

Appendix N Swan Haven Conceptual Flood Mitigation Design Options

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

N.1 Existing Conditions

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

N.1.1 POPULATION

Marsh Lake has a population of 746 with 527 private dwellings according to the 2021 census data (Statistics Canada 2023c). The population has increased by approximately 7% from 2016 when the population was 696 (Statistics Canada 2023c). Census data specific to Swan Haven community were not available. Based on available aerial imagery, there are approximately 17 properties with structures on them within the Study Area.

N.1.2 STUDY AREA

The Study Area in Figure N2 outlines the areas that are considered in this Project at Swan Haven. The boundaries of the Study Area are based on Stantec's understanding that the flood mitigations are to be considered for communities, and that individual properties outside of the main community consolidation are not included.

N.1.3 FIRST NATIONS

The Swan Haven area is within the Traditional Territories of the Kwanlin Dün First Nation (KDFN) and the Carcross/Tagish First Nation (CTFN). The KDFN have parcels of Category B Settlement Lands in the Swan Haven area. The land claim selection is KDFN R-78E and S-15 4B1/D. 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, should also be considered when engaging with local stakeholders. Figure N2 illustrates the KDFN, C/TFN, and TKC settlement lands within the Study Area.

N.1.4 BATHYMETRY AND TOPOGRAPHY

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

- 2022 LiDAR LAS files UTM Zone 8 CSRS NAD1983, CGVD2013 (McElhanney Ltd, GeoYukon 2023) and interpolated into a derivative 1m horizontal resolution Digital Elevation Model (DEM) (Government of Yukon 2022e).

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

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N.1.5 GEOLOGY

Based on the surficial geology mapping (Yukon Geological Survey 2020), the Study Area likely consists of undivided pre-Quaternary glaciolacustrine deposits. Glaciolacustrine sediments likely found at the Study Area likely consist of lakebed sediments of stratified fine sand, silt and/or clay and moderately sorted to well sorted sand and coarser beach sediment that were transported and deposited by wave action along the margins of the glacial lake. Slump structures and associated hummocky, kettled and irregular terrain, such as that seen at Swan Haven, are common in and along the margins of a glacially fed lake and are caused by the collapse of material due to melting ice.

Based on the Permafrost Probability Model (Bonnaventure et al. 2012), the Study Area is located within a region of sporadic discontinuous permafrost (10-20% of land area underlain by permafrost). The Canada Permafrost Map (National Atlas of Canada 1995) also indicates the Study Area is in a region of sporadic discontinuous permafrost (10-50% of land underlain by permafrost) with a low (<10% by volume of visible ice) ground ice content in the upper 10-20 m of the ground.

N.1.6 HYDROGEOLOGY

The sand, silt and/or clay and sorted sand and beach gravel encountered within the Study Area are likely to result in relatively medium to fast rates of groundwater flow. The deposits encompassing most of shoreline are likely to result in a groundwater table that would be highly dependant on the Marsh Lake water levels. During flooding, the high-water levels would result in high groundwater levels and after flood waters recede, it is likely that the groundwater levels would recede relatively quickly based on the permeability of the soil conditions in the area.

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

N.1.7 PAST FLOODING EVENTS AND RESPONSE

There was no documentation of past flooding events and their associated response in the Study Area available to Stantec at the time of writing.

N.1.8 EXISTING FLOOD MITIGATION INFRASTRUCTURE

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

N.1.9 WIND, WAVES, AND EROSION

The low flow velocities at Marsh Lake are not expected to introduce erosion risks to flood mitigations. Erosion protection from riverine flow velocities is not anticipated to be required at Swan Haven flood mitigations.

As a lake community, Swan Haven is affected by erosion due to wind and waves. Flood mitigations would need to be capable of withstanding not only the erosion potential from wind and waves, but higher WSEs

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due to wave runup and potential lake seiche. Natural beach processes and morphodynamics should be studied and considered in preliminary and detailed design phases of flood mitigations.

N.1.10 HYDROLOGY

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

Marsh Lake is the most downstream lake in the Southern Lakes system. The community of Swan Haven is located on the northwest side of Marsh Lake.

WSC Station 09AB004 (Marsh Lake near Whitehorse) is located on the northwest side of Marsh Lake. Gross drainage area to WSC Station 09AB004 is not reported by GoC (2023). The hydrology review considered WSEs at WSC Station 09AB004. Flood frequency analysis for WSEs was performed by both Morrison Hershfield (2022) and Yukon University (2022) for WSEs at WSC Station 09AB004. Table N1 summarizes the frequency results of these two studies.

Table N1 Flood Frequency Analyses at WSC Station 09AB004 from Morrison Hershfield (2022) and Yukon University (2022)

	Morrison Hershfield (2022)	Yukon University (2022)
Years Included in Analysis	1985-2022	1970- 2021
Number of Years	38	52
Selected Distribution	Log-Pearson Type 3	Gumbel
Water Surface Elevation (m) ¹		
1:2 Event (50% AEP)	656.70	656.70
1:20 Event (5% AEP)	657.45	657.60
1:100 Event (1% AEP)	657.83	not provided
1:200 Event (0.5% AEP)	657.98	658.30
Note:	¹ Elevations provided in CGVD2013 for WSC Station 09AB004	

The Yukon University (2022) flood frequency analysis results were adopted for the Project because the 1:200-year event WSE was higher and would yield more conservative designs.

Figure N1 illustrates the on-record daily minimum, mean, and maximum WSEs, the WSE during the highest year on record (2021), and the WSEs for the 1:2-year and 1:200-year event at WSC Station

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09AB004 from Yukon University (2022). The mentioned water levels do not include wave runup which could be affected by wind, its direction, intensity, duration, and the beach profile.

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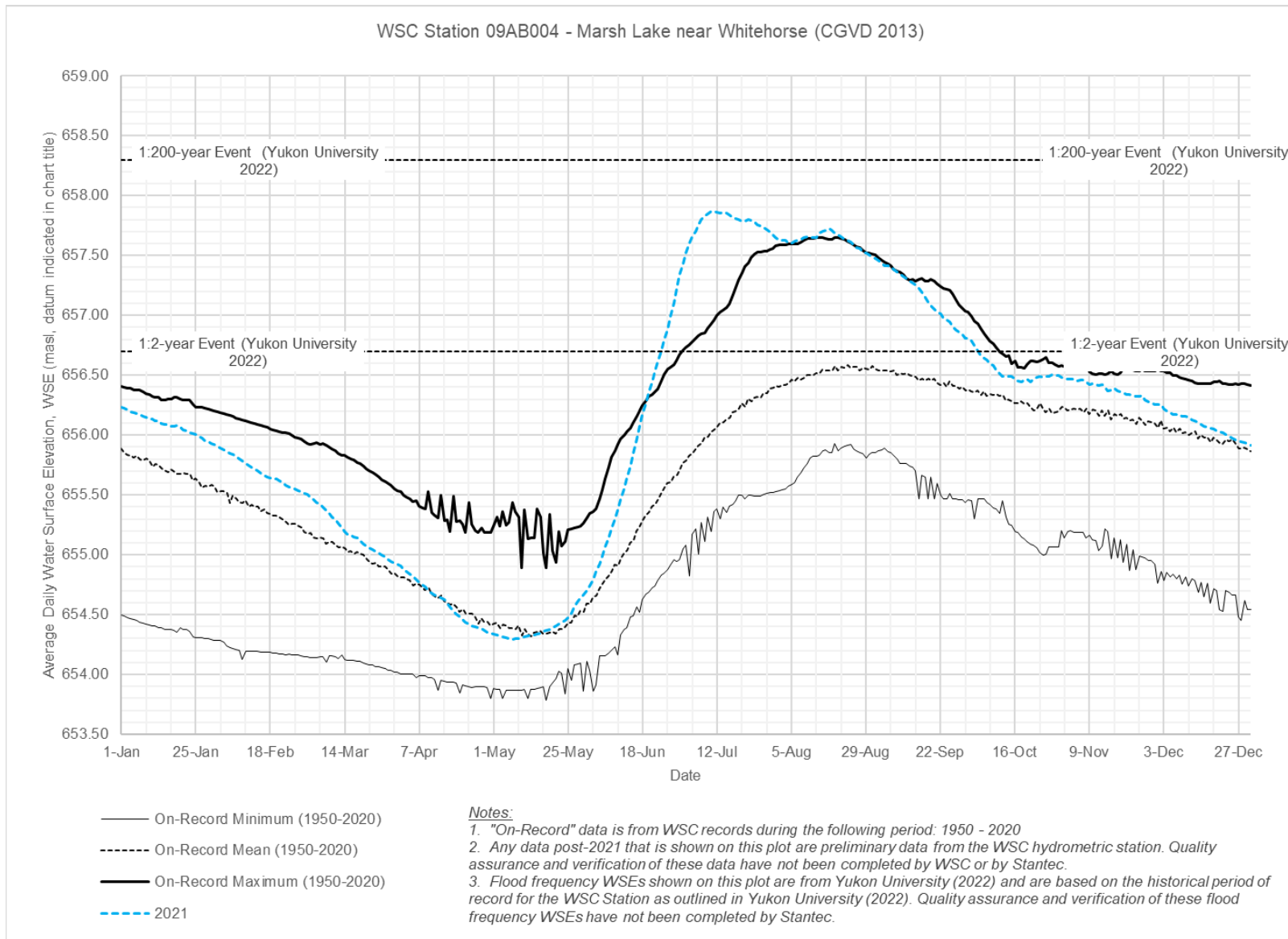


Figure N1 Historical Water Surface Elevations at WSC 09AB004 (Marsh Lake near Whitehorse)

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N.1.11 PRELIMINARY INUNDATION MAPPING

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

In lieu of floodplain mapping, Stantec performed preliminary existing conditions (no mitigation) inundation analysis for Swan Haven using WSEs. This analysis considered the 1:200-year event WSE (658.30 m) developed by Yukon University (2022) in a flat-water inundation scenario. The resulting water surface was overlain on the existing conditions topographic/bathymetric elevation data (McElhanney Ltd., GeoYukon 2023) and the limits of inundation were mapped (Figure N2). The inundation analysis performed herein is provided for information only and is considered a high-level estimate of the flood inundation under the 1:200-year WSE from Yukon University (2022). The preliminary inundation analysis does not take into account flow pathways and blockages. That is, if the land in a given location is below the 1:200 WSE surface, it presents as inundated whether or not there is an overland flow path for the water to arrive there.

The preliminary inundation analysis indicated that no properties were inundated at Swan Haven.

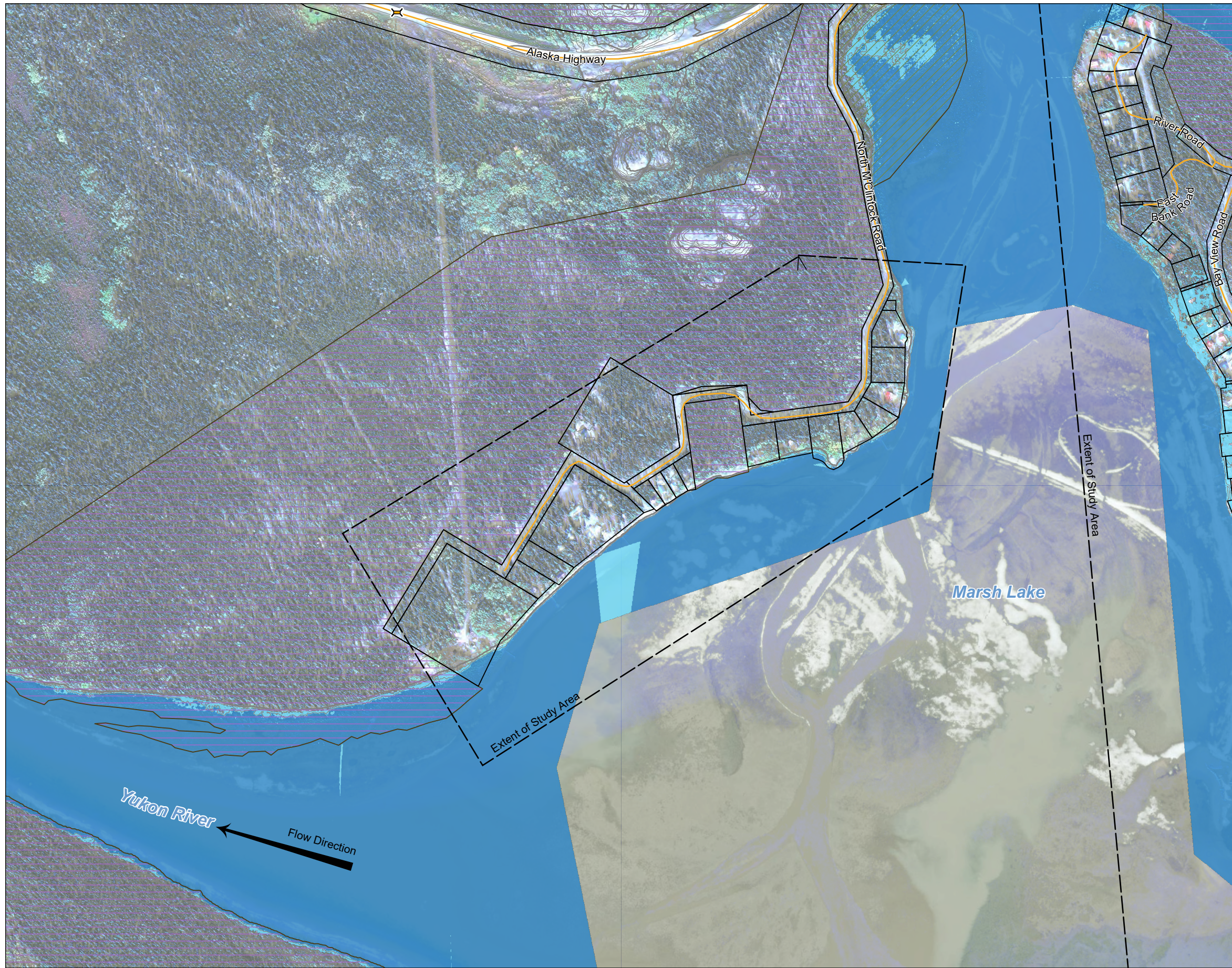
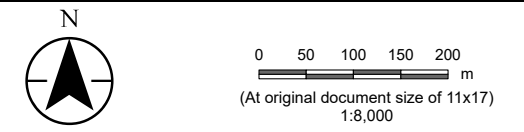


Figure No. **N2**
Existing Conditions and Preliminary Flood Inundation at Swan Haven

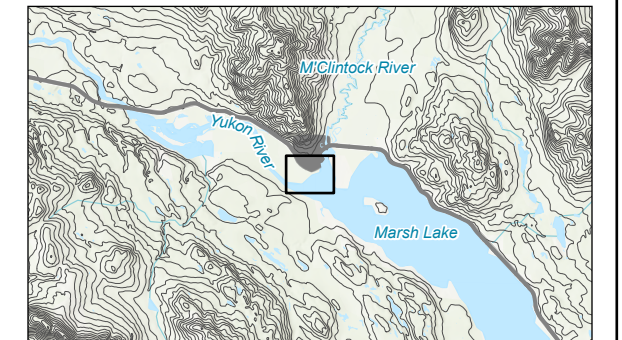
Client/Project: Government of Yukon
 Community Services | Infrastructure Development Branch
 Yukon Territory Flood Mitigation Conceptual Design Options

Project Location: Swan Haven, Yukon
 Prepared by LLT on 2023-05-08
 TR by JD on 2023-05-08



- Culvert/ Bridge
 - Highway Kilometre Post
 - Road
 - Topographic Contour (10 m)
 - Topographic Contour (2 m)
 - Land Parcel - Surveyed
 - First Nation Settlement Lands - Surveyed
 - First Nation Heritage Site
- Water Depth at 1:200 WSE Inundation (m)
- 0 - 1
 - 1 - 2
 - > 2

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



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



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N.2 Mitigation Options and Evaluation

Based on the objectives and assumptions presented in the main body this Report and the Preliminary Inundation Mapping (Figure N2), there are no properties or critical infrastructure that are anticipated to be inundated in a 1:200-year flood at Swan Haven. Therefore, no flood mitigation options were developed for Swan Haven.

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

Swan Haven is anticipated to be affected by wind and wave erosion. Mitigation of erosion hazards at Yukon communities is outside the scope of this Project, however these hazards should be studied at Swan Haven given its potential impact the community.