

## Appendix K Dawson City Conceptual Flood Mitigation Design Options

## **K.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 Dawson City.

### **K.1.1 POPULATION**

Dawson City has a population of 1,577 with 836 private dwellings according to 2021 census data (Statistics Canada 2023c). The population has increased by approximately 15% from 2016 when the population was 1,375 (Statistics Canada 2023c).

### **K.1.2 STUDY AREA**

The Study Area in Figure K3 outlines the areas that flood mitigations are being conceptually designed for in this Project at Dawson. These include the areas of downtown Dawson and developments to the east along the Klondike River valley. 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 to be included.

### **K.1.3 FIRST NATIONS**

Dawson City is within the Traditional Territories of the Tr'ondëk Hwëch'in First Nation (TH). The TH have parcels of Category A and B Settlement Lands on the along the Klondike River and Yukon River near Dawson City. The land claim selections include: C-13B, C-87FS, R-20A, C-4B/D, C-86FS/D, C-85FS/D, S-211B/D, C-76FS, S-104 FS/D, C-77FS/D, C-70B, C-42B, C-3B and S-160B. This means that TH has surface and subsurface ownership of this parcel of land (Government of Yukon 2022). Figure K3 illustrates the TH settlement lands within the Study Area.

### **K.1.4 BATHYMETRY AND TOPOGRAPHY**

Bathymetry data for the Yukon River and Klondike River at Dawson were not provided to Stantec.

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

- 2019 LiDAR derivative 1m horizontal resolution Digital Elevation Model (DEM), UTM Zone 7 CSRS NAD1983, CGVD1928 (Government of Yukon 2022d)

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).

### **K.1.5 GEOLOGY**

The Study Area can be broken into two distinct geological areas: Dawson City and Klondike Valley. Both areas are located within a region of extensive discontinuous permafrost (80-90% of land area underlain by permafrost) according to the Permafrost Probability Model (Bonnaventure et al. 2012). The Canada *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.*

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Permafrost Map (National Atlas of Canada 1995) also indicates the Study Area is in a region of extensive discontinuous permafrost (50-90% of land area underlain by permafrost) with a low to medium (<10-20% by volume of visible ice) ground ice content in the upper 10-20 m of the ground.

#### **Dawson City**

Based on the surficial geology mapping (Yukon Geological Survey 2020), the Dawson City portion of the Study Area consists of Holocene fluvial deposits of resedimented silt, sand, fill, and peat underlain at depth by coarse gravel. At the southern end of the city, the gravels are overlain by sand and are free of permafrost. Dawson City is bordered by colluvial deposits consisting of local bedrock clasts from gravity-driven processes such as landslides and avalanches. Bedrock outcrops form a substantial part of the surface cover (Bigras and Anderson 1984).

#### **Klondike Valley**

Based on the surficial geology mapping (Yukon Geological Survey 2020), the Klondike Valley portion of the Study Area consists of anthropogenic surficial material associated with dredge tailings along the Klondike highway extending to the south banks of the Klondike River. The material in this area is made predominantly of gravel, rubble and interstitial sand and contains minor sections of Holocene fluvial deposits made up of well sorted, stratified sand and gravel of subangular to rounded clasts. The sediment along the northern banks of the Klondike River and extending to the foothills of the highlands consists of colluvial deposits similar to the sediments bordering Dawson City.

#### **K.1.6 HYDROGEOLOGY**

The fluvial deposits made up of silt, sand, and peat underlain at depth by coarse gravel encountered within the Dawson City portion of the Study Area are likely to result in relatively slow to medium rates of groundwater flow within the shallow zone and fast groundwater flow at deeper depths. The anthropogenic deposits made up of gravel and rubble encountered within the Klondike Valley portion of the Study Area are likely to result in relatively fast rates of groundwater flow. The deposits encompassing most of the banks of the Klondike River are likely to result in a groundwater table that would be highly dependent on the Klondike River 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 slowly in the Dawson City portion and relatively quickly in the Klondike Valley portion, based on the permeability of the soil conditions in the area.

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

#### **K.1.7 PAST FLOODING EVENTS AND RESPONSE**

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

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Dawson City has been subject to numerous flooding events over the period of record dating back to 1898 (Klohn Leonoff 1986; WhatsUp Yukon 2014), with the first recorded flood event occurring in 1925 (Photograph 1, University of Calgary 2019). A summary of the documented flood events at Dawson City are provided below. The flood events summarized below are based on documentation provided to Stantec at the time of writing. Historical water surface elevations (WSEs) at Water Survey of Canada (WSC) Station 09EB001 (Yukon River at Dawson) and WSC Station 09EA003 (Klondike River above Bonanza Creek) are illustrated in Figure K1 and Figure K2, respectively.

The most severe flood events were a result of ice-jamming of the Yukon River (Jasek 1998); however, open water floods have also occurred on the Yukon River (Klohn Leonoff 1986). Orecklin (1981) identified that of the nine flood events pre-dating the date of their report, four were open water flood events (occurring in 1898, 1905, 1906, 1964), and five were floods resulting from ice jamming (1925, 1944, 1960, 1966, 1979). The Whitehorse Daily Star (1979) documents that Dawson City was flooded 22 times between 1898 and 1979, with four of them (1925, 1944, 1966, and 1969) causing considerable damages. A substantial ice jam event in the Klondike River caused overtopping of the Klondike Highway in 1986 (Turcotte and Saal 2022a).



**Photograph 1 Flooding in Downtown Dawson on May 14, 1925 (University of Calgary 2019)**

#### 1979 Flood Event

One of the largest floods on record for Dawson City occurred on May 3, 1979. Ice jams formed on each of the Yukon River, Klondike River, and Indian River. Despite efforts by residents to prevent floodwaters from entering the city by constructing a sandbag dike on top of the dike, the dike was overtopped and water poured into the community (Whitehorse Daily Star 1979; Janowicz 1990). Within 40 minutes, there was reportedly more than 2 m of water at several locations in the City (Whitehorse Daily Star 1979; Orecklin 1981). Water and ice damage to buildings and homes was extensive, historical items were

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washed away, and some structures were seen floating through the city. After the ice jam(s) released, water remained pooled in the city and the existing dike had to be breached so the floodwater could drain back to the Yukon River. Substantial damages (>\$2 million in 1979 dollars) were incurred, and a Disaster Assistance Policy was initiated by YG to assist with recovery (Whitehorse Daily Star 1979). No lives were lost in the flood of 1979.

#### **2023 Flood Event**

At the time of writing, portions of the Study Area in the Klondike River valley had recently experienced extreme flooding from ice jams in the Klondike River and Yukon River. Data, observations, and documentation of the flood event have not been completed and therefore could not be included in this Report. It is possible (and even likely) that the data, observations, and documentation from the 2023 flood would have an impact on the preliminary inundation analysis (Section K.1.11) and mitigation options (Section K.2) for the Study Area. Therefore, it is recommended that the contents of this report be reviewed and (if necessary) amended following comprehensive documentation of the 2023 flood event.

#### **K.1.8 EXISTING FLOOD MITIGATION INFRASTRUCTURE**

A protective dike was built in 1959 and subsequently raised in 1968 (McCreath 1988). It consists largely of material from the Moosehide Slide and White Channel Gravels, with a smaller percentage of silt, woodchips, peat, and gravels incorporated into the structure.

Dike improvements were carried out in the mid-1980's in response to the flooding event in the spring of 1979 (Klohn Leonoff 1986). The dike improvements were designed to protect against the 1:200-year ice-jamming flood event (as estimated at that time). The original dike had an inconsistent crest height and a low point near Duke Street. It also had 26 outlet drain pipes; the new design reduce the number of drains to 14 (Klohn Leonoff 1986). The dike was raised, on average, about 2.5 m. The landside slope was constructed at a 2:1 slope and grass covered. The riverside slope was construction at 2H:1V, below the 1:200-year event and 1.5H:1V, above the 1:200-year event. The riverside slope was protected with riprap. The dike was constructed from pitrun type material, mainly using White Channel Gravels. There were no seepage barriers or pumps considered during the design as the flood levels from ice-jamming usually recede within 24 hours and did not pose a saturation risk, and open water floods tend to have a longer duration but aren't expected to reach the same elevations as the ice-jam 1:200-year event (Klohn Leonoff 1986). Sections of the existing dike have been identified to be below the current 1:200-year flood elevation, and storm drains built into/beneath the dike may not be functional (Turcotte and Saal 2022a).

#### **K.1.9 WIND, WAVES, AND EROSION**

While floodplain mapping and associated hydraulic modelling of the DFSL has not been completed for Dawson to date, it is likely that flow velocities in the Yukon and Klondike Rivers during flood conditions would likely require any flood mitigations to include erosion protection. In addition, bank erosion and river migration should be studied and considered in preliminary and detailed design phases of flood mitigations.

Wind and wave effects are not anticipated to occur at a scale which would require additional flood mitigation design at Dawson.

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**K.1.10 HYDROLOGY**

The Study Area spans areas that are impacted by floodwaters from two rivers: the Yukon River and the Klondike River.

**Yukon River**

The Yukon River is the larger of the two rivers in the Study Area. The Yukon River conveys snowmelt, rainfall induced runoff, and glacier melt from southern Yukon and northern British Columbia northwards into Alaska and eventually the Bering Sea.

WSC Station 09EB001 (Yukon River at Dawson) is located on the east side of the Yukon River (river's right bank) at the northern (downstream) end of Dawson City. The Yukon River at WSC Station 09EB001 has a gross drainage area of 264,000 km<sup>2</sup> (GoC 2023). No hydraulic modeling of the Yukon River at Dawson City has been completed to date and is beyond the scope of this Project. Therefore, hydrology review for the Yukon River considered WSEs but not the discharges at WSC Station 09EB001.

Flood frequency analysis for WSEs was performed by both Morrison Hershfield (2022) and Yukon University (2022) at WSC Station 09EB001. Table K1 summarizes the frequency results of these two studies.

**Table K1 Flood Frequency Analyses at WSC Station 09EB001 from Morrison Hershfield (2022) and Yukon University (2022)**

	<b>Morrison Hershfield (2022)</b>	<b>Yukon University (2022)</b>
Years Included in Analysis	1982-2022 <sup>a</sup>	1970 - 2022
Number of Years	41	53
Selected Distribution	Log-Pearson Type 3	Lognormal 3
Water Surface Elevation (m) <sup>1</sup>		
1:2-Year Event (50% AEP)	316.44	316.60
1:20-Year Event (5% AEP)	317.87	318.40
1:100-Year Event (1% AEP)	318.45	not provided
1:200-Year Event (0.5% AEP)	318.66	320.50
Note:		
<sup>1</sup> Elevations provided in CGVD2013 for WSC Station 09EB001		

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. The Yukon University (2022) flood frequency analysis also included a longer period of record which included the flood event of 1979.

Figure K1 illustrates the on-record daily minimum, mean, and maximum WSEs, the WSE during the highest year on record (1964), and the WSEs for the 1:2-year and 1:200-year event at WSC Station 09EB001 from Yukon University (2022). The hydrograph of the Yukon River at Dawson is a relatively flat curve compared to other rivers in the Yukon. Orecklin (1981) attributes this to the moderating effects of Marsh, Tagish, Bennett, and Atlin Lakes and a late peak associated with glacier melt, however it is likely

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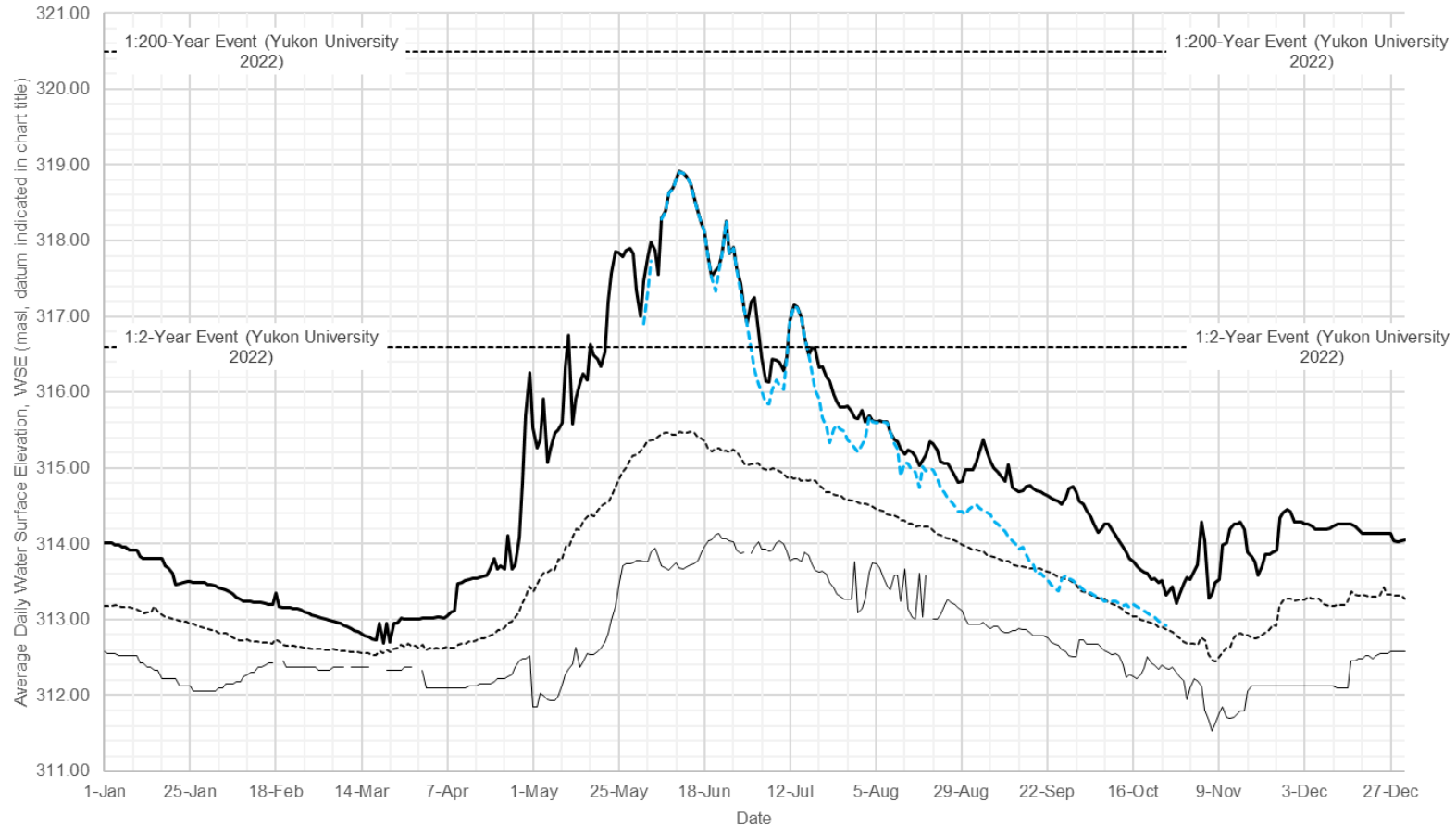
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that the dampened nature of the seasonal hydrograph is moreso due to multiple large contributing tributaries with a wide range of runoff processes. Flows typically increase in early April, rising steadily into early to mid-June, and gradually decreasing through the summer. While some flooding events in Dawson City have been the result of open water flows in the Yukon River (1898, 1964), the dominant flood process is breakup ice jams, which lead to flooding of the community in 1925, 1944, 1966, and 1979 (Yukon University 2022). Breakup ice jam flooding in the Yukon River has typically occurred between the end of April to mid May, while open water high flow events in the Yukon River have historically occurred between early June and early August (Yukon University 2022).

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WSC Station 09EB001 - Yukon River at Dawson (CGVD 1913)



- On-Record Minimum (1944; 1981-1998; 2014-2020)
- - - On-Record Mean (1944; 1981-1998; 2014-2020)
- On-Record Maximum (1944; 1981-1998; 2014-2020)
- - - 1964

Notes:

1. "On-Record" data is from WSC records during the following period: 1944; 1981-1998; 2014-2020
2. Any data post-2020 that is shown on this plot are preliminary data from the WSC hydrometric station. Quality assurance and verification of these data have not been completed by WSC or by Stantec.
3. Flood frequency WSEs shown on this plot are from Morrison Hershfield (2022) and are based on the historical period of record for the WSC Station as outlined in Morrison Hershfield (2022). Quality assurance and verification of these flood frequency WSEs have not been completed by Stantec.

**Figure K1 Historical Water Surface Elevations at WSC 09EB001 (Yukon River at Dawson)**

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**Klondike River**

The Klondike River initiates in the Ogilvie Mountains and flows to the West, draining snowmelt and rainfall induced runoff into the Yukon River. The confluence of the Yukon River and Klondike River is at the south end of Dawson City.

WSC Station 09EA003 (Klondike River at Bonanza) is located on the north side of the Klondike River (river's right bank) to the east of Dawson City and has a gross drainage area of 7,810 km<sup>2</sup> (GoC 2023). Flood frequency analysis for WSEs was performed by Morrison Hershfield (2022) at WSC Station 09EA003. Turcotte and Saal (2022a) document a 1:200-year WSE of 324.86 m (in CGVD2013) at the Klondike River bridge (where WSC Station 09EA003 is located), which is approximately equivalent to the 1986 ice jam which overtopped the Klondike Highway. Table K2 summarizes the results of these two studies.

**Table K2 Flood Frequency Analyses at WSC Station 09EA003 from Morrison Hershfield (2022) and Yukon University (2022)**

	Morrison Hershfield (2022)	Yukon University (2022)
Years Included in Analysis	1995-2022 <sup>a</sup>	Not Provided
Number of Years	27	Not Provided
Selected Distribution	Log-Pearson Type 3	Not Provided
Water Surface Elevation (m) <sup>1</sup>		Not Provided
1:2-year Event (50% AEP)	322.33	Not Provided
1:20-year Event (5% AEP)	323.73	Not Provided
1:100-year Event (1% AEP)	324.49	324.46
1:200-year Event (0.5% AEP)	324.80	324.86
<sup>1</sup> Elevations provided in CGVD2013 for WSC Station 09EA003		

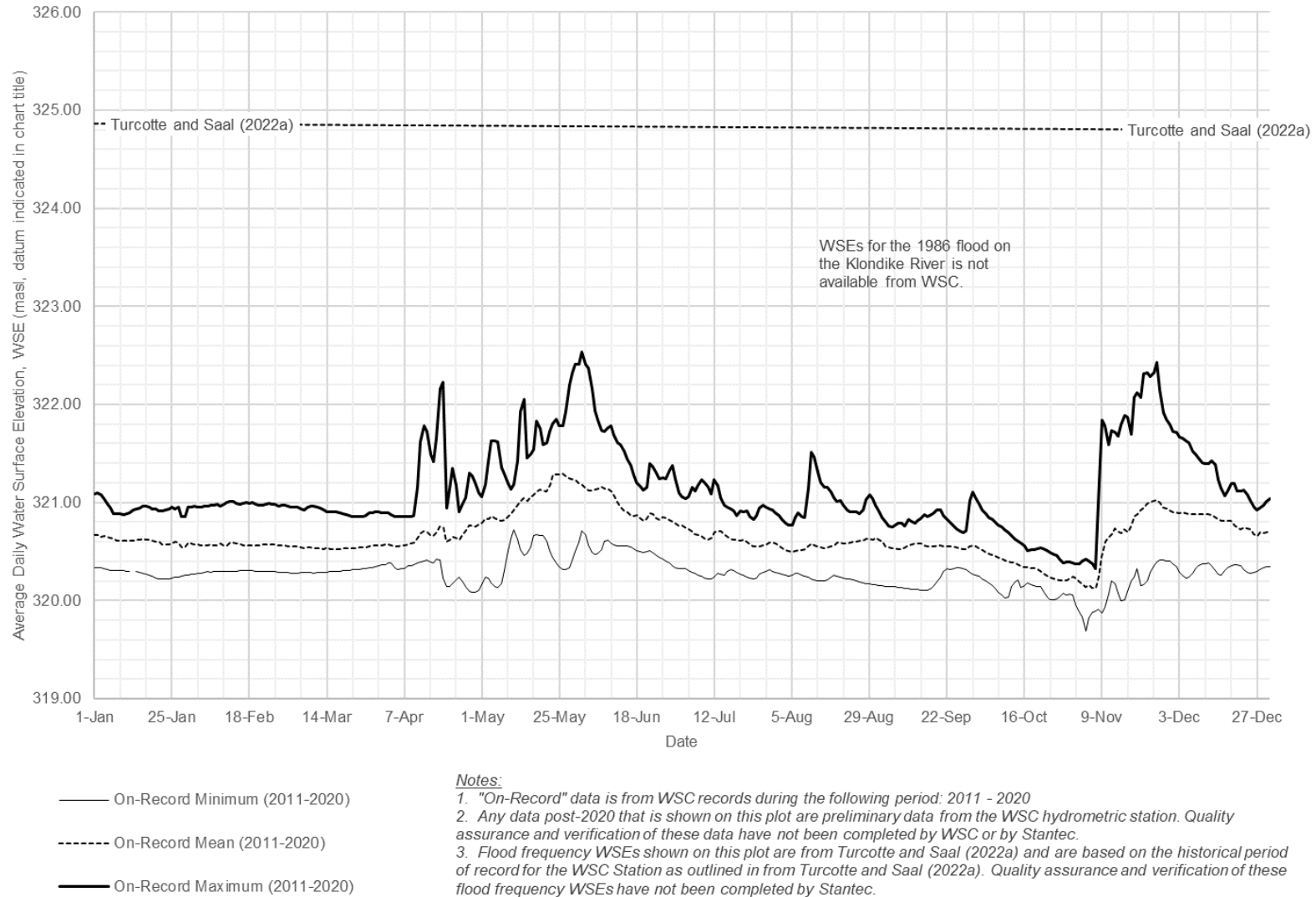
The 1:200-year WSE from Turcotte and Saal (2022a) was adopted for the Project because the 1:200-year event WSE was higher than Morrison Hershfield (2022) and would yield more conservative designs.

Figure K2 illustrates the on-record daily minimum, mean, and maximum WSEs at WSC Station 09AE003 and the 1:200 year WSE estimate from Turcotte and Saal (2022a). Flows typically increase in early April, rising steadily into early to mid-June, and gradually decreasing through the summer. Water levels rise in November and remain elevated in the winter owing to freeze-up jams (Turcotte et al. 2021). The Klondike River has wide capacity forming a delta before entering the Yukon River and can accommodate high flows and volumes of ice rubble. This hydraulic capacity serves to attenuate increasing flow volumes and this, along with the protection of the dike decreases the likelihood of flooding from the Klondike River in Dawson City (Turcotte and Saal 2022a).

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WSC Station 09EA003 - Klondike River above Bonanza (CGVD 2013)



**Figure K2 Historical Water Surface Elevations at WSC 09EA003 (Klondike River at Bonanza)**

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#### **K.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. Hydraulic analysis and floodplain mapping have not been completed to date at Dawson and is not within the scope of this Project. However, an understanding of inundation extents under the 1:200-year event(s) is required for conceptual design of flood mitigations.

In lieu of floodplain mapping, Stantec performed preliminary existing conditions (no mitigation) inundation analysis for the Study Area using WSEs and WSE slopes from previous studies:

- On the Yukon River, the preliminary inundation analysis considered the 1:200-year WSE from Yukon University (2022) of 320.50 m at WSC Station 09EB001 combined with a WSE gradient of 0.05% (as adopted by Turcotte and Saal 2022a).
- On the Klondike River, the preliminary inundation analysis considered the 1:200-year WSE from Turcotte and Saal (2022a) of 324.86 m at WSC Station 09EA003 combined with WSE gradients of 0.20% downstream of the WSC station and 0.27% upstream of the WSC station (as extracted from HEC-RAS profiles from Turcotte and Saal 2022a).

The resulting water surfaces for each of the Yukon River and Klondike River were overlain on the existing conditions topographic elevation data (GeoYukon 2023) and the limits of inundation were mapped. The boundary of the combined inundation areas (Yukon River and Klondike River) was adopted as the overall preliminary inundation for the Study Area (Figure K3). The inundation analysis performed herein is provided for information only and is considered a high-level estimate of the flood inundation using the 1:200-year WSEs and flood-stage WSE gradients from Yukon University (2022), Turcotte et al. (2021), and Turcotte and Saal (2022a). 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 indicates that substantial portions of downtown Dawson City would be flooded. Surface water would enter the city via overtopping of the dike in several locations towards the north end of Dawson, or through backflooding of the storm sewers. The storm sewers currently do not have functional backflow protection; flap gates at the downstream (river) end of 10 storm sewer outfalls have been badly damaged by river flows/ice. These inundation extents in Dawson are slightly greater than those in the flooding assessments completed by Turcotte et al. (2021) and Turcotte and Saal (2022a). This difference is a by-product of the preliminary inundation method applied in this Project, but results in a more severe flood inundation and is therefore adopted for conservatism.

In total, it is estimated that approximately 690 parcels (both residential, commercial, and government/municipal) would have at least 25% of their area inundated under the preliminary inundation scenario. It is assumed that the Klondike Highway, along with proper infrastructure on the cross culverts, would act as an impermeable barrier and act as a blockage to the inundation of the 1:200-year event from the Klondike River. Further analysis on the permeability of the Klondike Highway structure would be required.

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From west to east along the Klondike River valley, the following features/areas are inundated:

- Three private properties on TH land immediately southwest of the Klondike Highway at Dome Road
- Subdivision C4 south of the Klondike Highway south of the intersection with Dome Road (1 road and 21 private residences)
- Three commercial buildings in the Dawson RV park south of the Klondike Highway bridge
- Approximately 26 industrial lots south of the Klondike Highway off of Bonanza Road, Rabbit Creek Road, and Callison Way
- Dredge Pond Subdivision north of the Klondike Highway along Prospector Road, Tailing Drive, and Eureka Road (approximately 19 private residences and 1 road).
- Approximately 2 km of the Klondike Highway at the east end of the Study Area (1 road)

The above results in a total of approximately 765 properties (including residential, commercial, and government/municipal) would have at least 25% of their area inundated under the preliminary inundation scenario and therefore classified as “inundated properties”. Of the estimated 765 inundated properties, 690 are in downtown Dawson and 75 are in the Klondike River valley.

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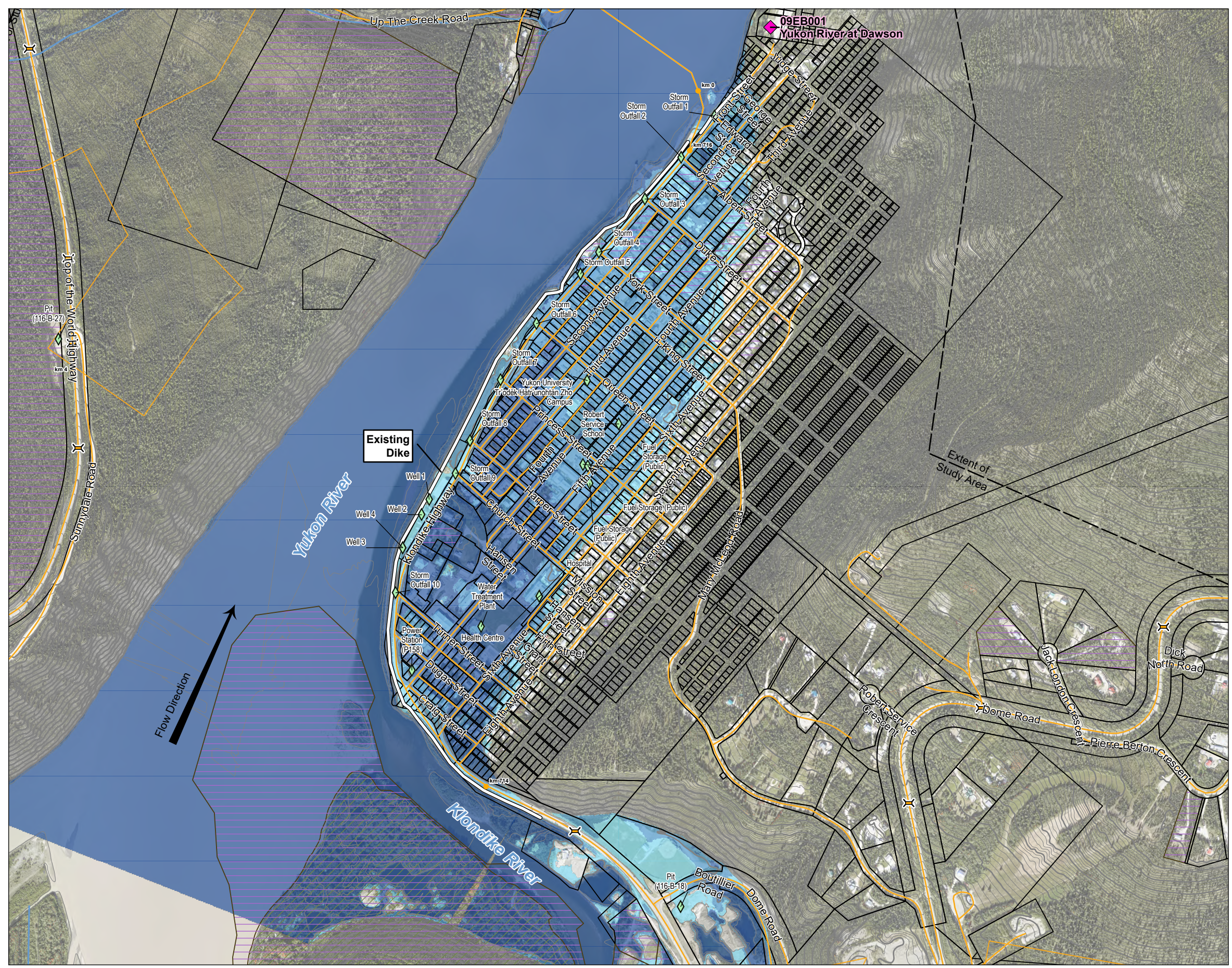
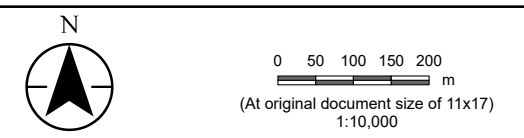


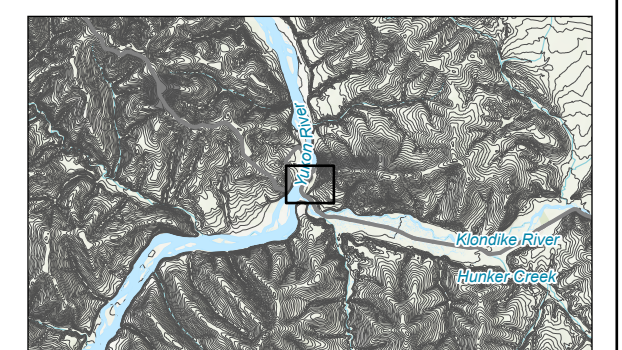
Figure No. **K3**  
**Existing Conditions and Preliminary Flood Inundation at Downtown Dawson City**  
 Client/Project: Government of Yukon  
 Community Services | Infrastructure Development Branch  
 Yukon Territory Flood Mitigation Conceptual Design Options  
 Project Location: Dawson City, Yukon  
 Prepared by LLT on 2023-05-08  
 TR by JM on 2023-05-08



- WSC Station
- Culvert/ Bridge
- Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- Placer Land Use Permit
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed
- First Nation Heritage Site
- Existing Dike

- 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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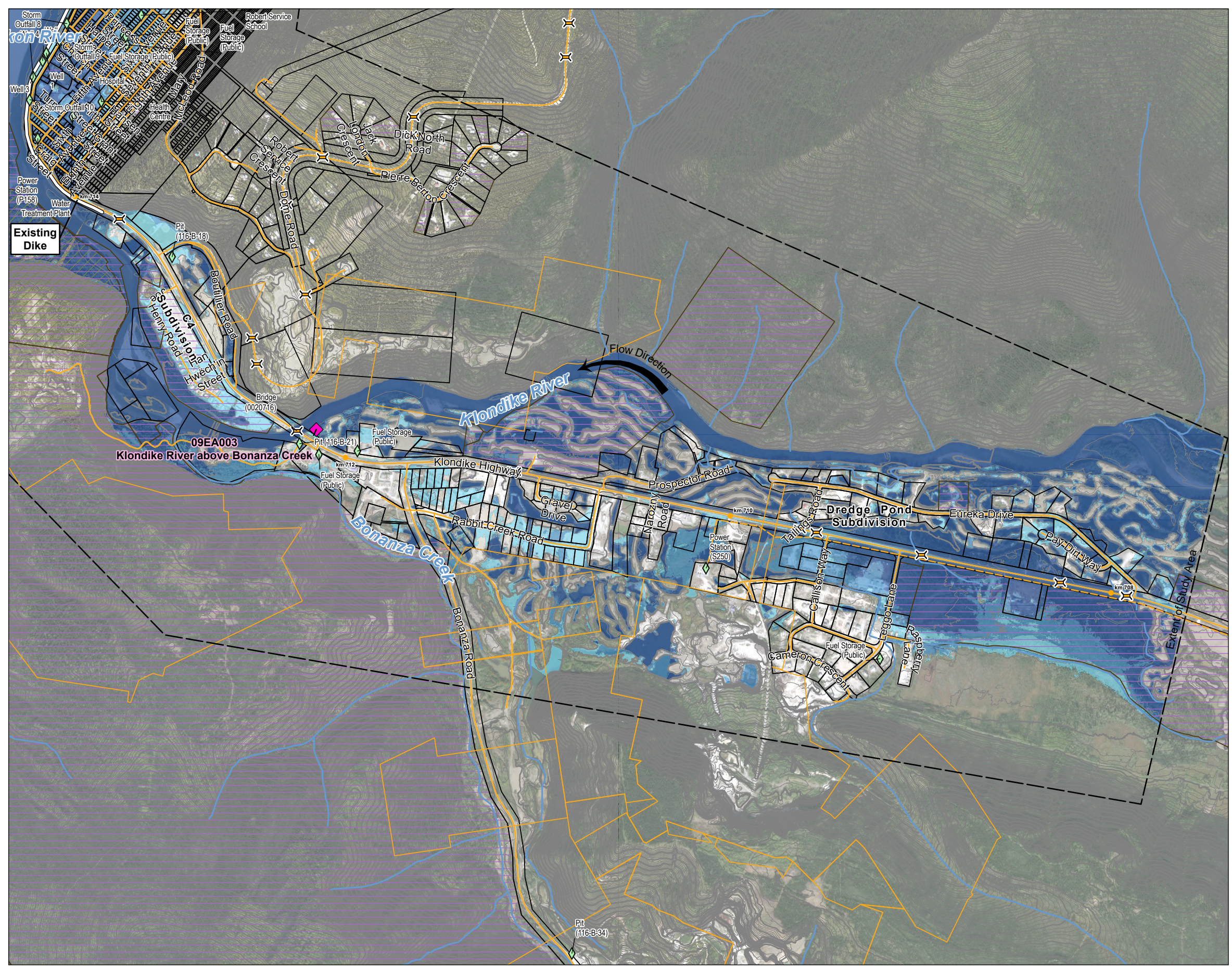


Figure No. **K4**  
**Existing Conditions and Preliminary Flood Inundation at Klondike River Valley**  
 Client/Project: Government of Yukon  
 Community Services | Infrastructure Development Branch  
 Yukon Territory Flood Mitigation Conceptual Design Options  
 Project Location: Dawson City, Yukon  
 Prepared by LLT on 2023-05-08  
 TR by JM on 2023-05-08

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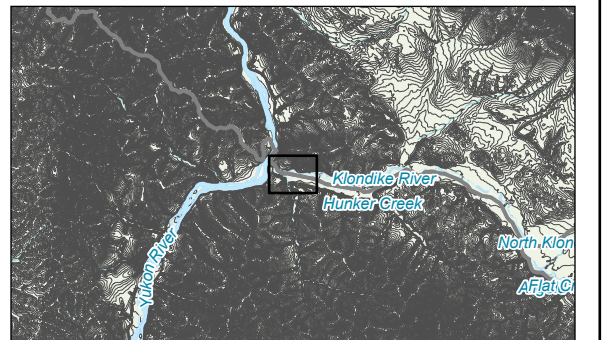
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- WSC Station
- Culvert/ Bridge
- Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- Placer Land Use Permit
- Powerline
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed
- First Nation Settlement Lands - Unsurveyed
- First Nation Heritage Site
- Existing Dike

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.



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## **K.2 Mitigation Options and Evaluation**

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

Based on the objectives and assumptions presented in the main body of this Report, two conceptual flood mitigation options were developed for Dawson City (Table K3) using multiple typical engineered flood mitigation designs from Section 3.3.2. Flood mitigations in the options were provided for areas which are inundated under the 1:200-year WSE in the preliminary inundation mapping (Figure K3). The top elevation of the flood mitigations would reach the DFSL which in the case of Dawson City (river site) is assumed to include 0.5 m of freeboard above the 1:200-year WSE as outlined for river sites in Section 3.2.

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

**Table K3 Summary of Conceptual Options**

<b>Location</b>	<b>Option 1</b>	<b>Option 2</b>
	<i>lower capital costs, higher response/maintenance</i>	<i>higher capital costs, lower response/maintenance</i>
Downtown Dawson	Dike Improvement (Earthen Dike) + Floodboxes	Dike Improvement (Earthen Dike) + Floodboxes
Private Property (North of C4)	Temporary Sandbag Dike	
C4 Subdivision (Including C4 Lift Station & TH Lands Building)	Platform with Temporary Superbag Dike (Culvert in Ditch)	Earthen Dike
Private Properties Near Dawson City RV Park & Campground	Temporary Sandbag Dike	
Private Properties on Prospector Road	Temporary Sandbag Dike	
Tailings Road	Road as Platform with Temporary Superbag Dikes (Both Sides)	Road Raising
Private Properties on Eureka Drive	Temporary Sandbag Dike	Temporary Sandbag Dike
Eureka Drive	Road as Platform with Temporary Superbag Dikes (Both Sides)	Road Raising

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**Yukon Territory Flood Mitigation Conceptual Design Options**  
**Appendix K Dawson City Conceptual Flood Mitigation Design Options**

August 2023

Klondike Highway	Superbags or Inflatable Plugs in Highway Culverts and Road Raising to Within 2 m of DFSL with Temporary Superbag Dikes (One Side)	Concrete Headwall with Flap Gates on Highway Culverts and Road Raising
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Section K.2.1 and K.2.2 provide a description, Class D OPC, and qualitative evaluation of conceptual options specified in Table K3.

Other engineered flood mitigation approaches that may have merit but were not advanced to conceptual design in this Project include:

- Bridge widening or highway alteration – The Klondike Highway bridge crossing the Klondike River likely acts as a hydraulic constriction during flood flows. Increasing bridge span or lowering adjacent highway approaches to increase hydraulic capacity and/or ice evacuation capacity may reduce flood risk but was not advanced due to substantial engineering studies to inform feasibility and anticipated high cost of construction.

**K.2.1 OPTION 1**

**Description**

The conceptual flood mitigations for Option 1 are illustrated in Figure K5 and Figure K6.

On the west and south side of Dawson City, the full ~2400 m length of the existing dike would be upgraded to meet the typical earthen dike design as outlined in Section 3.3.2. Background review did not identify instances where a flood event oversaturated the existing dike in the past; therefore this Report has assumed a clay core/seepage barrier would not be required. This assumption should be verified through intrusive testing programs and geotechnical analysis with reference to the current design standards.

Approximately 800 m of the existing dike would need to be raised by 0.5 – 0.75 m, and the remaining 1600 m must be raised from 0.25 to 0.50 m to reach the DFSL. The remainder of the dike meets or exceeds the DFSL. The existing dike embankment slopes do not consistently meet the required 3H:1V requirements in the typical earthen dike design; 3H:1V slopes (or shallower) would be established on both sides of the dike. The footprint of the upgraded earthen dike would be approximately 20 m on the river side of the dike and 5 to 10 m on the Dawson side of the dike. The river side of the earthen dike would be lined with rip rap to mitigate erosion risk on the dike from flow velocities. Slope stabilization measures may be required pending the findings of additional geotechnical investigations. The earthen dike footprint and the root-free zone may encroach onto private property meaning agreements may be required with landowners.

There are two areas within the existing dike that provide river access. The first area is at the ferry crossing; the access is at the same elevation as Front Street and provides an opening in the dike for vehicles to access the George Black Ferry. During flood conditions, this area would require a 50 m long double superbag dike. The second is another river access point, north of the SS Keno National Historic

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## **Yukon Territory Flood Mitigation Conceptual Design Options**

### **Appendix K Dawson City Conceptual Flood Mitigation Design Options**

August 2023

Site, at the same elevation as Front Street, that is mainly used by locals to access personal boats. This area would also require a 20 m long double superbag dike during flood conditions.

To mitigate against backflooding through the Dawson City sewer network and into the downtown, the existing 10 storm sewers (Turcotte et al. 2021) would be retrofitted with a maintenance access hole and a slide gate on the inside of the dike.

To mitigate against backflooding underneath the Klondike Highway and into the areas south of the highway, the 9 Klondike Highway cross-culverts (assumed diameter of 1200 mm) would be blocked with temporary superbags or inflatable pipe blockage systems.

At the C4 subdivision is on the south side of the Klondike Highway, a platform with 1100 m of temporary double superbag dike would be established around Joe Henry Road, behind the C4 Lift Station at the northwest end of the subdivision, along the backyards of the residents on Joe Henry Road, and then around the TH Lands Department property.

Approximately 2 km of the Klondike Highway would be raised to a height where it can act as a platform for a temporary double superbag dike (approximately 1 km long) or a temporary single superbag dike (also approximately 1 km long). The temporary double superbag dike would be on the north side of the highway (south side of highway would not have elevated WSEs because of aforementioned highway cross-culvert blockages). Approximately 1 km of the highway needs to be raised by 0.50 – 1.5 m to be within 2 m below the DFSL. Of the total 2 km length, approximately half (1 km) would be temporary double superbag dike and the other half (1 km) would be temporary single superbag dike.

Approximately 650 m of Eureka Drive and 50 m of Tailings Road would have a temporary single superbag dike would be constructed on both sides of the road. The construction of a superbag dike for these road segment would maintain access to dwellings located along Tailing Road and Eureka Drive.

The 25 private properties in the Study Area that are inundated would have temporary sandbag dikes around the structures:

- Private Property (north of C4) – total temporary sandbag dike length of 135 m
- Private properties near Dawson City RV Park & Campground – total temporary sandbag dike length of 245 m
- Private properties on or near Prospector Road – total temporary sandbag dike length of 740 m
- Private properties on Eureka Drive – total temporary sandbag dike length of 2,390 m

The depth of flooding around these properties is less than 1 m, meaning the temporary sandbag dikes would be up to 1.5 m high to meet the DFSL. The total length of temporary sandbag dikes would be approximately 3,510 m.

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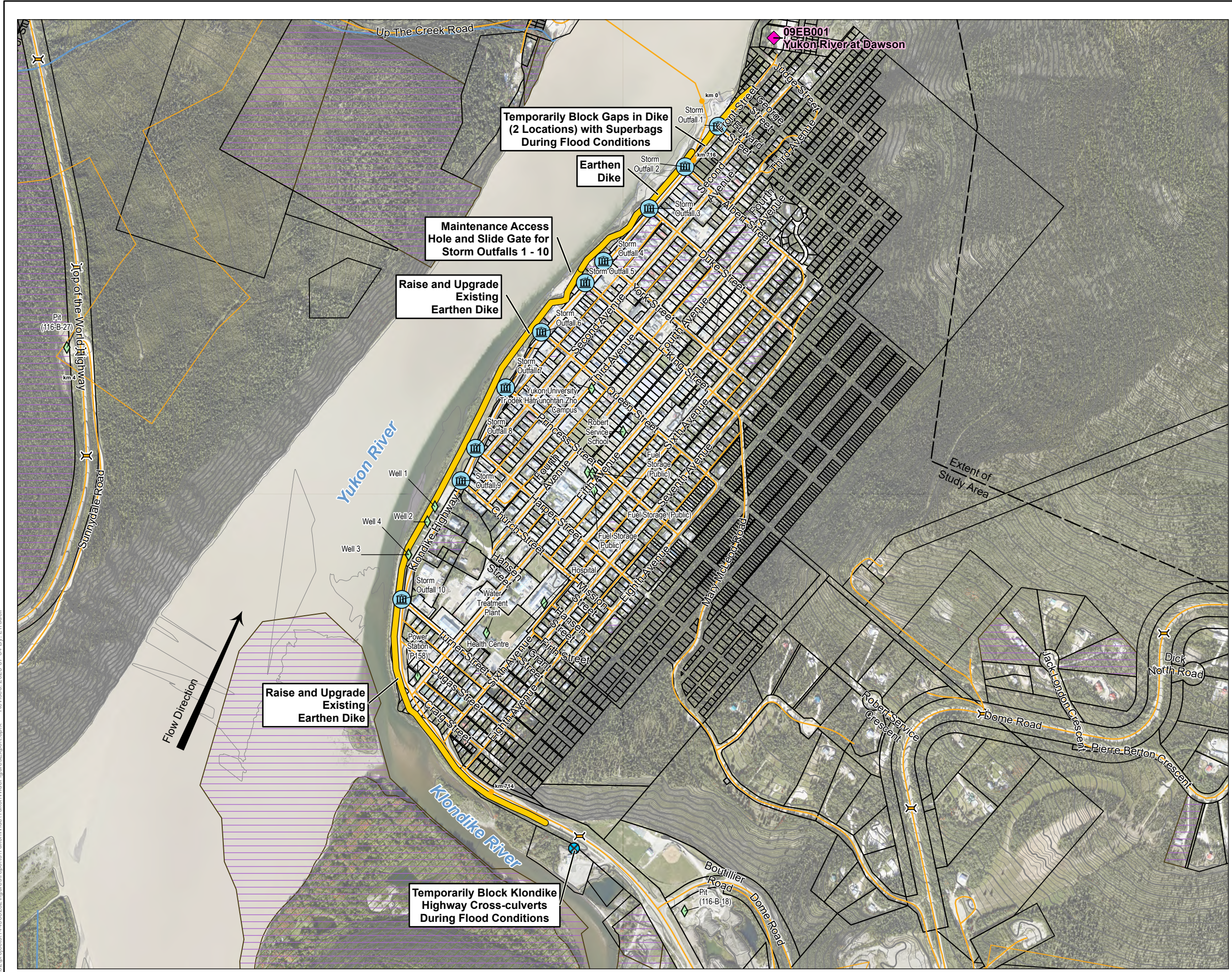


Figure No. **K5**  
 Title **Conceptual Flood Mitigation Design - Option 1 at Downtown Dawson City**  
 Client/Project Government of Yukon 144903232  
 Community Services | Infrastructure Development Branch  
 Yukon Territory Flood Mitigation Conceptual Design Options  
 Project Location Dawson City, Yukon Prepared by LLT on 2023-04-11 TR by JM on 2023-04-11

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- ◆ WSC Station
- ✕ Culvert/ Bridge
- ◇ Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- Placer Land Use Permit
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed
- First Nation Heritage Site

Proposed Mitigation Feature

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

- Ⓜ Maintenance Access Hole and Slide Gate
- ⊗ Temporarily Block Cross-culvert

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



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



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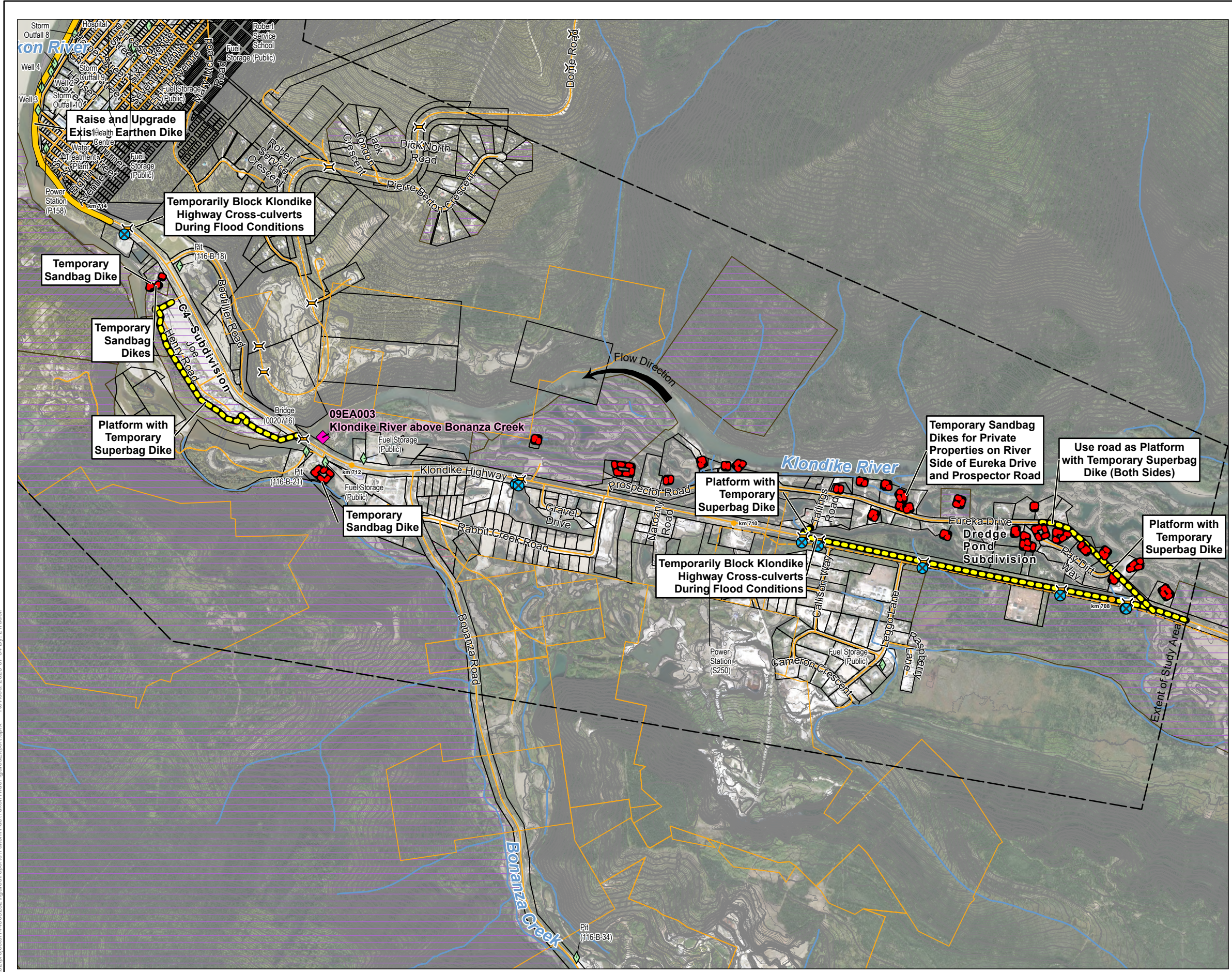


Figure No. **K6**  
**Conceptual Flood Mitigation Design - Option 1 at Klondike River Valley**

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

Project Location: Dawson City, Yukon  
 Prepared by LLT on 2023-04-11  
 TR by JM on 2023-04-11

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 (At original document size of 11x17)  
 1:10,000

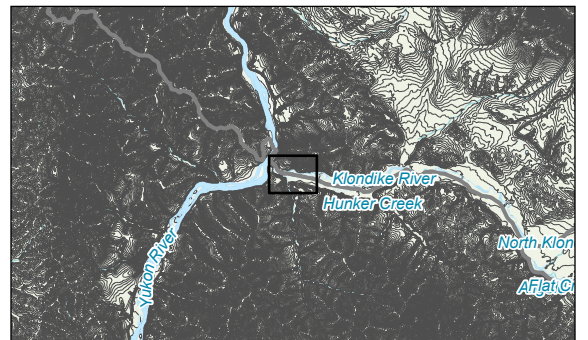
- WSC Station
- Culvert/ Bridge
- Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- Placer Land Use Permit
- Powerline
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed
- First Nation Settlement Lands - Unsurveyed
- First Nation Heritage Site

Proposed Mitigation Feature

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

Temporarily Block Cross-culvert

**CONCEPTUAL DESIGN**  
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Notes

- Coordinate System: NAD 1983 Yukon Albers
- Data Sources: Government of Yukon; Government of Canada
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**Yukon Territory Flood Mitigation Conceptual Design Options**  
**Appendix K Dawson City Conceptual Flood Mitigation Design Options**

August 2023

**Class D OPC**

The Class D OPC's for capital and annual costs are summarized in Table K4, considering the Class D level of accuracy (+/-50%). Table K4 also provides the Class D OPCs on a per inundated property basis (from Section K.1.11).

**Table K4 Option 1 Summary of Class D OPCs**

	Class D OPC	Number of Inundated Properties (Section K.1.11) <sup>1</sup>	Class D OPC per Inundated Property
Capital Cost	\$51,532,700 - \$77,299,050	765	\$67,364 - \$101,045
Annual Cost (Flood Year)	\$8,546,600 - \$12,819,900		\$11,173 - \$16,759
Annual Cost (Non-Flood Year)	\$29,000 - \$43,500		\$38 - \$57
<sup>1</sup> As described in Section K.1.11, the inundated properties from the preliminary inundation analysis consists of 765 properties including residential, commercial and government/municipal.			

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table K5 (capital costs), Table K6 (annual cost, flood year), and Table K7 (annual cost, non-flood year).

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**Yukon Territory Flood Mitigation Conceptual Design Options**  
**Appendix K Dawson City Conceptual Flood Mitigation Design Options**  
 August 2023

**Table K5 Option 1 Capital Costs Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
<b>Section 1A Option 1: General Conditions</b>					
a)	Mobilization/Demobilization	LS	1	\$2,457,870.00	\$2,457,870.00
b)	Site Preparation/Restoration	LS	1	\$491,600.00	\$491,600.00
<i>Total 1A</i>					\$2,949,470.00
<b>Section 1B Option 1: Earthworks &amp; Landscaping, Earthen Dike (Yukon River)</b>					
a)	Clearing and Grubbing	M2	25000	\$10.00	\$250,000.00
b)	Cut and Re-use Onsite - Native Material	M3	7750	\$15.00	\$116,250.00
c)	Import and Place Fill - Native Material	M3	7750	\$15.00	\$116,250.00
d)	Embankment Fill, Granular Shell	M3	14810	\$50.00	\$740,500.00
e)	Topsoil Stripping and Stockpiling, 300mm Depth	M3	7500	\$25.00	\$187,500.00
f)	Riprap	MT	48070	\$141.00	\$6,777,870.00
g)	Geotextile Fabric	M2	41080	\$10.00	\$410,800.00
h)	Embankment Seeding	M2	17910	\$5.00	\$89,550.00
i)	Embankment Topsoil	M2	17910	\$20.00	\$358,200.00
j)	Toe Drain: Perforated Pipe, Geotextile and Drain Rock	M	2400	\$300.00	\$720,000.00
k)	Slope Stabilization	M	2400	\$3,000.00	\$7,200,000.00
<i>Total 1B</i>					\$16,966,920.00
<b>Section 1C Option 1: Earthworks &amp; Landscaping, Platform (C4 Subdivision)</b>					
a)	Clearing and Grubbing	M2	12520	\$10.00	\$125,200.00
b)	Topsoil Stripping and Stockpiling, 300mm Depth	M3	3760	\$25.00	\$94,000.00
c)	Platform Topsoil	M2	10630	\$20.00	\$212,600.00
d)	Platform Seeding	M2	10630	\$5.00	\$53,150.00
e)	Geotextile Fabric	M2	2400	\$10.00	\$24,000.00
f)	Embankment Fill, Clay Core	M3	5000	\$100.00	\$500,000.00
g)	Embankment Fill, Granular Shell	M3	5890	\$50.00	\$294,500.00
h)	Riprap	MT	2800	\$141.00	\$394,800.00
i)	Toe Drain: Perforated Pipe, Geotextile and Drain Rock	M	1120	\$300.00	\$336,000.00
j)	Slope Stabilization	M	1120	\$3,000.00	\$3,360,000.00
<i>Total 1C</i>					\$5,394,250.00
<b>Section 1D Option 1: Floodboxes, Earthen Dike &amp; Platform (Yukon River Restoration &amp; C4 Subdivision)</b>					
a)	Reinforced Concrete Pipe	M	220	\$1,000.00	\$220,000.00
b)	Gatewell Manhole c/w Sluice Gate	EA	21	\$17,500.00	\$367,500.00
c)	Concrete Headwall	EA	22	\$5,000.00	\$110,000.00
d)	Flap Gate	EA	11	\$3,000.00	\$33,000.00
e)	Riprap	MT	220	\$141.00	\$31,020.00
<i>Total 1D</i>					\$761,520.00

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**Yukon Territory Flood Mitigation Conceptual Design Options**  
**Appendix K Dawson City Conceptual Flood Mitigation Design Options**  
 August 2023

<b>Section 1E</b>	<b>Option 1: Road Raising (Highway-2 &amp; Eureka Dr.)</b>				
a)	Rough Grading	M2	23300	\$5.00	\$116,500.00
b)	Subgrade Preparation	M2	23300	\$5.00	\$116,500.00
c)	80mm Minus Granular Subbase, Variable Depth	M3	14000	\$40.00	\$560,000.00
d)	100mm Minus Granular Base, 100mm Depth	M3	1460	\$50.00	\$73,000.00
e)	BST Surfacing	M2	11800	\$50.00	\$590,000.00
				<i>Total 1E</i>	\$1,456,000.00
				<i>Contingency (20%)</i>	\$5,505,632.00
				<i>Subtotal</i>	\$33,033,792.00
				<i>Location Adjustment Factor (LCAF)</i>	1.56
				<b>Capital Costs Base Price</b>	\$51,532,700.00
				<b>Capital Costs Upper Bound</b>	\$77,299,050.00

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**Yukon Territory Flood Mitigation Conceptual Design Options**  
**Appendix K Dawson City Conceptual Flood Mitigation Design Options**  
 August 2023

**Table K6 Option 1 Annual Costs During Flood Year Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
<b>Section 1F Option 1: Annual Costs, Flood Year</b>					
a)	Inspections	LS	1	\$100,000.00	\$100,000.00
b)	Minor Repairs & Vegetation Management	LS	1	\$10,000.00	\$10,000.00
c)	Storage of Sandbags & Superbags	LS	1	\$500.00	\$500.00
d)	Sandbags c/w Sandfill (2.0m - 3.0m)	M	3500	\$695.00	\$2,432,500.00
e)	Superbags c/w Sandfill (1.0m - 2.0m)	M	3910	\$500.00	\$1,955,000.00
f)	Superbags for Major Culverts	EA	9	\$7,500.00	\$67,500.00
<i>Total 1F</i>					\$4,565,500.00
<i>Contingency (20%)</i>					\$913,100.00
<i>Subtotal</i>					\$5,478,600.00
<i>Location Adjustment Factor (LCAF)</i>					1.56
<b>Annual Cost Flood Year Base Price</b>					\$8,546,600.00
<b>Annual Cost, Flood Year Upper Bound</b>					\$12,819,900.00

**Table K7 Option 1 Annual Costs During a Non-Flood Year Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
<b>Section 1G Option 1: Annual Costs, Non-Flood Year</b>					
a)	Inspections	LS	1	\$5,000.00	\$5,000.00
b)	Minor Repairs & Vegetation Management	LS	1	\$10,000.00	\$10,000.00
c)	Storage of Sandbags & Superbags	LS	1	\$500.00	\$500.00
<i>Total 1G</i>					\$15,500.00
<i>Contingency (20%)</i>					\$3,100.00
<i>Subtotal</i>					\$18,600.00
<i>Location Adjustment Factor (LCAF)</i>					1.56
<b>Annual Cost, Non-Flood Year Base Price</b>					\$29,000.00
<b>Annual Cost, Non-Flood Year Upper Bound</b>					\$43,500.00

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**Yukon Territory Flood Mitigation Conceptual Design Options**  
**Appendix K Dawson City Conceptual Flood Mitigation Design Options**  
August 2023

**Qualitative Evaluation**

Table K8 summarizes the performance of Option 1 with respect to the evaluation criteria which were previously outlined in the main body of this Report.

**Yukon Territory Flood Mitigation Conceptual Design Options**  
**Appendix K Dawson City Conceptual Flood Mitigation Design Options**  
 August 2023

**Table K8 Option 1 Qualitative Evaluation**

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating
1	Viability and Reliability under Extreme Conditions	flooding duration is relatively short (on the scale of weeks not months); wind/wave impacts minimal; permanent dike to withstand high velocities; seepage control measures likely required given history of flooding without overtopping of existing dike; temporary dikes may degrade under long duration of flooding (several weeks or months); risk of vandalism and degradation risk increases with duration that the temporary dikes are deployed;	Low Performance
2	Time to Implementation	medium regulatory risk; additional geotechnical borehole studies of the existing dike required; hydraulic modelling, river migration, and erosion risk studies required; property owner agreements may be required; moderate design requirements provided baseline studies have been completed; seepage studies required to evaluate rate of groundwater flow under dike and potential to cause flooding in community.	Medium Performance
3	Capital Cost Per Inundated Property	Permanent flood mitigation infrastructure provides increased capital costs in exchange for decreased operational and maintenance costs; per-inundated-property capital cost is \$67,364/property	High Performance
4	Maintenance and Storage	storage required for sandbags and superbags; stockpiling of material required for sandbags and superbags; maintenance needs for the sandbag dikes to be completed by private property owner dike will require inspections, maintenance, and vegetation clearing; floodbox maintenance will be required; inspections of road raising sections	Low Performance
5	Response and Activation	minimal response required during flooding event for permanent dike, floodbox slide gates need to be manually closed prior to arrival of flood and opened following abatement of the flood; may need to deploy seepage water mitigations within diked area; organization to provide sandbags and earthen material for private properties owners; property-owner deployed temporary sandbag dikes; temporary sandbag dikes require proper installation and a timely response in a flood scenario to be effective; superbag dikes to be deployed by organization along C4 and Klondike Hwy.	Low Performance
6	Aesthetics and Community Function	dike widening along entire length and minor extension at southeast end of community produces minor change to existing aesthetics and community function	High Performance
7	Future Adaptability	temporary superbag dike may be deployed on earthen dike crest in future for enhanced flood mitigation; permanent increases in height to dikes are possible but will require engineering study and are likely to require widening of structure. Limited potential to address existing groundwater flow potential under dike.	High Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	intrusions into Yukon River and Klondike River are not anticipated to disrupt existing river processes	High Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	moderate ROI due to upgrading of existing infrastructure that would reduce flood risk to substantial portion of the community	Medium Performance

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## **K.2.2 OPTION 2**

### **Description**

The conceptual flood mitigations for Option 2 are illustrated in Figure K7 and Figure K8.

The earthen dike improvements/raising, maintenance access hole/slide gate installation, and existing gap temporary superbag dike deployments described in Option 1 for downtown Dawson would be maintained in Option 2.

To mitigate against backflooding underneath the Klondike Highway and into the areas south of the highway, the 9 Klondike Highway cross-culverts (assumed diameter 1200 mm) would have a concrete headwall and slide gate installed on the Klondike River side to prevent backflooding of the area south of the highway during Klondike River flood conditions.

At the C4 subdivision is on the south side of the Klondike Highway, an approximately 1,100 m long earthen dike would be established around Joe Henry Road, behind the C4 Lift Station at the northwest end of the subdivision, along the backyards of the residents on Joe Henry Road, and then around the TH Lands Department property. The dike crest would be 1.0 – 1.5 m higher than existing ground for 600 m of its length, with the remaining 500 m being up to 2.5 m higher than existing ground. Riprap would be included on the river side of the dike to mitigate erosion.

Approximately 2 km of the Klondike Highway would be raised to meet the DFSL. Approximately 1,140 m between Leggo Lane and Eureka Drive would require raising by 2.0 – 3.5 m. The remaining 950 m of road raising is 1.0 – 2.0 m.

In addition to the Klondike Highway raising, approximately 650 m of Eureka Drive would be raised 0.5 – 0.75 m to reach the DFSL and approximately 50 m of Tailing Road needs to be raised 0.5 m to reach the DFSL.

The temporary sandbag dikes around the 25 private property structures described in Option 1 would be maintained in Option 2.

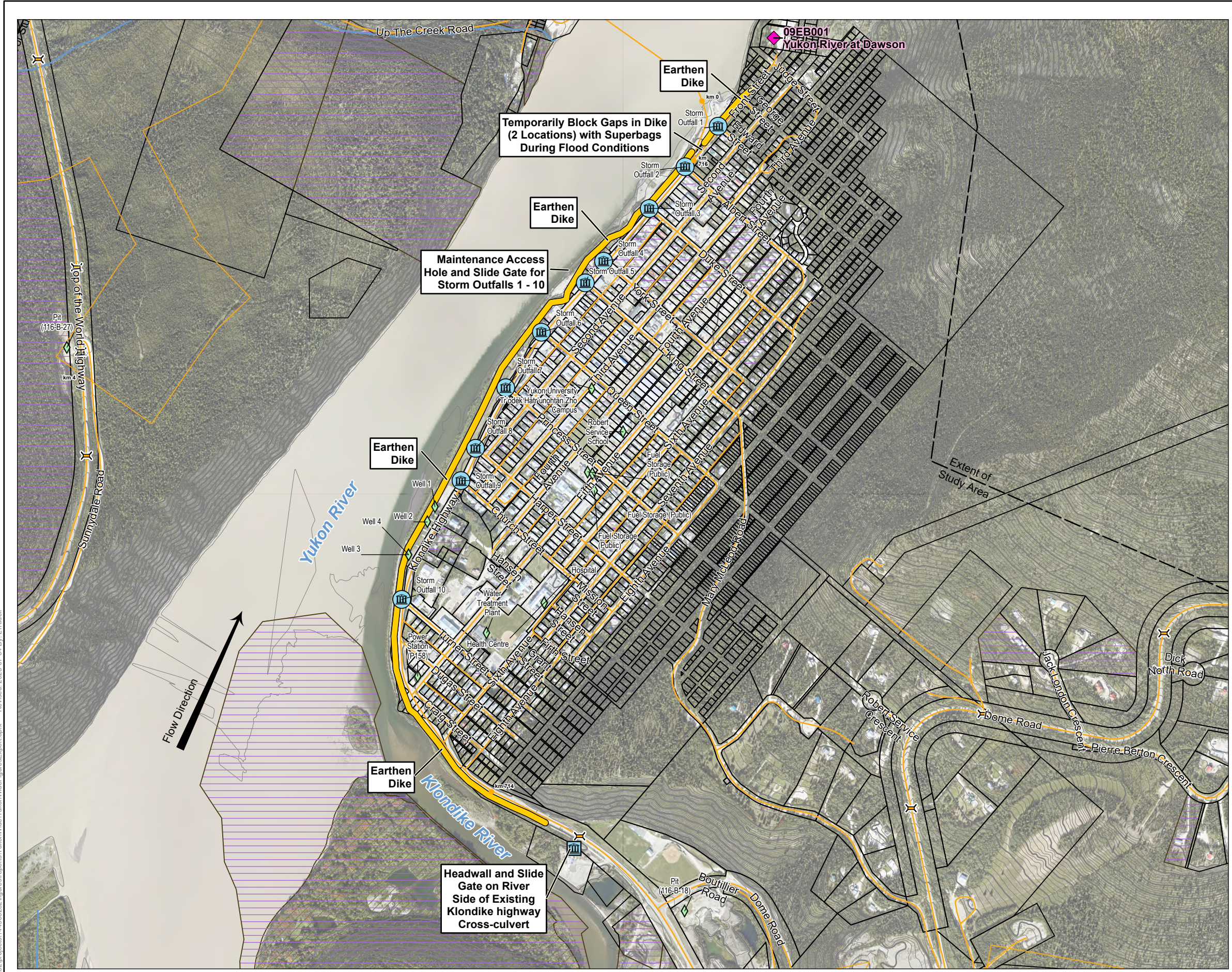


Figure No. **K7**  
 Title **Conceptual Flood Mitigation Design - Option 2 at Downtown Dawson City**  
 Client/Project **Government of Yukon** 144903232  
 Community Services | Infrastructure Development Branch  
 Yukon Territory Flood Mitigation Conceptual Design Options  
 Project Location **Dawson City, Yukon** Prepared by LLT on 2023-04-11  
 TR by JM on 2023-04-11

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- ◆ WSC Station
- ✂ Culvert/ Bridge
- ◇ Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- Placer Land Use Permit
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed
- First Nation Heritage Site

Proposed Mitigation Feature

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

- Maintenance Access Hole and Slide Gate
- Headwall and Slide Gate

**CONCEPTUAL DESIGN**  
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Notes  
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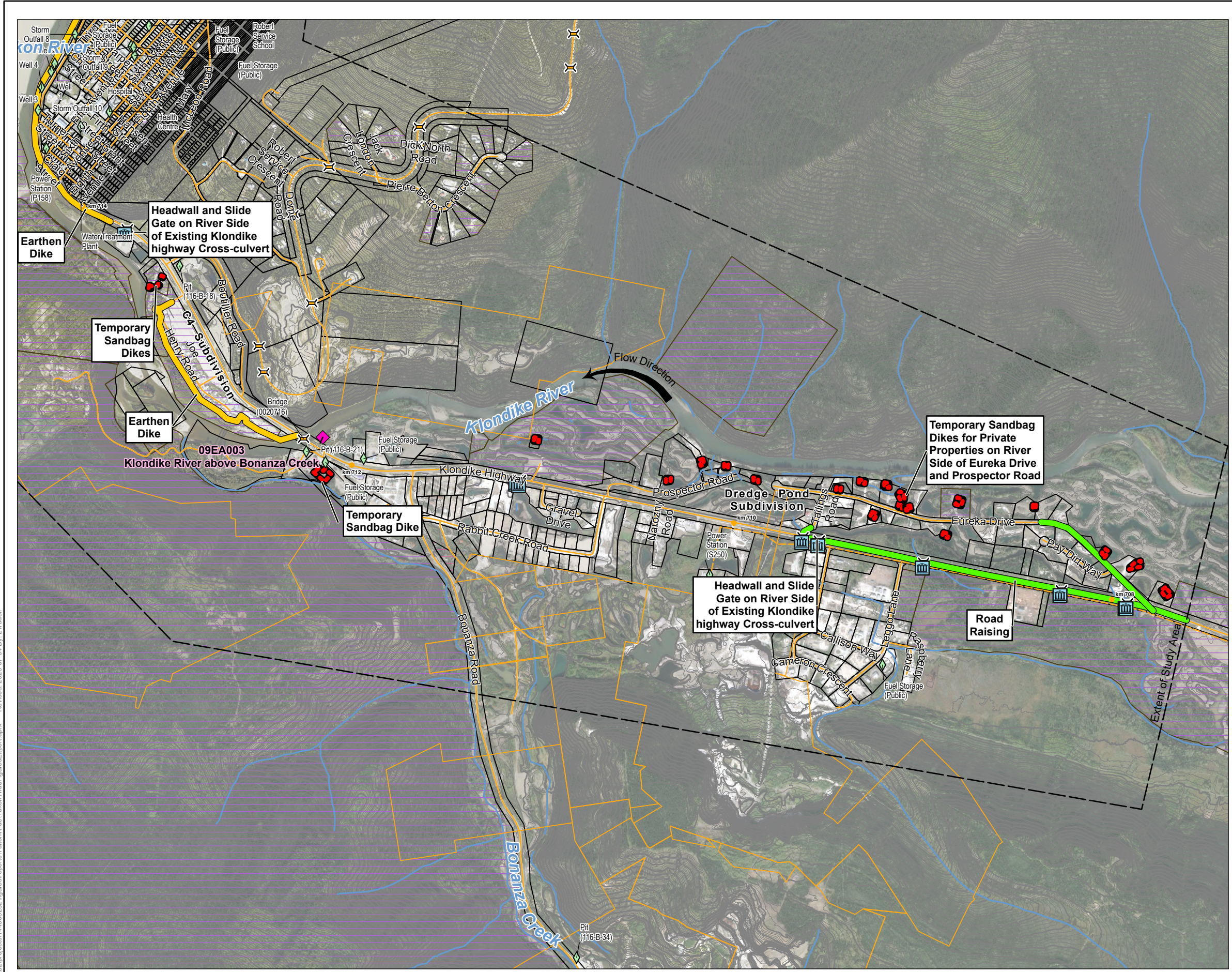


Figure No. **K8**  
 Title **Conceptual Flood Mitigation Design - Option 2 at Klondike River Valley**  
 Client/Project **Government of Yukon** 144903232  
 Community Services | Infrastructure Development Branch  
 Yukon Territory Flood Mitigation Conceptual Design Options  
 Project Location **Dawson City, Yukon** Prepared by LLT on 2023-04-11  
 TR by JM on 2023-04-11

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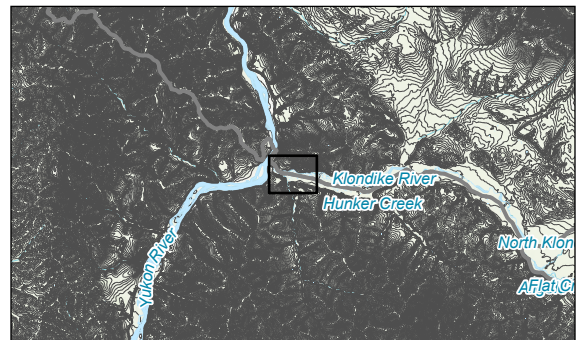
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- ◆ WSC Station
- ✂ Culvert/ Bridge
- ◇ Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- Placer Land Use Permit
- - - Powerline
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed
- First Nation Settlement Lands - Unsurveyed
- First Nation Heritage Site

Proposed Mitigation Feature

- Earthen Dike
- Platform with Temporary Superbag Dike
- Road Raising
- Structural Dike
- Temporary Sandbag Dike
- Headwall and Slide Gate

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



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



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**Class D OPC**

The Class D OPC's for capital and annual costs are summarized in Table K9, considering the Class D level of accuracy (+/-50%). Table K9 also provides the Class D OPCs on a per inundated property basis (from Section K.1.11).

**Table K9 Option 2 Summary of Class D OPCs**

	Class D OPC	Number of Inundated Properties (Section K.1.11) <sup>1</sup>	Class D OPC per Inundated Property
Capital Cost	\$70,829,300 - \$106,243,950	765	\$92,588 - \$138,881
Annual Cost (Flood Year)	\$4,666,900 - \$7,000,350		\$6,101 - \$9,151
Annual Cost (Non-Flood Year)	\$29,000 - \$43,500		\$38 - \$57
<sup>1</sup> As described in Section K.1.11, the inundated properties from the preliminary inundation analysis consists of 765 properties including residential, commercial and government/municipal.			

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table K10 (capital costs), Table K11 (annual cost, flood year), and Table K12 (annual cost, non-flood year).

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**Table K10 Option 2 Capital Costs Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
<b>Section 2A Option 2: General Conditions</b>					
a)	Mobilization/Demobilization	LS	1	\$3,378,230.00	\$3,378,230.00
b)	Site Preparation/Restoration	LS	1	\$675,700.00	\$675,700.00
<i>Total 2A</i>					\$4,053,930.00
<b>Section 2B Option 2: Earthworks &amp; Landscaping, Earthen Dike (Yukon River)</b>					
a)	Clearing and Grubbing	M2	47170	\$10.00	\$471,700.00
b)	Cut and Dispose Offsite - Native Material	M3	3320	\$30.00	\$99,600.00
c)	Cut and Re-use Onsite - Native Material	M3	7750	\$15.00	\$116,250.00
d)	Import and Place Fill - Native Material	M3	7750	\$15.00	\$116,250.00
e)	Embankment Fill, Clay Core	M3	12660	\$100.00	\$1,266,000.00
f)	Embankment Fill, Granular Shell	M3	46090	\$50.00	\$2,304,500.00
g)	Topsoil Stripping and Stockpiling, 300mm Depth	M3	14150	\$25.00	\$353,750.00
h)	Riprap	MT	62600	\$141.00	\$8,826,600.00
i)	Geotextile Fabric	M2	53510	\$10.00	\$535,100.00
j)	Embankment Seeding	M2	28670	\$5.00	\$143,350.00
k)	Embankment Topsoil	M2	28670	\$20.00	\$573,400.00
l)	Toe Drain: Perforated Pipe, Geotextile and Drain Rock	M	3520	\$300.00	\$1,056,000.00
m)	Slope Stabilization	M	3520	\$3,000.00	\$10,560,000.00
<i>Total 2B</i>					\$26,422,500.00
<b>Section 2C Option 2: Floodboxes, Earthen Dike (Yukon River Restoration &amp; C4 Subdivision)</b>					
a)	Reinforced Concrete Pipe	M	220	\$1,000.00	\$220,000.00
b)	Gatewell Manhole c/w Sluice Gate	EA	30	\$17,500.00	\$525,000.00
c)	Concrete Headwall	EA	20	\$5,000.00	\$100,000.00
d)	Flap Gate	EA	11	\$3,000.00	\$33,000.00
e)	Riprap	MT	220	\$141.00	\$31,020.00
<i>Total 2C</i>					\$909,020.00
<b>Section 2D Option 2: Road Raising (Highway-2 &amp; Eureka Dr.)</b>					
a)	Rough Grading	M2	75570	\$5.00	\$377,850.00
b)	Subgrade Preparation	M2	75570	\$5.00	\$377,850.00
c)	80mm Minus Granular Subbase, Variable Depth	M3	100000	\$40.00	\$4,000,000.00
d)	100mm Minus Granular Base, 100mm Depth	M3	3780	\$50.00	\$189,000.00
e)	BST Surfacing	M2	30120	\$50.00	\$1,506,000.00
<i>Total 2D</i>					\$6,450,700.00
<i>Contingency (20%)</i>					\$7,567,230.00
<i>Subtotal</i>					\$45,403,380.00

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<i>Location Adjustment Factor (LCAF)</i>	1.56
<b>Capital Costs Base Price</b>	\$70,829,300.00
<b>Capital Costs Upper Bound</b>	\$106,243,950.00

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**Table K11 Option 2 Annual Costs During Flood Year Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
<b>Section 2E Option 2: Annual Costs, Flood Year</b>					
a)	Inspections	LS	1	\$50,000.00	\$50,000.00
b)	Minor Repairs & Vegetation Management	LS	1	\$10,000.00	\$10,000.00
c)	Storage of Sandbags & Superbags	LS	1	\$500.00	\$500.00
d)	Sandbags c/w Sandfill (2.0m - 3.0m)	M	3500	\$695.00	\$2,432,500.00
<i>Total 2E</i>					\$2,493,000.00
<i>Contingency (20%)</i>					\$498,600.00
<i>Subtotal</i>					\$2,991,600.00
<i>Location Adjustment Factor (LCAF)</i>					1.56
<b>Annual Cost Flood Year Base Price</b>					\$4,666,900.00
<b>Annual Cost, Flood Year Upper Bound</b>					\$7,000,350.00

**Table K12 Option 2 Annual Costs During a Non-Flood Year Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
<b>Section 2F Option 2: Annual Costs, Non-Flood Year</b>					
a)	Inspections	LS	1	\$5,000.00	\$5,000.00
b)	Minor Repairs & Vegetation Management	LS	1	\$10,000.00	\$10,000.00
c)	Storage of Sandbags & Superbags	LS	1	\$500.00	\$500.00
<i>Total 2F</i>					\$15,500.00
<i>Contingency (20%)</i>					\$3,100.00
<i>Subtotal</i>					\$18,600.00
<i>Location Adjustment Factor (LCAF)</i>					1.56
<b>Annual Cost, Non-Flood Year Base Price</b>					\$29,000.00
<b>Annual Cost, Non-Flood Year Upper Bound</b>					\$43,500.00

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### **Qualitative Evaluation**

Table K13 summarizes the performance of Option 2 with respect to the evaluation criteria which were previously outlined in the main body of this Report.

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**Table K13 Option 2 Qualitative Evaluation**

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating
1	Viability and Reliability under Extreme Conditions	flooding duration is relatively short (on the scale of weeks not months); wind/wave impacts minimal; permanent dike to withstand high velocities; seepage control measures likely required given history of flooding without overtopping of existing dike; temporary dikes may degrade under long duration of flooding (several weeks or months); risk of vandalism and degradation risk increases with duration that the temporary dikes are deployed;	Medium Performance
2	Time to Implementation	medium regulatory risk; additional geotechnical borehole studies of the existing dike and Klondike Hwy required; hydraulic modelling, river migration, and erosion risk studies required; property owner agreements may be required; moderate design requirements provided baseline studies have been completed; seepage studies required to evaluate rate of groundwater flow under dike and potential to cause flooding in community.	Low Performance
3	Capital Cost Per Inundated Property	Permanent flood mitigation infrastructure provides increased capital costs in exchange for decreased operational and maintenance costs; per-inundated-property capital cost is \$92,588/property	High Performance
4	Maintenance and Storage	storage required for sandbags; stockpiling of material required for sandbags; maintenance needs for the sandbag dikes to be completed by private property owner dike will require inspections, maintenance, and vegetation clearing; floodbox maintenance will be required; inspections of road raising sections	High Performance
5	Response and Activation	minimal response required during flooding event for permanent dike, floodbox slide gates need to be manually closed prior to arrival of flood and opened following abatement of the flood; may need to deploy seepage water mitigations within diked area; organization to provide sandbags and earthen material for private properties owners; property-owner deployed temporary sandbag dikes; temporary sandbag dikes require proper installation and a timely response in a flood scenario to be effective;	High Performance
6	Aesthetics and Community Function	dike widening along entire length and minor extension at southeast end of community produces minor change to existing aesthetics and community function	Medium Performance
7	Future Adaptability	temporary superbag dike may be deployed on earthen dike crest in future for enhanced flood mitigation; permanent increases in height to dikes are possible but will require engineering study and are likely to require widening of structure. Limited potential to address existing groundwater flow potential under dike.	High Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	intrusions into Yukon River and Klondike River are not anticipated to disrupt existing river processes	High Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	relatively high ROI due to upgrading of existing infrastructure that would reduce flood risk to substantial portion of the community	High Performance

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**K.2.3 SUMMARY TABLES**

Table K14 summarizes the Class D OPC for the conceptual design option.

**Table K14 Summary of Class D OPCs**

	Option 1 Class D OPCs		Option 2 Class D OPCs	
Capital Cost	\$51,532,700	- \$77,299,050	\$70,829,300	- \$106,243,950
Annual Cost (Flood Year)	\$8,546,600	- \$12,819,900	\$4,666,900	- \$7,000,350
Annual Cost (Non-Flood Year)	\$29,000	- \$43,500	\$29,000	- \$43,500

Table K15 provides a summary of the evaluation of the conceptual design option.

**Table K15 Summary of Qualitative Evaluation of Conceptual Options**

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

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