrison Hershfield (2022)

3.0 OBJECTIVES AND CRITERIA

Stantec's scope of work in this Project is to develop, cost, and evaluate conceptual options for flood mitigation at Marsh Lake.

The primary and secondary objectives that Stantec considered in the development, costing, and evaluation of those options are detailed in Section 3.1 and Section 3.2.

3.1 PRIMARY OBJECTIVE

As discussed with YG IDB, the primary objective of the options is to reduce flood risk to public infrastructure, such as roads and the water treatment plant, and to private residences on the lakefront along Army Beach and South McClintock (Figure 1.1) from a design flood service level (DFSL).

We note that reduction in risk of damages from a given flood event requires defenses to be provided to an elevation above the flood elevation to account for climate change adaptation, wind and wave effects, and freeboard required by the structure. This study considered a hypothetical DFSL of 2 m above the 200-year flood event (WSE provided by Morrison Hershfield 2022). The DFSL is discussed further in Section 2.8 and Section 4.1.

The primary objective for each mitigation option was evaluated as a likelihood for success (low, medium, high) based on the information available at the time of writing. Each mitigation option was evaluated as if it were the only option being implemented, however we acknowledge that YG may elect for multiple complementary options to be further investigated and implemented.

3.2 SECONDARY OBJECTIVES

Mitigation options were also evaluated with respect to the ten secondary objects described below. For each of the ten (10) secondary objectives, each objective was given a rating of anticipated performance rating of low, medium, or high based on the information available at the time of writing. For ease of comparison of options, each option was evaluated as if it were the only option being implemented. However, we acknowledge that YG may elect for multiple complementary options to be further investigated and potentially implemented.

1. Viability and Reliability under Extreme Conditions. The Marsh Lake flood events are different from most other floods in Canada in three ways. First, the duration of flooding may last for several weeks or even months, which is longer than most other floods. Second, flood conditions may be coupled with significant wind and wave events on this large lake, adding water level fluctuation and erosion risks that is not as significant during flooding on rivers or smaller lakes. Third, the cold climate introduces complexities to geotechnical engineering and may pose ice erosion risks to defense structures if they are to maintain structural integrity over their lifespan. Flood mitigations for the Study Area should be able to maintain structural integrity and flood mitigation performance under these unique Marsh Lake conditions.

2. Time to Implementation. The time to implement the option to a constructed, flood response-ready state is important for project planning. Evaluation of this criteria consists of a qualitative assessment of anticipated time to implementation (low, medium, high) of the option according to the following quantitative ranges:
   - >5 years = Anticipated to take a relatively long time to implement, receives a low performance rating
   - 2–5 years = Anticipated to take a relatively moderate time to implement, receives a medium performance rating
   - <2 years = Anticipated to take a relatively short time to implement, receives a high performance rating

   The evaluation of this criterion does not consider the response and activation time for a given option (e.g., assembling demountables) in the above ranges.
3. Capital Cost. Capital cost is a crucial consideration in any engineering project. Capital costs to implement the option, resources, and political effort to have an option implemented. A range of costs are described in the evaluation tables and are based on the following
   - >$25 million = Relatively expensive, receives a low performance rating
   - $5 million - $25 million = Moderately expensive, receives a medium performance rating
   - <$5 million = Relatively inexpensive, receives a high performance rating
4. Maintenance and Storage. The flood events being considered in the options development are high in severity and low in frequency (e.g., 200-year event). Therefore, in most years, the option will not be activated but will need to be maintained and may have components requiring storage. Evaluation of this criteria consists of a qualitative assessment of maintenance and storage requirements (low, medium, high) to keep the option ready to perform should a flood occur.
5. Response and Activation. Some options may require a degree of response or action to provide the requisite protection if and when a flood is forecasted. Evaluation of this criteria consists of a qualitative assessment of financial and human resources (low, medium, high) needed to enact the flood-protection configuration of the option upon notification that a flood is forecasted, and the maintenance requirements of the option during the flood event.
6. Serviceable Life. The serviceable life (e.g., time to decommissioning or reconstructions) of any engineering project is a crucial consideration in the project economics and cost-benefit analysis. Evaluation of this criteria consists of a qualitative assessment of the anticipated serviceable life of the option according to the following quantitative ranges:
   - <5 years = low
   - 5–50 years = medium
   - >50 years = high
7. Aesthetics. The Marsh Lake community is a highly valued area for both the property owners and for visitors. A main part of that appeal is the views of Marsh Lake, and the naturalized appearance of the shoreline. Evaluation of this criteria consists of a qualitative assessment of impact (low, medium high) to the aesthetic appeal to the users of the Marsh Lake area.

8. Regulatory Outlook. Applicable Yukon regulations could be a significant challenge for the implementation of options and the ability for the works to be approved may weigh on selection of a preferred option. Evaluation of this criteria consists of a qualitative assessment of performance (low, medium high) of the relative ease and speed that an option could be permitted, such that it could be constructed.
9. Future Adaptability. Flood levels, flood mitigation approaches, and flood policy may change in future years. Evaluation of this criteria consists of a qualitative assessment of the ability (low, medium high) of the option to be upgraded and/or adapted for a wide range of potential requirements in the future.
10. Precedent. The flood options developed in this Project are for private properties on Marsh Lake. However, there are other private properties throughout the Yukon which are vulnerable to flooding and may need or request flood mitigation. The actions taken at Marsh Lake may therefore represent a precedent for territory-wide flood policy. Evaluation of this criteria consists of a qualitative assessment of the degree and general advisability of potential precedent setting that the option may cause territory-wide (low, medium, high). This criterion assumes that there is no territorial flood policy in place at the time of the option being implemented. Our evaluation of this criteria is intended to be technical advice to inform YG decision making and does not constitute legal opinion. Stantec recommends that YG retain legal counsel for more detailed discussions regarding legal precedents.

4.0 ASSUMPTIONS

4.1 DESIGN SCENARIO

It is our understanding that flooding design standard and other flood policies have not been formally set for Marsh Lake (or the rest of the Yukon). The determination of a design standard, referred to in this report as the Design Flood Service Level (DFSL) in this report, is as much a policy decision as a scientific one as it includes a wide range of considerations including (but not limited to): risk tolerance for various infrastructure types, return period water level estimates, climate change projections, wave runup, wave height, and freeboard requirements. Determining the DFSL is not part of this scope of work and is the responsibility of YG.

In the absence of a defined DFSL from YG, Stantec developed options and produced Class D cost estimates (CEBC and APEGBC 2009, Section 4.2) for a scenario where DFSL was 2 m (wind/wave action, freeboard, etc.) above the 200-year flood level from Morrison Hershfield (2022) (657.94 m + 2 m = 659.94 m). All engineering options in this Project were described and costed for this test scenario DFSL of 659.94 m (referenced to CGVD2013).

The details, plausibility, evaluation, and costing of the options are subject to change following the prescription of a DFSL and the development of associated flood policy by YG.

4.2 OPINION OF PROBABLE COST FOR CONSTRUCTION

As requested by YG, a Class D Opinion of Probable Cost (OPC) for construction has been prepared for the engineering options (i.e., Options 5, 6, 7 and 8). In accordance with the Class D definition in CEBC and APEGBC (2009), the Class D OPC estimates:

- Are prepared for projects with little or no site information.
- Indicate the approximate magnitude of cost of the proposed project.
- Are calculated using approximate values, contingencies, professional judgement, and/or analogies to similar projects.
- Has an expected accuracy range of ±50%.

4.3 ASSUMPTIONS

Additional assumptions included in the options development, evaluation, and costing are listed below:

- Quantities used in the Class D cost estimates are based on the topographic and bathymetric data made available to Stantec as of January 2022.
- For Option 6 (Section 5.6), Options 7B and 7C (Section 5.8), and Options 8B and 8C (Section 5.10) involving demountable defenses, the individual options and their costing and evaluation assumes that YG will successfully mobilize and implement the demountables as required in the option, in advance of the flood occurring

5.0 MITIGATION OPTIONS AND EVALUATION

Based on the objectives and assumptions presented in Section 3.0 and Section 0, the following flood mitigation options were developed for the Army Beach and South McClintock Road areas at Marsh Lake:

1. Option 1 – maintain the status quo with respect to flood defenses of private property.
2. Option 2 – Funding provided to property owners for flood mitigation (i.e., improvements) of their private property.
3. Option 3 – Expropriation of private properties within an established design flood limit.
4. Option 4 – Adaptive water management approaches incorporated into water management to mitigate the severity of the peak flood elevations.
5. Option 5 – Raising of public roads and trails to improve emergency access to private properties while also functioning as a dike preventing surface water from entering the interior of the Marsh Lake peninsula.
6. Option 6 – Easement along the approximate location of the 2021 temporary defense structure, with an on-grade platform and erosion protection allowing for emergency responders to efficiently deploy demountable flood barriers.
7. Option 7A – Dike comprised of clay soil with 3:1 side slopes and a top elevation of the DFSL.
8. Option 7B – Dike comprised of clay soil with 3:1 side slopes and a top elevation of 1 m below the DFSL (7B) and 1 m of demountable flood barriers.
9. Option 7C – Dike comprised of clay soil with 3:1 side slopes and a top elevation of 2 m below the DFSL and 2 m of demountable flood barriers.
10. Option 8A – Dike comprised of clay soil with structural elements installed for side slope stability and a top elevation of the DFSL.
11. Option 8B – Dike comprised of clay soil with structural elements installed for side slope stability and a top elevation of 1 m below the DFSL, with 1 m of demountable flood barriers.
12. Option 8C – Dike comprised of clay soil with structural elements installed for side slope stability and a top elevation of 1 m below the DFSL, with 2 m of demountable flood barriers.

Section 5.1 through Section 5.10 provide a description, Class D cost estimate (per Section 4.2), and qualitative evaluation (per Section 3.0) of the above listed options. Given their similarities, Option 7B and 7C are presented together in Section 5.8 and Option 8B and 8C are presented together in Section 5.10.

While each option was evaluated in a mutually exclusive manner, the options themselves are not mutually exclusive and a combination of the options could be completed to suit the characteristics of different areas within Marsh Lake.

5.1 OPTION 1 – STATUS QUO

5.1.1 Description

The status quo option would consist of YG adopting comparable approaches to those implemented during the emergency response of the 2007 and 2021 floods (i.e. not implementing any long-term flood mitigation measures). For this option, future floods would cause significant damage unless YG were to deploy emergency flood defense measures.

For this option, it is recommended that YG develop a policy on government response level and type to help guide responses to flood events.

5.1.2 Evaluation

Table 5.1 summarizes the performance of Option 1 with respect to the evaluation criteria which was previously outlined in Section 3.0.

Table 5.1 Option 1 Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
Primary Objective			
	Reduce Flood Risk During the 200-Year Flood	• No proactive measures to protect against the DFSL • Relies on emergency response in a comparable fashion to 2007 and 2021	Low Score
Secondary Objectives			
1	Viability and Reliability under Extreme Conditions	• Would allow for a similar response to 2021 flood, which would only be temporary flood defense and not designed to be reliable under extreme conditions • Temporary non-designed flood defense structures for the Marsh Lake situation	Low Score
2	Time to Implementation	• Nothing to implement ahead of emergency response (refer to criteria 5 for response considerations)	High Score
3	Capital Cost	• Not applicable	High Score
4	Maintenance and Storage	• No maintenance and storage requirements	High Score
5	Response and Activation	• Could incur a significant cost during a flood event and requires significant human resources. Can take a long time to activate depending on the organization of the response effort.	Low Score
6	Serviceable Life	• Temporary flood measures only, typically used for one flood event	Low Score

Table 5.1 Option 1 Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
7	Aesthetics	• No effect in non-flood years. In flood years, could affect aesthetics if temporary measures are deployed.	Medium Score
8	Regulatory Outlook	• If state of emergency is declared for a flood, no regulatory requirements would be required.	High Score
9	Future Adaptability	• Reactive approach responding to flood events, ability to adapt is good. • Physical constraints (e.g. access, berm building surfaces, location of buildings, decks) may limit course of action.	Medium Score
10	Precedent	• Emergency response not guided by flood response policy or triggers. Risks inconsistent response levels different land owners.	Low Score

5.2 OPTION 2 – MITIGATION FUNDING TO PROPERTY OWNERS

5.2.1 Description

Option 2 consists of grants or other funding provided to property owners by YG to install discrete flood mitigation measures on their private properties. Flood mitigation measures (included in this option) *improve* the flood defenses on a given property whereas flood recovery measures (not included in this option) repair the damage done by a past flood event (e.g., 2021 event). This option would allow property owners to protect their own property on a lot-by-lot basis and therefore is not intended to be a continuous flood mitigation option for multiple lots.

The funding model can vary depending on the requirements or desired outcome(s) of the funding agency. Components of the funding that can vary include:

- Amount of funding available, and method of calculation of eligible funding. For example, the funding amount may be determined on a per property basis, on a linear distance of lakeshore frontage basis, or on a property area basis.
- Administration of the funding. Funding may be provided up front to property owners, YG could reimburse contractors directly, or the property owner may need to pay for the mitigation expenditures and be reimbursed by YG following inspection or approval of the mitigation.

- Conditional requirements of the funding. For example, the funding may only be provided for an approved list of approved mitigation types, must provide flood defenses to a minimum level, or must be approved by certain agencies for funding eligibility, whether future YG emergency flood response on the property is dependent on the type or level of mitigations implemented by the property owner. Funding may also be dependent on an audit process to validate that the approved mitigation measures were installed/implemented correctly.
- Amendments to land classification and flood policy following administration of funding. For example, once this funding is provided, affected properties may be officially designated as being within a flood hazard zone (or equivalent), which may then be connected to YG's emergency flood response policy for the affected properties (e.g., YG will not deploy public resources to protect private properties for flood events of less than a certain return period or threshold elevation).

The funding mitigation to property owners option has been implemented in Canadian jurisdictions in the past. Select examples are provided below:

- Yukon, 2007/2008. Following the 2007 Marsh Lake flood event, YG offered loans of up to $35,000 for property owners for flood mitigation (improvements) of primary residences or structures, or for flood recovery (repairs) of secondary structures (YG 2007).
- Manitoba, 1997. In response to the 1997 Red River flood, the Government of Manitoba reached an agreement with the Government of Canada for Disaster Financial Assistance Arrangement (DFAA) funding. Included in the agreement was up to $100,000 of compensation available to individual property owners. The $100,000 was for cost-sharing of projects for "losses of real and personal property" and for "flood proofing and enhanced diking" (Government of Manitoba 1997).
- Manitoba, 2015. Following the 2014 flooding, the Government of Manitoba initiated the 2015 Individual Flood Protection Initiative (IFPI) to provide financial assistance to owners of flood prone home, farm, and business buildings to implement flood defense measures for their property (Government of Manitoba 2015). The 2015 IFPI specified, among other program details, the eligible building types, acceptable flood defense methods (earthworks, structural works), minimum required elevations of the flood defense (Flood Protection Level), the reimbursable amounts (86% of eligible costs to a maximum cost-shared project cost of $100,000), program procedures and submission requirements, and engineering/construction requirements (Government of Manitoba 2015).

If this option is to be implemented by YG, it is recommended that YG include guidance for the property owners to improve program execution in a similar way to other recent Canadian examples (e.g., Government of Manitoba 2015). Items in the program should include, but is not limited to, the following:

1. Territorial flood standard (DFSL).
2. Flood policy (i.e., implications of achieving protection levels, title amendments/land-classifications/encumbrances).
3. Eligible structures or properties.
4. Recommended/eligible mitigation types (i.e., berms, erosion protection, seepage control, raising of structures, etc.).

5. Funding model (reimbursable amounts, reimbursement requirements).
6. Permitting pathways and templates for the potential mitigation types.
7. Engineering and construction guidelines or requirements.

5.2.2 Evaluation

Table 5.2 summarizes the performance of Option 2 with respect to the evaluation criteria which was previously outlined in Section 3.0.

Table 5.2 Option 2 Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
Primary Objective			
	Reduce Flood Risk During the 200-Year Flood	• This option has the potential to reduce the risk to properties from the 200-year flood if mitigation measures are installed at properties at risk of inundation. • Up to the individual property owners to protect private property; protection level may vary spatially • There could be requirements as part of the funding conditions that require mitigations to meet a certain flood threshold level and design standards	Medium Score
Secondary Objectives			
1	Viability and Reliability under Extreme Conditions	• Individual property owner driven, dependent on the mitigation they implement and the flood policy that is enacted • Funding conditions to improve the viability and reliability may be incorporated into the funding program • Mitigations must be completed within the private property limits, which may restrict the property owners' ability to mitigate effectively • Likely will result in discontinuous flood defenses	Medium Score
2	Time to Implementation	• YG is not directly constructing anything, and therefore rollout of the funds could, with an efficient program design, occur relatively quickly (potentially within a year) • Construction of the mitigations will be dependent on the property owner	Medium Score
3	Capital Cost	• Program development costs • Mitigation funding costs • Costs largely depend on funding amounts	Medium Score
4	Maintenance and Storage	• No maintenance and storage requirements on the part of YG would be necessary	High Score

Table 5.2 Option 2 Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
5	Response and Activation	• Mitigation funding would be applicable for property owners in the floodplain, and would be accompanied by potential title amendments and territorial flood policy informing territorial response at certain flood levels • Dependent on flood and response policy	Medium Score
6	Serviceable Life	• One-time payment which transfers responsibility of flood defenses of private property to the property owner • Encumbrances of land-title changes may be necessary to document that one-time flood defenses was granted.	Medium Score
7	Aesthetics	• Property owner driven	High Score
8	Regulatory Outlook	• Mitigations must be within private property boundaries • Dependent on the mitigation chosen by the property owner	Medium Score
9	Future Adaptability	• Additional funding mitigations could be provided in the future	High Score
10	Precedent	• If funding is made available to property owners in the floodplain at Marsh Lake, a precedent may be set for equivalent funding to other property owners in the floodplain in other areas of the Yukon	Low Score

5.3 OPTION 3 – LAND PURCHASE

5.3.1 Description

Option 3 consists of government purchase of the private properties within the DFSL or other flood threshold. Such a threshold may be a component of future territorial flood policy. The *Expropriation Act* (Government of Yukon 2002) of the Yukon states that a Minister may expropriate any land that the Minister deems necessary for public purposes. The purchased land may be repurposed for land uses appropriate for flood vulnerable areas, such as recreation or naturalized areas.

The determination of the DFSL or flood threshold for land purchase is required for further investigation and costing of this option, as it is by this threshold that the properties to be expropriated would be identified. The requirement for expropriation could also be dependent on whether the property owner has made necessary flood mitigations on their property (e.g., Section 5.2).

For general context, Table 2.2 provides the assessed value of inundated properties under a range of return period events for general understanding of the scale of this option. However, the *Expropriation Act* (Government of Yukon 2002) requires the expropriating authority to compensate a homeowner an amount at current prices to allow them to purchase or build another house equivalent to the one that is being expropriated, which can reasonably be expected to be substantially higher than the assessed value.

The model for expropriation can also vary. Initially, a willing-buyer, willing-seller arrangement would determine the property owners willing to sell their properties to YG. Any property owners who are not willing to sell could be subject to expropriation. YG would need to submit a plan of the land to the land titles office and provide notice of the plan to property owners withing 60 days of registering the plan. YG and property owners would need to agree on a compensation amount, and if no agreement is reached, a board of negotiation is formed to mediate that process. If YG and the property owner still fail to reach an agreement, the case will be determined by a judge in the Supreme Court (Government of Yukon 2002). Stantec recommends YG seek legal counsel if this option is chosen for further exploration.

5.3.2 Evaluation

Table 5.3 summarizes the performance of Option 3 with respect to the evaluation criteria which was previously outlined in Section 3.0.

Table 5.3 Option 3 Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
Primary Objective			
	Reduce Flood Risk During the 200-Year Flood	• Does not prevent area from being flooded, but removes the risk to private property	High Score
Secondary Objectives			
1	Viability and Reliability under Extreme Conditions	• Purchase and reclassification of land would remove the risk of flooding to private homeowners as they would no longer reside at Marsh Lake	High Score
2	Time to Implementation	• Could be immediate to long-term depending on the approach taken willing-buyer/willing-seller, expropriation, phased) • May take considerable amount of time to sort out property owner negotiations	Low Score

Table 5.3 Option 3 Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
3	Capital Cost	• YG would need to purchase all affected private residences • Total assessed property values at Marsh Lake (V. Lloyd 2022, email communication titled "Re: Marsh Lake Property Assessment Values", 20 January) is approximately $25 million • YG may be required to either move structures, or to decommission all existing buildings and appurtenances • Landowners may claim business losses or other currently unforeseen losses that may raise costs	Low Score
4	Maintenance and Storage	• None	High Score
5	Response and Activation	• None	High Score
6	Serviceable Life	• Long term solution to flooding of private residences	High Score
7	Aesthetics	• Property owners no longer residing at Marsh Lake	Low Score
8	Regulatory Outlook	• Environmental requirements for decommissioning and disposal of existing buildings and appurtenances	Low Score
9	Future Adaptability	• Expropriated land could be repurposed for public use in accordance with flood policy	High Score
10	Precedent	• May set a precedent for YG to buy out properties at risk from flooding in other areas of the Yukon.	Medium Score

5.4 OPTION 4 – ADAPTIVE WATER MANAGEMENT

5.4.1 Description

Option 4 consists of additional adaptive water management protocols being implemented into the management of Marsh Lake WSEs.

As outlined in Section 2.6.1, the Marsh Lake WSEs are regulated for a portion of the year (mid-August to mid-May) by the Lewes Dam, the operation of which is governed by YEC's water license for the Whitehorse Rapids Generating Station and Lewes Dam (Hy99-010, Amendment 1, Yukon Water Board 2021). The existing HY99-010 water license includes protocols for low water conditions (Clause 20), and a temporary high-water protocol was incorporated for the spring of 2021 only given the forecasted flood (Clause 19.1). There are no active clauses in HY99-010 which specify protocols for high water or flood-forecasted conditions.

There is evidence to support the notion that specialized protocols for high flow or flood-forecasted conditions may lessen the severity of flooding in the Southern Lakes. During the 2021 flood, YEC lowered Schwatka Lake (downstream of Miles Canyon, directly upstream of Whitehorse Rapids Generating Station) to increase hydraulic head differential across the canyon and increase overall Yukon River discharge. YEC states that according to their simulations, this action reduced the peak WSE in Marsh Lake by up to 0.44 m from what peak WSE would have been if the Schwatka Lake lowering was not performed (T. Ritchie, personal communication, 18 January). In accordance with this observation and the since expired Clause 19.1 in HY99-010, YEC has indicted that more permanent amendments to HY99-010 for high flow or flood-forecasted conditions, with specific activation triggers, are currently being investigated by YEC water managers (T. Ritchie, personal communication, 18 January).

Feasibility of Option 4 will be dependent upon results of more detailed investigation which were beyond the scope of this assessment. The evaluation presented herein assumed that it is feasible and is intended to inform early decision making.

5.4.2 Evaluation

Table 5.4 summarizes the performance of Option 4 with respect to the evaluation criteria which was previously outlined in Section 3.0.

Table 5.4 Option 4 Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
Primary Objective			
	Reduce Flood Risk During the 200-Year Flood	• May reduce the severity of flood events, but is unlikely to completely protect against them	Low Score
Secondary Objectives			
1	Viability and Reliability under Extreme Conditions	• Physical constraints to the Southern Lakes and Yukon River system which limits the effectiveness	Low Score
2	Time to Implementation	• May require additional studies and an amendment to YEC's water license; discussions have been ongoing regarding this option	High Score
3	Capital Cost	• Minimal capital cost; YG may need to assist in funding of studies. • There may be financial implications of lost hydro production opportunities due to modification of the operational rules. It is possible that costs associated with this offset would be on an annual basis.	High Score
4	Maintenance and Storage	• None required	High Score

Table 5.4 Option 4 Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
5	Response and Activation	• Require flood forecasting to inform YEC to lower lake levels in the spring; coordination between YEC and YG WRB	High Score
6	Serviceable Life	• Long term change to water management of the system	High Score
7	Aesthetics	• No changes to private property or nearby areas	High Score
8	Regulatory Outlook	• YEC may need to amend their water license	Medium Score
9	Future Adaptability	• Additional adaptive water management approaches can be implemented in the future	High Score
10	Precedent	• High and low flow protocols are commonly included in water management of regulated systems. • May set precedent for high flow protocols to be incorporated into all YEC water licenses.	High Score

5.5 OPTION 5 – RAISING ROADS AND TRAILS

5.5.1 Description

As experienced during the 2021 flood event, access to flood-affected properties is essential during a flood response to deploy any flood defense measures. Option 5 consists of raising the road or trail crest elevation to 0.3 m above the 1 in 200-year flood event elevation, which is lower than the DSFL of 2 m above the 200-year flood event. CSA (2020) identifies different levels of service (in terms of return period events) for infrastructure of varying importance; to maintain consistency with the other options presented in this report, we have described, evaluated, and provided cost estimates for raising of roads and trails for the 200-year event. Figure 5.2 demonstrates the roads that would be inundated by the 200-year event.

Freeboard is a factor of safety used in road design that represents the vertical distance from the top of the design floe elevation to the edge of the travel lane (Figure 5.1, Ontario Ministry of Transportation 2008). The 0.3 m of freeboard recommendation is based on reviews of standards for road clearance applied in other Canadian jurisdictions (e.g., Ontario Ministry of Transportation 2008).

We note that Option 5 does not fully protect the private properties from the 200-year flood event; it provides the required access to provide emergency response capabilities. If designed appropriately, the raised roads and trails can also act as a dike, preventing surface water from accessing the interior of the Marsh Lake peninsula, thereby mitigating the flooding of private properties from the non-lake side (as occurred in 2007, refer to Section 2.2.1). If required, improvement to road drainage infrastructure for non-flood periods would be incorporated.

The volumes calculated to supplement the costing were based on the following standards:

- Edge of travelled way elevation is 0.3 m above the 1 in 200-year flood event
- Length of road based on existing road inundated by the 1 in 200-year flood event
- 20 mm crushed base coarse – 100 mm depth
- 80 mm pit-run sub-base – depth varies depending on existing road elevations
- Bituminous Surface Treatment (BST) on travel surface
- 9 m wide traveled road surface
- 10% shoulders, daylighting to existing ground

All roads maintained by the Government of Yukon in the area of interest were reviewed for this option; the roads include South McClintock Road, Bay View Road, River Road, Taylor Way, Army Beach Road, East Bank Road and the connector trail between South McClintock and Army Beach Road. Pearson Way was not considered in the road and trail raising option because it was unclear if this road was under YG jurisdiction, and no road profile data was available.

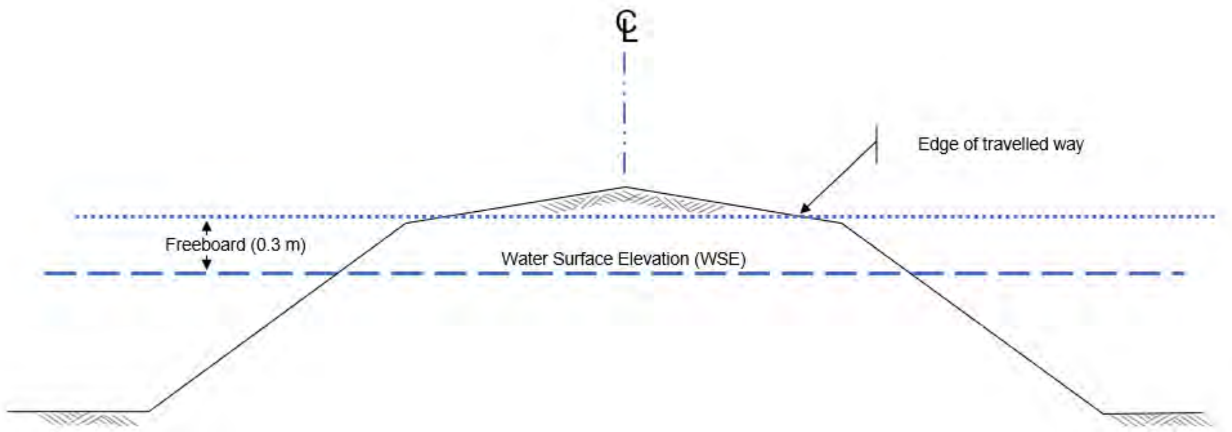
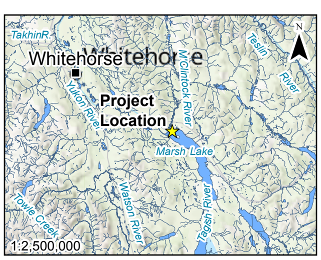


Figure 5.1 Freeboard Road Cross Section Example

5.5.2 OPC for Construction

The Class D OPC for construction of the conceptual design is \$4.5 million - \$6.8 million as outlined on Table B.1 in Appendix B.



Property Boundary
Local Street
Waterbody

Depth of Road Raising (m)
- >0 and =<0.3
- >0.3 and =<0.6
- >0.6 and =<0.9
- >0.9 and =<1.2

0 100 200 300 400 500 m
1:10,000 (at original document size of 8.5x11)

Notes
1. Coordinate System: NAD 1983 UTM Zone 8N
2. Data Sources: GeoYukon Open Data; Natural Resources Canada
3. Imagery Source: ESRI World Imagery

Stantec

Project Location:
Marsh Lake,
Yukon

Project Number: 144903232
Prepared by LTRUDELL on 20220125
Requested by JMUIRHEAD on 20220125
Checked by CDEAN on 20220125

Client/Project/Report
Government of Yukon
Community Services | Infrastructure
Marsh Lake Flood Mitigation Options

Figure No.
5.2

Title
Depth of Road Raising

S:\1232\projects\144903232\figures\Marsh_Lake_Study_Areas.aprx Revised: 2022-03-22 By: LTrudell

5.5.3 Evaluation

Table 5.5 summarizes the performance of Option 5 with respect to the evaluation criteria which was previously outlined in Section 3.0.

Table 5.5 Option 5 Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
Primary Objective			
	Reduce Flood Risk During the 200-Year Flood	• Provides access to private properties • Functions as a berm preventing water from entering the low lying area behind the private properties (as occurred in 2007 flood) • Enables property owner and response access • Does not stop water from entering properties from the lake side of the property.	Low Score
Secondary Objectives			
1	Viability and Reliability under Extreme Conditions	• Addresses a mechanism of flooding specific to Marsh Lake • Not subject to significant wave erosion risk • Long duration of flooding and rate of rise/fall may impact structural stability of road	High Score
2	Time to Implementation	• Roads are within YG jurisdiction • Standard road design potentially with some flood resiliency additions • Limited by Yukon construction seasons	High Score
3	Capital Cost	• Costing includes mobilization / demobilization, traffic control, construction survey, utilization of YG forces, rough grading, sub-grade preparation, sub-base (depth varies), 100mm base and BST resurfacing for all inundated roads • Capital costs are described in Section 5.5.2	Medium Score
4	Maintenance and Storage	• Standard road maintenance in normal years • May need assessments and repairs after flood events	High Score
5	Response and Activation	• No response or activation needed during a flood event to maintain the access and partial flood defenses the roads provide • Requires additional flood defenses for properties	Low Score
6	Serviceable Life	• Standard serviceable life for Yukon roads is typically 10–15 years	Medium Score
7	Aesthetics	• This option is not expected to affect the aesthetics.	High Score
8	Regulatory Outlook	• Expected to be relatively easy to permit	High Score

Table 5.5 Option 5 Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
9	Future Adaptability	• Roads can be raised further in future if needed	High Score
10	Precedent	• Standards for road crest freeboard above design flood elevations are published for many Canadian jurisdictions. • This could set a precedent that YG should raise roads in other locations that experience flooding to maintain access for flood response efforts.	Medium Score

5.6 OPTION 6 – EASEMENT WITH ON-GRADE PLATFORM

5.6.1 Description

This option involves creating a stable on-grade platform along the South McClintock and Army Beach lakefront. This on-grade platform would allow for the deployment of demountable barriers in the event of a flood, similar to the 2021 response, but with formalized access and ground preparation for the entirety of South McClintock and Army Beach (total length equals 4.5 km). The platform would be 5 m wide, which is sufficient width to allow for temporary installation of demountable flood barriers up to 2m in height. In areas where the existing ground is not adequate to act as a platform, fillings, raising, or grading may be required to allow for the height of the 2 m of demountable flood barriers to be within 2 m of the DSFL. This option requires the platform to be an easement due to it being on private land in some locations which would allow YG the ability to respond appropriately to flood events.

In areas where the existing ground is not suitable to support 2 m height of demountable flood defense measures, the slope into the lake would be filled with clay and topped with topsoil and grass. A portion of the clay would extend below the existing ground surface to also provide a seepage barrier. The clay fill would be covered with a geotextile layer and erosion protection (e.g. rip rap). If access to the lake is blocked due to the placement of erosion protection, access points (i.e. ramps, stairs, etc.) could be installed. Figure 5.3 depicts this option in plan view and cross sections showing scenarios in non-flood years and flood years.

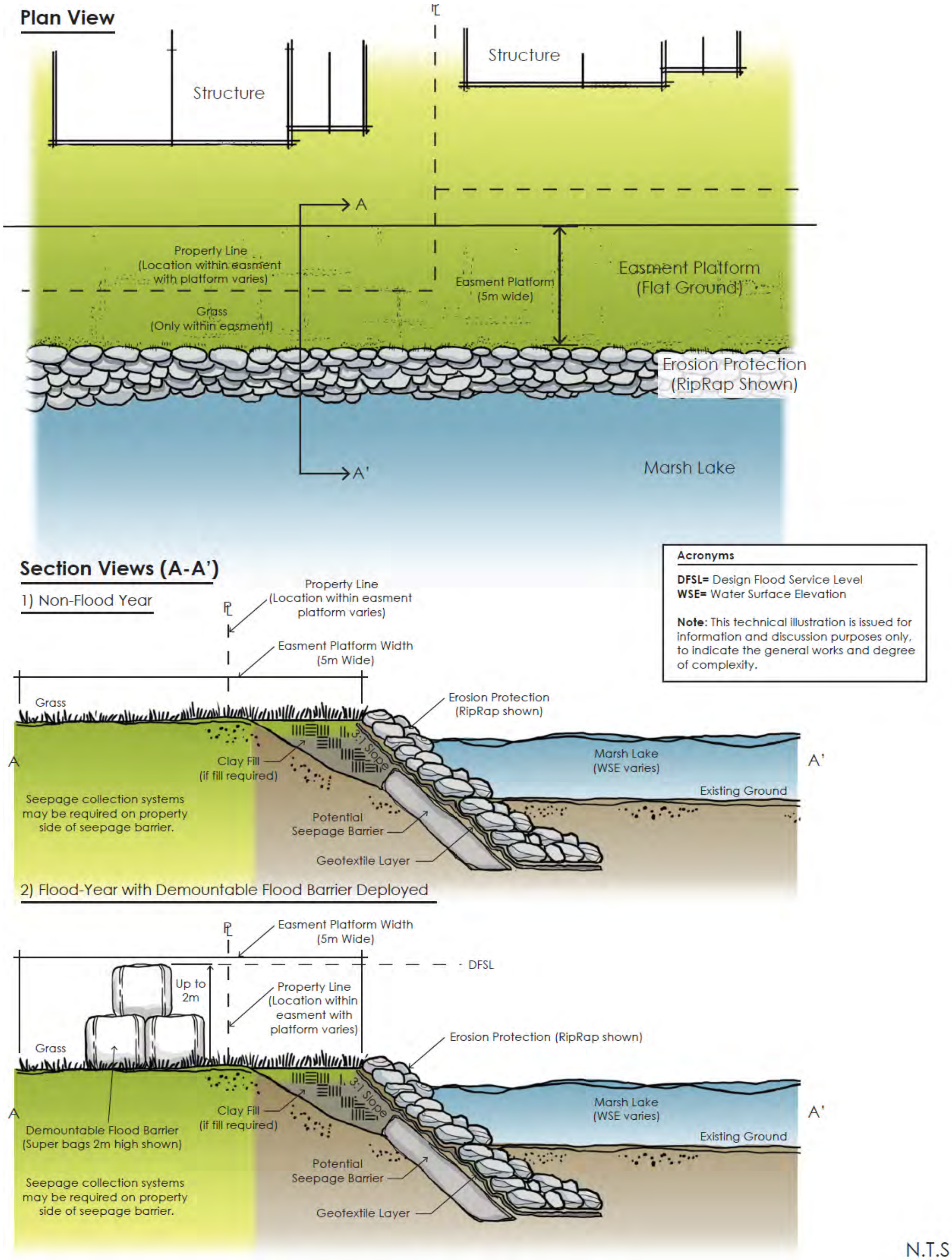


Figure 5.3 Option 6 – Easement with Platform

General details for the easement platform are outlined in the following points.

- Minimum 3H:1V side slopes has been assumed. The side slopes of the clay dike would need to be confirmed to meet slope stability and seepage requirements.
- A 1 m wide by 2 m deep seepage barrier consisting of clay soil would be installed below the clay dike. The dimensions of the seepage barrier would need to be confirmed to meet seepage requirements.
- The platform would be covered with topsoil and seeded. Larger vegetation such as shrubs and trees would not permitted and maintenance to keep trees and shrubs out of the easement would be necessary.
- The wet side slope (i.e. lake side) would have geotextile and erosion protection (e.g., rip rap) placed on the slope.

Demountable options were considered for up to 1 m high and up to 2 m high for temporary flood defenses during flood events. Demountable options included sandbags, superbags, concrete blocks, Aquadams, Tiger Dams, Hesco Barriers, Defencell, Muscle walls, Inero flood barriers, and RS demountable barriers. Further information on these demountable flood defense measures is provided in Appendix A. The frequency of deployment of demountables is dependent on the return period and freeboard tolerance that YG specifies in the DFSL. Section 2.8 provides context for these values.

5.6.2 OPC for Construction

For conservatism in cost estimation, the OPC was developed assuming the easement would require clay fill to create a flat base, a seepage barrier, erosion protection, geotextile, topsoil and seeding for the entire 4.5 km of the easement. The OPC did not include costs for access points or the costs of establishing or maintaining easement agreements with land owners.

The Class D OPC for construction of the conceptual design is $9.3 million – $13.9 million as outlined in Table B.2 in Appendix B.

The OPC for 1 m of demountable (protecting to 1 m below DFSL) options ranged from $0.4 million - $5.4 million as outlined in Table B.3 in Appendix B. The OPC for 2 m of demountable (protection to the DFSL) options ranged from $0.5 million - $20.4 million.

The OPC for operations and maintenance were developed for non-flood years and flood years (Tables B.4 and B.5 in Appendix B). Operations and maintenance costs included inspections, repairs, storage of demountable flood defenses, and for flood-years, demountable mobilization and demobilization. The OPC is estimated to be $110,000 to $165,000 for a non-flood year and $650,000 to $975,000 for a flood year.

5.6.3 Evaluation

Table 5.6 summarizes the performance of Option 6 with respect to the evaluation criteria which was previously outlined in Section 3.0.

Table 5.6 Option 6 Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
Primary Objective			
	Reduce Flood Risk During the 200-Year Flood	• 2 m of demountables on the platform would be required to be installed to the DPFE.	High Score
Secondary Objectives			
1	Viability and Reliability under Extreme Conditions	• This option could include the installation of erosion protection and temporary flood defenses along the entire length of the existing temporary dike. Viability and reliability would depend on the materials chosen . • Depending on demountables selected, erosion from waves or ice may be an issue.	Medium Score
2	Time to Implementation	• Property owner negotiations for easement may slow implementation. • Surveys would be needed to determine which areas/properties require platform extension and erosion protection.	Medium Score
3	Capital Cost	• Capital costs are described in Section 5.6.2 • Substantial capital costs and resources required. Expected that these options would also require substantial political effort for implementation.	Medium Score
4	Maintenance and Storage	• Easement platform would require annual maintenance and repairs as needed. • Depending on the demountable option selected, demountables would require maintenance and storage	Low Score
5	Response and Activation	• Moderate financial and human resources needed during a flood event to deploy demountable flood defenses and monitor is performance, depending on type of demountable options are used. • Improved access compared to 2021 will likely reduce comparative costs. • Standard demountable design compared to 2021 flood defenses will likely reduce comparative costs. • Response and activation time likely significantly reduced compared to 2021.	Medium Score

Table 5.6 Option 6 Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
6	Serviceable Life	• Easement platform, if maintained, >50 years • Dependent on type of demountable flood defenses used; the demountable options outlined in Appendix A range from 5 years to >50 years.	Medium Score
7	Aesthetics	• Only affect aesthetics during a flood year while demountable flood defenses are deployed.	High Score
8	Regulatory Outlook	• Establishing easement may be challenging, require landowner engagement • Platform and erosion protection may extend below ordinary high water mark (OHWM), may require regulatory approvals	Medium Score
9	Future Adaptability	• Highly adaptable option as flood defense height can change and demountable options can be mixed or replaced as needed. • Easement platform provides location for potential future flood defense dike.	High Score
10	Precedent	• If this option is implemented, it could set a precedent for YG to take a similar approach (response infrastructure, response plans) for other private residences/communities affected by flooding.	Low Score

5.7 OPTION 7A – CLAY DIKE

5.7.1 Description

This option consists of installing a flood defense dike comprised of clay soil with a top elevation at the DFSL. General details for the clay dike are outlined in the following points.

- The top width of the dike would be minimum 3 m.
- Minimum 3H:1V side slopes has been assumed. The side slopes of the clay dike would need to be confirmed to meet slope stability and seepage requirements.
- A 1 m wide by 2 m deep seepage barrier consisting of clay soil would be installed below the clay dike. The dimensions of the seepage barrier would need to be confirmed to meet seepage requirements.
- The dry side slope (i.e. property side) would be topsoiled and seeded. Larger vegetation such as shrubs and trees are not permitted
- A minimum vegetation-free zone of 5 m extending from each side slope toe of the dike is required.
- The wet side slope (i.e. lake side) would have geotextile and rip rap erosion protection placed on the slope.
- Drainage culverts would be required to be installed through the dike to allow for internal water drainage. The culverts would require a sluice gate on the dry side of the dike and a flap gate on the wet side of the dike.

Figure 5.4 depicts this option in plan view and cross sections showing scenarios with a full clay dike, a partial clay dike with a platform and up to 1 m of demountable flood defenses, and a partial clay dike with a platform and up to 2 m of demountable flood defenses.

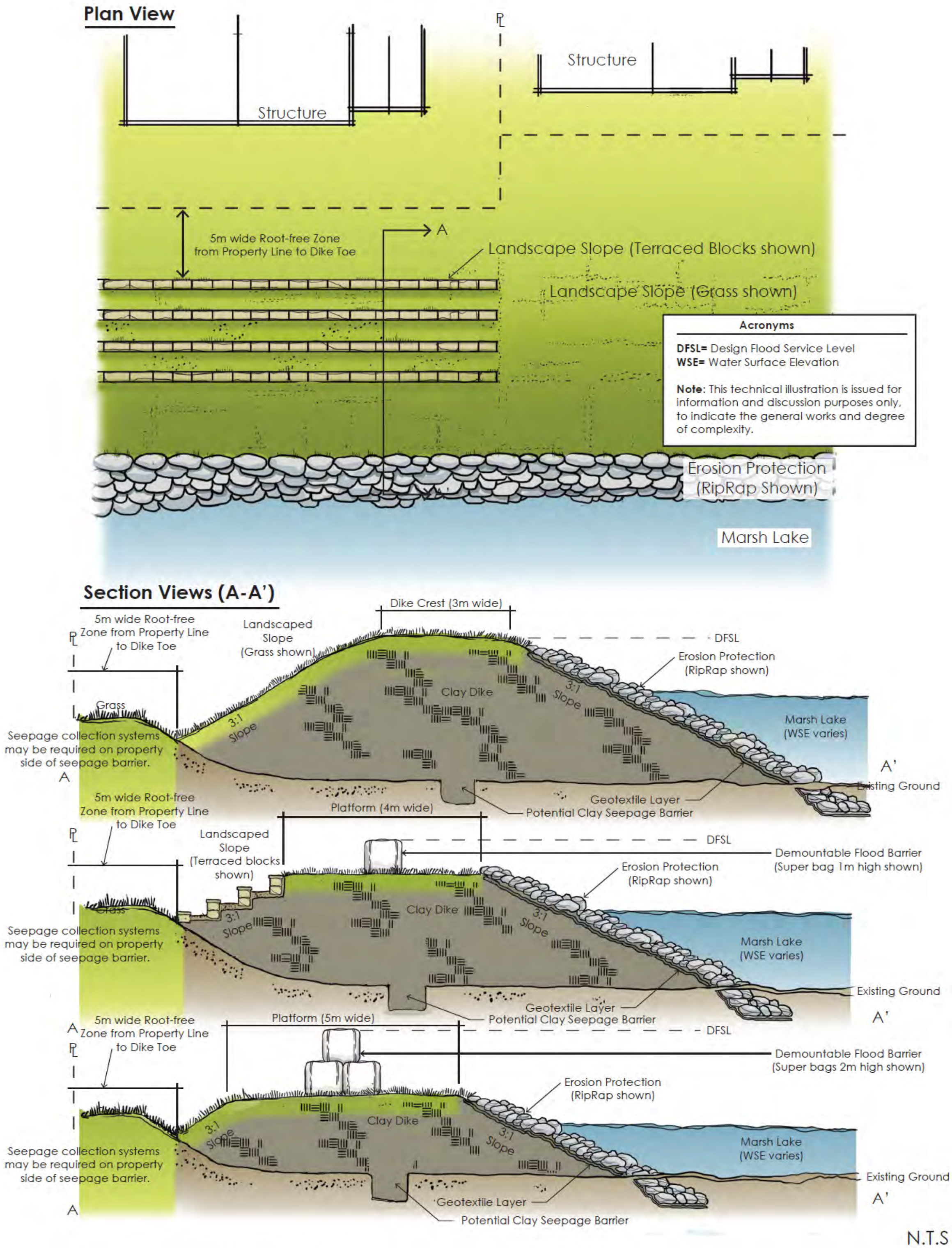


Figure 5.4 **Options 7A, B & C – Clay Dike and Clay Dike with Platform and Varying Demountable Flood Defenses**

5.7.2 OPC for Construction

The Class D OPC for construction of the conceptual design is $39.7 million (structure line) to $47.3 million (property line) as outlined on Table B.6 in Appendix B.

The OPC for operations and maintenance were developed for non-flood years and flood years (Tables B.7 and B.8 in Appendix B). Operations and maintenance costs included inspections and repairs. The OPC is estimated to be $60,000 to $90,000 for a non-flood year and $225,000 to $337,500 for a flood year.

5.7.3 Evaluation

Table 5.7 summarizes the performance of Option 7A with respect to the evaluation criteria which was previously outlined in Section 3.0.

Table 5.7 Option 7A Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
Primary Objective			
	Reduce Flood Risk During the 200-Year Flood	• This option would be designed to reduce the flood risk against the 200-year flood.	High Score
Secondary Objectives			
1	Viability and Reliability under Extreme Conditions	• This option would be designed to be in contact with water for long periods of time and withstand significant wind and wave action, cold temperatures and freeze/thaw cycles.	High Score
2	Time to Implementation	• This option would take a substantial amount of time to construct due to the large fill volume required, the landowner engagement that would be required, and the anticipated permitting requirements • Would require a, easement of land use change to prevent encroachment of private development.	Low Score
3	Capital Cost	• Capital costs are described in Section 5.7.2 • Substantial capital costs and resources required. Expected that this option would also require substantial political effort for implementation.	Low Score
4	Maintenance and Storage	• Would require routine inspections and repairs as needed. • No storage requirements.	High Score
5	Response and Activation	• No anticipated financial or human resources needed during a flood event.	High Score
6	Serviceable Life	• A designed clay dike would provide long-term flood defenses >50 years.	High Score

Table 5.7 Option 7A Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
7	Aesthetics	• This option would substantially impact aesthetics by blocking homeowner's lake views and access.	Low Score
8	Regulatory Outlook	• Substantial parts located below OHWM triggering DFO regulations, other environmental permitting requirements • It is expected that this option would require substantial permitting and engagement activities	Low Score
9	Future Adaptability	• Adaptable option as flood defense height can increase with demountable options if needed. • Minor changes to the inside slope of the dike can be performed to increase aesthetics. • Access ramps can be constructed as required.	Medium Score
10	Precedent	• Implementing this option may set a precedent that YG also protect other flood-prone private properties with similar protection measures.	Low Score

5.8 OPTIONS 7B & 7C – CLAY DIKE WITH PLATFORM

5.8.1 Description

These two options are similar and have been considered to reduce the overall footprint a clay dike and reduce the overall height of the permanent dike (Figure 5.4). Options 7B and 7C both consist of installing a flood defense dike comprised of clay soil with a top elevation below the design elevation of 659.94 m and having a wider platform so YG can access the top of the dike and deploy demountables up to the design elevation of 659.94 m. Demountable options may consist of many forms, some typical options that could be utilized are provided in Appendix A. The frequency of deployment of demountables is dependent on the return period and freeboard tolerance that YG specifies in the DFSL. Section 2.8 provides context for these values. General details for the clay dike with a platform are outlined in the following points.

- Option 7B would have a top elevation of 658.94 m and a top width of the dike platform would be minimum 4 m. Option 7B would require 1 m of demountables placed on top of the clay dike platform.
- Option 7C would have a top elevation of 657.94 m and a top width of the dike platform would be minimum 5 m. Option 7C would require 2 m of demountables placed on top of the clay dike platform.
- Minimum 3H:1V side slopes has been assumed. The side slopes of the clay dike would need to be confirmed to meet slope stability and seepage requirements.
- A 1 m wide by 2 m deep seepage barrier consisting of clay soil would be installed below the clay dike. The dimensions of the seepage barrier would need to be confirmed to meet seepage requirements.

- The dry side slope (i.e. property side) would be topsoiled and seeded. Larger vegetation such as shrubs and trees are not permitted.
- The wet side slope (i.e. lake side) would have geotextile and rip rap erosion protection placed on the slope.
- A minimum vegetation-free zone of 5 m extending from each side slope toe of the dike is required.
- Drainage culverts would be required to be installed through the dike to allow for internal water drainage. The culverts would require a sluice gate on the dry side of the dike and a flap gate on the wet side of the dike.

5.8.2 OPC for Construction

Class D OPC for Option 7B

The Class D OPC for construction of the conceptual design for Option 7B is $28.3 million (structure line) to $50.7 million (property line) as outlined in Table B.9 in Appendix B.

The Class D OPC for 1 m high demountable flood defenses for Option 7B is minimum $403,000 to maximum $5.3 million, depending on the demountable chosen, as outlined in Table B.10 in Appendix B.

The OPC for operations and maintenance for Option 7B were developed for non-flood years and flood years (Tables B.11 and B.12 in Appendix B). Operations and maintenance costs included inspections, repairs, storage of demountable flood defenses, and for flood-years, demountable mobilization and demobilization. The OPC is estimated to be $85,000 to $127,500 for a non-flood year and $625,000 to $937,500 for a flood year.

Class D OPC for Option 7C

The Class D OPC for construction of the conceptual design for Option 7C is $18.8 million (structure line) to $34.1 million (property line) as outlined in Table B.13 in Appendix B.

The Class D OPC for 2 m high demountable flood defenses for Option 7C is minimum $496,000 to maximum $19.9 million, depending on the demountable chosen, as outlined in Table B.14 in Appendix B.

The OPC for operations and maintenance for Option 7C were developed for non-flood years and flood years (Tables B.15 and B.16 in Appendix B). Operations and maintenance costs included inspections, repairs, storage of demountable flood defenses, and for flood-years, demountable mobilization and demobilization. The OPC is estimated to be $110,000 to $165,000 for a non-flood year and $650,000 to $975,000 for a flood year.

5.8.3 Evaluation

Table 5.8 summarizes the performance of Options 7B and 7C with respect to the evaluation criteria which was previously outlined in Section 3.0.

Table 5.8 Options 7B & 7C Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
		Primary Objective	
	Reduce Flood Risk During the 200-Year Flood	• 1 or 2 m of demountables on the platform would be required to be installed to the DFSL.	High Score
		Secondary Objectives	
1	Viability and Reliability under Extreme Conditions	• The platform for this option would be designed to be in contact with water for long periods of time and withstand significant wind and wave action, cold temperatures and freeze/thaw cycles. • Depending on demountables selected, erosion from waves or ice may be an issue.	Medium Score
2	Time to Implementation	• This option would take a substantial amount of time to construct due to the large fill volume required, the landowner engagement that would be required, and the anticipated permitting requirements.	Low Score
3	Capital Cost	• Capital costs are described in Section 5.8.2 • Substantial capital costs and resources required. Expected that this option would also require substantial political effort for implementation.	Low Score
4	Maintenance and Storage	• Platform would require routine inspections and repairs as needed. • Depending on the demountable option selected, demountables would require maintenance and storage	Medium Score
5	Response and Activation	• Moderate financial and human resources needed during a flood event to deploy demountable flood defenses, depending on type of demountable options are used and depending on Option 7B or 7C. • Improved access compared to 2021 will likely reduce comparative costs. • Standard demountable design compared to 2021 flood defenses will likely reduce comparative costs. • Response and activation time likely significantly reduced compared to 2021.	Medium Score

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
Primary Objective			
6	Serviceable Life	• A designed clay dike would provide long-term flood risk reduction >50 years. • Dependent on type of demountable flood defenses used; the demountable options outlined in Appendix A range from 5 years to >50 years.	Medium Score
7	Aesthetics	• During flood event this is dependent on height of demountables (Option 7B = 1 m, Option 7C = 2 m) • This option could impact aesthetics by blocking homeowner's lake views and access. The lake view would be less blocked in Option 7C during non-flood events.	Medium Score
8	Regulatory Outlook	• Substantial parts located below OHWM triggering DFO regulations, other environmental permitting requirements • It is expected that this option would require substantial permitting and engagement activities	Low Score
9	Future Adaptability	• Highly adaptable option as flood defense height can change as necessary from demountable options and demountable options can be mixed or replaced as needed. • Dike platform provides location for potential future raise of the dike. • Access ramps can be constructed as required.	High Score
10	Precedent	• Implementing this option may set a precedent that YG also protect other flood-prone private properties with similar protection measures.	Low Score

5.9 OPTION 8A – STRUCTURAL DIKE

5.9.1 Description

To reduce the overall footprint of a clay dike without lowering the overall height of the dike, structural elements could be installed along the wet and/or dry side slopes of the clay dike. The structural dike option would consist of a clay soil dike with structural elements installed in place of the side slopes of the dike to act as a retaining structure. The top of the structural dike would be installed to the DFSL. The structural elements may consist of, but not limited to, steel sheet pile walls, concrete blocks, or segmental block walls. A combination of the structural elements can also be implemented, for example a steel sheet pile wall on the wet side of the dike and a segmental block wall on the dry side of the dike. General details for the structural dike are outlined in the following points:

- The top width of the dike would be minimum 3 m.
- Depending on the structural element installed, the side slopes of the dike would be near vertical to approximately 0.25H:1V. For the quantity and costing calculations for this report, it has been assumed that a vertical steel sheet pile wall would be installed on the wet side slope and a modular block wall or a concrete block wall at 0.25H:1V would be installed on the dry side slope. Concrete blocks would consist of generic concrete blocks approximately 0.6 m wide, 0.6 m high and 1.2 m long with studs (male ends) on the top and recesses (female ends) on the bottom to provide a vertical interlocking system. Modular blocks consist of smaller blocks typically made of concrete that are more aesthetic than generic concrete blocks. The modular blocks consist of two (2) units including the facing unit (aesthetic concrete block) and the anchoring unit (typically granular backfill with geogrid). Modular blocks come in many different shapes, sizes and colours.
- Pending detailed investigation, the steel sheet pile wall is assumed to extend a minimum of 5 m below the existing ground surface and could be also serve as a seepage barrier. The depth of the steel sheet pile wall would need to be confirmed to meet retaining wall stability requirements and design criteria for seepage control.
- The segmental block wall would need to be checked for internal and external retaining wall stability requirements.
- Clay soil would be placed between the structural elements.
- The top of the structural dike would be topsoiled and seeded. Larger vegetation such as shrubs and trees are not permitted.
- A minimum vegetation-free zone of 5 m extending from each side slope toe of the dike is required, though there may be opportunities to relax this requirement on the steel sheet pile side, subject to review.
- Drainage culverts would be required to be installed through the dike to allow for internal water drainage. The culverts would require a sluice gate on the dry side of the dike and a flap gate on the wet side of the dike. Provision to mitigate risk of piping from seepage along the anulus of the culverts will be required in the form of a granular filter.

Figure 5.5 depicts this option in plan view and cross sections showing scenarios with a full structural dike, a partial structural dike with a platform and up to 1 m of demountable flood defenses (Option 8B), and a partial structural dike with a platform and up to 2 m of demountable flood defenses (Option 8C).

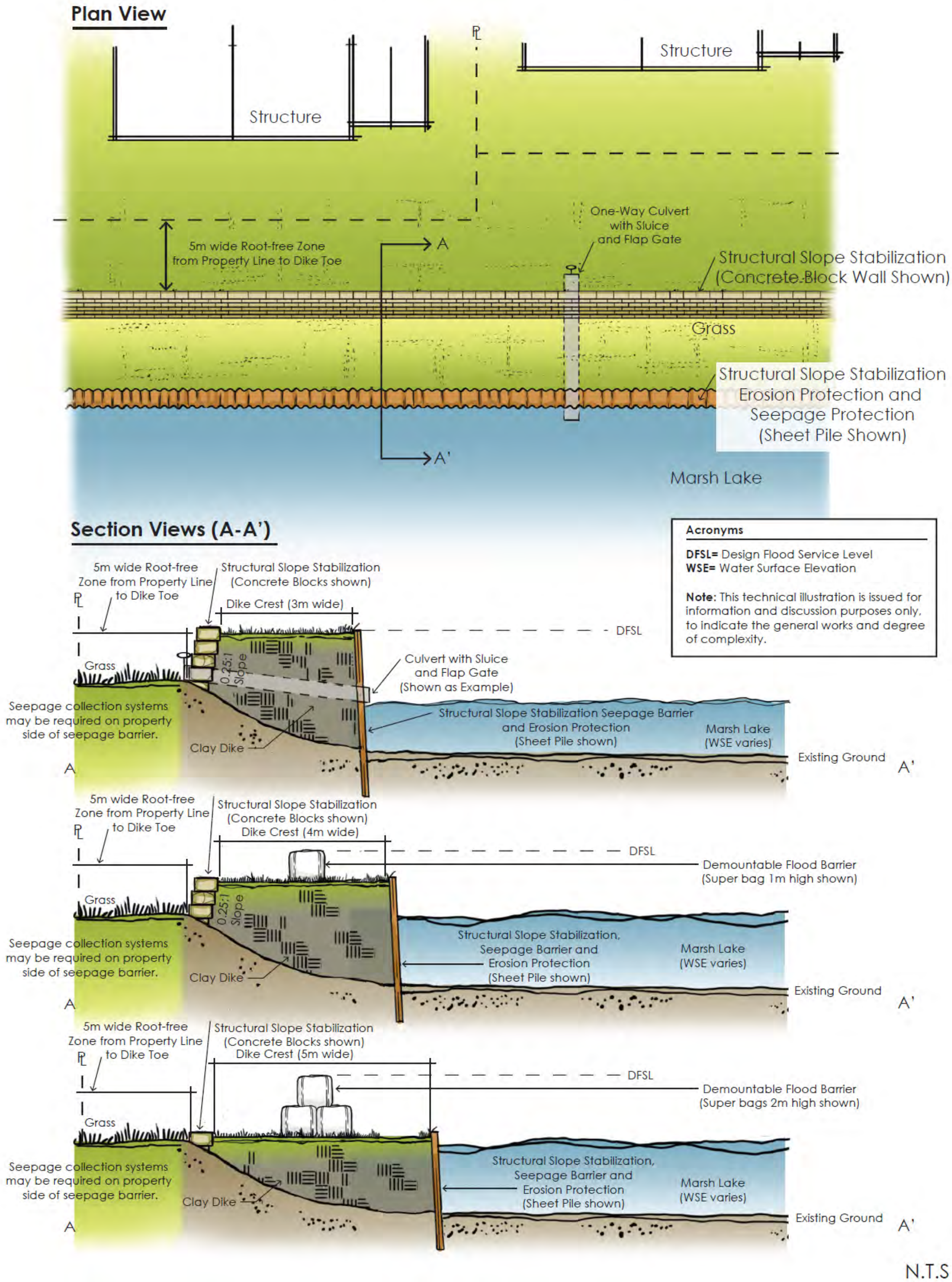


Figure 5.5 Option 8A, B, C – Structural Dike and Structural Dike with Platform and Demountable Flood Defenses

5.9.2 OPC for Construction

The Class D OPC for construction of the conceptual design of modular blocks is $51.7 million (structure line) to $84.9 million (property line) as outlined on Table B.17 in Appendix B.

The Class D OPC for construction of the conceptual design of concrete blocks is $49.2 million (structure line) to $79.4 million (property line) as outlined on Table B.17 in Appendix B.

The OPC for operations and maintenance for both modular and concrete blocks were developed for non-flood years and flood years (Tables B.18 and B.19 in Appendix B). Operations and maintenance costs included inspections and repairs. The OPC is estimated to be $60,000 to $90,000 for a non-flood year and $225,000 to $337,500 for a flood year.

5.9.3 Evaluation

Table 5.9 summarizes the performance of Option 8A with respect to the evaluation criteria which was previously outlined in Section 3.0.

Table 5.9 Option 8A Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
Primary Objective			
	Reduce Flood Risk During the 200-Year Flood	• This option would be designed to reduce the flood risk during the 200-year flood.	High Score
Secondary Objectives			
1	Viability and Reliability under Extreme Conditions	• This option would be designed to be in contact with water for long periods of time and withstand significant wind and wave action, cold temperatures and freeze/thaw cycles.	High Score
2	Time to Implementation	• This option would take a substantial amount of time to construct due to the materials required, the landowner engagement that would be required, and the anticipated permitting requirements.	Low Score
3	Capital Cost	• Capital costs are described in Section 5.9.2 • Substantial capital costs and resources required. Expected that this option would also require substantial political effort for implementation.	Low Score
4	Maintenance and Storage	• Would require routine inspections and repairs as needed. • No storage requirements.	High Score
5	Response and Activation	• No anticipated financial or human resources needed during a flood event.	High Score

Table 5.9 Option 8A Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
6	Serviceable Life	• A designed clay dike with a sheet pile wall and retaining wall would provide long-term reduction in flood risk >50 years.	High Score
7	Aesthetics	• This option could substantially impact aesthetics by blocking homeowner's lake views and access. • Structural retaining wall on inside of the dike can be made into an aesthetic feature.	Medium Score
8	Regulatory Outlook	• Substantial parts located below OHWM triggering DFO regulations, other environmental permitting requirements • It is expected that this option would require substantial permitting and engagement activities.	Low Score
9	Future Adaptability	• Adaptable option as flood defense height can increase with demountable options if needed. • Minor changes to the inside slope of the dike can be performed to increase aesthetics. • Access ramps can be constructed as required.	Medium Score
10	Precedent	• Implementing this option may set a precedent that YG also protect other flood-prone private properties with similar protection measures.	Low Score

5.10 OPTIONS 8B & 8C – STRUCTURAL DIKE WITH PLATFORM

5.10.1 Description

These two options are similar and have been considered to reduce the overall height of the permanent dike. Similar to Option 8A, structural elements could be installed along the wet and/or dry side slopes of the clay dike. The top of the structural dike would be installed to a top elevation below the DFSL and having a wider platform so YG can access the top of the dike and deploy demountables up to the DFSL (Figure 5.5). Demountable options may consist of many forms, some typical options that could be utilized are provided in Appendix A. The frequency of deployment of demountables is dependent on the return period and freeboard tolerance that YG specifies in the DFSL. Section 2.8 provides context for these values. General details for the structural dike are outlined in the following points.

- Option 8B would have a top elevation of 658.94 m and a top width of the dike platform would be minimum 4 m. Option 8B would require 1 m of demountables placed on top of the dike platform.
- Option 8C would have a top elevation of 657.94 m and a top width of the dike platform would be minimum 5 m. Option 8C would require 2 m of demountables placed on top of the dike platform.

- Depending on the structural element installed, the side slopes of the dike would be near vertical to approximately 0.25H:1V. For the quantity and costing calculations for this report, it has been assumed that a vertical steel sheet pile wall would be installed on the wet side slope and a segmental block wall or concrete block wall at 0.25H:1V would be installed on the dry side slope.
- Pending detailed investigation, the steel sheet pile wall is assumed to extend a minimum of 5 m below the existing ground surface and could be also serve as a seepage barrier. The depth of the steel sheet pile wall would need to be confirmed to meet retaining wall stability requirements and design criteria for seepage control.
- The segmental block wall would need to be checked for internal and external retaining wall stability requirements.
- Clay soil would be placed between the structural elements.
- The top of the structural dike platforms would be topsoiled and seeded. Larger vegetation such as shrubs and trees are not permitted.
- A minimum vegetation-free zone of 5 m extending from each side slope toe of the dike is required.
- Drainage culverts would be required to be installed through the dike to allow for internal water drainage. The culverts would require a sluice gate on the dry side of the dike and a flap gate on the wet side of the dike.

5.10.2 OPC for Construction

Class D OPC for Option 8B

The Class D OPC for construction of the conceptual design (modular blocks) for Option 8B is $42.9 million (structure line) to $70.5 million (property line) as outlined in Table B.20 in Appendix B.

The Class D OPC for construction of the conceptual design (concrete blocks) for Option 8B is $47.0 million (structure line) to $66.5 million (property line) as outlined in Table B.20 in Appendix B.

The Class D OPC for 1 m high demountable flood defenses for Option 8B is minimum $397,000 to maximum $5.3 million, depending on the demountable chosen, as outlined in Table B.21 in Appendix B.

The OPC for operations and maintenance for Option 8B were developed for non-flood years and flood years (Tables B.22 and B.23 in Appendix B). Operations and maintenance costs included inspections, repairs, storage of demountable flood defenses, and for flood-years, demountable mobilization and demobilization. The OPC is estimated to be $85,000 to $127,500 for a non-flood year and $625,000 to $937,500 for a flood year.

Class D OPC for Option 8C

The Class D OPC for construction of the conceptual design (modular blocks) for Option 8C is $30.7 million (structure line) to $54.2 million (property line) as outlined in Table B.24 in Appendix B.

The Class D OPC for construction of the conceptual design (concrete blocks) for Option 8C is $28.3 million (structure line) to $47.4 million (property line) as outlined in Table B.24 in Appendix B.

The Class D OPC for 2 m high demountable flood defenses for Option 8C is minimum $491,000 to maximum $19.7 million, depending on the demountable chosen, as outlined in Table B.25 in Appendix B.

The OPC for operations and maintenance for Option 8C were developed for non-flood years and flood years (Tables B.15 and B.16 in Appendix B). Operations and maintenance costs included inspections, repairs, storage of demountable flood defenses, and for flood-years, demountable mobilization and demobilization. The OPC is estimated to be $110,000 to $165,000 for a non-flood year and $650,000 to $975,000 for a flood year.

5.10.3 Evaluation

Table 5.10 summarizes the performance of Options 8B and 8C with respect to the evaluation criteria which was previously outlined in Section 3.0.

Table 5.10 Options 8B & 8C Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
Primary Objective			
	Reduce Flood Risk During the 200-Year Flood	• 1 or 2 m of demountables on the platform would be required to be installed to the DPFE.	High Score
Secondary Objectives			
1	Viability and Reliability under Extreme Conditions	• The platform for this option would be designed to be in contact with water for long periods of time and withstand significant wind and wave action, cold temperatures and freeze/thaw cycles. • Depending on demountables selected, erosion from waves or ice may be an issue.	Medium Score
2	Time to Implementation	• This option would take a substantial amount of time to construct due to the large fill volume required, the landowner engagement that would be required, and the anticipated permitting requirements.	Low Score
3	Capital Cost	• Capital costs are described in Section 4.11.2 • Substantial capital costs and resources required. Expected that these options would also require substantial political effort for implementation.	Low Score
4	Maintenance and Storage	• Platform would require routine inspections and repairs as needed. • Depending on the demountable option selected, demountables would require maintenance and storage	Medium Score

Table 5.10 Options 8B & 8C Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating (Low/Medium/High)
5	Response and Activation	• Moderate financial and human resources needed during a flood event to deploy demountable flood defenses, depending on type of demountable options are used and depending on Option 8B or 8C. • Improved access compared to 2021 will likely reduce comparative costs. • Standard demountable design compared to 2021 flood defenses will likely reduce comparative costs. • Response and activation time likely significantly reduced compared to 2021.	Medium Score
6	Serviceable Life	• A clay dike with a sheet pile wall and retaining wall would provide long-term reduction in flood risk >50 years. • Dependent on type of demountable flood defenses used; the demountable options outlined in Appendix A range from 5 years to >50 years.	Medium Score
7	Aesthetics	• During flood event this is dependent on height of demountables (Option 8B = 1 m, Option 8C = 2 m) • This option could impact aesthetics by blocking homeowner's lake views and access. The lake view would be less blocked in Option 8C during non-flood events. • Structural retaining wall on inside of the dike can be made into an aesthetic feature.	Medium Score
8	Regulatory Outlook	• Substantial parts located below OHWM triggering DFO regulations, other environmental permitting requirements • It is expected that this option would require substantial permitting and engagement activities.	Low Score
9	Future Adaptability	• Highly adaptable option as height of defenses can change as necessary from demountable options and demountable options can be mixed or replaced as needed. • Dike platform provides location for potential future raise of the flood defense dike. The steel sheet pile wall would be challenging to raise but not impossible. • Access ramps and stairs can be constructed as required.	Low Score
10	Precedent	• Implementing this option may set a precedent that YG also protect other flood-prone private properties with similar protection measures.	Low Score

5.11 SUMMARY OF OPTIONS EVALUATION AND COSTING

Table 5.11 provides a summary of the evaluation of each of the options.

Table 5.11 Summary of Evaluation of Options

Options		Primary Objective	Secondary Objectives									
		Reduces Flood Risk from 200-year flood	Viability and Reliability under Extreme Conditions	Time to Implementation	Capital Cost	Maintenance and Storage	Response and Activation	Serviceable Life	Aesthetics	Regulatory Outlook	Future Adaptability	Precedent
1	Status Quo	Low	Low	High	High	High	Low	Low	Medium	High	Medium	Low
2	Mitigation Funding to Property Owners	Medium	Medium	Medium	Medium	High	Medium	Medium	High	Medium	High	Low
3	Land Purchase	High	High	Low	Low	High	High	High	Low	Low	High	Medium
4	Adaptive Water Management	Low	Low	High	High	High	High	High	High	Medium	High	High
5	Raising Roads	Low	High	High	Medium	High	Low	Medium	High	High	High	Medium
6	Easement with Platform	High	Medium	Medium	Medium	Low	Medium	Medium	High	Medium	High	Low
7A	Clay Dike	High	High	Low	Low	High	High	High	Low	Low	Medium	Low
7B/C	Clay Dike with Platform	High	Medium	Low	Low	Medium	Medium	Medium	Medium	Low	High	Low
8A	Structural Dike	High	High	Low	Low	High	High	High	Medium	Low	Medium	Low
8B/C	Structural Dike with Platform	High	Medium	Low	Low	Medium	Medium	Medium	Medium	Low	Low	Low

Table 5.12 below summarizes the opinion of probable costs for Options 5 through 8.

Table 5.12 Summary of Class D Cost Estimates for Option 5 through Option 8

Option No.	Option		Permanent Structures	Demountables		Table
				Min.	Max.	
5	Raising Roads		$4.5M - $6.8M	N/A		B.1
6	Easement with Platform	1 m Demountables	$9.3M - $13.9M	$0.4M	$5.4M	B.2 B.3
		2 m Demountables		$0.5M	$20.4M	
7A	Clay Dike	Structure Line	$39.4M - $59.6M	N/A		B.6
		Property Line	$47.3M - $71.0M			
7B	Clay Dike with Platform (1m)	Structure Line	$28.3M - $42.5M	$0.4M	$5.3M	B.9
		Property Line	$33.8M - $50.7M			
7C	Clay Dike with Platform (2m)	Structure Line	$18.8M - $28.1M	$0.5M	$19.9M	B.13, B.14
		Property Line	$22.8M - $34.1M			
8A	Structural Dike (Modular)	Structure Line	$51.7M - $77.6M	N/A		B.17
		Property Line	$56.6M - $84.9M			
	Structural Dike (Concrete)	Structure Line	$49.2M - $73.8M	N/A		
		Property Line	$52.9M - $79.4M			
8B	Structural Dike with Platform (1m, modular)	Structure Line	$42.9M - $64.3M	$0.4M	$5.3M	B.20, B.21
		Property Line	$41.3M - $70.5M			
	Structural Dike with Platform (1m, concrete)	Structure Line	$47.0M - $62.0M			
		Property Line	$44.4M - $66.5M			
8C	Structural Dike with Platform (2m, modular)	Structure Line	$30.7M - $46.0M	$0.5M	$19.7M	B.24, B.25
		Property Line	$36.1M - $54.2M			
	Structural Dike with Platform (2m, concrete)	Structure Line	$28.3M - $42.5M			
		Property Line	$31.6M - $47.4M			

NOTES:
Color grading relates to the definitions in Section 3.2.
Red: Low Score (> $25 million)
Yellow: Medium Score ($5 - $25 million)
Green: High Score (< $5 million)

Table 5.13 below summarizes the opinion of probable costs for the operations and maintenance for Options 5 through 8.

Table 5.13 Operations & Maintenance Summary

No.	Option Description	Non-Flood Year	Flood Year	Table
5	Raising Roads	No change to current operations & maintenance		
6	Easement with Platform	$110k - $165k	$650k - $975k	B.4, B.5
7A	Clay Dike	$60k - $90k	$225k - $338k	B.7, B.8
7B	Clay Dike with Platform (1m)	$85k - $128k	$625k – $938k	B.11, B.12
7C	Clay Dike with Platform (2m)	$110k - $165k	$650k - $975k	B.15, B.16
8A	Structural Dike	$60k - $90k	$225k - $338k	B.18, B.19
8B	Structural Dike with Platform (1m)	$85k - $128k	$625k – $938k	B.22, B.23
8C	Structural Dike with Platform (2m)	$110k - $165k	$650k - $975k	B.26, B.27

6.0 SUMMARY

The southern region of the Yukon experienced severe flooding in the spring and summer of 2021. The flooding was largely attributed to high snowpack accumulation in south/central Yukon over the winter of 2020/2021. The flooding consisted of local snowmelt and site drainage flooding in May/June and elevated water levels in the Southern Lakes and the downstream Yukon River in July/August. A State of Emergency was declared for the Southern Lakes region on July 9, 2021 and significant increases to resources and labour were allocated to the Southern Lakes Flooding Incident. Flood defense construction occurred from late June through to early/mid-August, and included temporary superbag and sandbag dikes, earthfill berms, concrete blocks, and occasional water bag systems used by private property owners.

The Government of Yukon retained Stantec to complete a review and evaluation of potential flood mitigation options at Marsh Lake (within the Southern Lakes region).

A part of Stantec's scope of work for this study consisted of reviewing the existing conditions of Marsh Lake and the Study Area that were pertinent to the development and evaluation of mitigation options including but not limited to a general review of past flood events, the existing bathymetry and topography, and the existing geology, hydrogeology, and hydrology of the area. The review of the existing conditions was completed utilizing documentation available to Stantec at the time of this report.

Following the review of the existing conditions, Stantec developed and qualitatively evaluated eight (8) mitigation options for the Army Beach and South McClintock Road areas at Marsh Lake. The mitigation options were qualitatively evaluated for a primary objective which was to reduce flood risk to public infrastructure and private residences on the lakefront along Army Beach and South McClintock from the 200-year flood event and ten secondary objectives for various performance and requirement items. The qualitative evaluation was performed by providing a rating of anticipated performance of low, medium, or high for each objective which is summarized for each mitigation option in Table 5.11. A Class D OPC and operations and maintenance costs were also reviewed for each engineering option (Options 5 through 8) and are summarized on Table 5.12 and Table 5.13, respectively.

To simplify the evaluation of the mitigation options, each option was evaluated in a mutually exclusive manner, however, the options themselves are not mutually exclusive and a combination of the options could be implemented to suit the characteristics of different properties, owners and areas within Marsh Lake.

7.0 CLOSURE

This report has been prepared for the sole benefit of the Government of Yukon and its agents, and may not be used by any third party without the express written consent of Stantec Consulting Ltd. Any use, which a third party makes of this report, is the responsibility of such third party. Use of this report is subject to the Statement of General Conditions provided in **Appendix C**. It is the responsibility of the Government of Yukon who is identified as "the Client" within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec Consulting Ltd. should any of these not be satisfied. The Statement of General Conditions addresses the following:

- Use of the report.
- Basis of the report.
- Standard of care.
- Interpretation of site conditions.
- Varying or unexpected site conditions.
- Planning, design, or construction.

Stantec remains committed to supporting the Government of Yukon and our fellow Yukoners with the ongoing flooding challenge. As a multidisciplinary consulting firm with significant local presence (26 full-time employees spanning multiple disciplines in our Whitehorse office) and extensive experience in flood management planning and implementation across Canada, Stantec is capable of assisting the Government of Yukon with the full scope of technical, planning, and policy development components of Yukon flooding. At your request, we can prepare a proposal to provide additional flood management and technical/planning services (or components thereof) for your consideration, whether that be as an addition to our current contract with YG or in response to an invitational or public procurement process.

We trust the above information meets with your present requirements. Should you have any questions or require further information, please contact us. We appreciate the opportunity to assist you in this project.

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Appendix A DEMOUNTABLE OPTIONS

Table A.1 Demountable Options Summary

     

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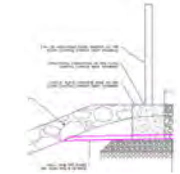

Cost Information

Demountable Options	AquaDam - Leyfield	Tiger Dams	Hesco Barrier	Defencell (Hesco)	Muscle Wall (Hesco)	Inero Flood Barriers	RS Demountable	Sandbags	Superbags	Concrete Blocks
Website	https://www.layfieldgroup.com/ge	https://usfloodcontrol.com/flood-t	https://www.flooddefensegroup.co	Defencecell flood prevention soluti	https://www.flooddefensegroup.co	https://www.floodcontrolcanada.com/copy-of-inero-h50		n/a	n/a	n/a
Unit cost - 1m high- $/m	CAD$106.70	CAD$496.72	US$21.41	USD$ 68.4	USD$ 104.83	CAD$677.46	CAD$802.90	CAD$97.09	CAD$108.00	CAD$777.00
Base width (m) for 1m high	2.40	2.13	0.6	2.7	0.5	1m	0.40	1m	1	1.5
Unit cost - 2m high- $/m	-	CAD$1,281.17	US$53.95	-	USD$ 599.75	CAD$1,555.05	CAD$3,042.65	CAD$291.26	CAD$324.00	CAD$1,554.00
Base width (m) for 2m high	-	4.20	1.52	4.05	1.3	1.7	1.40	2m	2	1.5
Capital	$30,000	-	-	-	-	-	-	-	-	-
Taxes	not included	included above	not included	not included	not included	not included	not included	not included	not included	not included
Shipping	not included	included above	not included	not included	not included	not included	not included	not included	not included	not included
What are they made of? How do they work?	High strength geotextile tubes, stuffed with a sized poly tube that is made from geomembrane resins. They have to be filled with water. The geomembrane tube is encased within a protective UV stabilized high strength woven geotextile that protects the inner geomembrane core from physical and UV damages.	Tiger Dam is made out of a polypropylene mixed with a nylon scrim to allow for expansion. The tubes are filled with water.	Wire cages with geotextile lining, that are then filled with sand/gravel mix	Defencell is comprised of a heavy-duty nonwoven geotextile. They are filled with sand/gravel mix. An external frame is required during construction. These can be stacked to gain flood protection elevation.	Plastic water-filled barriers that lock together to form a continuous barrier.	The flood barrier sections, support legs and foot beams are made from marine-grade aluminum. The material has high durability and withstands extremely tough outdoor conditions. The sections are erected using a sturdy aluminum support leg with a conical foot beam. The polyethylene membrane is then rolled out along the barriers and fixed with clips. The membrane must be anchored firmly to the ground using loose gravel or similar material.	Stop log system made out of aluminum. No limitations to length, and can be multi-directional. HILTI Sleeves M20 (for concrete slab foundation)	Small sand-filled plastic bags that are stacked and can be wrapped in plastic for further waterproofing	Large sand-filled plastic bags that are stacked and can be wrapped in plastic for further waterproofing	Preformed concrete blocks that can stack together and can be wrapped in plastic for further waterproofing
Do they have a good track record?	They have 25 projects on their website, first in 2014. The concept and the technology have been in use since the 1980's and have an excellent track record. Such dams are used every year in BC for flood control dams, as coffer dams etc. They were also used during the recent flood in the lower mainland BC (2021) by the Emergency Management in BC and BC municipalities also keep a healthy stock of them.	A Canadian company that has been around for over 20+ years now	This is the most popular option on the market for governmental organizations when it comes to long distances of flood protection.	Tested and approved by the USACE as a flood barrier.	n/a	15 years in the market. Installed in the U.K., Sweden, Germany and the Balkan. Flood Control Canada is the exclusive distributor for INERO TM Flood Barriers, manufactured in Sweden.	35 years in the market; 66,000 systems in 34 countries . Flood Control Canada is the exclusive distributor for all RS Products, manufactured in Germany.	Common flood protection measure	Common flood protection measure	Common flood protection measure
How fast can they be deployed?	10 times faster to install than sandbag dikes. For 30m length with 2 people takes 20 min (1.54 m/min). It is a rapid installation, simply a matter of unrolling on the crest of the dike, securing the ends, and pumping water. In reverse during removal.	A 42" Tiger Dam can be deployed in as fast as 15 mins up to 45 mins, depending on type of pump	Generally, a crew of 1 piece of earth moving machinery and 3-4 workers to support it in compacting the soils after each lift of about 30 cm, you can expect to fill 300 cubic meters of soil in a day.	n/a	With a small team of people, 30 m can be deployed in 30 minutes.	Four people can install 100 meter of the INERO Flood Barrier in less than an hour. A forklift is required to manouver the steel pallets to the location.	A forklift is required to manouver the storage trolleys to the location. ESH-LN (medium impact) 1.2 m height (4 workers) 50m in 1 hr ESH-KN (heavy impact) 2.1 m height (4 workers) 25m in 1 hr	Slow, requires many people to fill sandbags and manually place to build a dike.	Slow, requires equipment to fill with sand and place.	Relatively fast, required equipment to unload and install.
Maximum height that can be deployed	Up to 4.9 m high.	No maximum	No maximum	No maximum.	Height options: 2', 3', 4', 6', and 8' (max 2.4m)	Standard height = 1.7 m. Higher options can be produced upon request. Existing brochure shows maximum height dimensions = 2.24 m H x 0.5m W.	The ESH-LN system can be used for heights up to 1.5 m without back braces. This is an important fact as the berm/dike top width can be limited. The ESH-KN system can be used for heights up to 4.05 m and requires back braces.	No maximum.	No maximum.	No maximum.

Freeboard requirement	30cm - for the 1.2 m option	Typical freeboard requirements are 25% freeboard, but, because Tiger Dams are anchored down, no freeboard is required and they can take overtopping.	None	None. Can take overtopping	None	None	n/a	0.6m	0.6m	None
Deployment Requirements	2-3 people to install. Water source, pump, long hose.	Pumps and hoses to draw water. Labor requirements for size of job, depending on critical time, anywhere from 20-40 people.	Machinery for filling the soil filled options.	Machinery for filling the soil filled options.	Machinery for filling the soil filled options.	No site preparation required. Assembly of the INERO system is easy and can be done with 2-4 people. No foundation required.	n/a	Many people, fill, bags	Machines to fill the bags and move them into place	Machines to move the blocks
Foundation Requirements	A smooth foundation is preferred. To keep a surface smooth and improve the bearing capacity, GeoWebs or Geogrids are recommended.	Anchors are supplied for all surface types	Suitably firm foundation free of organic material. If installing on an eroding surface, place a plastic liner prior to deployment to reduce further erosion of the foundation.	Suitably firm foundation free of organic material. If installing on an eroding surface, place a plastic liner prior to deployment to reduce further erosion of the foundation.	Suitably firm foundation free of organic material. If installing on an eroding surface, place a plastic liner prior to deployment to reduce further erosion of the foundation.	n/a	the RS Demountable Flood Barriers require a concrete slab on which the intermediate posts can be installed.	Stable foundation	Stable foundation	Stable foundation
Inspection and Training Requirements	Some training required for connecting the sections and filling in. There are also videos and training presentations for contractors.	Training would be provided by the company.	No inspections required	No inspections required	No inspections required	Training will we supplied upon commissioning.	Training will we supplied upon commissioning.	None	None	None
Storage Requirements	Indoors and away from sources of heat or UV light.	n/a	n/a	n/a	nested storage abilities	Recommended warehouse, container storage	Recommended warehouse, container storage	Store empty bags inside	Store empty bags inside	Could store inside or outside
Shelf Life/Reusability	Long shelf life, but unique based on the exposed conditions. There are patch kits available to fix small damages, where needed, which will help prolong the use of the dams.	5 year manufacturers warranty, a shelf life of 20 years.	'design life' of 5 years even though they can easily be expected to last upwards of 10 years.	'design life' of 5 years even though they can easily be expected to last upwards of 10 years.	The Muscle Wall can be placed outside for a number of years without issue and there is a 10 year warranty against UV damage.	50+ years. To keep your Demountable Flood Barriers long lasting and organized, please see our storage solutions.	50+ years. To keep your Demountable Flood Barriers long lasting and organized, please see our storage solutions.	Bags unlikely reusable	Bags may be reusable	blocks are reusable. Long shelf life
Ability to Withstand Prolonged Contact with Flood Waters	It will be okay as long as the freeboard is maintained and the fluid that is in contact does not have chemicals to damage geosynthetics. Lake water should be fine.	That it was they are designed for. Tiger Dams can be deployed outside for months at a time, all 4 seasons if need be, as they have a UV coating.	n/a	n/a	n/a	n/a	No time limit. We have our systems permanently installed and exposed to harsh weather conditions.	Good, especially if wrapped in plastic	Good, especially if wrapped in plastic	Good, especially if wrapped in plastic
Ability to Withstand Prolonged Wave Action	It should be okay as long as the freeboard is maintained. The design should account for the loading due to the waves.	Tiger Dam is an FM Approved product so we went through rigorous testing with the Army Corps of Engineers and FM Global. Riverine, 1ft 2ft 3ft wave testing and overtopping tests, also seepage tests were down where Tiger Dam received the highest level of Platinum Certification.	n/a	The Defencell product is great to create a long term, reinforced berm, that can take overtopping.	n/a	n/a	n/a	Good, especially if wrapped in plastic	Good, especially if wrapped in plastic	Good, especially if wrapped in plastic
How Could this Option Fail?	Loss of freeboard, failure of the dyke, dyke erosion/settlement causing undercutting, bearing capacity issues, improper installation, vandalism.	Human error	The greatest point of failure would come from water eroding or scouring away the soil they are sitting on. This is easily mitigated against by using a plastic liner as detailed above.	The greatest point of failure would come from water eroding or scouring away the soil they are sitting on. This is easily mitigated against by using a plastic liner as detailed above.	The greatest point of failure would come from water eroding or scouring away the soil they are sitting on. This is easily mitigated against by using a plastic liner as detailed above.	None	Mechanical Failure: mechanical impact by heavy duty truck or similar (can be prevented)	Holes in the plastic wrap or bags, foundation instability	Holes in the plastic wrap or bags, foundation instability	Blocks could crack or fall from foundation instability

Appendix B DETAILED OPINION OF PROBABLE COSTS

Table B.1. Class D Opinion of Probable Cost for Option 5- Raising Roads & Trails

Item No.	Description	Unit	Unit Cost	Quanitity	Total Cost
General					
1.1	Mobilization & Demobilization (10% of subtotal)	ls	$ 410,000.00	1	$ 410,000.00
1.2	Traffic Control	ls	$ 5,000.00	1	$ 5,000.00
1.3	Utility Coordination	ls	$ 5,000.00	1	$ 5,000.00
1.4	Construction Survey	ls	$ 15,000.00	1	$ 15,000.00
1.5	Utilization of Government of Yukon	ls	$ 5,000.00	1	$ 5,000.00
				Subtotal	**$ 440,000.00**
Army Beach Road					
2.1	Rough Grading	sq.m.	$ 5.00	11100	$ 55,500.00
2.2	Sub-grade prepartion	sq.m.	$ 5.00	11100	$ 55,500.00
2.3	Sub-base, depth varies	cu.m.	$ 50.00	31500	$ 1,575,000.00
2.4	Base, 100 mm depth	cu.m.	$ 45.00	1200	$ 54,000.00
2.5	BST Surfacing	sq.m.	$ 35.00	11100	$ 388,500.00
				Subtotal	**$ 2,128,500.00**
South McClintock Road					
3.1	Rough Grading	sq.m.	$ 5.00	6500	$ 32,500.00
3.2	Sub-grade prepartion	sq.m.	$ 5.00	6500	$ 32,500.00
3.3	Sub-base, depth varies	cu.m.	$ 50.00	14800	$ 740,000.00
3.4	Base, 100 mm depth	cu.m.	$ 45.00	700	$ 31,500.00
3.5	BST Surfacing	sq.m.	$ 35.00	6500	$ 227,500.00
				Subtotal	**$ 1,064,000.00**
Bay View					
4.1	Rough Grading	sq.m.	$ 5.00	4400	$ 22,000.00
4.2	Sub-grade prepartion	sq.m.	$ 5.00	4400	$ 22,000.00
4.3	Sub-base, depth varies	cu.m.	$ 50.00	6100	$ 305,000.00
4.4	Base, 100 mm depth	cu.m.	$ 45.00	500	$ 22,500.00
4.5	BST Surfacing	sq.m.	$ 35.00	4400	$ 154,000.00
				Subtotal	**$ 525,500.00**
Taylor Way					
5.1	Rough Grading	sq.m.	$ 5.00	2800	$ 14,000.00
5.2	Sub-grade prepartion	sq.m.	$ 5.00	2800	$ 14,000.00
5.3	Sub-base, depth varies	cu.m.	$ 50.00	3200	$ 160,000.00
5.4	Base, 100 mm depth	cu.m.	$ 45.00	300	$ 13,500.00
5.5	BST Surfacing	sq.m.	$ 35.00	2800	$ 98,000.00
				Subtotal	**$ 299,500.00**
Connector Trail (trail between South Mclintok & Army Beach Rd)					
6.1	Rough Grading	sq.m.	$ 5.00	4100	$ 20,500.00
6.2	Sub-grade prepartion	sq.m.	$ 5.00	4100	$ 20,500.00
6.3	Sub-base, depth varies	cu.m.	$ 50.00	100	$ 5,000.00
6.4	Base, 100 mm depth	cu.m.	$ 45.00	300	$ 13,500.00
6.5	BST Surfacing	sq.m.	$ 35.00	0	$ -
				Subtotal	**$ 59,500.00**
				Total	**$ 4,517,000.00**
				Class D Accuracy Upper Range	$ 6,775,500.00

Table B.2. Class D Opinion of Probable Cost for Option 6 - Easement Platform

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
Site Preparation						
1.1	Mobilization/Demobilization	L.S.	$ 100,000.00	1	$ 100,000.00	
1.2	Site Preparation/Restoration	L.S.	$ 250,000.00	1	$ 250,000.00	
1.3	Clearing and Grubbing	m^2	$ 10.00	33,540	$ 335,400.00	
	Subtotal				**$ 685,400.00**	
Dike Materials & Installation						
2.1	Platform Fill	m^3	$ 91.00	11,623	$ 1,057,693.00	Fill ($31/m3), roundtrip hauling ($35/m3), and placement/compaction (assumed $25/m3)
2.2	Import Topsoil	m^2	$ 10.00	22,360	$ 223,600.00	Assumed for 5m platform
2.3	Seeding	m^2	$ 5.00	22,360	$ 111,800.00	Assumed for 5m platform
2.4	Erosion Protection	m^3	$ 275.00	22,390	$ 6,157,250.00	Assumed 1m thick; assumed toe tie-in is 2 m deep x 1 m thick
2.5	Seepage Cutoff Wall - Clay	m^3	$ 91.00	8,950	$ 814,450.00	Assumed 2m deep by 1m wide
2.5	Geotextile	m^2	$ 10.00	22,390	$ 223,900.00	
	Subtotal				**$ 8,588,693.00**	
	Platform Total				**$ 9,274,093.00**	
	Class D Accuracy Upper Range				$ 13,911,139.50	

Table B.3. Class D Opinion of Probable Cost for Option 6 - Demountable Flood Protection

Item No.	Description	Unit	1 Meters High			2 Meters High			Notes
			Unit Cost	Quantity	Total Cost	Unit Cost	Quantity	Total Cost	
3.1	Sandbags	ea.	1	434,175	$ 434,174.76	1	1302525	$ 1,302,525.00	Average unit cost for sandbags that YG paid in 2021
	Sand fill	m^3	$ 50.00	4,472	$ 223,600.00	$ 50.00	13416	$ 670,800.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Sandbags				**$ 657,774.76**			**$ 1,973,325.00**	
3.2	Superbags	ea.	$ 58.00	4,472	$ 259,376.00	$ 58.00	13416	$ 778,128.00	Average unit cost for superbags that YG paid in 2021
	Sand fill	m^3	$ 50.00	4,472	$ 223,600.00	$ 50.00	13416	$ 670,800.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Superbags				**$ 482,976.00**			**$ 1,448,928.00**	
3.3	Concrete Blocks	ea.	$ 777.00	2,933	$ 2,278,941.00	$ 777.00	5865	$ 4,557,105.00	Local estimate, includes material supply cost and hauling, and assumed $50 per block for unloading and installation. Estimate for 0.765m height.
3.4	AquaDam	m	$ 107.00	4,472	$ 508,504.00	$ 107.00	4472	$ 478,504.00	Includes one-time installation fee of $30,000. This cost does not include shipping
3.5	Tiger Dam	m	$ 497.00	4,472	$ 2,252,584.00	$ 1,282.00	4472	$ 5,733,104.00	Includes shipping and taxes
3.6	Hesco Barrier	m	$ 28.00	4,472	$ 155,216.00	$ 70.00	4472	$ 313,040.00	1.28 CAD:USD exchange rate used; Shipping and taxes not included
	Sand fill	m^3	$ 50.00	4,472	$ 253,600.00	$ 50.00	4472	$ 223,600.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Hesco Barrier				**$ 408,816.00**			**$ 536,640.00**	
3.7	Defencell (Hesco)	m	$ 88.00	4,472	$ 423,536.00	Not applicable			1.28 CAD:USD exchange rate used; Shipping and taxes not included
	Sand fill	m^3	$ 50.00	4,472	$ 253,600.00				Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Defencell				**$ 677,136.00**				
3.8	Muscle Wall	m	$ 135.00	4,472	$ 633,720.00	$ 768.00	4472	$ 3,434,496.00	1.28 CAD:USD exchange rate used; Shipping and taxes not included
3.9	Inero Flood Barrier	m	$ 678.00	4,472	$ 3,062,016.00	$ 1,556.00	4472	$ 6,958,432.00	Shipping and taxes not included
3.10	RS Demountable	m	$ 803.00	4,472	$ 3,621,016.00	$ 3,043.00	4472	$ 13,608,296.00	0.9 m high; Shipping and taxes not included
	Minimum				**$ 408,816.00**	**Minimum**		**$ 478,504.00**	
	Class D Accuracy Upper Range				$ 5,431,524.00	Class D Accuracy Upper Range		$ 20,412,444.00	

Table B.4. Class D Opinion of Probable Cost for Option 6 - Operations and Maintenance - Non-Flood Year

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
4.1	Inspections	L.S.	$ 10,000.00	1	$ 10,000.00	
4.2	Upkeep/Repairs	L.S.	$ 50,000.00	1	$ 50,000.00	
4.3	Storage of Demountables	L.S.	$ 50,000.00	1	$ 50,000.00	
	Subtotal				**$ 110,000.00**	
	Class D Accuracy Upper Range				$ 165,000.00	

Table B.5. Class D Opinion of Probable Cost for Option 6 - Operations and Maintenance - Flood Year

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
5.1	Inspections	L.S.	$ 100,000.00	1	$ 100,000.00	
5.2	Repairs	L.S.	$ 200,000.00	1	$ 200,000.00	
5.3	Storage of Demountables	L.S.	$ 50,000.00	1	$ 50,000.00	
5.4	Demountable mobilization/demobilization	L.S.	$ 300,000.00	1	$ 300,000.00	
	Subtotal				**$ 650,000.00**	
	Class D Accuracy Upper Range				$ 975,000.00	

Table B.6. Class D Opinion of Probable Cost for Option 7A - Clay Dike

Item No.	Description	Unit	Unit Cost	Structure Line Quantity	Structure Line Total Cost	Property Line Quantity	Property Line Total Cost	Notes
Site Preparation								
1.1	Mobilization/Demobilization	L.S.	$ 250,000.00	1	$ 250,000.00	1	$ 250,000.00	
1.2	Site Preparation/Restoration	L.S.	$ 500,000.00	1	$ 500,000.00	1	$ 500,000.00	
1.3	Clearing and Grubbing	m^2	$ 10.00	139,000	$ 1,390,000.00	160,200	$ 1,602,000.00	Includes 5m root-free zone on inside of dike
1.4	Topsoil Excavation and Disposal Offsite	m^3	$ 25.00	45,200	$ 1,130,000.00	51,600	$ 1,290,000.00	Assumed 0.3m topsoil depth removal plus seepage cut-off wall of 2m deep and 1 m wide
	Subtotal				**$ 3,270,000.00**		**$ 3,642,000.00**	
Dike Materials & Installation								
2.1	Dike Fill	m^3	$ 91.00	180,800	$ 16,452,800.00	239,400	$ 21,785,400.00	Fill ($31/m3), roundtrip hauling ($35/m3), and placement/compaction (assumed $25/m3)
2.2	Import Topsoil	m^2	$ 10.00	65,600	$ 656,000.00	83,700	$ 837,000.00	Assumed dry-side, top of dike and 5 m cleared area on inside of dike
2.3	Seeding	m^2	$ 5.00	65,600	$ 328,000.00	83,700	$ 418,500.00	Assumed dry-side, top of dike and 5 m cleared area on inside of dike
2.4	Erosion Protection	m^3	$ 275.00	61,500	$ 16,912,500.00	66,900	$ 18,397,500.00	Assumed 1m thick; assumed toe tie-in is 2 m deep x 1 m thick
2.5	Seepage Cutoff Wall - Clay Fill	m^3	$ 91.00	9,800	$ 891,800.00	9,800	$ 891,800.00	Assumed 2m deep by 1m wide
2.6	Geotextile	m^2	$ 10.00	61,500	$ 615,000.00	66,900	$ 669,000.00	Below riprap on wet side slope
2.7	Culverts	lm	$ 500.00	800	$ 400,000.00	1,000	$ 500,000.00	Assumed 0.3m diameter, every 3-5 properties
2.8	Culvert Gates - Wetside (flap gates)	ea.	$ 2,000.00	34	$ 68,000.00	34	$ 68,000.00	
2.9	Culvert Gates - Dryside (canal gates/sluice)	ea.	$ 3,500.00	34	$ 119,000.00	34	$ 119,000.00	
	Subtotal				**$ 36,443,100.00**		**$ 43,686,200.00**	
	Dike Total				**$ 39,713,100.00**		**$ 47,328,200.00**	
	Class D Accuracy Upper Range				$ 59,569,650.00		$ 70,992,300.00	

Table B.7. Class D Opinion of Probable Cost for Option 7A - Operations and Maintenance - Non-Flood Year

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
3.1	Inspections	L.S.	$ 10,000.00	1	$ 10,000.00	
3.2	Upkeep/Repairs	L.S.	$ 50,000.00	1	$ 50,000.00	
	Subtotal				**$ 60,000.00**	
	Class D Accuracy Upper Range				$ 90,000.00	

Table B.8. Class D Opinion of Probable Cost for Option 7A - Operations and Maintenance - Flood Year

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
4.1	Inspections	L.S.	$ 25,000.00	1	$ 25,000.00	
4.2	Repairs	L.S.	$ 200,000.00	1	$ 200,000.00	
	Subtotal				**$ 225,000.00**	
	Class D Accuracy Upper Range				$ 337,500.00	

Table B.9. Class D Opinion of Probable Cost for Option 7B - Clay Dike with Platform and 1 m Demountable Flood Barrier

Item No.	Description	Unit	Unit Cost	Structure Line		Property Line		Notes
				Quantity	Total Cost	Quantity	Total Cost	
Site Preparation								
1.1	Mobilization/Demobilization	L.S.	$ 250,000.00	1	$ 250,000.00	1	$ 250,000.00	
1.2	Site Preparation/Restoration	L.S.	$ 500,000.00	1	$ 500,000.00	1	$ 500,000.00	
1.3	Clearing and Grubbing	m^2	$ 10.00	110,600	$ 1,106,000.00	126,800	$ 1,268,000.00	Includes 5m root-free zone on inside of dike
1.4	Topsoil Excavation and Disposal Offsite	m^3	$ 25.00	36,700	$ 917,500.00	41,400	$ 1,035,000.00	Assumed 0.3m topsoil depth removal plus seepage cut-off wall of 2m deep and 1 m wide
	Subtotal				**$ 2,773,500.00**		**$ 3,053,000.00**	
Permanent Dike Materials & Installation								
2.1	Dike Fill	m^3	$ 91.00	100,900	$ 9,181,900.00	146,800	$ 13,358,800.00	Fill ($31/m3), roundtrip hauling ($35/m3), and placement/compaction (assumed $25/m3)
2.2	Import Topsoil	m^2	$ 10.00	62,300	$ 623,000.00	75,300	$ 753,000.00	Assumed dry-side, top of dike and 5 m cleared area on inside of dike
2.3	Seeding	m^2	$ 5.00	62,300	$ 311,500.00	75,300	$ 376,500.00	Assumed dry-side, top of dike and 5 m cleared area on inside of dike
2.4	Erosion Protection	m^3	$ 275.00	49,400	$ 13,585,000.00	51,900	$ 14,272,500.00	Assumed 1m thick; assumed toe tie-in is 2 m deep x 1 m thick
2.5	Seepage Cutoff Wall - Clay	m^3	$ 91.00	9,700	$ 882,700.00	9,600	$ 873,600.00	Assumed 2m deep by 1m wide
2.6	Geotextile	m^2	$ 10.00	49,400	$ 494,000.00	51,900	$ 519,000.00	Below riprap on wet side slope
2.7	Culverts	lm	$ 500.00	600	$ 300,000.00	800	$ 400,000.00	Assumed 0.3m diameter, every 3-5 properties
2.8	Culvert Gates - Wetside (flap gates)	ea.	$ 2,000.00	34	$ 68,000.00	34	$ 68,000.00	
2.9	Culvert Gates - Dryside (canal gates/sluice)	ea.	$ 3,500.00	34	$ 119,000.00	34	$ 119,000.00	
	Subtotal				**$ 25,565,100.00**		**$ 30,740,400.00**	
	Permanent Dike Total				**$ 28,338,600.00**		**$ 33,793,400.00**	
	Class D Accuracy Lower Range				$ 14,169,300.00		$ 16,896,700.00	
	Class D Accuracy Upper Range				$ 42,507,900.00		$ 50,690,100.00	

Table B.10. Class D Opinion of Probable Cost for Option 7B - 1 m High Demountable Flood Protection

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
3.1	Sandbags	ea.	1	426,214	$ 426,213.59	Average unit cost for sandbags that YG paid in 2021
3.1.1	Sand fill	m^3	$ 50.00	4,390	$ 219,500.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Sandbags				**$ 645,713.59**	
3.2	Superbags	ea.	$ 58.00	4,390	$ 254,620.00	Average unit cost for superbags that YG paid in 2021
3.2.1	Sand fill	m^3	$ 50.00	4,390	$ 219,500.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Superbags				**$ 474,120.00**	
3.3	Concrete Blocks	ea.	$ 777.00	2,879	$ 2,236,983.00	Local estimate, includes material supply cost and hauling, and assumed $50 per block for unloading and installation. Estimate
3.4	AquaDam	m	$ 107.00	4,390	$ 499,730.00	Includes one-time installation fee of $30,000. This cost does not include shipping
3.5	Tiger Dam	m	$ 497.00	4,390	$ 2,211,830.00	Includes shipping and taxes
3.6	Hesco Barrier	m	$ 28.00	4,390	$ 152,920.00	1.28 CAD:USD exchange rate used; Shipping and taxes not included
3.6.1	Sand fill	m^3	$ 50.00	4,390	$ 249,500.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Hesco Barrier				**$ 402,420.00**	
3.7	Defencell (Hesco)	m	$ 88.00	4,390	$ 416,320.00	1.28 CAD:USD exchange rate used; Shipping and taxes not included
3.7.1	Sand fill	m^3	$ 50.00	4,390	$ 249,500.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Defencell				**$ 665,820.00**	
3.8	Muscle Wall	m	$ 135.00	4,390	$ 622,650.00	1.28 CAD:USD exchange rate used; Shipping and taxes not included
3.9	Inero Flood Barrier	m	$ 678.00	4,390	$ 3,006,420.00	Shipping and taxes not included
3.10	RS Demountable	m	$ 803.00	4,390	$ 3,555,170.00	0.9 m high; Shipping and taxes not included
	Minimum				**$ 402,420.00**	
	Class D Accuracy Upper Range				$ 5,332,755.00	

Table B.11. Class D Opinion of Probable Cost for Option 7B - Operations and Maintenance - Non-Flood Year

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
4.1	Inspections	L.S.	$ 10,000.00	1	$ 10,000.00	
4.2	Upkeep/Repairs	L.S.	$ 50,000.00	1	$ 50,000.00	
4.3	Storage of Demountables	L.S.	$ 25,000.00	1	$ 25,000.00	
	Subtotal				**$ 85,000.00**	
	Class D Accuracy Upper Range				$ 127,500.00	

Table B.12. Class D Opinion of Probable Cost for Option 7B - Operations and Maintenance - Flood Year

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
5.1	Inspections	L.S.	$ 100,000.00	1	$ 100,000.00	
5.2	Repairs	L.S.	$ 200,000.00	1	$ 200,000.00	
5.3	Storage of Demountables	L.S.	$ 25,000.00	1	$ 25,000.00	
5.4	Demountable mobilization/demobilization	L.S.	$ 300,000.00	1	$ 300,000.00	
	Subtotal				**$ 625,000.00**	
	Class D Accuracy Upper Range				$ 937,500.00	

Table B.13. Class D Opinion of Probable Cost for Option 7C - Clay Dike with Platform and 2 m Demountable Flood Barrier

Item No.	Description	Unit	Unit Cost	Structure Line		Property Line		Notes
				Quantity	Total Cost	Quantity	Total Cost	
Site Preparation								
1.1	Mobilization/Demobilization	L.S.	$ 250,000.00	1	$ 250,000.00	1	$ 250,000.00	
1.2	Site Preparation/Restoration	L.S.	$ 500,000.00	1	$ 500,000.00	1	$ 500,000.00	
1.3	Clearing and Grubbing	m^2	$ 10.00	79,200	$ 792,000.00	96,300	$ 963,000.00	Includes 5m root-free zone on inside of dike
1.4	Topsoil Excavation and Disposal Offsite	m^3	$ 25.00	27,200	$ 680,000.00	32,300	$ 807,500.00	Assumed 0.3m topsoil depth removal plus seepage cut-off wall of 2m deep and 1 m wide
					$ 2,222,000.00		**$ 2,520,500.00**	
Permanent Dike Materials & Installation								
2.1	Dike Fill	m^3	$ 91.00	44,200	$ 4,022,200.00	76,000	$ 6,916,000.00	Fill ($31/m3), roundtrip hauling ($35/m3), and placement/compaction (assumed $25/m3)
2.2	Import Topsoil	m^2	$ 10.00	64,000	$ 640,000.00	68,300	$ 683,000.00	Assumed dry-side, top of dike and 5 m cleared area on inside of dike
2.3	Seeding	m^2	$ 5.00	64,000	$ 320,000.00	68,300	$ 341,500.00	Assumed dry-side, top of dike and 5 m cleared area on inside of dike
2.4	Erosion Protection	m^2	$ 275.00	36,100	$ 9,927,500.00	38,400	$ 10,560,000.00	Assumed 1m thick; assumed toe tie-in is 2 m deep x 1 m thick
2.5	Seepage Cutoff Wall - Clay	m^3	$ 91.00	9,600	$ 873,600.00	9,600	$ 873,600.00	Assumed 2m deep by 1m wide
2.6	Geotextile	m^2	$ 10.00	36,100	$ 361,000.00	38,400	$ 384,000.00	
2.7	Culverts	lm	$ 500.00	400	$ 200,000.00	600	$ 300,000.00	Assumed 0.3m diameter, every 3-5 properties
2.8	Culvert Gates - Wetside (flap gates)	ea.	$ 2,000.00	34	$ 68,000.00	34	$ 68,000.00	
2.9	Culvert Gates - Dryside (canal gates/sluice)	ea.	$ 3,500.00	34	$ 119,000.00	34	$ 119,000.00	
	Subtotal				**$ 16,531,300.00**		**$ 20,245,100.00**	
	Permanent Dike Total				**$ 18,753,300.00**		**$ 22,765,600.00**	
	Class D Accuracy Upper Range				$ 28,129,950.00		$ 34,148,400.00	

Table B.14. Class D Opinion of Probable Cost for Option 7C - 2 m High Demountable Flood Protection

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
3.1	Sandbags	ea.	1	1,269,612	$ 1,269,611.65	Average unit cost for sandbags that YG paid in 2021
3.1.1	Sand fill	m^3	$ 50.00	13,077	$ 653,850.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Sandbags				**$ 1,923,461.65**	
3.2	Superbags	ea.	$ 58.00	13,077	$ 758,466.00	Average unit cost for superbags that YG paid in 2021
3.2.1	Sand fill	m^3	$ 50.00	13,077	$ 653,850.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Superbags				**$ 1,412,316.00**	
3.3	Concrete Blocks	ea.	$ 777.00	5,717	$ 4,442,109.00	Local estimate, includes material supply cost and hauling, and assumed $50 per block for unloading and
3.4	AquaDam	m	$ 107.00	4,359	$ 496,413.00	Includes one-time installation fee of $30,000. This cost does not include shipping
3.5	Tiger Dam	m	$ 1,282.00	4,359	$ 5,588,238.00	Includes shipping and taxes
3.6	Hesco Barrier	m	$ 70.00	4,359	$ 305,130.00	1.28 CAD:USD exchange rate used; Shipping and taxes not included
3.6.1	Sand fill	m^3	$ 50.00	4,359	$ 247,950.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Hesco Barrier				**$ 553,080.00**	
3.8	Muscle Wall	m	$ 768.00	4,359	$ 3,347,712.00	1.28 CAD:USD exchange rate used; Shipping and taxes not included
3.9	Inero Flood Barrier	m	$ 1,556.00	4,359	$ 6,782,604.00	Shipping and taxes not included
3.10	RS Demountable	m	$ 3,043.00	4,359	$ 13,264,437.00	0.9 m high; Shipping and taxes not included
	Minimum				**$ 496,413.00**	
	Class D Accuracy Upper Range				$ 19,896,655.50	

Table B.15. Class D Opinion of Probable Cost for Option 7C - Operations and Maintenance - Non-Flood Year

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
4.1	Inspections	L.S.	$ 10,000.00	1	$ 10,000.00	
4.2	Upkeep/Repairs	L.S.	$ 50,000.00	1	$ 50,000.00	
4.3	Storage of Demountables	L.S.	$ 50,000.00	1	$ 50,000.00	
	Subtotal				**$ 110,000.00**	
	Class D Accuracy Upper Range				$ 165,000.00	

Table B.16. Class D Opinion of Probable Cost for Option 7C - Operations and Maintenance - Flood Year

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
5.1	Inspections	L.S.	$ 100,000.00	1	$ 100,000.00	
5.2	Repairs	L.S.	$ 200,000.00	1	$ 200,000.00	
5.3	Storage of Demountables	L.S.	$ 50,000.00	1	$ 50,000.00	
5.4	Demountable mobilization/demobilization	L.S.	$ 300,000.00	1	$ 300,000.00	
	Subtotal				**$ 650,000.00**	
	Class D Accuracy Upper Range				$ 975,000.00	

Table B.17. Class D Opinion of Probable Cost for Option 8A - Structural Dike

Item No.	Description	Unit	Unit Cost	Structure Line		Property Line		Notes
				Quantity	Total Cost	Quantity	Total Cost	
Site Preparation								
1.1	Mobilization/Demobilization	L.S.	$ 300,000.00	1	$ 300,000.00	1	$ 300,000.00	
1.2	Site Preparation/Restoration	L.S.	$ 700,000.00	1	$ 700,000.00	1	$ 700,000.00	
1.3	Clearing and Grubbing	m^2	$ 10.00	45,200	$ 452,000.00	45,300	$ 453,000.00	Includes 5m root-free zone on inside of dike
1.4	Topsoil Excavation and Disposal Offsite	m^3	$ 20.00	18,300	$ 366,000.00	23,600	$ 472,000.00	Assumed 0.3m topsoil depth removal plus seepage cut-off wall of 2m deep and 1 m wide
	Subtotal				**$ 1,818,000.00**		**$ 1,925,000.00**	
Dike Materials								
2.1	Dike Fill	m^3	$ 91.00	52,600	$ 4,786,600.00	56,400	$ 5,132,400.00	Fill ($31/m3), roundtrip hauling ($35/m3), and placement/compaction (assumed $25/m3)
	Structural items for dike							
2.2	Sheet Pile (Lakeside dike wall)	m^2	$ 1,000.00	34,536	$ 34,536,000.00	34,640	$ 34,640,000.00	Assumed to be 8 m long (4 m above existing ground, acts as erosion protection; 4 m below existing ground, acts as seepage cutoff)
2.3	Property Side Dike Wall							
2.3.1	Modular blocks (property side dike wall)	m^2	$ 900.00	10,793	$ 9,713,700.00	15,588	$ 14,029,200.00	assumes blocks, geogrid, granular, and internal drainage
2.3.2	Concrete blocks (property side dike wall)	m^2	$ 666.00	10,793	$ 7,188,138.00	15,588	$ 10,381,608.00	
2.4	Import Topsoil	m^2	$ 10.00	38,000	$ 380,000.00	38,200	$ 382,000.00	Assumed for top of dike, and 5 m cleared area on inside of dike
2.5	Seeding	m^2	$ 5.00	38,000	$ 190,000.00	38,200	$ 191,000.00	Assumed for top of dike, and 5 m cleared area on inside of dike
2.6	Culverts	lm	$ 500.00	200	$ 100,000.00	200	$ 100,000.00	Assumed 0.3m diameter, every 3-5 properties
2.7	Culvert Gates - Wetside (flap gates)	ea.	$ 2,000.00	34	$ 68,000.00	34	$ 68,000.00	
2.8	Culvert Gates - Dryside (canal gates)	ea.	$ 3,500.00	34	$ 119,000.00	34	$ 119,000.00	
	Modular Blocks Dike Subtotal				**$ 49,893,300.00**		**$ 54,661,600.00**	
	Concrete Blocks Dike Subtotal				**$ 47,367,738.00**		**$ 51,014,008.00**	
	Modular Blocks Dike Total				**$ 51,711,300.00**		**$ 56,586,600.00**	
	Class D Accuracy Upper Range				$ 77,566,950.00		$ 84,879,900.00	
	Concrete Blocks Dike Total				**$ 49,185,738.00**		**$ 52,939,008.00**	
	Class D Accuracy Upper Range				$ 73,778,607.00		$ 79,408,512.00	

Table B.18. Class D Opinion of Probable Cost for Option 8A - Operations and Maintenance - Non-Flood Year

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
3.1	Inspections	L.S.	$ 10,000.00	1	$ 10,000.00	
3.2	Upkeep/Repairs	L.S.	$ 50,000.00	1	$ 50,000.00	
	Subtotal				**$ 60,000.00**	
	Class D Accuracy Upper Range				$ 90,000.00	

Table B.19. Class D Opinion of Probable Cost for Option 8A - Operations and Maintenance - Flood Year

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
4.1	Inspections	L.S.	$ 100,000.00	1	$ 100,000.00	
4.2	Repairs	L.S.	$ 200,000.00	1	$ 200,000.00	
	Subtotal				**$ 300,000.00**	
	Class D Accuracy Upper Range				$ 450,000.00	

Table B.20. Class D Opinion of Probable Cost for Option 8B - Structural Dike with Platform and 1 m Demountable Flood Barrier

Item No.	Description	Unit	Unit Cost	Structure Line Quantity	Structure Line Total Cost	Property Line Quantity	Property Line Total Cost	Notes
Site Preparation								
1.1	Mobilization/Demobilization	L.S.	$ 300,000.00	1	$ 300,000.00	1	$ 300,000.00	
1.2	Site Preparation/Restoration	L.S.	$ 700,000.00	1	$ 700,000.00	1	$ 700,000.00	
1.3	Clearing and Grubbing	m^2	$ 10.00	47,400	$ 474,000.00	47,600	$ 476,000.00	Includes 5m root-free zone on inside of dike
1.4	Topsoil Excavation and Disposal Offsite	m^3	$ 20.00	14,300	$ 286,000.00	19,500	$ 390,000.00	Assumed 0.3m topsoil depth removal plus seepage cut-off wall of 2m deep and 1 m wide
	Subtotal				**$ 1,760,000.00**		**$ 1,866,000.00**	
Dike Materials								
2.1	Dike Fill	m^3	$ 91.00	46,600	$ 4,240,600.00	42,100	$ 3,831,100.00	Fill ($31/m3), roundtrip hauling ($35/m3), and placement/compaction (assumed $25/m3)
	Structural items for dike							
2.2	Sheet Pile (Lakeside dike wall)	m^2	$ 1,000.00	30,121	$ 30,121,000.00	30,254	$ 30,254,000.00	Assumed to be 7 m long (3 m above existing ground, acts as erosion protection; 4 m below existing ground, acts as seepage cutoff)
2.3	Property Side Dike Wall							
2.3.1	Modular blocks (property side dike wall)	m^2	$ 900.00	6,455	$ 5,809,500.00	11,237	$ 10,113,300.00	assumes blocks, geogrid, granular, and internal drainage
2.3.2	Concrete blocks (property side dike wall)	m^3	$ 666.00	6,455	$ 4,299,030.00	11,237	$ 7,483,842.00	
2.4	Import Topsoil	m^2	$ 10.00	42,600	$ 426,000.00	42,800	$ 428,000.00	Assumed for top of dike
2.5	Seeding	m^2	$ 5.00	42,600	$ 213,000.00	42,800	$ 214,000.00	Assumed for top of dike
2.6	Culverts	lm	$ 500.00	200	$ 100,000.00	200	$ 100,000.00	Assumed 0.3m diameter, every 3-5 properties
2.7	Culvert Gates - Wetside (flap gates)	ea.	$ 2,000.00	34	$ 68,000.00	34	$ 68,000.00	
2.8	Culvert Gates - Dryside (canal gates)	ea.	$ 3,500.00	34	$ 119,000.00	34	$ 119,000.00	
	Modular Blocks Dike Subtotal				**$ 41,097,100.00**		**$ 45,127,400.00**	
	Concrete Blocks Dike Subtotal				**$ 39,586,630.00**		**$ 42,497,942.00**	
	Modular Blocks Dike Total				**$ 42,857,100.00**		**$ 46,993,400.00**	
	Class D Accuracy Upper Range				$ 64,285,650.00		$ 70,490,100.00	
	Concrete Blocks Dike Total				**$ 41,346,630.00**		**$ 44,363,942.00**	
	Class D Accuracy Upper Range				$ 62,019,945.00		$ 66,545,913.00	

Table B.21. Class D Opinion of Probable Cost for Option 8B - 1 m High Demountable Flood Protection

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
3.1	Sandbags	ea.	1	419,612	$ 419,611.65	Average unit cost for sandbags that YG paid in 2021
3.1.1	Sand fill	m^3	$ 50.00	4,322	$ 216,100.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Sandbags				**$ 635,711.65**	
3.2	Superbags	ea.	$ 58.00	4,322	$ 250,676.00	Average unit cost for superbags that YG paid in 2021
3.2.1	Sand fill	m^3	$ 50.00	4,322	$ 216,100.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Superbags				**$ 466,776.00**	
3.3	Concrete Blocks	ea.	$ 777.00	2,835	$ 2,202,795.00	Local estimate, includes material supply cost and hauling, and assumed $50 per block for unloading and installation. Estimate for 1.53m height.
3.4	AquaDam	m	$ 107.00	4,322	$ 492,454.00	Includes one-time installation fee of $30,000. This cost does not include shipping
3.5	Tiger Dam	m	$ 497.00	4,322	$ 2,178,034.00	Includes shipping and taxes
3.6	Hesco Barrier	m	$ 28.00	4,322	$ 151,016.00	1.28 CAD:USD exchange rate used; Shipping and taxes not included
3.6.1	Sand fill	m^3	$ 50.00	4,322	$ 246,100.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Hesco Barrier				**$ 397,116.00**	
3.7	Defencell (Hesco)	m	$ 88.00	4,322	$ 410,336.00	1.28 CAD:USD exchange rate used; Shipping and taxes not included
3.7.1	Sand fill	m^3	$ 50.00	4,322	$ 246,100.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Defencell				**$ 656,436.00**	
3.8	Muscle Wall	m	$ 135.00	4,322	$ 613,470.00	1.28 CAD:USD exchange rate used; Shipping and taxes not included
3.9	Inero Flood Barrier	m	$ 678.00	4,322	$ 2,960,316.00	Shipping and taxes not included
3.10	RS Demountable	m	$ 803.00	4,322	$ 3,500,566.00	0.9 m high; Shipping and taxes not included
	Minimum				**$ 397,116.00**	
	Class D Accuracy Upper Range				$ 5,250,849.00	

Table B.22. Class D Opinion of Probable Cost for Option 8B - Operations and Maintenance - Non-Flood Year

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
4.1	Inspections	L.S.	$ 10,000.00	1	$ 10,000.00	
4.2	Upkeep/Repairs	L.S.	$ 50,000.00	1	$ 50,000.00	
4.3	Storage of Demountables	L.S.	$ 25,000.00	1	$ 25,000.00	
	Subtotal				**$ 85,000.00**	
	Class D Accuracy Upper Range				$ 127,500.00	

Table B.23. Class D Opinion of Probable Cost for Option 8B - Operations and Maintenance - Flood Year

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
5.1	Inspections	L.S.	$ 100,000.00	1	$ 100,000.00	
5.2	Repairs	L.S.	$ 200,000.00	1	$ 200,000.00	
5.3	Storage of Demountables	L.S.	$ 25,000.00	1	$ 25,000.00	
5.4	Demountable mobilization/demobilization	L.S.	$ 300,000.00	1	$ 300,000.00	
	Subtotal				**$ 625,000.00**	
	Class D Accuracy Upper Range				$ 937,500.00	

Table B.24. Class D Opinion of Probable Cost for Option 8C - Structural Dike with Platform and 2 m Demountable Flood Barrier

Item No.	Description	Unit	Unit Cost	Structure Line		Property Line		Notes
				Quantity	Total Cost	Quantity	Total Cost	
Site Preparation								
1.1	Mobilization/Demobilization	L.S.	$ 300,000.00	1	$ 300,000.00	1	$ 300,000.00	
1.2	Site Preparation/Restoration	L.S.	$ 700,000.00	1	$ 700,000.00	1	$ 700,000.00	
1.3	Clearing and Grubbing	m^2	$ 10.00	49,600	$ 496,000.00	49,800	$ 498,000.00	Includes 5m root-free zone on inside of dike
1.4	Topsoil Excavation and Disposal Offsite	m^3	$ 20.00	10,200	$ 204,000.00	15,500	$ 310,000.00	Assumed 0.3m topsoil depth removal plus seepage cut-off wall of 2m deep and 1 m wide
	Subtotal				**$ 1,700,000.00**		**$ 1,808,000.00**	
Dike Materials								
2.1	Dike Fill	m^3	$ 91.00	20,500	$ 1,865,500.00	31,900	$ 2,902,900.00	Fill ($31/m3), roundtrip hauling ($35/m3), and placement/compaction (assumed $25/m3)
	Structural items for dike							
2.2	Sheet Pile (Lakeside dike wall)	m^2	$ 1,000.00	25,740	$ 25,740,000.00	25,860	$ 25,860,000.00	Assumed to be 6 m long (2 m above existing ground, acts as erosion protection; 4 m below existing ground, acts as seepage cutoff)
2.3	Property Side Dike Wall							
2.3.1	Modular blocks (property side dike wall)	m^2	$ 900.00	2,145	$ 1,930,500.00	6,896	$ 6,206,400.00	assumes blocks, geogrid, granular, and internal drainage
2.3.2	Concrete blocks (property side dike wall)	m^2	$ 666.00	2,145	$ 1,428,570.00	6,896	$ 4,592,736.00	
2.5	Import Topsoil	m^2	$ 10.00	47,200	$ 472,000.00	47,500	$ 475,000.00	Assumed for top of dike, and 5 m cleared area on inside of dike
2.6	Seeding	m^2	$ 5.00	47,200	$ 236,000.00	47,500	$ 237,500.00	Assumed for top of dike, and 5 m cleared area on inside of dike
2.7	Geotextile	m^2	$ 10.00	15,015	$ 150,150.00	17,240	$ 172,400.00	
2.8	Culverts	lm	$ 500.00	200	$ 100,000.00	200	$ 100,000.00	Assumed 0.3m diameter, every 3-5 properties
2.9	Culvert Gates - Wetside (flap gates)	ea.	$ 2,000.00	34	$ 68,000.00	34	$ 68,000.00	
2.10	Culvert Gates - Dryside (canal gates)	ea.	$ 3,500.00	34	$ 119,000.00	34	$ 119,000.00	
	Modular Blocks Dike Subtotal				**$ 30,681,150.00**		**$ 36,141,200.00**	
	Concrete Blocks Dike Subtotal				**$ 28,313,720.00**		**$ 31,624,636.00**	
	Modular Blocks Dike Total				**$ 30,681,150.00**		**$ 36,141,200.00**	
	Class D Accuracy Upper Range				$ 46,021,725.00		$ 54,211,800.00	
	Concrete Blocks Dike Total				**$ 28,313,720.00**		**$ 31,624,636.00**	
	Class D Accuracy Upper Range				$ 42,470,580.00		$ 47,436,954.00	

Table B.25. Class D Opinion of Probable Cost for Option 8C - 2 m High Demountable Flood Protection

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
3.1	Sandbags	ea.	1	1,255,340	$ 1,255,339.81	Average unit cost for sandbags that YG paid in 2021
3.1.1	Sand fill	m^3	$ 50.00	12,930	$ 646,500.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Sandbags				**$ 1,901,839.81**	
3.2	Superbags	ea.	$ 58.00	12,930	$ 749,940.00	Average unit cost for superbags that YG paid in 2021
3.2.1	Sand fill	m^3	$ 50.00	12,930	$ 646,500.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Superbags				**$ 1,396,440.00**	
3.3	Concrete Blocks	ea.	$ 777.00	5,653	$ 4,392,381.00	Local estimate, includes material supply cost and hauling, and assumed $50 per block for unloading and installation. Estimate for 1.53m height.
3.4	AquaDam	m	$ 107.00	4,310	$ 491,170.00	Includes one-time installation fee of $30,000. This cost does not include shipping
3.5	Tiger Dam	m	$ 1,282.00	4,310	$ 5,525,420.00	Includes shipping and taxes
3.6	Hesco Barrier	m	$ 70.00	4,310	$ 301,700.00	1.28 CAD:USD exchange rate used; Shipping and taxes not included
3.6.1	Sand fill	m^3	$ 50.00	4,310	$ 245,500.00	Quantity calculated based on CAF-style dikes. Local unit cost estimates ranged from $40 - $63/m3
	Total for Hesco Barrier				**$ 547,200.00**	
3.8	Muscle Wall	m	$ 768.00	4,310	$ 3,310,080.00	1.28 CAD:USD exchange rate used; Shipping and taxes not included
3.9	Inero Flood Barrier	m	$ 1,556.00	4,310	$ 6,706,360.00	Shipping and taxes not included
3.10	RS Demountable	m	$ 3,043.00	4,310	$ 13,115,330.00	0.9 m high; Shipping and taxes not included
	Minimum				**$ 491,170.00**	
	Class D Accuracy Upper Range				$ 19,672,995.00	

Table B.26. Class D Opinion of Probable Cost for Option 8C - Operations and Maintenance - Non-Flood Year

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
	Inspections	L.S.	$ 10,000.00	1	$ 10,000.00	
	Upkeep/Repairs	L.S.	$ 50,000.00	1	$ 50,000.00	
	Storage of Demountables	L.S.	$ 50,000.00	1	$ 50,000.00	
	Subtotal				**$ 110,000.00**	
	Class D Accuracy Upper Range				$ 165,000.00	

Table B.27. Class D Opinion of Probable Cost for Option 8C - Operations and Maintenance - Flood Year

Item No.	Description	Unit	Unit Cost	Quantity	Total Cost	Notes
	Inspections	L.S.	$ 100,000.00	1	$ 100,000.00	
	Repairs	L.S.	$ 200,000.00	1	$ 200,000.00	
	Storage of Demountables	L.S.	$ 50,000.00	1	$ 50,000.00	
	Demountable mobilization/demobilization	L.S.	$ 300,000.00	1	$ 300,000.00	
	Subtotal				**$ 650,000.00**	
	Class D Accuracy Upper Range				$ 975,000.00	

Appendix C STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec's present understanding of the site-specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site-specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock, and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec will not be responsible to any party for damages incurred as a result of failing to notify Stantec that differing site or sub-surface conditions are present upon becoming aware of such conditions.

PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec, sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc.), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec cannot be responsible for site work carried out without being present.