Yukon University

Flooding in Dawson: Exposure analysis and risk reduction recommendations

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Executive Summary

The YukonU Research Centre (YRC) is working with the Infrastructure Branch (IB) of the Department of Community Service (CS), Government of Yukon (YG), to assess the flood vulnerability and protection in Dawson (downtown area), in the Traditional Territory of the Tr'ondëk Hwëch'in First Nation.

The objectives of this project are to assess key aspects of community exposure to flooding, focusing on critical buildings, assets, and infrastructure, and to document the effectiveness of current and proposed flood risk reduction strategies. The YukonU Research Centre conducted two main activities:

- Elevation survey of various buildings and assets, and assessment of the flood protection infrastructure in Dawson. This was completed using a digital elevation model.
- Water level frequency analyses based on available historical records. This means that water surface elevation (and its corresponding gradient) was associated to specific annual probabilities (in %/year) or return periods (in years).

Results are presented in this Table:

Return period	**2 years**	**20 years**	**200 years**
Annual probability	**50%**	**5%**	**0.5%**
Water level at downstream end of **Dawson**	316.6 m	318.2 m	320.5 m
Water level at upstream end of **Dawson**	317.5 m	319.1 m	321.4 m

An analysis of the impact of climate change based on both historical data and knowledge of hydrological processes forced by future weather conditions revealed no clear trend in the frequency and intensity of future floods. Flood extent results suggest that the community is relatively well protected against high water levels from Tágà Shäw (Yukon River) because of the dike, but unreasonably vulnerable through storm drains and a handful of low points in the dike. Given the current probability of flooding through storm drains, estimated to 10% on an annual basis, an effective flood risk reduction strategy would be relatively inexpensive to implement. Recommended flood reduction adaptation actions for Dawson include:

- Dike elevation adjustments and dike maintenance
- Modification or improvement of storm drain valves
- Protection of vulnerable assets on the river side of the dike
- Weakening the ice cover of the ice bridge prior to spring breakup
- Improving the resilience and reliability of the Water Survey of Canada hydrometric station
- Improving flood forecasting models and implementing a breakup detection system
- Making adjustments to the Klondike Highway bridge on the Tr'ondëk (Klondike River)
- Protecting the riverbank of the Klondike River at Trans North Helicopter
- Sharing information about flooding processes and probabilities with the population
- Adopting or continuing the tradition of flood medallions or marks on buildings
- Assessing the quantitative risk associated with critical community assets
- Updating flood emergency protocols and flood risk tools considering climate change

Dawson has not been affected by a significant flood in recent years. This might not be a sign that the risk of flooding is decreasing (or low) but an adaptation opportunity before the next event.

Project Team

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Table of Contents

List of Figures

List of Tables

1. Context

1.1 General perspective

The Department of Community Services (CS), Infrastructure Branch (IB), of the Yukon Government (YG) is interested in understanding the risk of flooding and in identifying flood risk reduction strategies for communities of Yukon. The YukonU Research Centre (YRC) has offered to prepare a report that would meet these needs for the City of Dawson (downtown area), in the Traditional Territory of the Tr'ondëk Hwëch'in First Nation.

In addition to IB-CS financially supporting this project, the National Disaster Mitigation Program (NDMP) of the Government of Canada is providing significant support whereas the YRC provides some in-kind contribution through the ArcticNet North by North program.

1.2 Project objectives

Dawson has been flooded several times in past decades, with the ice-jam flood of 1979 corresponding to the most significant event on historical hydrometric records. This event led to the construction of a (second, higher) dike in the mid-1980s around downtown Dawson. Quantifying the current and future risk of flooding for a community is a necessary step in adapting flood response strategies. It is also known that each dollar invested in Natural hazard exposure prevention saves six dollars in the future (UN Press Release, 2019).

The objectives of this project are to 1. assess key aspects of community exposure to flooding, focusing on critical buildings, assets, and infrastructure, and to 2. document the effectiveness of current and proposed flood risk reduction strategies. While the approach could be applied in any Yukon community, it was identified that Dawson City is associated with the greatest flood risk in the Territory (the risk is a combination of hazard likelihood and hazard consequence).

Meeting the first objective involved surveying the elevation of buildings, assets and infrastructure in the downtown area (Section 2) and developing a flood frequency analysis using historical hydrometric records (Section 3). Results of this analysis are presented in Section 4. After a discussion about the documented and expected impact of climate change (Section 5), the second objective of the project is met through a discussion on the expected performance of current and potential flood protection measures (Section 6). A conclusion is then presented in Section 7.

2. Asset Elevation Surveys

Surveys of key assets in Dawson were completed in May 2021 during river ice breakup. These assets can be divided in four categories, with some overlap: 1. Important buildings and fixed infrastructure for critical community operations (e.g., water and electricity production, firehall), 2. Public service buildings (e.g., Government buildings, machinery warehouses, RCMP, schools), 3. Flood protection and surface drainage-related infrastructure (e.g., dike, culverts), and 4. Other valuable assets (e.g., boats). In most cases, the surveyed feature or component of each asset was:

- First floor (for buildings)
- Electric system (when lower than first floor, if visible and accessible)
- Lowest elevation (fuel tanks, storm drains, culverts, bridges, etc.)
- Elevation at which the asset would float (e.g., barges)

The approach used for all the surveyed assets was to measure, on site, the differential elevation between the asset and an open, horizontal area that is far enough from any building using a high-accuracy pressure differential instrument (ZipLevel Pro-2000 from Technidea Corporation). Back in the office, the absolute elevation of each open area was obtained using a LiDAR-derived Digital Elevation Model (DEM). Then, the elevation of the surveyed asset was calculated back using the measured elevation differential and the absolute elevation. We expect this survey to be associated with an accuracy of +/-20 cm, which compared with the uncertainty associated with hydrological (water level and statistical) factors.

A total of 59 assets were surveyed. The elevation of the surveyed features varied from 314.8 m (a storm drain outlet) to 321.7 m (upper level of Dänojà Zho Cultural Centre). Appendix A presents a table of the surveyed assets with their respective elevation and flood return period (for different dike protection scenarios).

Visiting Dawson during breakup also allowed the YRC team to document the community preparation for the flood season, and to initiate a brainstorming exercise on flood mitigation strategies.

3. Flooding processes chronology and flood scenarios

3.1 General perspective on floods in Dawson

The downtown area of Dawson may be affected by two river flooding processes: ice jams in Tágà Shäw (Yukon River) between the end of April to mid-May and high flow conditions in the Yukon River between early June and early August. In turn, dynamic river ice formation events in November do not represent a common flood hazard in Tágà Shäw in the Tr'ondëk (Klondike River) outlet reach.

Based on data from recent years at hydrometric station 09EB001 (Yukon River at Dawson) operated by the Water Survey of Canada (WSC), it seems that the highest water level on an annual basis is most often caused by open water conditions. However, as Figure 3.1.1 reveals, ice jams are more likely to be associated with the most extreme events (Turcotte, 2021). As a result, ice jam water levels should be used for engineering design and emergency response planning.

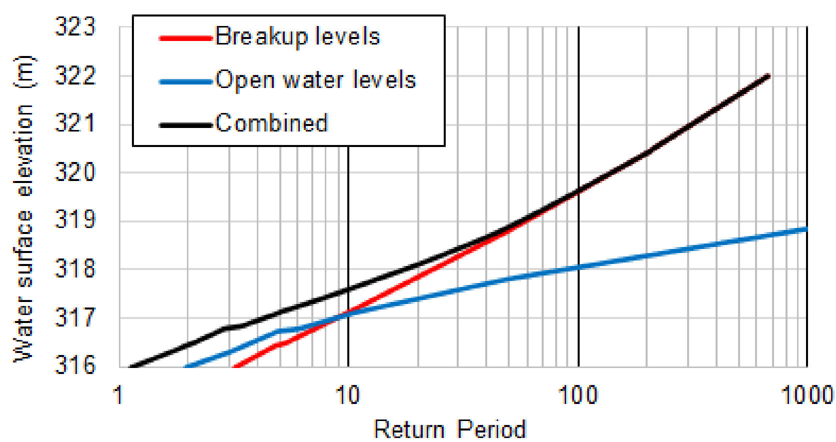

FIGURE 3.1.1. RELATIONSHIP BETWEEN THE WATER SURFACE ELEVATION AND THE RETURN PERIOD OF BREAKUP AND OPEN WATER EVENTS (AS WELL AS COMBINED STATISTICS) AT STATION 09EB001 LOCATED DOWNSTREAM OF DAWSON.

The Klondike River forms a wide delta as it reaches the Yukon River at the southern tip of the downtown Dawson area. Not only is the upstream side of town protected by the extension of the dike (which closes the community perimeter against an elevated segment of the Klondike Highway), but the delta also has a significant ice storage and water evacuation capacity, with several gravel bars. The combination of dike protection and significant hydraulic capacity means that a flood in downtown Dawson that would only be caused by the Klondike River is unlikely. There is a greater probability that flooding of the Klondike River could affect the access to Dawson, mainly because of erosion risks at several points along 50 km of the Klondike Highway or through potential damage to the Klondike Highway bridge on the Klondike River. This perspective will be presented in Section 4, then discussed in Section 6.

The next subsections present the synopsis of the most recent flood event in Dawson followed by the flooding scenarios that were retained for this flood vulnerability assessment.

3.2 Flood of Record

The flood of Spring, 1979 is the most significant flood on record since the late 1890s (which would mathematically make this an approximate 100-year flood event). The interim Fire Chief at Dawson (Dave "Buffalo" Tailor, personal communication, 2021) reported that the flood started around midnight on May 3rd. The ice cover was still very thick in the Yukon River when sustained movement started. An ice jam formed downstream of town, probably downstream of Moosehide, and the overflow seemed to first happen at the downstream end of town, on top of the former dike that used to be front street itself. It is unclear if the perimeter of this former dike had been properly designed to reflect the longitudinal profile of the water surface under open water or ice jam conditions. The overflow soon breached the dike and the water poured into town going southward (upstream). In 40 minutes, there was more than 2 m of water at several locations in town (Whitehorse Star, 1979).

Buffalo also reported that people had to relocate several times to higher ground as the water level kept on rising. Some citizens barely escaped buildings that started to be crushed by ice being pushed against and on top of the dike. At some point, the water reached and then flooded 6th Street near the Hospital, an elevation of approximately 320.6 m, which corresponds to WSC records for the event. Some buildings were seen floating around in town, silty water filled homes, and historical artifacts were washed away (Whitehorse Star, 1979).

When the ice jam released and the water level in the river dropped later the same day, the dike had to be breached by workers to evacuate the stagnant water from low areas of town. The damage was estimated at more than $2M (in 1979 dollars), several people were left homeless, and a Disaster Assistance Policy was created by the Yukon Government to support recovery (Whitehorse Star, 1979).

3.3 Proposed flood scenarios

Station 09EB001, located just downstream of downtown Dawson, has been operated quite consistently since 1944 by the Water Survey of Canada (WSC) and the Yukon Government (YG). Although it contains some historical gaps, mostly during the ice season (as the station was only operated 6 months per year until recently), maximum water levels associated with breakup ice jams and open water events have been recovered from different sources (e.g., Klohn Leonoff, 1986; Janowicz, 2010).

The record, given is length and quality, is deemed suitable for a frequency analysis (analyses result presented in Figure 3.1.1). A datum correction of 311.83 m, provided by the Water Survey of Canada (validated at +/-10 cm by an independent survey shared by the Department of Environment), was applied to the station data to obtain absolute elevations. These elevations are only valid at the WSC station, which is about 100 m downstream from where the dike ends at the northern (downstream) edge of town. This means that water levels for a corresponding event (or return period) at Dawson would be higher going upstream, following the river channel gradient. At low flow, the channel gradient of the Yukon River at Dawson is in the order of 0.01% (10 cm per km of river length). However, it is steeper at high flow because the local gradient then corresponds to the reach-average gradient, which includes steep sections at Moosehide and at the Klondike River delta. This gradient was estimated at 0.04% by Klohn Leonoff (1986), but significant sediment deposition at the Klondike River delta is believed to have created a slightly steeper hydraulic gradient at Dawson (therefore affecting river ice formation conditions, Turcotte, 2020). In the absence of recent water surface surveys at a very high discharge, a value of 0.05% (50 cm difference for every km of river) was adopted and is considered a balance between reality and conservatism.

In the presence of an ice jam that would form a few kilometers (e.g., less than 40 km) downstream of town, like in 1979, it is assumed that the profile would be comparable to what prevails under open water conditions. Indeed, the theory of ice jams (e.g., Beltaos, 2008) suggests that the water level profile should compare with that of the open water conditions along an equilibrium section located between the toe of the jam (Moosehide or downstream) and the head of the jam (far upstream of Dawson). This applies if the river channel shape is relatively constant, which is the case for the Yukon River. Therefore, the same gradient of 0.05% is applied to all retained ice-jam flood scenarios. Figure 3.3.1 presents the profile of the water surface in the Yukon River at Dawson for the different hydrological scenarios. The surface dike, as derived from LiDAR data, is also presented as a reference (it was designed to contain a 200-year flood at the time of design [Klohn Leonoff, 1986]).

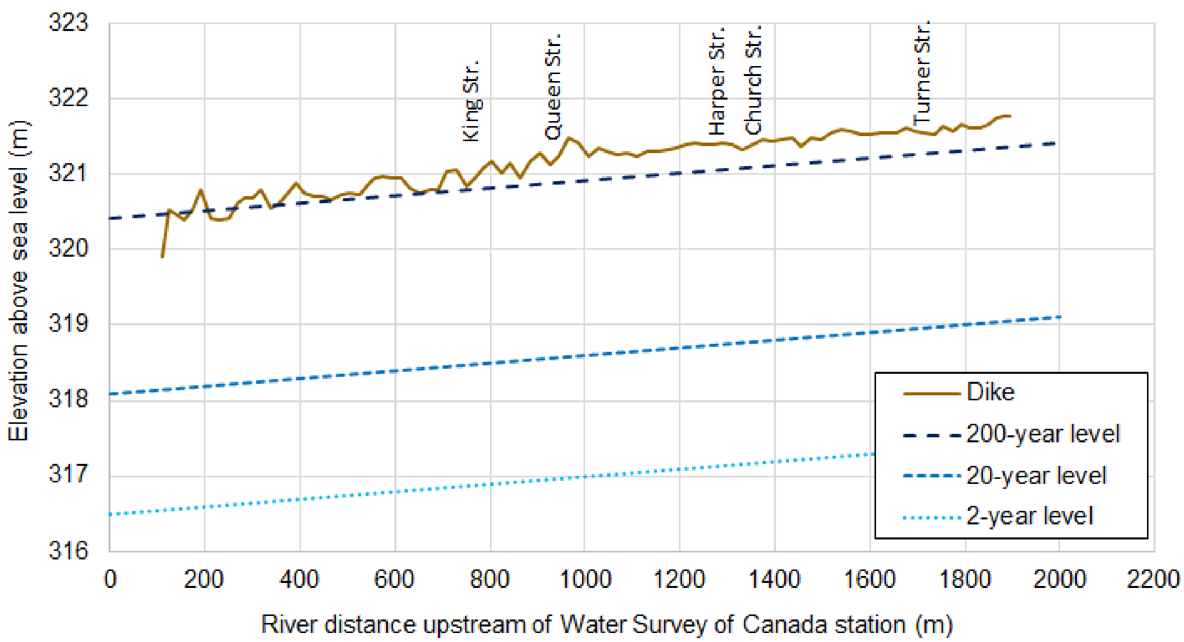

FIGURE 3.3.1 WATER SURFACE PROFILE OF THE YUKON RIVER AT DAWSON FOR 2-YEAR, 20-YEAR, AND 200-YEAR HYDROLOGICAL EVENTS, INCLUDING THE SURFACE OF THE DIKE.

Conditions that could lead to a 200-year flood scenario in Dawson are:

- A thick ice cover in the Yukon River at and downstream of Dawson (very cold winter or very dynamic river ice formation event in November).
- A higher-than-normal snowpack in the White, Pelly, and Steward River systems that would represent a high snowmelt rate potential.
- Sudden warm weather moving from south to north after a cold spring.

Questions may arise regarding the real, updated annual probability of an event that would compare to the 1979 ice jam (associated with a return period of 200 years based on the current record). It is, in fact, interesting to note that no winter has been colder than the 1979 winter since then, and that air temperatures are warming as a result of climate change. However, a 40-year period (1980 to 2020) with no significant ice jam events in the Yukon River at Dawson does not mean that the risk of a major ice jam has disappeared. Moreover, major ice-jam floods have been reported in recent years along the Yukon River in Alaska (e.g., at Galena in 2013). This topic is discussed in more detail in Section 5.

4. Results summary

This section presents the results from two spatial perspectives: A side view of Dawson as if someone was going upriver in a boat (and could see through the dike) and an aerial view, as if someone was flying above downtown. A table is also provided to summarize flood return period statistics for some assets, and the detailed information for each asset is presented in Appendices A and B.

4.1 Spatial Flood Modelling

Table 4.1.1 presents water levels and channel gradients for each flood scenario. As proposed in Section 3, water surface gradients were assumed to be constant, a reasonable assumption considering that:

- The channel gradient is low
- Downtown Dawson is short in the river direction compared with the size of the river

This assumption allows for a significant and cost-saving simplification of the hydrodynamic approach, avoiding the collection of detailed bathymetric information and by-passing the development and calibration of a hydrodynamic model.

TABLE 4.1.1. WATER SURFACE ELEVATION AND GRADIENTS FOR THE 2-YEAR, 20-YEAR, AND 200-YEAR FLOODS IN DAWSON CITY.

Dawson City	2-year flood	20-year flood	200-year flood
Water level at WCS station	316.5m	318.1m	320.4m
Gradient	0.05%	0.05%	0.05%
Water level at downstream end	316.6 m	318.2 m	320.5 m
Water level at upstream end	317.5 m	319.1 m	321.4 m

To perform spatial flood analyses, digital elevation models (DEMs) were obtained from the Government of Yukon's geodata base. The compatibility of both DEMs with Water Survey of Canada (WSC) data was verified by comparing water surface elevations at the date and time of LiDAR (ground elevation data) acquisition and water levels measured by the WSC station. Then, high water levels were superposed to each DEM for different flood scenarios: a gradient was applied at 100m increments upstream of the WCS station in Dawson along the Yukon River. These distances were applied along a main-channel centerline, which is represented by the x axis in Figure 3.1.1. Cross sections at 90° angles to the river centerline were created, and equal water levels were applied in 100m increments along each cross section, extending sideways from the river. This created a point grid of 100m x 100m resolution. An Inverse distance weighted (IDW) interpolation was applied to the grid, resulting in water level DEMs for each flood scenario. Initial flood depths were retrieved by subtracting the DEM's of the communities from the corresponding water levels. Positive values display water depth, while negative values show areas that are not flooded and are hence removed from the flood extent. Additionally, any positive areas that are not connected to the river were removed, since the water has no way of reaching these low areas. The result was essentially comparable to the output of a 1D hydrodynamic model on a 3D terrain.

When this was completed, there was a need to emulate a 2D flow in some areas for some flood scenarios. For the modelling in Dawson city, we considered that the dike contained several storm drains with valves that may or may not be closed (a reality that is not presented in Klohn Leonoff, 1986). Whenever relevant, we provided (tight) all-valves-closed and all-valves-open scenarios. In the latter, water can access the storm drains and enter town through manholes if the elevation of the water at a specific river cross-section is higher than the area surrounding the manhole (at a street corner). For the 2-year high-water level scenario, water levels remain below the dike as well as below all manholes in Dawson and there is no flooding.

For the 20-year scenario, water cannot enter the town over the dike, but may come up through manholes if storm drain valves are open (or if the valves are not tightly closed). It was therefore decided to present two versions of this scenario (all valves open and valves closed). When the valves are closed, only the river side of the dike shoreline is affected by high water levels in the river. When valves are left open and the dike is therefore porous, the flood extent in Dawson essentially depends on the elevation of each street corner relative to water levels in the river. It was identified that Princess Street would be the first to flood, given its low elevation (318.2 m). At that river cross section, the water level associated with a 20-year water level in the river is 318.6 m. However, water would mostly come from manholes along Turner Street (lowest elevation of 318.5 m), reaching an elevation of 319.0 m (water surface elevation at that cross-section). This elevation, 319.0 m, was used to determine the flooded area in Dawson. Considering that the water would have nowhere to flow (being hydraulically isolated from the river upstream and downstream and considering that downstream manholes would eventually be blocks by urban debris), a bathtub filling approach was applied.

For a 200-year event simulation, it is obvious that water could enter town over the dike on several low points at the downstream end of town. This represents the dominant flooding factor over the status of the storm drain valves and manhole elevations. The water surface elevation at the location where water would flow over the dike (middle of the 4 low points identified in Figure 4.1.1) is 320.6 m. For the simulation, upstream and downstream areas in town were filled up to this level, assuming that the flood event would last long-enough to reach an equilibrium hydraulic condition, with largely stagnant water in Dawson (like in 1979).

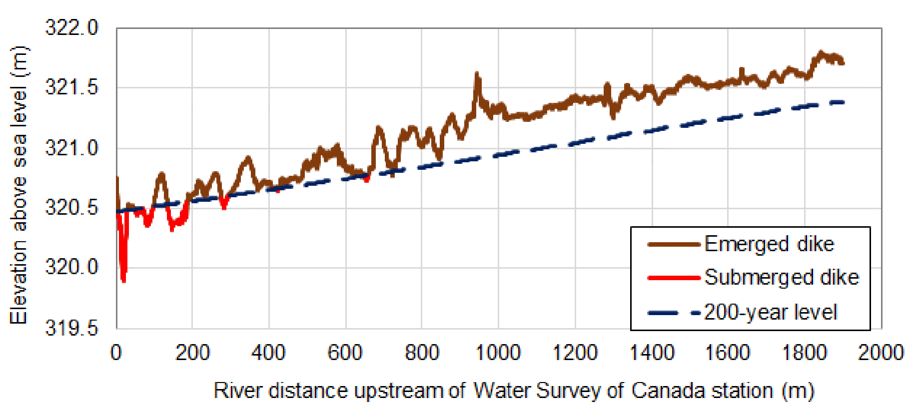

FIGURE 4.1.1 PROFILE OF THE 200-YEAR WATER SURFACE (RIVER SIDE) AND SURFACE ELEVATION OF THE DIKE. LOW POINTS THAT WOULD ALLOW WATER TO FLOOD DOWNTOWN ARE DEPICTED IN RED.

An approximate hydraulic analysis revealed that, under this 200-year ice-jam flood scenario, water levels in Dawson would rise from an elevation of 318.2 m (lowest ground level) to 319.7 m in 5 hours after the beginning of dike overtopping (with several assets affected), then 320.5 m in 20 hours (water inflow slows down as the difference between water levels on each side of the overtopped dike diminishes). It is likely that large ice blocks would be pushed against and on the dike surface during such a dynamic event, not only downstream, but also upstream of town.

4.2 Flood extent results

Figures 4.2.1 presents the lateral (from the river looking through town) view of the high-water event profiles including surveyed assets. It shows, for example, that drain outlets are regularly underwater, preventing access to the valves that should be closed manually to prevent backwater flooding in Dawson. On the other hand, very few buildings and assets would be affected by a backwater flood more frequently than once every 20 years, on average.

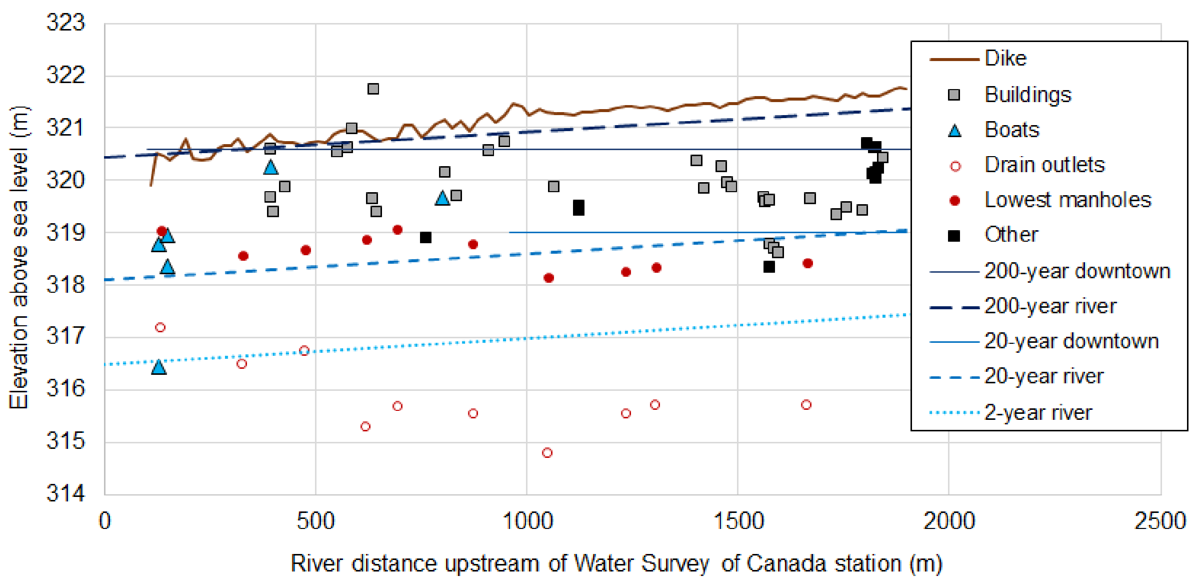

FIGURE 4.2.1. SURVEYED ASSETS, WATER SURFACE PROFILES OF THE YUKON RIVER AT DAWSON FOR 2-YEAR, 20-YEAR, AND 200-YEAR HYDROLOGICAL EVENTS, AND WATER SURFACE ELEVATION ASSOCIATED WITH A STORM DRAIN BACKWATER FOR CORRESPONDING EVENTS.

Figures 4.2.2 to 4.2.5 present this information, but from a spatial point of view, superposed to the digital elevation model (DEM). Four flood scenarios are presented:

- 2-year flood event (water contained on the river side of the dike, regardless of the presence and condition of the dike)
- 20-year flood event with storm drains or manholes adequately blocked
- 20-year flood event with no storm drain or manhole overflow mitigation
- 200-year flood event (overtopping the current dike downstream of town)

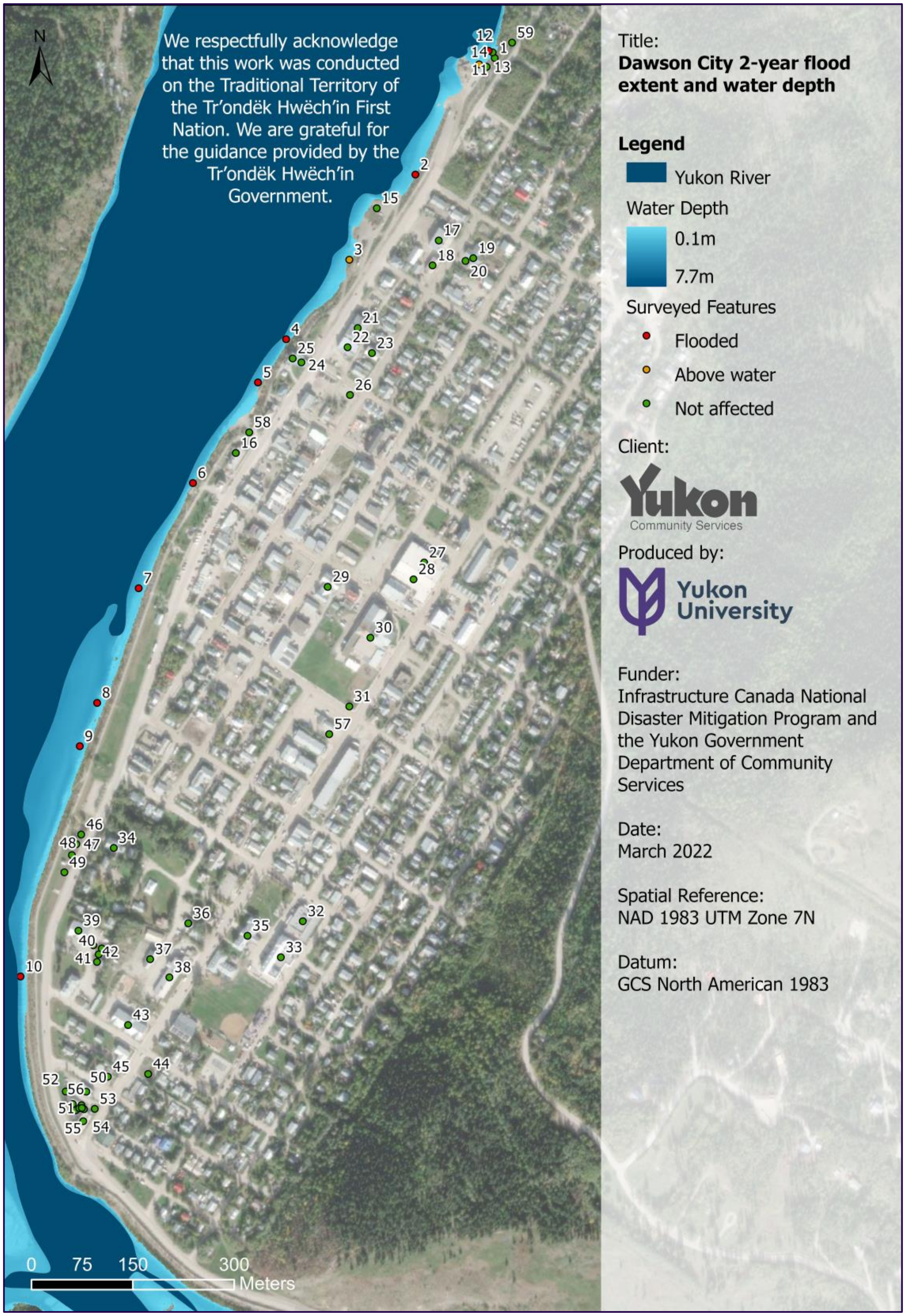

FIGURE 4.2.2. 2-YEAR FLOOD EXTENT, WATER DEPTH, AND SURVEYED ASSETS CATEGORIZED BY FLOOD EXPOSURE. NO FLOOD DAMAGE TO REPORT.

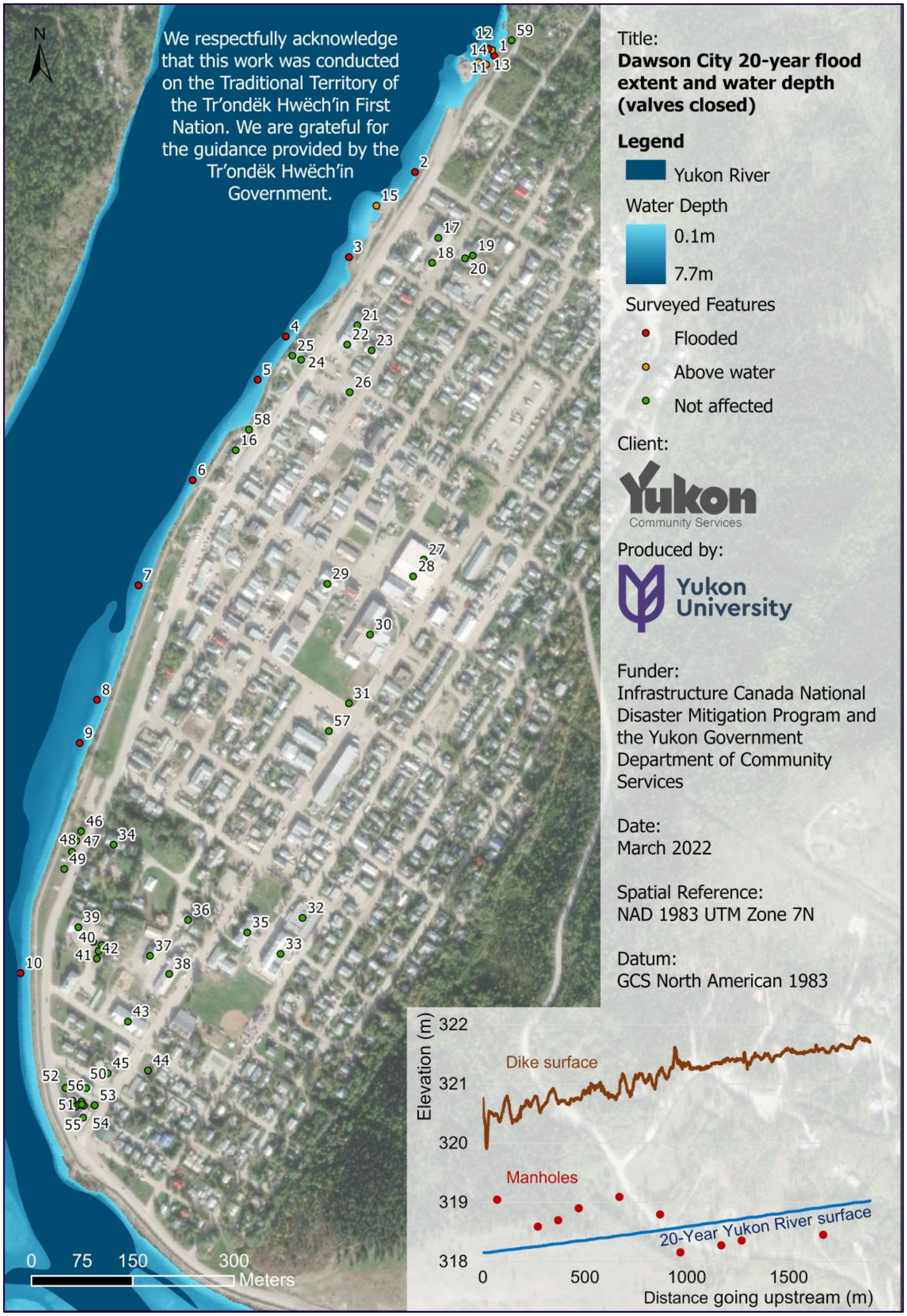

FIGURE 4.2.3. 20-YEAR FLOOD EXTENT (WITH STORM DRAIN VALVES OR MANHOLES CLOSED), WATER DEPTH, AND SURVEYED ASSETS CATEGORIZED BY FLOOD EXPOSURE. NO FLOOD DAMAGE TO REPORT.

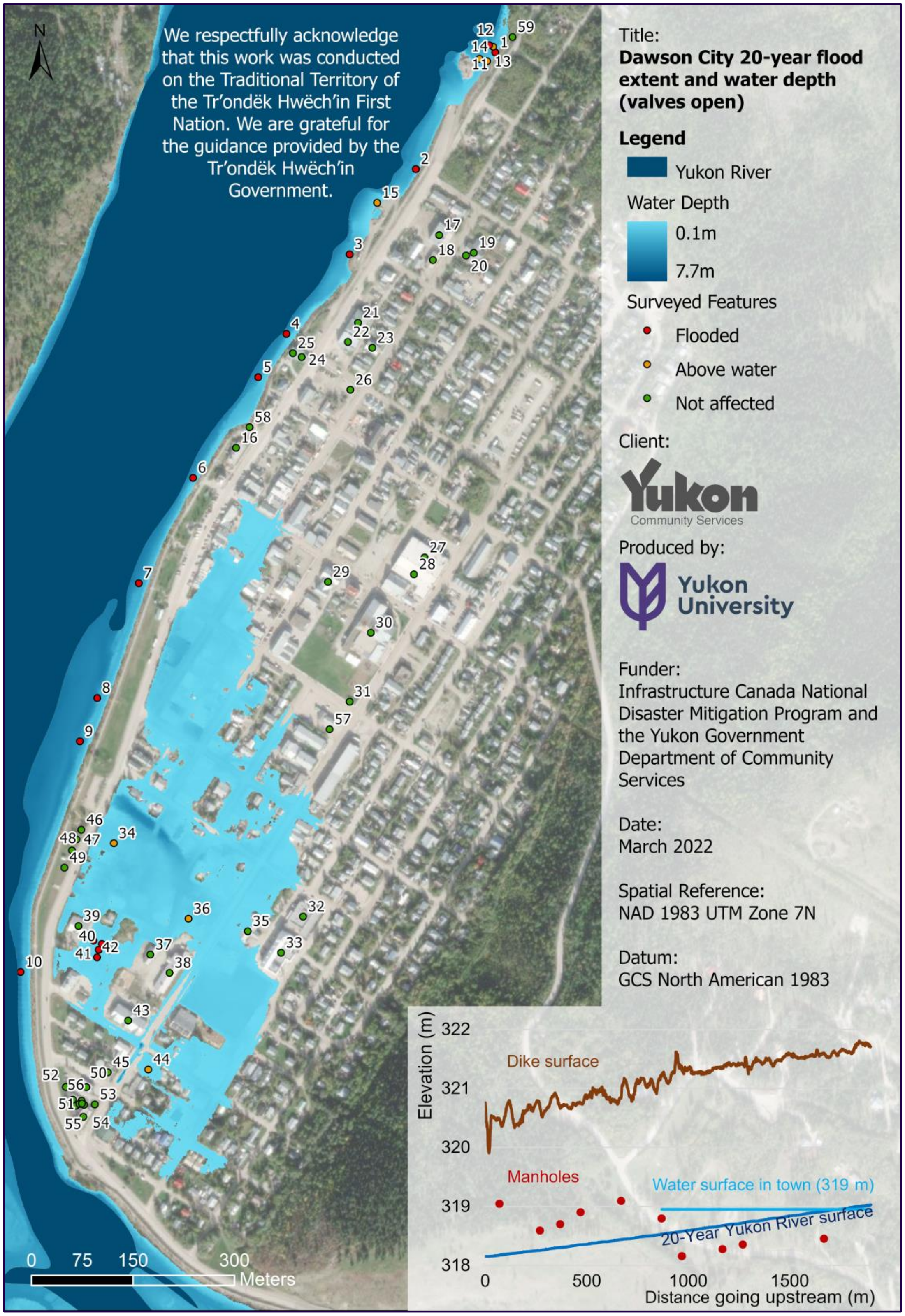

FIGURE 4.2.4. 20-YEAR FLOOD EXTENT (WITH OPEN STORM DRAINS AND MANHOLES), WATER DEPTH, AND SURVEYED ASSETS CATEGORIZED BY FLOOD EXPOSURE. SOME FLOOD DAMAGE TO REPORT.

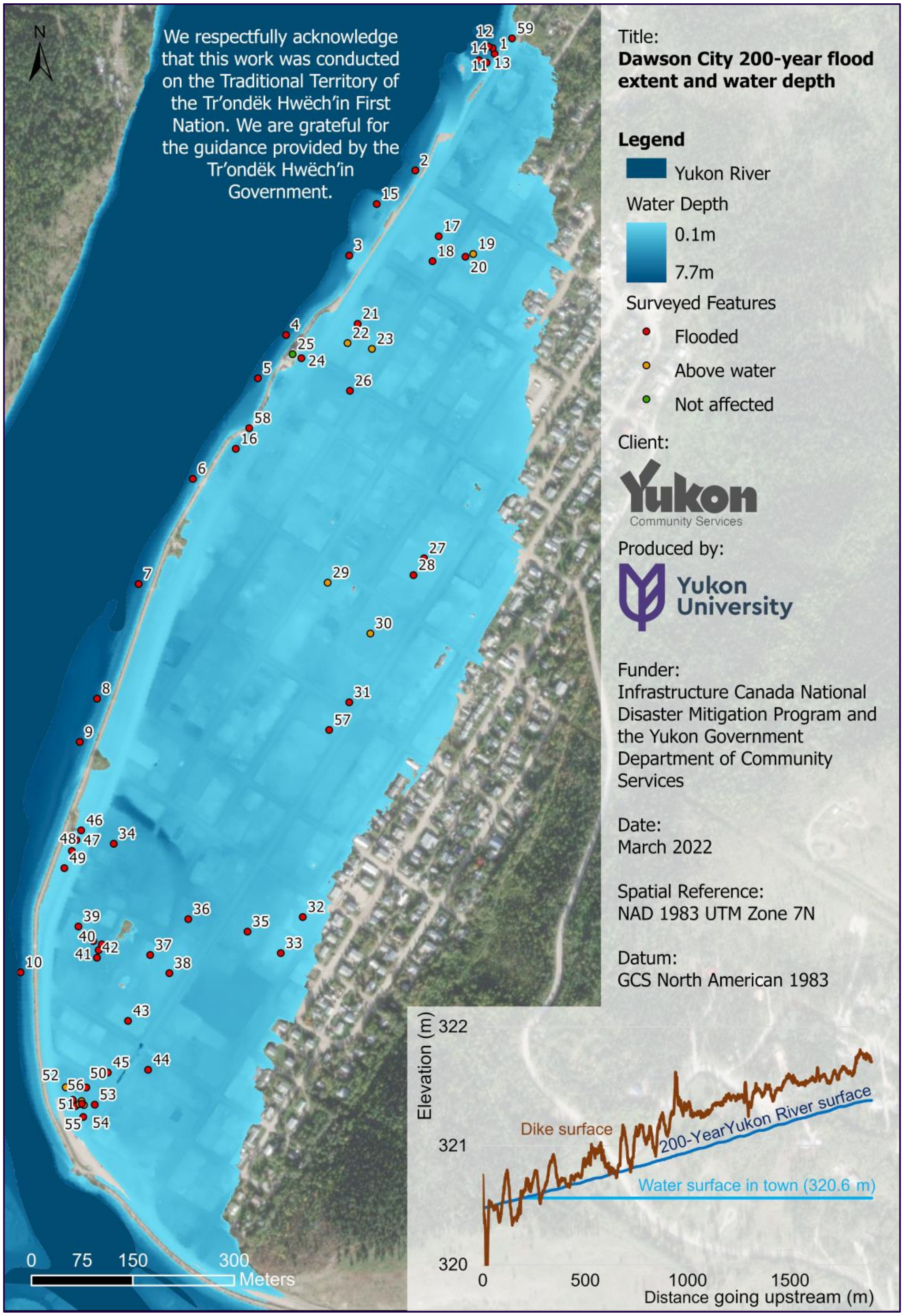

Figure 4.2.5. 200-year flood extent, water depth, and surveyed assets categorized by flood exposure. Extreme flood damage to report.

The water depth on each figure is shown when the water level is higher than the DEM. Since no bathymetric information was used in this project (LiDAR data cannot be obtained under water), the Yukon and Klondike Rivers are presented in dark blue, with an exact depth that is unknown. In addition to the flood extent and depth, the flood impact for each asset is categorized as not affected (green), above water (surrounded by water, orange), and flooded (red).

For a 20-year flood event, water could enter the dike perimeter through storm drains and flood a portion of the downtown area (Figure 4.2.4). For slightly higher water levels in the Yukon River, a larger portion of the downtown area would be flooded. Section 6 presents mitigation measures that could be used to prevent water infiltration in Dawson for the 20-year flood scenario (and the flood extend would therefore correspond to what is presented in Figure 4.2.3, with no damage).

During a 200-year hydrological event (ice jam with a toe located downstream of Dawson, like in 1979), the water would overtop the dike in four main segments on the northern side of downtown (Figure 4.2.6, also presented from a lateral perspective in Figure 4.1.1). These sections sum up to a total distance of 140 m, with the most significant water depth at 0.6 m (Table 4.2.1) and an inflow area of roughly 15 m^2. Potential flood risk reduction approaches to address this matter are discussed in Section 6.

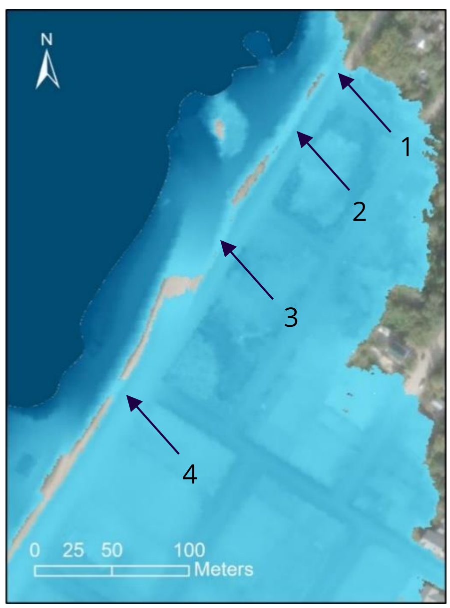

FIGURE 4.2.6. FOUR LOW SEGMENTS OF THE DIKE ON THE NORTH SIDE OF DAWSON WHERE A 200-YEAR HYDROLOGICAL EVENT GENERATES A FLOOD IN DOWNTOWN DAWSON.

TABLE 4.2.1. MAXIMUM DIMENSIONS OF OVERFLOW POINTS IN THE DIKE AT THE NORTH END OF DAWSON IN THE PRESENCE OF A 200-YEAR EVENT IN THE YUKON RIVER.

Section #	Length (m)	Max Depth (m)
1	25	0.6
2	50	0.15
3	50	0.2
4	15	0.1

4.3 Flood exposure assessment for specific community assets

The following list of surveyed assets are associated with a range of flood return periods (the complete list, with corresponding numbers in Figures 4.2.2 to 4.2.5, is presented in Appendices A and B):

- Ships and barges (including the Keno and George Black Ferry in its winter location) would start to float in place for water levels associated with a return period of 1.5 to 140 years. It could be dangerous, even impossible, to secure these vessels once a major ice jam has formed.
- Storm drains would become non-accessible (valves could not be closed manually) for water levels associated with a return period of 0.1 (not accessible several days per year) to 5 years. In turn, water would emerge from the lowest manhole (on Princess Street) once every 8 years, on average (therefore, this is the frequency at which Dawsonites may expect storm drain backwater from the Yukon River).
- The lowest portion of the dike, in its current state, would be flooded every 120 years (for a dike that is designed to protect Dawsonites against a 200-year event).
- The Fire Hall would be affected by a flood, on average, once every 60 years (for a storm drain backwater scenario) to 120 years (if drains or manholes are closed).
- The Hospital (First floor) would be affected by a flood once every 110 to 125 years, depending on the storm drain status.
- The Robert Service school's main floor would be flooded once every 210 years but would be surrounded by water more frequently.
- Yukon Energy assets (degree of importance to confirm as it includes offices, fuel tanks and turbines) would be flooded with a return period of 45 years to 200 years, depending on storm drain backwater.
- RCMP assets (storage / garages) could be flooded as often as every 15 years and the main RCMP office building would be affected by water from the Yukon River every 50 years, on average, in a storm drain backwater scenario. If storm drains or manholes could be shut, flooding would only occur once every 120 years, on average.
- The main floor (ground level) of the sewage treatment plant would be affected by the Yukon River through storm drains every 60 years, on average, but the current dike would offer a 120-year flood protection otherwise.
- The water station would be affected by a storm drain flood once every 40 years whereas a similar flood process would affect water wells every 125 years or so. If storm drains and manholes were blocked, the minimum flood return period would be 120 years for these assets.
- In terms of access to Dawson, a sister report (Turcotte and Saal, 2022) reveals that water from the Klondike River would touch the lower part of the Klondike Highway bridge structure (elevation 325.6 m) once every 200 years, on average. In turn, given that ice jams also represent the most likely flooding process at that location, and considering that ice slabs can emerge well-above the water surface (about 1 m), the return period of an ice run or ice jam pushing against the bridge structure could be higher, as presented in Section 6.7.

5 Climate change perspective

5.1 General concepts

Flood return periods presented so far in this report are based on hydrometric data for the 1970-2021 period. This data may not be representative of future, climate-change-driven, flood probabilities. Trends in both open water and ice-jam floods have been identified for several rivers of Yukon, including Tágà Shäw (Yukon River) at Dawson (Turcotte, 2021). However, the climate change signal, as it relates to high water levels, is unclear and much uncertainty remains.

Three aspect of climate change may play a direct or indirect role in current and future runoff rates and flooding processes in Yukon:

- Changes in watershed scale precipitation patterns (both in winter and spring)
- Extreme watershed scale warm conditions (mainly in the spring)
- Extreme sub watershed scale (convective) precipitation (in the summer)

The consequences of these hydrological processes, combined with the influence of a progressive rise in average temperatures, may also trigger changes in other parameters affecting floods:

- Altered river ice cover thickness (e.g., affecting the potential intensity of ice-jam floods)
- Increased forest fire hazards (e.g., impacting surface runoff rates and evaporation)
- Thawing permafrost (e.g., affecting surface runoff rates)
- Shrubification of tundra areas (e.g., altering evaporation and snow interception)
- Increased landslide hazards (e.g., modifying channel bed elevation and channel width)

In recent decades, Dawson has been mainly exposed to ice jam-floods, but this may change.

5.2 Future floods in downtown Dawson

5.2.1 Ice-jam floods

As described in Section 3.2 the most recent ice jam-flood in Dawson occurred in 1979, when the dike essentially consisted in an elevated Front Street, and when winters where colder. Three simple criteria must be met for a significant ice jam to threaten the current dike at Dawson (this theory is covered in Turcotte et al., 2019):

- The ice cover resistance must be high
- The breakup driving force must be sudden and high
- A site of significant breakup resistance must be located not too far downstream of town

In terms of high ice cover strength, high resistance could be achieved through a cold winter (the ice cover becomes very thick by thermal condition, or because of heat loss) or through a very dynamic freeze-up. On one hand, Figure 5.2.1 presents the maximum freezing degree-days at Dawson since 1961 and clearly shows that extremely cold winters seemed to become less frequent (each winter, a day at -11ºC is replaced by a day at 0ºC). This aligns with declining measured ice cover thicknesses by the WSC on the Yukon River upstream of the White River outlet since 2006 (admittedly a short record). On the other hand, flows in the fall are apparently becoming more significant (Figure 5.2.2), which might cause more frequent dynamic ice cover formations (like in the fall of 2020), at least at specific locations.

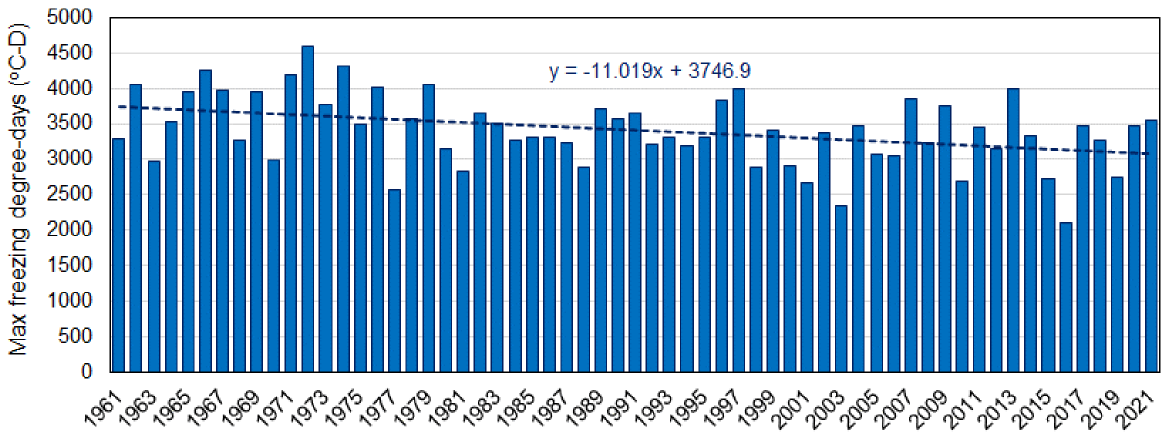

FIGURE 5.2.1. MAXIMUM FREEZING DEGREE-DAYS AT DAWSON SINCE 1961. THE TREND IS DECREASING, WITH A VARIABILITY THAT REMAINING HIGH.

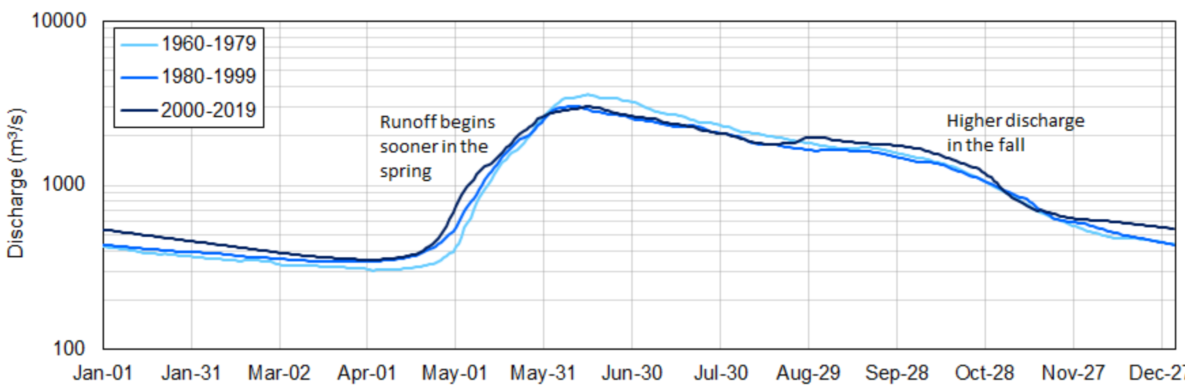

FIGURE 5.2.2. DAILY-AVERAGED DISCHARGE FROM THE YUKON RIVER UPSTREAM OF WHITE RIVER FOR THREE PERIODS OF 20 YEARS. THE 2000-2019 PERIOD SEEMS TO PRESENT HIGHER DISCHARGE VALUES IN THE SPRING AND FALL.

Some river ice scientists propose that the elevation of the water level at freeze-up plays a major role in the spring ice cover resistance (e.g., Beltaos, 1995), but this factor, also influenced by late-fall flows, does not seem dominant in all rivers (e.g., Jasek et al., 2021).

In terms of breakup driving force mostly dictated by runoff rates, more extreme precipitation (and snowpack) and air temperature conditions seem conducive for a weather sequence that would generate a higher discharge sooner in the spring (as suggested by Figure 5.2.2). However, more instability in spring air temperatures, with warm conditions intercepted by colder air masses, may break the momentum of runoff waves in large watersheds more often than in the past, therefore attenuating the rate of rise in spring flow (the Yukon River needs a strong multi-day warm temperature anomaly to generate consistent high runoff). Permafrost thaw does not seem to play a significant role in spring snowmelt since the ground is mostly frozen at the end of winter. The impact of forest fires on snowmelt and runoff rates is also complex: snow sublimation will increase, therefore reducing the snow water equivalent, but snowmelt rates could increase as the snowpack in entire sub watersheds would be exposed to short wave radiation.

The last parameter that may dictate the occurrence of high ice-jam water levels in Dawson is the location of the ice jam toe. It is possible that the geometry and local morphology of the Yukon River at Dawson is changing over time, and therefore that ice jamming locations are also changing. This would explain why the ice cover does not form as it used to in front of town (Turcotte, 2020). The combination of the new (1980s) dike (that creates a narrow in the Yukon River channel at Dawson) and ice bridge (a river location where the ice cover is artificially thicker) likely generate a significant river ice breakup resistance that turns out to be beneficial in most springs. Indeed, in the presence of the normal open area at Moosehide, the small ice jam that forms in front of Dawson in most springs gets pushed far downstream when it releases. In turn, it would be dangerously inappropriate to pretend that the likelihood of an ice jam forming downstream of Dawson is diminishing over the years without a proper historical investigation.

Altogether, this analysis suggests that ice-jam floods in Dawson may become slightly less likely in the future, and the declining trend in maximum breakup water level presented by Turcotte (2021) aligns with that conclusion. Nevertheless, a study of the Athabasca River at Fort McMurray had identified that ice-jam floods could become less likely in a changing climate (Das et al., 2017) just a few years before a record ice-jam flood impacted the community (Nafziger et al., 2021). Given the increased climate variability and the occurrence of more frequent weather extremes, it is reasonable to assume that a significant ice jam may affect Dawson in any future spring. Ice-jam flood return periods based on the 1970-2020 period for the Yukon River at Dawson should therefore be maintained until a detailed study, inclusive of Traditional Knowledge, is completed.

5.2.2 Open-water floods

It may be argued that significant open water events could become a dominant flooding process in the future at Dawson. However, the current tendency suggests a drop in maximum open water levels in the summer (Turcotte, 2021, also somewhat visible in Figure 5.2.2). This aligns with what is observed along many other rivers in Yukon, a potential result of permafrost thaw and increased water absorption capacity of the ground. Moreover, hydrological processes leading to high flow conditions in tributaries of the Yukon River are different. For example, significant glacier melt rates only add to the Yukon River flow later during the summer, once the snowmelt period in both the Pelly and Stewart Rivers is over. Finally, as revealed in Figure 3.1.1, open water conditions are still far away, at least statistically, from threatening the dike as frequently as ice jams.

5.2.3 Morphological considerations

The mining legacy of the Dawson area (with altered sediment supplies to the Yukon River), in addition to a relatively recent glacier retreat, could imply that the geometry and gradient of the Yukon River channel is gradually evolving, with a proportional consequence on water levels. Another process may also affect ice-jam water levels at Dawson: a landslide of the Moosehide cliff (such a landslide would have limited impacts on open water levels, given the significant width of the Yukon River at that location). The likelihood of this hazard is currently unknown, and even if it was, it could only be qualitatively included in the probability assessment of future ice-jam floods in Dawson.

6. Recommendations to improve flood protection and reduce flood vulnerability

Previous sections of the report demonstrate that ice jams represent the greatest flood hazard in Dawson, also that the impact of climate change remains uncertain. The next large flood may hit soon or may not happen in the next 100 years, but the level of adaptation or the consequences depend on decisions made sooner than later. This section presents a series of recommendations to reduce the risk of flooding, not by altering the probability of high water levels (which would be difficult in such a large river), but by limiting the exposure of vulnerable assets and infrastructure. Appendix B presents all surveyed assets with their corresponding flooding return period.

6.1 Dike elevation

The dike was designed to protect Dawson against 200-year flood events (or any lower water level). Klohn Leonoff (1986) had evaluated, from a benefit-cost perspective (at least back in the days) that a higher dike was not worth the investment. Nowadays, there is probably a significant benefit in investing in small dike elevation adjustments (Figure 4.2.1) as this relatively small investment would bring the level of protection from a 120-year to a 200-year return period for the entire downtown area. Future studies, involving assessing the value of buildings and assets in Dawson, could reveal if it would be worth (from an economical perspective) adjusting the level of protection that is offered by a dike, including a quantification of the impact of climate change (the dike should resist to future floods, not historical floods).

6.2 Storm drain valves

When the water level in the Yukon River is higher than the lowest streets in Dawson (this happens every 10 years or so, based on the frequency analysis presented in this work), water can enter the dike perimeter through the storm drain system. When this happens, valves (Figure 6.1.1) are unlikely to be accessible (water level submerges the drain outlet) or they may not be tight enough to prevent minor to major flooding (the inflow through each drain depends on the water level in the river, obstructions in the drain [e.g., ice], as well as on the duration of high-water levels).

FIGURE 6.2.1. STORM DRAIN OUTLET AND VALVE OBSTRUCTED BY ICE AND DEBRIS (QUEEN STREET DRAIN).

Since valves on the river side do not represent a sustainable and functional flood risk reduction system to complement the presence of the dike, it may be worth exploring other technical options, such as:

- Installing underground valves accessible manually from the ground surface on the dry (downtown) side of the dike: This would require excavation, would represent an expensive option, but likely should have been implemented when the dike was constructed.
- Installing valves on each manhole that would be closed manually when needed: This may also represent a significant investment, but this approach has the merit of limiting excavation activities while providing a way to prevent backwater when river water levels are already too high for a storm drain outlet access.
- Having sandbags accessible prior to breakup and an official protocol in place for a fast deployment. This option would be cheaper but could hardly work for significant floods as the water level may rise fast and the pressure in the drainage system could be high. During the record flood of 1979, the ice jam occurred at night when there was minimal response capacity.

Note that Duke Street drain outlet was buried at the time of visit. This condition may lead to water accumulation in the street during snowmelt and intense rain events, and it should be addressed.

6.3 Dike maintenance

Dikes are engineering structures that need to be inspected and maintained (we have recently heard about orphan dikes in Abbotsford, BC, that may be partly responsible for the massive flood of November 2021). In a context where norms and codes may have evolved since design (1980s), vegetation has been growing on the river side of the dike, the Klondike and Yukon Rivers channel alignment has changed over the years, and freeze-thaw cycles may have affected the structural integrity of the dike since its construction, it may be appropriate to seek advice from engineering experts to ensure that the dike remains fully functional.

Moreover, given that the dike has apparently not been threatened by high water levels since its construction, because it is an aging structure, and as its presence was initially perceived as a barrier by Dawson residents (preventing access to the Yukon River), alternate flood protection options could eventually be considered, independently of the future flood probability.

6.4 Vulnerable assets on the river side of the dike

It has been observed several years in a row that vulnerable assets, including boats and vehicles, are left on the river side of the dike prior to spring breakup. Even large vessels grounded at the north end of town could be pulled by water or pushed by ice at breakup. It is important to take flood hazards seriously, at least when models and experts suggest that water levels could be high in the coming months, weeks, or days. Assets should be secured or removed at the onset of breakup. From an environmental point of view, garbage accumulated (intentional littering or wind-blown garbage) during the winter season could also be picked up before the Yukon River carries it towards Alaska.

6.5 Resilience of WSC hydrometric station 09EB001

There have been several instances in recent years where the real-time water level signal from station 09EB001 was intermittent, interrupted, or unreliable during spring breakup. Since this is the most critical station to detect and forecast threatening hydrological processes at Dawson, it would be worth investing in a technology and in a robust installation (including bank and aquatic segments) that would minimize the probability of station malfunction when it is the most needed.

6.6 Ice bridge

Every winter, West Dawsonites and mining companies, among others, rely on the certification of an ice bridge to drive vehicles across the Yukon River at Dawson. In recent years, altered river ice formation patterns have apparently impeded the formation of an ice cover at the normal ice bridge location (Turcotte, 2020).

Once the ice cover has formed (if it does not form naturally, few techniques exist to force ice cover development on a relatively fast flowing river), it is artificially thickened to support heavy vehicles as soon as possible during the cold season. Snowpack compaction (or snow removal) during winter, a matter of safe transit conditions for vehicles, reduces channel insulation and promotes heat loss compared to what a normal, low-density snow cover would do. Therefore, in addition to early-winter artificial ice thickening, this additional heat loss yields a thicker and stronger ice cover compared to that of upstream and downstream Yukon River segments. A point of high ice cover resistance at breakup represents a location where an ice jam is likely to form, which is not ideal for Dawson. Even when the ice cover is pushed downstream by the increasing flow or by an upstream ice run, ice slabs and sheets from the original ice bridge can still contribute to generating an ice jam downstream, still affecting Dawson.

It is recommended to break the ice cover along the channel banks with machinery, and prior to that, to drill series of holes in the ice cover prior to breakup each spring in order to reduce the probability of ice jamming caused by this stronger ice cover sheet. This recommendation also applies to any winter racing track or ice rink that would extend over a significant width of the Yukon River at Dawson.

6.7 Breakup timing and intensity forecast tools

A conversation between the Water Resources Branch (WRB) and the YRC in 2021 inferred that the two models used to forecast river ice breakup at Dawson have limitations. Hydrological models, especially when involving ice processes, rarely accurately predict what is going to happen, and they represent tools to guide forecasters judgment. However, several years of observations, hydrometric records, paper maps, and satellite products could be analyzed in order to improve existing models or to develop more reliable ones.

There may also be a need for an improved water level fluctuation detection capacity upstream of Dawson. Hydrometric stations operated by the WSC are either too close to Dawson (09EB001 does not provide enough warning time) or too far from Dawson (09CD001 does not provide the most useful information). As a complement to an improved forecast capacity, installing real-time instruments 5 to 10 km upstream of Dawson may represent an option to consider as this would give a warning time prior to ice cover mobilization at Dawson, and it would also give a few hours to prepare for a potential flood caused by an ice jam forming downstream of Dawson.

6.8 Klondike Highway bridge structure and approaches

The Klondike highway bridge that crosses Tr'ondëk (Klondike River) at Dawson represents a critical transportation link to the community. It's elevation relative to maximum open water levels is safe (corresponds to a return period well-above 1000 years, a probability much lower than 0.1% per year). When considering ice jams, the annual probability of water levels touching the bridge structure rises significantly to about 0.5% (200-year return period). In addition, observations made at the bridge during breakup, combined with an investigation of the local channel geometry and floodplain conditions, suggest that the annual probability of structural damage to the bridge could be even higher:

- Although bridge abutments do not seem to initiate ice jams, they have been seen to interfere with the passage of ice runs and with the evacuation of local ice jams. In the case of a very dynamic breakup with thick and large ice pieces, bridge abutments would act as anchor points and ice floes, while pivoting around this obstacle, could flip and push sidesways and upward on the structure (see a smaller scale result from 2021 in Figure 6.7.1)
- If a major ice jam was to form at or immediately downstream of the bridge (this is a dominant ice jam location), water would normally seek lateral evacuation. The floodplain of the river at that location is blocked by the Klondike Highway on both banks. This means that, if a major ice jam was in place, it could push on the bridge structure (expensive) well-before (or more frequently than) water would flow on the surface of the highway (less expensive).

FIGURE 6.8.1. INTERFERENCE OF THE KLONDIKE HIGHWAY BRIDGE ABUTMENT DURING 2021 BREAKUP (LEFT BANK, UPSTREAM SIDE). ICE FLOES COULD ALMOST REACH THE LOWER PART OF THE BRIDGE STRUCTURE AT BREAKUP DESPITE AN ONLY MODERATE INTENSITY EVENT.

It is expected that ice jams in the Klondike River could become more frequent in the future (Turcotte and Saal, 2022). It is therefore recommended to:

- Perform an engineering investigation of ice-jam flood hazards at the bridge.
- Independently of the official ice jam risk to the bridge integrity, consider one or multiple mitigation options:
  - Providing access to machinery that would break the toe of an ice jam from the banks, downstream of the bridge (along C-4 subdivision).
  - Designing water evacuation structures downstream of the Klondike Highway bridge at an elevation that would protect the bridge structure
  - Lowering the eastern approach of the Klondike Highway to the bridge (possibly an erosion-triggered controlled failure mode) in order to provide excess-water evacuation capacity around a major ice jam (in the order of 200 m^3/s).

The highway is also vulnerable to flooding at other locations upstream of the bridge. Ice jams do seem to form on a regular basis at Henderson Corner, close to the highway, but the low elevation of the opposite floodplain seems to protect the highway against water and ice damage. On the other hand, high flows from Hunker Creek seem to represent a concern, at least in recent years.

6.9 Trans North Helicopters

If the Klondike Highway was closed due to flooding or for any other reason, this could prevent goods and emergency teams from accessing Dawson. Trans North Helicopters is located on the Dawson side of the Klondike Highway bridge, which is a convenient location for emergency access to and from downtown Dawson. The Trans North helipad, given its high elevation relative to the floodplain on the opposite (left) bank, does not seem vulnerable to floods from the Klondike River. However, the right bank of the Klondike River is located downstream of a bend and is made of easily erodible material (Figure 6.8.1). It is currently actively eroding. There is still some distance between the river channel and the current helipad, but a significant portion of the bank could be lost in a single hydrological event because of massive water erosion and ice abrasion. It is recommended to monitor the upper bank locations using markers and it could become appropriate to protect the bank against erosion before the bend moves to far outward.

FIGURE 6.9.1. ERODIBLE BANK IN THE KLONDIKE RIVER AT TRANS NORTH HELICOPTERS JUST DOWNSTREAM OF A BEND.

6.10 Flood information diffusion within the population

Any community protected against floods by a dike remains vulnerable to floods. Considering that the population of Dawson is exposed to floods that could occur with little lead time to react or evacuate, it would be appropriate to communicate information about the risk of flooding. Considerations should be given to different worldview as well as to different levels of familiarity with past floods. Flood information could be presented in a simple document, or this could be shared through meetings with the population. Key aspects of floods would include:

- Expected frequency of specific water levels on the river side of the dike
- Probable flood scenarios with or without improved flood protection
- Probable duration of a flood event
- Expected flood event sequence (time of day, rate of water level rise, water temperatures, first streets and assets to be affected, etc.)

6.11 Flood tags and medallions on buildings

Disseminating information about historical floods has been done very efficiently at Dawson. Anyone taking a walk on the dike has access to useful information that tells the story of the town with a focus on water and river ice. In some communities established on floodplains, tags, or medallions, installed on buildings show the water elevation of historical floods, and this also contribute to keeping that memory alive. It is suggested that such a project, that could be artistic and involve tourist activities, be initiated (or continued) at Dawson.

6.12 Critical community assets

Essential services in each community include access to drinking water, water treatment, access to food, communication, and electricity. Several surveyed assets (their first floor, concrete pad, etc.) provide these services, but the lowest elevation of the weakest component of each asset could not be confirmed, and the real impact of their exposure to water could only be revealed through knowledge exchange with the various owners (Community Services, the City of Dawson, Vuntut Gwitchin, ATCO, YEC, etc.). This report, and the data presented in Appendices A and B, is meant to provide information about different flood levels at the location of each asset and to let owners and emergency managers measure the level of consequence that this represents.

6.13 Updating flood emergency protocols

A review of emergency protocols for flood preparation, management, and recovery falls outside the scope of this study. However, emergency protocols prepared by communities and by the Emergency Measure Organization (EMO), an entity of Community Services (CS), should be regularly reviewed and updated, as communication and flood fighting techniques are constantly evolving. It should be considered that:

- In the case of a major ice-jam flood, water levels would most likely rise downstream first (as reported in 1979). The rate at which water levels would rise in the river could be as high as several centimeters per minute, potentially providing less than one hour between the first sustained ice movement in the Yukon River (and the siren) and dike overtopping. Then, the rate at which water levels would rise in Dawson would largely depend on the depth of dike overtopping as well as on the length of overtopping: a more likely rise of a few vertical centimeters per hour to a less-likely lateral surge rushing into town could be expected. An ice-jam flood could last a few hours to several days.
- In the less likely scenario of an open-water flood, water levels would rise by about one centimeter per hour on the river side of the dike, providing a more reasonable lead time for preparation. On the other hand, the flooding event could be prolonged.
- With adequate tools and models (Section 6.6), an ice-jam flood could be forecasted a few days in advanced and detected a few hours in advance. In turn, with current tools, an open-water flood can be foreseen a few weeks in advance and accurately forecasted several days in advance.

If invited in meetings, the YRC would like to extend a standing offer to contribute relevant technical expertise.

6.14 Update flood risk tools regularly

The impact of climate change on the frequency of high water levels remains uncertain (Section 5). Continued record of annual maximum water levels is important to evaluate the statistical probability of a flood. It is recommended to update water level frequency analyses on an annual basis, and to create new flood maps when deemed appropriate (if flood levels have sensibly changed, or if the impact of climate change is now better defined). The current study could also be updated when needed.

7. Conclusions

This project, through elevation surveys and GIS analyses using LiDAR-derived digital elevation models, has documented the flood exposure of different assets in Dawson. The current frequency of flooding in Dawson might be as high as once every 10 years through storm drains, but relatively accessible and affordable improvements to the current flood protection infrastructure (Section 6) could bring that frequency down to once every 200 years, with a consequent reduction of the flood risk (or damage associated with water) from Tágà Shäw (Yukon River).

This report represents a scientific basis on which Government decision makers and expert consultants can confirm flood protection weaknesses, and design adapted flood protection assets. As presented in Section 6, improving the resilience to floods in Dawson does not only imply engineering structures, but also the development of computational tools and models, adapted river monitoring strategies, as well as the dissemination of information related to this natural hazard, the second in importance after forest fires (EMO, personal communication, 2019).

The impact of climate change on the frequency and severity of floods in Yukon is difficult to assess and to isolate from the natural variability of hydrological processes (Section 5). In winter, air temperatures in Dawson may be as high as 0ºC (with light rain, a new reality identified by Janowicz, 2010) and as low as -50ºC. This significant range, added to the overall sequence of atmospheric systems during the long sub-arctic winter, and influenced by increased carbon dioxide concentrations, dictate hydrological processes leading to ice-jam floods. The complexity of interacting factors that influence river water levels and our embryonic ability to simulate winter hydrological processes represent significant limitations to foreseeing the future risk of flooding in downtown Dawson. Long periods without significant floods (currently the case for Dawson) combined with other societal challenges, such as COVID19, also tend to slow flood adaptation efforts. However, at a larger scale, in neighboring provinces and even in other watersheds of Yukon, significant floods continue to generate increasing damage.

In a context of uncertainty in which the next flood will happen sooner than sought, agencies around the world remind us that every dollar invested in climate change adaptation can save many dollars in the future (UN Press Release, 2019). It is never too early to adapt.

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Appendix A: List of surveyed assets

ID#	Surveyed assets		Elev. (m)	Flood return Period
	Description	Surveyed feature		
1	Storm drain George - Edward St.	Top of drain (no valve)	317.2	5
	Lowest street corner / manhole	Based on DEM	319.0	
2	Storm drain Albert St.	Top of drain (valve is not usable)	316.5	2
	Lowest street corner / manhole	Based on DEM	318.6	
3	Storm drain Duke St.	Ground (drain outlet burried)	316.8	2
	Lowest street corner / manhole	Based on DEM	318.7	
4	Storm drain York St.	Top of drain (valve open)	315.3	0.3
	Lowest street corner / manhole	Based on DEM	318.9	
5	Storm drain King St.	Top of drain (valve open, ice)	315.7	0.5
	Lowest street corner / manhole	Based on DEM	319.1	
6	Storm drain Queen St.	Top of drain (valve open, ice)	315.6	0.4
	Lowest street corner / manhole	Based on DEM	318.8	
7	Storm drain Princess St.	Top of drain (valve open)	314.8	0.1
	Lowest street corner / manhole	Based on DEM	318.2	
8	Storm drain Harper St.	Top of drain (valve open)	315.6	0.3
	Lowest street corner / manhole	Based on DEM	318.3	
9	Storm drain Church St.	Top of drain (valve cannot be closed)	315.7	0.3
	Lowest street corner / manhole	Based on DEM	318.4	
10	Storm drain Turner St.	Top of drain (valve system broken)	315.7	0.3
	Lowest street corner / manhole	Based on DEM	318.5	
11	Ship on trailer	Approx floating line	318.8	45
12	Barge, anchored to bank	Approx floating line	316.4	2
13	Tourist ship, three floors, white	Approx floating line	319.0	50
14	Barge or ship, Jasmine B	Approx floating line	318.4	25
15	George Black Ferry	Approx floating line	320.3	145

ID#	Surveyed assets		Elev. (m)	Flood return Period		
	Description	Surveyed feature		Open drains	Closed drains	Repaired dike
16	Keno	Approx floating line (red line)	319.7	75	120	200
17	Firehall - City of Dawson Building	Concrete slab	319.7	75	120	200
18	Public Work Garage besides Fire Hall	Beside Firehall, concrete slab	319.9	95	120	200
19	New Tr'inkè Zho Daycare	Door step, first floor	320.6	200	200	200
20	Access to Daycare	Lower step of outside stairs	319.4	50	120	200
21	Tr'ondëk Hwëch'in Government Left Entrance	Door step, first floor	320.5	195	195	200
22	Tr'ondëk Hwëch'in Community Hall	Door step, first floor	321.0	250	250	250
23	Wellness Center	Door step, first floor	320.6	200	200	200
24	Dänojà Zho Cultural Centre theater	Assumed lowest floor elevation	319.7	75	120	200
25	Dänojà Zho Cultural Centre	Door step, upper level floor	321.7	400	400	400
26	Lift station, York St. and 2nd Ave.	Concrete slab (electric features)	319.4	50	120	200
27	Recreation Centre	Foot step, north side, main entrance	320.1	130	145	200
28	Art and Margaret Fry Recreation Centre	(old) Concrete slab, south door	319.7	75	120	200
29	Yukon U. Tr'odëk Hätr'unohtän Zho Campus	Door step, first floor	320.6	200	200	200
30	Robert Service School	Door step, first floor	320.7	210	210	210
31	Dawson City Water Valve Chamber, Princess St.	Door step, first floor	319.9	100	120	200
32	McDonald Residence	Door step, first floor	320.4	180	180	200
33	Hospital	Door step, first floor	320.0	110	125	200
34	Governor House	Door step, first floor	319.8	90	120	200
35	Museum	Door step, first floor	320.3	160	160	200
36	YG Property Management Division	Door step, first flood (1 m above slab)	319.9	100	120	200
37	Sewage Treatment Green Plant Garage	Bottom of garage door	319.7	75	120	200
38	Sewage Treatment Plant back	Door step, first floor	319.6	65	120	200
38	Sewage Treatment Plant front	Door step, first floor	319.4	50	120	200

ID#	Surveyed assets		Elev. (m)	Flood return Period		
	Description	Surveyed feature		Open drains	Closed drains	Repaired dike
39	RCMP main building	Door step, first floor	319.6	65	120	200
40	RCMP smaller garage (north)	Concrete slab, door step	318.8	20	120	200
41	RCMP 2 garage doors	Concrete slab, door step	318.7	15	120	200
42	RCMP garage, purple (south)	Concrete slab, door step	318.6	15	120	200
43	Yukon Housing, Turner St.	Wood boardwalk, door step, first floor	319.7	75	120	200
44	Water station	Wood boardwalk, door step	319.3	45	120	200
45	Water related infrastructure	Approximate concrete slab / first floor	319.5	55	120	200
46	Water well PW-1N	Based on DEM	320.3	165	165	200
47	Water well PW-2N	Based on DEM	320.3	170	170	200
48	Water wellPW-3N	Based on DEM	320.4	180	180	200
49	Water well PW-4N	Based on DEM	320.3	165	165	200
50	YEC Main blue building / office	Door step, first floor	319.4	50	120	200
51	YEC blue diesel plant	Door step, first floor	320.4	190	190	200
52	YEC blue turbine on a trailer	Door step, first floor	320.7	210	210	210
53	YEC transformer, between two buildings	Approx. elevation of slab. High Voltage	320.1	130	145	200
54	YEC metal dike around slab	Top of metal dike	320.6	200	200	200
55	YEC main metal slab with fuel tanks	Metal floor	320.0	115	130	200
56	YEC grey electric boxes	Concrete slab or footing	320.2	150	160	200
57	Gasoline station, Princess St. and 5th Ave.	Lowest visible underground reservoir valve	319.5	60	120	200
58	Gate in the dike	Concrete slab, bottom of gate	318.9	20	120	200
59	Dip in dike, North end of town	Lowest elevation of dike depression	319.9	120	120	200

Appendix B. Detailed surveyed assets

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">1</td></tr>
<tr><td>Asset</td><td colspan="4">Storm Drain George - Edward St.</td></tr>
<tr><td>Location</td><td colspan="4">River side of dike, close to ferry crossing</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Top of drain (no valve)</td></tr>
<tr><td>Elevation</td><td>317.2 m</td><td>Flood return period</td><td>(river side of dike)</td><td>5 years</td></tr>
<tr><td colspan="2">Note: Elevation of lowest manhole connected to this drain is 319.0 m</td><td>Annual flood probability</td><td>(river side of dike)</td><td>20%</td></tr>
</table>

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">2</td></tr>
<tr><td>Asset</td><td colspan="4">Storm Drain Albert St.</td></tr>
<tr><td>Location</td><td colspan="4">River side of dike, aligned with Albert St.</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Top of drain</td></tr>
<tr><td>Elevation</td><td>316.5 m</td><td>Flood return period</td><td>(river side of dike)</td><td>2 years</td></tr>
<tr><td colspan="2">Note: Elevation of lowest manhole connected to this drain is 318.6 m</td><td>Annual flood probability</td><td>(river side of dike)</td><td>55%</td></tr>
</table>

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">3</td></tr>
<tr><td>Asset</td><td colspan="4">Storm Drain Duke St.</td></tr>
<tr><td>Location</td><td colspan="4">River side of dike, aligned with Duke St. (buried when surveyed)</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Ground level at approximate drain location (water flowing from ground)</td></tr>
<tr><td>Elevation</td><td>316.8 m</td><td>Flood return period</td><td>(river side of dike)</td><td>2 years</td></tr>
<tr><td colspan="2">Note: Elevation of lowest manhole connected to this drain is 318.7 m</td><td>Annual flood probability</td><td>(river side of dike)</td><td>50%</td></tr>
</table>

Community	Dawson			
ID #	4			
Asset	Storm Drain York St.			
Location	River side of dike, aligned with Duke St. (below Dänojà Zho Cultural Centre)			
				
Surveyed feature	Top of drain			
Elevation	315.3 m	Flood return period	(river side of dike)	0.3 years
Note: Elevation of lowest manhole connected to this drain is 318.9 m		Annual flood probability	(river side of dike)	300 %

Community	Dawson			
ID #	5			
Asset	Storm Drain King St.			
Location	River side of dike, aligned with King St.			
				
Surveyed feature	Top of drain			
Elevation	315.7 m	Flood return period	(river side of dike)	0.5 years
Note: Elevation of lowest manhole connected to this drain is 319.1m		Annual flood probability	(river side of dike)	220 %

Community	Dawson			
ID #	6			
Asset	Storm Drain Queen St.			
Location	River side of dike, aligned with Queen St.			
				
Surveyed feature	Top of drain			
Elevation	315.6 m	Flood return period	(river side of dike)	0.4 years
Note: Elevation of lowest manhole connected to this drain is 318.8 m		Annual flood probability	(river side of dike)	280 %

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">7</td></tr>
<tr><td>Asset</td><td colspan="4">Storm Drain Princess St.</td></tr>
<tr><td>Location</td><td colspan="4">River side of dike, aligned with Princess St.</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Top of drain</td></tr>
<tr><td>Elevation</td><td>314.8 m</td><td>Flood return period</td><td>(river side of dike)</td><td>0.1 years</td></tr>
<tr><td colspan="2">Note: Elevation of lowest manhole connected to this drain is 318.2 m (lowest drain outlet in Dawson connected to the probably lowest manhole in Dawson)</td><td>Annual flood probability</td><td>(river side of dike)</td><td>800 %</td></tr>
</table>

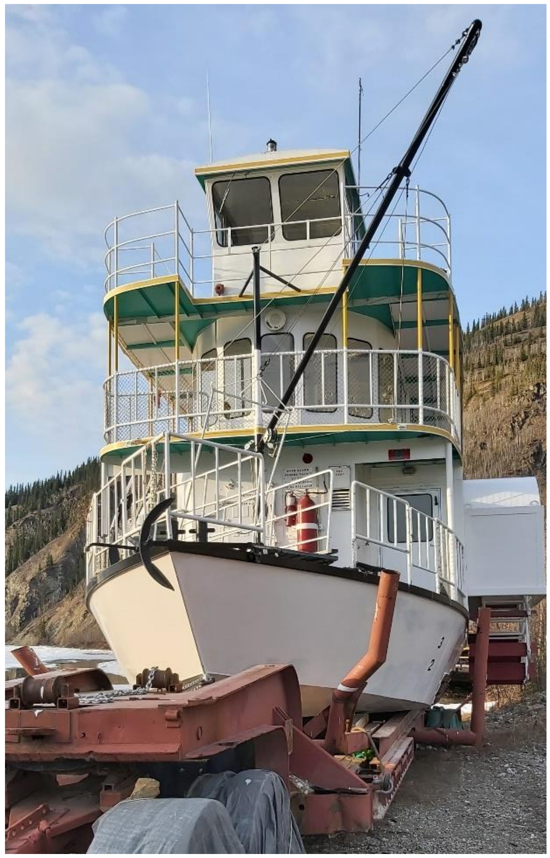
Community	Dawson			
ID #	8			
Asset	Storm Drain Harper St.			
Location	River side of dike, aligned with Harper St.			
				
Surveyed feature	Top of drain			
Elevation	315.6 m	Flood return period	(river side of dike)	0.3 years
Note: Elevation of lowest manhole connected to this drain is 318.3 m		Annual flood probability	(river side of dike)	350 %

Community	Dawson			
ID #	9			
Asset	Storm Drain Church St.			
Location	River side of dike, aligned with Church St.			
				
Surveyed feature	Top of drain			
Elevation	315.7 m	Flood return period	(river side of dike)	0.3 years
Note: Elevation of lowest manhole connected to this drain is 318.4 m		Annual flood probability	(river side of dike)	300 %

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">10</td></tr>
<tr><td>Asset</td><td colspan="4">Storm Drain Turner St.</td></tr>
<tr><td>Location</td><td colspan="4">River side of dike, aligned with Turner St.</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Top of drain</td></tr>
<tr><td>Elevation</td><td>315.7 m</td><td>Flood return period</td><td>(river side of dike)</td><td>0.3 years</td></tr>
<tr><td colspan="2">Note: Elevation of lowest manhole connected to this drain is 318.5 m</td><td>Annual flood probability</td><td>(river side of dike)</td><td>400 %</td></tr>
</table>

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">11</td></tr>
<tr><td>Asset</td><td colspan="4">Ship on trailer</td></tr>
<tr><td>Location</td><td colspan="4">North end of community (location at breakup)</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Approximate floating line</td></tr>
<tr><td>Elevation</td><td>318.8 m</td><td>Float return period</td><td>(river side of dike)</td><td>45</td></tr>
<tr><td colspan="2">Note: This is a mobile asset, and it could be moved or anchored properly to resist a major flood</td><td>Annual float probability</td><td>(river side of dike)</td><td>2 %</td></tr>
</table>

Community	Dawson			
ID #	12			
Asset	Barge, anchored to trailer			
Location	North end of community (location at breakup)			
				
Surveyed feature	Approximate floating line			
Elevation	316.4 m	Float return period	(river side of dike)	2
Note: This is a mobile asset, and it could be moved or anchored properly to resist a major flood		Annual float probability	(river side of dike)	57%

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">13</td></tr>
<tr><td>Asset</td><td colspan="4">Tourist ship, three floors, white</td></tr>
<tr><td>Location</td><td colspan="4">North end of community (location at breakup)</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Approximate floating line</td></tr>
<tr><td>Elevation</td><td>319.0 m</td><td>Float return period</td><td>(river side of dike)</td><td>50</td></tr>
<tr><td colspan="2">Note: This is a mobile asset, and it could be moved or anchored properly to resist a major flood</td><td>Annual float probability</td><td>(river side of dike)</td><td>2%</td></tr>
</table>

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">14</td></tr>
<tr><td>Asset</td><td colspan="4">Barge or ship, Jasmine B</td></tr>
<tr><td>Location</td><td colspan="4">North end of community (location at breakup)</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Approximate floating line</td></tr>
<tr><td>Elevation</td><td>318.4 m</td><td>Float return period</td><td>(river side of dike)</td><td>25</td></tr>
<tr><td colspan="2">Note: This is a mobile asset, and it could be moved or anchored properly to resist a major flood. In this position, it is expose to ice runs and ice jamming (even more the small boat hanging on the left).</td><td>Annual float probability</td><td>(river side of dike)</td><td>4%</td></tr>
</table>

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">15</td></tr>
<tr><td>Asset</td><td colspan="4">George Black Ferry</td></tr>
<tr><td>Location</td><td colspan="4">Top of dike, between Albert St. and Duke St. (location at breakup)</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Approximate floating line</td></tr>
<tr><td>Elevation</td><td>320.3 m</td><td>Float return period</td><td>(river side of dike)</td><td>145</td></tr>
<tr><td colspan="2">Note: This asset could be anchored properly to resist a major ice jam.</td><td>Annual float probability</td><td>(river side of dike)</td><td>0.7%</td></tr>
</table>

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">16</td></tr>
<tr><td>Asset</td><td colspan="4">Keno (Park Canada)</td></tr>
<tr><td>Location</td><td colspan="4">Downtown side of dike, beside dike, between King St. and Queen St.</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Approximate floating line (red line below first deck)</td></tr>
<tr><td>Elevation</td><td>319.7 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>75 years</td></tr>
<tr><td colspan="2" rowspan="5">Note: It is unclear whether the Keno can float freely or not.</td><td>Closed storm drains</td><td>120 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>1.4%</td></tr>
<tr><td>Closed storm drains</td><td>0.8%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">17</td></tr>
<tr><td>Asset</td><td colspan="4">Fire Hall / City of Dawson Building</td></tr>
<tr><td>Location</td><td colspan="4">Front St. / North side of downtown</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Ground level / First floor</td></tr>
<tr><td>Elevation</td><td>319.7 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>75 years</td></tr>
<tr><td colspan="2" rowspan="5"></td><td>Closed storm drains</td><td>120 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>1.4%</td></tr>
<tr><td>Closed storm drains</td><td>0.8%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

Community	Dawson
ID #	18
Asset	Public Work Garage
Location	Beside Firehall / South side

Surveyed feature	First floor / Concrete slab			
Elevation	319.9 m	Flood return period	Open storm drains	95 years
			Closed storm drains	120 years
			Optimal dike	200 years
		Annual flood probability	Open storm drains	1.0%
			Closed storm drains	0.8%
			Optimal dike	0.5%

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">19-20</td></tr>
<tr><td>Asset</td><td colspan="4">New Tr’inkè Zho Daycare</td></tr>
<tr><td>Location</td><td colspan="4">Behind Firehall / Second Ave.</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><td>Surveyed feature</td><td colspan="4">First floor / top of stairs (Bottom of outside stairs / Parking)</td></tr>
<tr><td>Elevation</td><td>320.6 m (319.4 m)</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>200 years (50 years)</td></tr>
<tr><td colspan="2" rowspan="5"></td><td>Closed storm drains</td><td>200 years (120 years)</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>0.5% (2%)</td></tr>
<tr><td>Closed storm drains</td><td>0.5% (0.8%)</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

Community	Dawson
ID #	21
Asset	Tr'ondëk Hwëch'in Government
Location	Front St. between Duke St. and York St.

<table>
<tr><td>Surveyed feature</td><td colspan="4">First Floor / Main entrance / Top of outdoor stairs</td></tr>
<tr><td>Elevation</td><td>320.5 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>195 years</td></tr>
<tr><td colspan="2" rowspan="5"></td><td>Closed storm drains</td><td>195 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>0.5%</td></tr>
<tr><td>Closed storm drains</td><td>0.5%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">22</td></tr>
<tr><td>Asset</td><td colspan="4">Tr'ondëk Hwëch'in Community Hall</td></tr>
<tr><td>Location</td><td colspan="4">Front St. besides Tr'ondëk Hwëch'in Government building</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><td>Surveyed feature</td><td colspan="4">First Floor / Top of outdoor stairs and ramp</td></tr>
<tr><td>Elevation</td><td>321.0 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>250 years</td></tr>
<tr><td colspan="2" rowspan="5"></td><td>Closed storm drains</td><td>250 years</td></tr>
<tr><td>Optimal dike</td><td>250 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>0.4%</td></tr>
<tr><td>Closed storm drains</td><td>0.4%</td></tr>
<tr><td>Optimal dike</td><td>0.4%</td></tr>
</table>

Community	Dawson
ID #	23
Asset	Wellness Centre
Location	Second Ave. between Duke St. and York St.

Surveyed feature	First Floor / Main entrance / Top of outdoor stairs			
Elevation	320.6 m	Flood return period	Open storm drains	200 years
			Closed storm drains	200 years
			Optimal dike	200 years
		Annual flood probability	Open storm drains	0.5%
			Closed storm drains	0.5%
			Optimal dike	0.5%

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">24-25</td></tr>
<tr><td>Asset</td><td colspan="4">Dänojà Zho Cultural Centre (and theater)</td></tr>
<tr><td>Location</td><td colspan="4">Dike / Maint St. / across York St.</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">First Floor / Main entrance (Lower Theater level, assumed floor elev.)</td></tr>
<tr><td>Elevation</td><td>321.7 m
(319.7 m)</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>400 years
(75 years)</td></tr>
<tr><td colspan="2" rowspan="5"></td><td>Closed storm drains</td><td>400 years
(120 years)</td></tr>
<tr><td>Optimal dike</td><td>400 years
(200 years)</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>0.25% (1.4%)</td></tr>
<tr><td>Closed storm drains</td><td>0.25% (0.8%)</td></tr>
<tr><td>Optimal dike</td><td>0.25% (0.4%)</td></tr>
</table>

Community	Dawson
ID #	26
Asset	Lift station
Location	York St. and 2nd Ave.

Surveyed feature	First floor / Concrete slab / Level of lower electronics			
Elevation	319.4 m	Flood return period	Open storm drains	50 years
			Closed storm drains	120 years
			Optimal dike	200 years
		Annual flood probability	Open storm drains	2%
			Closed storm drains	0.8%
			Optimal dike	0.5%

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">27</td></tr>
<tr><td>Asset</td><td colspan="4">Recreation Centre / North wing</td></tr>
<tr><td>Location</td><td colspan="4">4th Ave.</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">First floor / Main entrance / North side of building</td></tr>
<tr><td>Elevation</td><td>320.1 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>130 years</td></tr>
<tr><td colspan="2" rowspan="5"></td><td>Closed storm drains</td><td>145 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>0.8%</td></tr>
<tr><td>Closed storm drains</td><td>0.7%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

Community	Dawson
ID #	28
Asset	Art and Margaret Fry Recreation Centre / South wing
Location	4th Ave.

Surveyed feature	First floor / West side door / old concrete slab			
Elevation	319.7 m	Flood return period	Open storm drains	75 years
			Closed storm drains	120 years
			Optimal dike	200 years
		Annual flood probability	Open storm drains	1.3%
			Closed storm drains	0.8%
			Optimal dike	0.5%

Community	Dawson
ID #	29
Asset	Yukon University Tr'odëk Hätr'unohtän Zho Campus
Location	3rd Ave. and Queen St.

Surveyed feature	First floor / Doorstep / Main entrance			
Elevation	320.6 m	Flood return period	Open storm drains	200 years
			Closed storm drains	200 years
			Optimal dike	200 years
		Annual flood probability	Open storm drains	0.5%
			Closed storm drains	0.5%
			Optimal dike	0.5%

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">30</td></tr>
<tr><td>Asset</td><td colspan="4">Robert Service School</td></tr>
<tr><td>Location</td><td colspan="4">5th Ave. and Queen St.</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><td>Surveyed feature</td><td colspan="4">First floor / Doorstep / Main entrance</td></tr>
<tr><td>Elevation</td><td>320.7 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>210 years</td></tr>
<tr><td colspan="2" rowspan="5">Note: The school is now painted in orange with yellow and red.</td><td>Closed storm drains</td><td>210 years</td></tr>
<tr><td>Optimal dike</td><td>210 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>0.5%</td></tr>
<tr><td>Closed storm drains</td><td>0.5%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

Community	Dawson			
ID #	31			
Asset	Dawson City Water Valve Chamber			
Location	Princess St. and 5th Ave.			

Surveyed feature	First floor / Top of stairs			
Elevation	319.9 m	Flood return period	Open storm drains	100 years
			Closed storm drains	120 years
			Optimal dike	200 years
		Annual flood probability	Open storm drains	1.0%
			Closed storm drains	0.8%
			Optimal dike	0.5%

Community	Dawson
ID #	32
Asset	McDonald Residence
Location	Church St. and 7th Ave.

Surveyed feature	First floor / Doorstep			
Elevation	320.4 m	Flood return period	Open storm drains	180 years
			Closed storm drains	180 years
			Optimal dike	200 years
		Annual flood probability	Open storm drains	0.6%
			Closed storm drains	0.6%
			Optimal dike	0.5%

Community	Dawson
ID #	33
Asset	Hospital
Location	Church St. and 6 Ave., behind Museum

Surveyed feature	First floor / Doorstep			
Elevation	320.0 m	Flood return period	Open storm drains	110 years
Note: Measurements indicate that the McDonald Residence attached to the Hospital is 0.4 m higher.			Closed storm drains	125 years
			Optimal dike	200 years
		Annual flood probability	Open storm drains	0.9%
			Closed storm drains	0.8%
			Optimal dike	0.5%

Community	Dawson
ID #	34
Asset	Governor's House
Location	Front St. south of Church St.

<table>
<tr><td>Surveyed feature</td><td colspan="4">First floor / Top of outdoor stairs</td></tr>
<tr><td>Elevation</td><td>319.8 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>90 years</td></tr>
<tr><td colspan="2" rowspan="6">Note: Photo taken from the back</td><td>Closed storm drains</td><td>120 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>1.1%</td></tr>
<tr><td>Closed storm drains</td><td>0.8%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

Community	Dawson
ID #	35
Asset	Museum
Location	5th Ave. south of Church St.

Surveyed feature	First floor / Top of outdoor stairs			
Elevation	320.3 m	Flood return period	Open storm drains	160 years
			Closed storm drains	160 years
			Optimal dike	200 years
		Annual flood probability	Open storm drains	0.6%
			Closed storm drains	0.6%
			Optimal dike	0.5%

Community	Dawson
ID #	36
Asset	Yukon Government Property Management Division
Location	5th Ave. front of Museum (access in the back)

<table>
<tr><td>Surveyed feature</td><td colspan="4">First floor / Top of outdoor stairs</td></tr>
<tr><td>Elevation</td><td>319.9 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>100 years</td></tr>
<tr><td colspan="2" rowspan="5">Note: Photo taken from main entrance, at the back.</td><td>Closed storm drains</td><td>120 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>1.0%</td></tr>
<tr><td>Closed storm drains</td><td>0.8%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

Community	Dawson
ID #	37
Asset	Green garage behind Sewage Treatment Plant
Location	5th Ave. front of park, behind Sewage Treatment Plant

Surveyed feature	Bottom of garage door / main floor			
Elevation	319.7 m	Flood return period	Open storm drains	75 years
			Closed storm drains	120 years
			Optimal dike	200 years
		Annual flood probability	Open storm drains	1.3%
			Closed storm drains	0.8%
			Optimal dike	0.5%

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">38</td></tr>
<tr><td>Asset</td><td colspan="4">Sewage Treatment Plant</td></tr>
<tr><td>Location</td><td colspan="4">5th Ave. front of Museum</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">First floor / Doorstep (wood slab below large blue door at the back)</td></tr>
<tr><td>Elevation</td><td>319.4 m
(319.6 m)</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>50 years
(65 years)</td></tr>
<tr><td colspan="2" rowspan="5">Note: There is uncertainty here regarding level of main floor since back and front elevations do not correspond (0.2 m difference). This may be due to street grading combined with expect DEM accuracy.</td><td>Closed storm drains</td><td>120 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>2.0%
(1.5%)</td></tr>
<tr><td>Closed storm drains</td><td>0.8%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

Community	Dawson
ID #	39
Asset	RCMP Main building (offices)
Location	Turner St. and Front St.

<table>
<tr><td>Surveyed feature</td><td colspan="4">First floor / Doorstep</td></tr>
<tr><td>Elevation</td><td>319.6 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>65 years</td></tr>
<tr><td colspan="2" rowspan="5"></td><td>Closed storm drains</td><td>120 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>1.5%</td></tr>
<tr><td>Closed storm drains</td><td>0.8%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">40-41-42</td></tr>
<tr><td>Asset</td><td colspan="4">RCMP Main building (offices)</td></tr>
<tr><td>Location</td><td colspan="4">Turner St. and Front St.</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Concrete slab / Doorstep (four doors from South to North)</td></tr>
<tr><td>Elevation</td><td>318.6 m to 318.8 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>15-20 years</td></tr>
<tr><td colspan="2" rowspan="5"></td><td>Closed storm drains</td><td>120 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>6%-7%</td></tr>
<tr><td>Closed storm drains</td><td>0.8%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">43</td></tr>
<tr><td>Asset</td><td colspan="4">Yukon Housing</td></tr>
<tr><td>Location</td><td colspan="4">Turner St. and 5th Ave.</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">First floor / Doorstep / Wood boardwalk</td></tr>
<tr><td>Elevation</td><td>319.7 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>75 years</td></tr>
<tr><td colspan="2" rowspan="5"></td><td>Closed storm drains</td><td>120 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>1.3%</td></tr>
<tr><td>Closed storm drains</td><td>0.8%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

Community	Dawson
ID #	44
Asset	Water Station
Location	Turner St. and 5th Ave.

<table>
<tr><td>Surveyed feature</td><td colspan="4">First floor / Doorstep / Wood boardwalk</td></tr>
<tr><td>Elevation</td><td>319.3 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>45 years</td></tr>
<tr><td colspan="2" rowspan="5"></td><td>Closed storm drains</td><td>120 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>2.2%</td></tr>
<tr><td>Closed storm drains</td><td>0.8%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

Community	Dawson
ID #	45
Asset	Water-related building
Location	Dugas St. and 5th Ave.

Surveyed feature	First floor / Concrete slab (approximate because no access)			
Elevation	319.5 m	Flood return period	Open storm drains	55 years
			Closed storm drains	120 years
			Optimal dike	200 years
		Annual flood probability	Open storm drains	1.8%
			Closed storm drains	0.8%
			Optimal dike	0.5%

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">46-47-48-49</td></tr>
<tr><td>Asset</td><td colspan="4">Water wells (PW-1N, PW-2N, PW-3N and PW-4N)</td></tr>
<tr><td>Location</td><td colspan="4">Between Front St. and dike, between Turner St. and Church St.</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Ground level</td></tr>
<tr><td>Elevation</td><td>320.3 m to 320.4 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>165-180 years</td></tr>
<tr><td colspan="2" rowspan="5">Note: Photo is a satellite image from Google Earth</td><td>Closed storm drains</td><td>165-180 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>0.6%</td></tr>
<tr><td>Closed storm drains</td><td>0.6%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

Community	Dawson
ID #	50
Asset	Yukon Energy Corporation (YEC) main office building (Blue)
Location	5th Ave. between Dugas St. and Front St.

<table>
<tr><td>Surveyed feature</td><td colspan="4">First floor / Doorstep</td></tr>
<tr><td>Elevation</td><td>319.4 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>50 years</td></tr>
<tr><td colspan="2" rowspan="5"></td><td>Closed storm drains</td><td>120 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>2%</td></tr>
<tr><td>Closed storm drains</td><td>0.8%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">51</td></tr>
<tr><td>Asset</td><td colspan="4">Yukon Energy Corporation (YEC) Diesel Plant (Blue)</td></tr>
<tr><td>Location</td><td colspan="4">5th Ave. between Dugas St. and Front St.</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">First floor / Doorstep</td></tr>
<tr><td>Elevation</td><td>320.4 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>190 years</td></tr>
<tr><td colspan="2" rowspan="5"></td><td>Closed storm drains</td><td>190 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>0.5%</td></tr>
<tr><td>Closed storm drains</td><td>0.5%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

Community	Dawson			
ID #	52			
Asset	Yukon Energy Corporation (YEC) Diesel Turbine on trailer (Blue)			
Location	5th Ave. between Dugas St. and Front St.			
				
Surveyed feature	First floor / Top of stairs			
Elevation	320.7 m	Flood return period	Open storm drains	210 years
			Closed storm drains	210 years
			Optimal dike	210 years
		Annual flood probability	Open storm drains	0.5%
			Closed storm drains	0.5%
			Optimal dike	0.5%

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">53</td></tr>
<tr><td>Asset</td><td colspan="4">Yukon Energy Corporation (YEC) Transformer (fenced)</td></tr>
<tr><td>Location</td><td colspan="4">5th Ave. between Dugas St. and Front St.</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Concrete slab / Ground level</td></tr>
<tr><td>Elevation</td><td>320.1 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>130 years</td></tr>
<tr><td colspan="2" rowspan="5">Note: Photo from Google Street View.</td><td>Closed storm drains</td><td>145 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>0.8%</td></tr>
<tr><td>Closed storm drains</td><td>0.7%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

<table>
<tr><td>Community</td><td colspan="4">Dawson</td></tr>
<tr><td>ID #</td><td colspan="4">54-55</td></tr>
<tr><td>Asset</td><td colspan="4">Yukon Energy Corporation (YEC) metal dike (and metal slab for fuel tanks)</td></tr>
<tr><td>Location</td><td colspan="4">5th Ave. between Dugas St. and Front St.</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><td>Surveyed feature</td><td colspan="4">Metal dike surface / Green arrow (Metal floor surface / black arrow)</td></tr>
<tr><td>Elevation</td><td>320.6 m
(320.0 m)</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>200 years
(115 years)</td></tr>
<tr><td colspan="2" rowspan="6"></td><td>Closed storm drains</td><td>200 years
(130 years)</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>0.5 %
(0.9%)</td></tr>
<tr><td>Closed storm drains</td><td>0.5%
(0.8%)</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

Community	Dawson
ID #	56
Asset	Yukon Energy Corporation (YEC) electric boxes
Location	5th Ave. between Dugas St. and Front St.

Surveyed feature	Concrete slab / Footing			
Elevation	320.2 m	Flood return period	Open storm drains	150 years
			Closed storm drains	160 years
			Optimal dike	200 years
		Annual flood probability	Open storm drains	0.7%
			Closed storm drains	0.6%
			Optimal dike	0.5%

Community	Dawson
ID #	57
Asset	North of 60 Petro gas station
Location	5th Ave. and Princess St.

Surveyed feature	Lowest visible underground reservoir valve (ground surface)
Elevation	319.5 m

Flood return period	Open storm drains	60 years
	Closed storm drains	120 years
	Optimal dike	200 years
Annual flood probability	Open storm drains	1.7%
	Closed storm drains	0.8%
	Optimal dike	0.5%

Community	Dawson
ID #	58
Asset	Gate in dike
Location	Dike / North of Keno

<table>
<tr><td>Surveyed feature</td><td colspan="4">Ground level / Concrete slab</td></tr>
<tr><td>Elevation</td><td>318.9 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>20 years</td></tr>
<tr><td colspan="2" rowspan="5">Note: This gate must be closed prior to a dynamic river ice breakup event.</td><td>Closed storm drains</td><td>120 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>5%</td></tr>
<tr><td>Closed storm drains</td><td>0.8%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>

Community	Dawson
ID #	59
Asset	Dip at the North end of dike
Location	North end of front street on the left

<table>
<tr><td colspan="2">Surveyed feature</td><td colspan="3">Lowest point, center of dike</td></tr>
<tr><td>Elevation</td><td>319.9 m</td><td rowspan="3">Flood return period</td><td>Open storm drains</td><td>120 years</td></tr>
<tr><td colspan="2" rowspan="5">Note: This is the reason why most assets in Dawson are protected against a 120-year event rather than a 200-year event.</td><td>Closed storm drains</td><td>120 years</td></tr>
<tr><td>Optimal dike</td><td>200 years</td></tr>
<tr><td rowspan="3">Annual flood probability</td><td>Open storm drains</td><td>0.9%</td></tr>
<tr><td>Closed storm drains</td><td>0.9%</td></tr>
<tr><td>Optimal dike</td><td>0.5%</td></tr>
</table>