September 2022

TO: Honourable Caroline Cochrane- Premier of the Northwest Territories
Honourable Shane Thompson- GNWT Minister of Municipal and Community Affairs, GNWT Minister of Environment and Natural Resources
Honourable Diane Archie- GNWT Minister or Infrastructure

CC: Honourable Chief April Martel- Chief of K'átł'odeeche First Nation
Honourable Kandis Jameson- Town of Hay River Mayor
Honourable Rocky Simpson- Hay River South MLA
Honourable R.J. Simpson- Hay River North MLA

Analysis of Regional Flood Risk Planning and Evacuation Procedures following the May 2022 Hay River Flood

Hello,

I have prepared the following memo to provide some analysis and recommendations regarding regional flood risk planning and evacuation procedures and policies following the unprecedented flooding that occurred in May 2022 on the Hay River, Northwest Territories (NWT) and the corresponding community wide evacuations that took place for the communities of Hay River, K'átł'odeeche First Nation (KFN) and surrounding areas.

I have studied and worked in water resource engineering, flood modeling, and municipal and transportation drainage design in various jurisdictions across Canada. I am also a resident of Hay River that was present in the community for the flood and took part in the evacuation. Based on my experience I feel the current approach to flood risk and evacuation planning in the NWT is not sufficient for the high risk of flooding that is present for many communities and the challenges associated with evacuation planning for remote communities. This evidence-based assessment will present tools, policies and methods that are being employed in other jurisdictions across Canada that could be implemented in the NWT to improve future flood risk and evacuation planning and which will improve public safety and reduce costs for future flooding and evacuation events.

I have directed this memo to the Premier and the Government of the Northwest Territories (GNWT) Ministers responsible for flood risk planning and response. I have also included leaders of the two communities impacted by the 2022 Hay River flood. My aim in gathering this information is to outline some deficiencies in the current NWT approach for regional flood risk and evacuation planning and provide some potential mitigations based on policies, procedures and planning approaches that are used in other jurisdictions in Canada. My hope is that the government leaders responsible for flood and evacuation planning use this information to update current policies and procedures to ensure the NWT and its communities are better prepared for future flooding events. The GNWT currently has a Request for Proposal for the "Spring Flood After Action Review" (EV6057). The successful proponent should be provided a copy of this memo as it will provide helpful information for the project and the After-Action Review results.

1. Summary of Conclusions and Mitigations

- Many Canadian flood forecasting, mitigation, management and financial policies and governmental frameworks have been developed directly in response to major flooding events that have occurred in that region to ensure the region is better prepared for future flooding events.
- The GNWT has very clearly defined flooding as a high-risk natural disaster with a high probability/certainty of impacting communities in the NWT.;
    - Numerous mitigation strategies have been defined in GNWT risk assessment reports along with risk matrices, maps, and significant information on risks to infrastructure; and
- Given some of the deficiencies in flood forecasting and evacuation procedures outlined in this memo there is clearly a gap between the GNWT risk assessments and the actual implementation of recommended mitigation and adaptation measures during recent flooding events in 2021 and 2022.
- Ice jam floods, such as those that occur on the Hay, Mackenzie and Laird Rivers in the NWT, are more dangerous than open water flooding which occurs across much of Southern Canada as;
    - Ice jam floods are very difficult to forecast and predict;
    - Ice jam floods can occur very quickly with flood waters rising sharply within minutes; and
    - Ice jam floods often have large amounts of moving debris and ice that can damage infrastructure and result in injury and/or death.
- Deficiency 1- Evacuation Alerts/Orders Timing and Location
    - No evacuation alert was provided for Paradise Gardens and surrounding areas prior to the evacuation order to allow residents time to pack for evacuations, prepare their homes, farms and business for flooding;
    - The evacuation order for Paradise Gardens and Riverview Drive was sent after flash flood waters began flooding homes and roads which did not provide sufficient time for a safe evacuation;
    - Although the lower part of the 553 area was heavily impacted by the flooding this area never received an evacuation alert or order until approximately 2 hours after it had been flooded when the community wide evacuation order was issued which was not sufficient for a safe evacuation; and
    - The evacuation orders and alerts did not properly employ all of the hydrological factors and available data such as upstream flow and water levels.
- Mitigation 1A- Flood Inundation Mapping
    - In advance of completing formal floodplain risk/hazard mapping "Flood Inundation Maps" should be developed for all high-risk communities in the NWT to improve the safety of future evacuations in the short term. These flood inundation maps should:
        - Include entire communities;
        - Follow the Federal Floodplain Mapping Guidelines;
        - Work in conjunction with the water levels from local water monitoring stations;
        - Define zones and properties at risk in relation to water levels based on elevation;
        - Be publicly available to all residents;
        - Be developed in conjunction with local communities needs and priorities; and

        - Include flood water elevations higher than historical flooding as climate change is leading to unprecedented flooding.
- Mitigation 1B- Use of Real-time Monitoring Data and Increased Monitoring for High-Risk Areas
    - Install additional water level gauges where required for areas within or outside high-risk communities where no water level gauge exists; and
    - Use real-time water level and flow data with the flood inundation maps to develop clearly defined evacuation procedures and zones for high-risk communities.
- Mitigation 1C- Ensure Flood Evacuation Alerts and Orders are issued by Subject Matter Experts
    - Ensure real-time WSC water level and flow data is used in developing future flood evacuation alerts and orders;
    - Qualified water resource engineers and/or hydrologists should be the party responsible for issuing evacuation alerts and orders for flooding;
    - Transfer the responsibility for developing detailed flood inundation mapping and evacuation thresholds to qualified water resource engineers and/or hydrologists in the GNWT;
        - This will be more a more efficient, cheaper and more standardized approach if completed at the territorial level for all communities;
        - GNWT will need to engage with communities to ensure the plans meet the community/indigenous governments needs and expectations.
- Deficiency 2- Evacuation Destination
    - Directing the community-wide evacuation to Enterprise, a community that does not have sufficient lodging, healthcare and/or grocery services to accommodate the approximately 3500 residents of Hay River, resulted in:
        - Residents not evacuating;
        - Residents spending the night in vehicles/local centers or businesses before returning to Hay River or moving to another community and/or;
        - Residents evacuating directly to communities spread areas across a radius of 1400km in the NWT and northern Alberta with an evacuation time of 5-24 hours depending on circumstances.
- Mitigation 2A- Evacuation Destination with Sufficient Services and Accommodation for Evacuees
    - Evacuation plans during flooding events should be reviewed for NWT communities and updated to ensure a community wide evacuation directs residents to the closest community that has sufficient healthcare, food and lodging capacity to accommodate evacuees and includes additional scenarios for blocked routes, high risk individuals, etc.
- Mitigation 2B- Increasing Territorial Responsibility for Community Wide Evacuations
    - Transfer the responsibility for developing and implementing community-wide evacuation plans for flooding events to the GNWT and use technical experts from various departments to coordinate the plans on a regional level while also engaging with communities to ensure the plans meet the community/indigenous governments needs and expectations.
- Deficiency 3- Safety of Evacuation Route
    - The NWT highway system is prone to overtopping and washout during flood events which results in:
        - Public safety risks during community evacuations;
        - Costly disruptions to the supply chain of the NWT; and
        - Emergency repairs which are very costly and financially wasteful.

- Mitigation 3A- Additional Preventative Maintenance
    - Implement additional preventative maintenance during spring break up, and before freshet during high water years for territorial highway culverts and crossings to ensure culverts and bridges are flowing at full capacity and problem areas are flagged before they overtop the highway.
- Mitigation 3B- Implementation of Territorial Highway Drainage Design Standards
    - The NWT could significantly reduce the risk of future highway overtopping by developing and implementing highway drainage standards for all NWT highways that take the upstream drainage area and peak flow into account when sizing culverts and bridges similar to other jurisdictions in Canada;
    - These standards should be developed specifically for the NWT climate and highway system and be scoped for implementation in the NWT.

2. Limitations and Context

- ***This memo comes from a place of extreme gratitude and respect for the first responders, staff and volunteers involved 2022 flood response and recovery who worked tirelessly to reduce the damage to people and infrastructure throughout the flood and to support those impacted throughout the clean-up and rebuild.***
- All mitigations and/or recommendations must be verified through detailed site-specific calculations and a quality assurance/quality control process by the Federal, Municipal, Territorial, Indigenous Government Organizations responsible and/or 3rd party engineers.
- This memo is prepared using publicly available information.
- Any conclusions or recommendations are directed at a system of governance and not the people working within that system.
- This memo is focused on deficiencies and potential mitigations for regional flood risk planning, mapping and forecasting and evacuation procedures and policies only.
    - There are many other facets of floods that are not covered in this document such as flood mitigation, flood recovery funding, flood clean up, short- and long-term repairs for infrastructure etc.
    - For some of these other facets of flood response, such as government flood recovery funding, the NWT exceeds other jurisdictions in Canada.
- The analyses and recommendations in this document are quite detailed and technical in nature; I hope that the technical specialists within your respective departments and organizations can review it.
- I am writing this memo on behalf of no company, organization or government body only as a resident of Hay River with formal technical training in this area.

3. Background

3.1. Evolution of Canadian Flood Policies following Major Flooding Events

Natural disasters, especially unprecedented major events, are often a catalyst for policy change to make improvements to be better prepared for when future events occur (Brundiers & Eakin, 2018). This has become even more evident as natural disasters across Canada and the world have become more severe, unpredictable, destructive and costly as the global climate has changed over the late 20th and early 21st century (Brundiers & Eakin, 2018).). Table 1 below summarizes several examples of major flood events in Canada and corresponding policy changes

that followed across Canada. This is not an exhaustive review just a snapshot into some policy changes for reference in this discussion.

The GNWT has also updated some of its flood policy in response to flooding in 2021 and 2022; two examples include increasing the disaster assistance coverage limit for residents and small businesses up to $240,000 from the previous maximum amount of $100,000 and completing the ongoing "Spring Flood After Action Review".

Table 1- Major Flooding Events and Corresponding Policy Changes

Event	Policy Change
Soil loss and extensive flooding throughout Ontario as a result of poor land, water and forestry practices during the 1930s and 1940s.[1]	The Conservation Authorities Act passed in 1946 provided the means by which the province and the municipalities could form a Conservation Authority to manage natural resources based on watershed boundaries.[1]
October 1954: Hurricane Hazel flood in Toronto. Caused damages ranging from CAD 152 million to 769 million.[1]	After Hurricane Hazel the provincial government amended the Conservation Authorities Act to enable Conservation Authorities to acquire lands for recreation and conservation purposes, and to regulate that land for the safety of the community.[1]
May 1948: Fraser River Flooding (British Columbia). Ten fatalities, 16,000 evacuated, almost 10% of the area of the Fraser Valley was flooded.[2]	1968: Fraser River Flood Control Program established by the Government of British Columbia and the federal government to reconstruct and maintain dykes in the lower Fraser Valley.[2]
May 1972: Fraser River at Prince George (British Columbia). The Fraser River peaked three times in June, flooding both the upper and lower Fraser River Valley and affecting several communities and causing significant damage.[2]	1972: Initiation of floodplain management in British Columbia due to the large Fraser River flood of 1972.[2]
July–August 1993: Winnipeg (Manitoba). The city was declared a disaster area as a result of prolonged heavy rainfall, including three severe rainstorms in a five-week period. Estimated costs in excess of CAD 214 million. Actual costs were more than CAD 498 million April 1997: Red River Flood in Manitoba. The province declared a state of emergency on 22 April. Five days later, Emerson was hit. Over 25,447 people were evacuated.[2]	2005: Governments of Canada and Manitoba invested CAD 628 million to further expand the Red River Floodway.[2]
2004: Severe storm in Edmonton resulted in approximately CAD 166 million in insured damages; CAD 143 million was associated with sewer backup. Water was ankle deep and roof damages resulted in the evacuation of 30,000 people from the West Edmonton Mall.[2]	July 2004: Flood Prevention Home Check-up service developed as a direct response to the flooding of 4,000 Edmonton homes in July 2004.[2]
May 2012: A storm system affected Thunder Bay and moved through to Montreal. Resulted in CAD 260 million in insured damages June 2013: Flooding in southern Alberta. Largest disaster loss ever recorded in western Canada. A massive storm system crept through Alberta then British Columbia, causing significant flooding throughout the provinces. Four deaths were attributed to the floods. Insurance payments estimated at CAD 1.7 billion; total payments amounted to nearly CAD 2.71 billion. An additional CAD 10 million in federal disaster aid flowed to British Columbia July 2013: Toronto (Ontario). A thunderstorm producing 126 mm in precipitation caused flash flooding in the Greater Toronto area (GTA), resulting in over CAD 1 billion insured losses.[2]	2013: The federal government commissioned a National Floodplain Mapping Assessment. The final report was completed in 2014 2015: Study (The Financial Management of Flood Risk – An International Review) initiated following the 2013 Alberta and GTA flooding completed by the Insurance Bureau of Canada (IBC). Outlined four preconditions necessary for the establishment of private flood insurance in Canada.[2]

1- Referenced from (Conservation Ontario, 2018)
2- Referenced from (The Geneva Association, 2020).

Conclusion

- **Many Canadian flood forecasting, mitigation, management and financial policies and governmental frameworks have been developed directly in response to major flooding events that have occurred in that region to ensure the region is better prepared for future flooding events.**

3.2. Flood Hazard Identification and Risk Assessments in the NWT

In 2014 the Government of Northwest Territories (GNWT) Department of Municipal and Community Affairs (MACA) commissioned Vanguard EMC Inc. to complete the *Northwest Territories Hazard Identification Risk Assessment* (Vanguard, 2014). This report was created to identify hazards and examine the risks that pose a threat to the people, property, environment and economy of the NWT (Vanguard, 2014). Identified hazards were to be used in preparedness programs, mitigation strategies, emergency response plan exercises, and training and awareness programs (Vanguard, 2014). The full report is located here: nwt-hira-final.pdf (gov.nt.ca).

Referring to Figure 1 and Table 2, both of which are directly from the report, it can be seen that Floods and Fires were found to be the highest risk hazards throughout the NWT with a high impact and a probability of occurring within 1-3 years. The report stated that floods have:

- *Potential to cause multiple deaths;*
- *Current and frequent historical experience in the NWT;*
- *High damage potential when near or in a community; and*
- *Potential to affect any community in the NWT* (Vanguard, 2014).

Figure 1- NWT HIRA Risk Matrix from 2014 Northwest Territories Hazard Identification Risk Assessment (Vanguard, 2014)

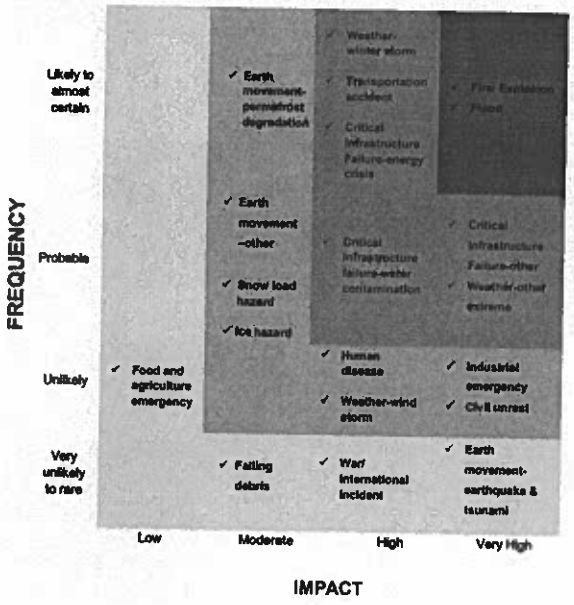


Table 2- Frequency Categories from 2014 Northwest Territories Hazard Identification Risk Assessment (Vanguard, 2014)

Frequency	Category	Return Period
1	Rare	>201 years
2	Very Unlikely	101-200 years
3	Unlikely	31-100 years
4	Probable	11-30 years
5	Likely	4-10 years
6	Almost Certain	1-3 years

Recommended mitigation options from the report are listed below:

- *Outline a water management and community development policy.*

- *Develop and exercise plans/programs for:*
  - *Watershed management*
  - *River/lake/ocean modelling/prediction and monitoring*
  - *Erosion control*
  - *Flood response*
- *In the face of rapid snowmelt and intense rains in spring and summer, communities susceptible to flash flooding should review and improve their drainage facilities and protect vulnerable building and facilities (Black, et al, 2010)* (Vanguard, 2014).

More recently in 2021 GNWT MACA commissioned WSP Canada Inc. to complete the *Assessment of Climate Change Impacts on Infrastructure in all NWT Communities* (WSP, 2021). The objective of the report was to conduct a high-level climate change vulnerability assessment of all GNWT- and community-owned infrastructure located within or associated with NWT communities (WSP, 2021). Table 3 below presents the climate related hazard risk level for NWT regions from the report (WSP, 2021). Floods and wildfire again were rated at the high-risk level for all regions with the exception of North Slave for floods (WSP, 2021). The full report is located here: gnwt_pievc_report_final_released.pdf (gov.nt.ca).

Table 3- Climate Related Hazard Risk Level for NWT Regions from the Assessment of Climate Change Impacts on Infrastructure in all NWT Communities (WSP, 2021)

Climate-related hazard	Region				
	North Slave	South Slave	Dehcho	Sahtu	Beaufort Delta
Flood (open-water, ice jam and coastal submersion)	L	H	H	H	H
Snow load	M	M	M	M	M
Winter storm	M	M	M	M	H
Wind storm	M	L	L	L	M
Extreme weather	M	L	L	L	L
Ice hazard	L	L	L	M	L
Permafrost degradation	M	L	L	L	M
Wildfire	H	H	H	H	H
Earth movement – Other[2]	L	M	L	M	H

1. H: High risk level | M: Moderate risk level | L: Low risk level.
2. Includes fluvial erosion (Beaufort Delta), landslides (South Slave, Sahtu) and riverbank erosion (N. Slave, S. Slave, Dehcho).
Adapted from MACA (2014).

The communities of the NWT are particularly vulnerable to the increasing severity of climate change related natural disasters, including floods, given the remoteness and inaccessibility of NWT communities, the lack of infrastructure and services and the accelerated rate at which the climate is changing in the arctic and subarctic regions of the globe. (Black, et al, 2010, Vanguard, 2014, WSP, 2021). Although these studies were completed at the territorial government level the responsibility for flood emergency planning and evacuations for floods falls on the community level of government.

Conclusion

- **The GNWT has very clearly defined flooding as a high-risk natural disaster with a high probability/certainty of impacting communities in the NWT.;**
  - **Numerous mitigation strategies have been defined in GNWT risk assessment reports along with risk matrices, maps, and significant information on risks to infrastructure; and**
- **Given some of the deficiencies in flood forecasting and evacuation procedures outlined in this memo there is clearly a gap between the GNWT risk assessments and the actual implementation of recommended mitigation and adaptation measures during recent flooding events in 2021 and 2022.**

3.3. Ice Jam Floods

Ice Jam floods, such as those that occur on the Hay, Mackenzie and Laird Rivers in the NWT, are different from open water floods. Open water floods are related directly to rainfall while ice jam floods are related to a variety of factors including amount of snow, speed of melt, water levels, flow in the watercourse, thickness of ice, air temperature and shape of the river (Government of Alberta, 2018). The wide variety of contributing factors make ice jam floods very difficult to predict and forecast (Government of Alberta, 2018).

Ice jam floods also happen much quicker than open water floods (Government of Alberta, 2018). During an open water floods water levels rise slowly over days or hours while in ice jam floods water levels can rise very sharply in a matter of minutes or hours (Government of Alberta, 2018). This sharp rise of water levels within minutes occurred in several areas on the Hay River in 2022 where waters rose 6-12 ft (1.8-3.6m) in minutes. Given the speed of the rising water and power of the ice and water in an ice jam flood there can also be large amounts of debris present which can result in damage to infrastructure and increased risk to human health.

Conclusion

- **Ice jam floods, such as those that occur on the Hay, Mackenzie and Laird Rivers in the NWT, are more dangerous than open water flooding which occurs across much of Southern Canada as;**
  - **Ice jam floods are very difficult to forecast and predict;**
  - **Ice jam floods can occur very quickly with flood waters rising sharply within minutes; and**
  - **Ice jam floods often have large amounts of moving debris and ice that can damage infrastructure and result in injury and/or death.**

4. Deficiencies and Potential Mitigations based on 2022 Hay River Flood Planning, Forecasting, and Evacuations Summary

The following sections outline three main deficiencies with the regional flood risk planning and evacuation procedures and policies currently employed in the NWT. With each deficiency potential mitigations are presented based on tools, policies and methods that are being employed in other jurisdictions across Canada that could be implemented in the NWT to improve public safety and reduce costs. This is not an exhaustive list of mitigations but presents some proposals based on what has been successful in other jurisdictions. The deficiencies and mitigations presented are:

- Deficiency 1- Evacuation Alerts/Orders Timing and Location
  - Mitigation 1A- Flood Inundation Mapping
  - Mitigation 1B- Use of Real-time Monitoring Data and Increased Monitoring for High-Risk Areas
  - Mitigation 1C- Ensure Flood Evacuation Alerts and Orders are issued by Subject Matter Experts
- Deficiency 2- Evacuation Destination
  - Mitigation 2A- Evacuation Destination with Sufficient Services and Accommodation for Evacuees
  - Mitigation 2B- Increasing Territorial Responsibility for Community Wide Evacuations
- Deficiency 3- Safety of Evacuation Route

- Mitigation 3A- Additional Preventative Maintenance
- Mitigation 3B- Implementation of Territorial Highway Drainage Design Standards

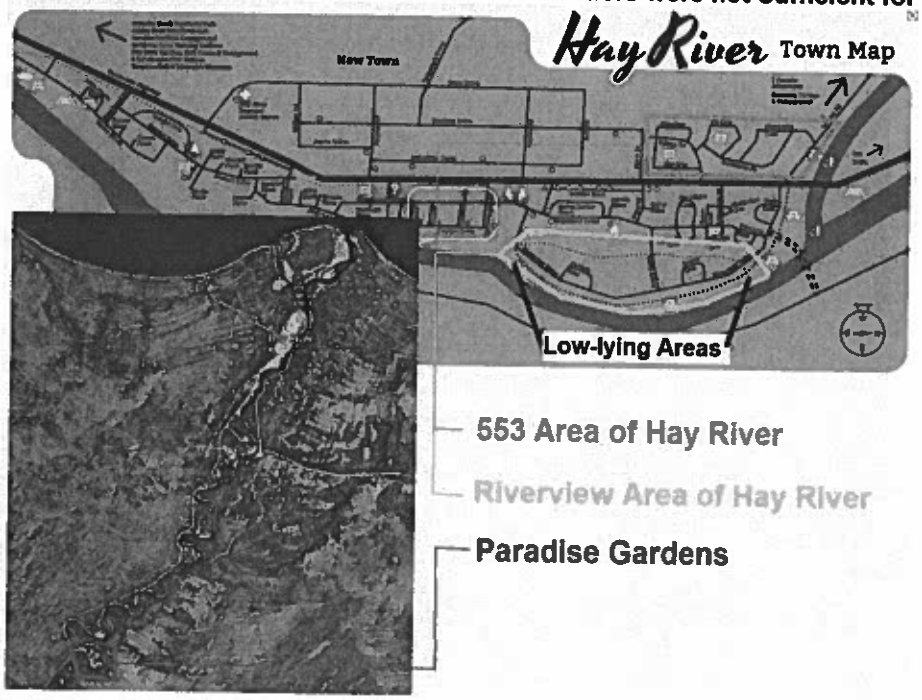
5. Deficiency 1- Evacuation Alerts/Orders Timing and Location

The evacuation alerts and orders were communicated in various ways including emergency alert notifications sent to all mobile devices in the area. An *evacuation alert* is notification that an evacuation order may be issued and all residents should be prepared to evacuate. An *evacuation order* is an order to evacuate the area immediately. The emergency alert notification method of communication is very effective as most residents have at least one mobile device that automatically receives the information.

Although the method of communication was effective the timing and location of the evacuation alerts and orders was not sufficient or conservative enough to allow a safe evacuation for some areas of Hay River and surrounding areas. Some locations did not receive an evacuation order or alert until flood waters, ice and debris was already blocking roadways and flooding homes. This resulted in people in these locations having to evacuate with very few possessions and in some cases through very dangerous conditions such as walking through cold, fast flowing water with significant debris with small children and pets in hand to higher ground.

There are many examples from the 2022 Hay River flood of first responders, neighbours and friends performing daring and brave rescues to get people that were trapped by the quickly rising waters out to safety. These rescues could have been avoided all together if more conservative and properly located evacuation orders and alerts were sent out prior to the flooding. Some locations in Hay River did receive evacuation orders with sufficient time for a safe evacuation and some did not. Details on the locations that did not receive sufficient time for evacuation are presented below.

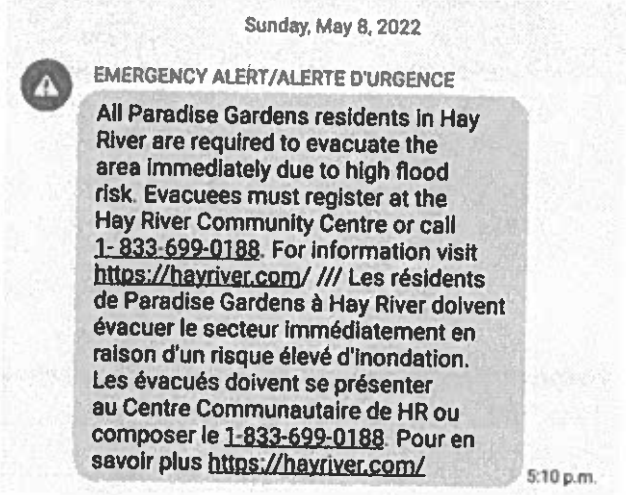
Figure 2- Locations where Evacuation Alerts/Orders were not Sufficient for Safe Evacuation



5.1.1. Paradise Gardens and Surrounding Areas

Paradise Gardens received an evacuation order at 5:10pm on Sunday May 8. No evacuation alert was sent prior to the order. The evacuation order was sent after flood waters had already overtopped the banks of the river upstream of the area and began flooding homes and properties. This resulted in a last-minute evacuation for many residents who had to quickly gather belongings, tend to their farms, properties and livestock and drive through flowing water to higher ground. A high-risk rescue was completed by local first responders on the evening of Sunday May 8 to remove a resident upstream of Paradise Gardens that was trapped on their roof. Some of these escapes have been documented here: https://cabinradio.ca/92458/news/south-slave/they-just-bought-their-dream-home-a-flood-washed-that-dream-away/

Figure 3- Paradise Gardens Evacuation Order



5.1.2. Riverview Drive

Riverview Drive was included on the evacuation alert that was sent out at 8:53pm Sunday May 8 after the flooding occurred at Paradise Gardens.

Figure 4- Riverfront Areas Evacuation Alert

The Hay River began moving in the area around the town of Hay River around 10:30pm on Wednesday May 11 after being frozen from the storm the previous weekend. An evacuation order was issued at 11:13pm for residents of Riverfront areas (Corridor, Miron, McBryan, Capital, Riverview). Low lying areas along Riverview had already begun to flood before the 11:13pm order with quickly rising, fast flowing water, especially at the low-lying areas, and many residents had to drive out through flood waters. Some residents of the low-lying areas of Riverview along the drainage ditch had very close escapes from their houses that were quickly filling with water that involved heavy equipment to clear debris that was thankfully in the area.

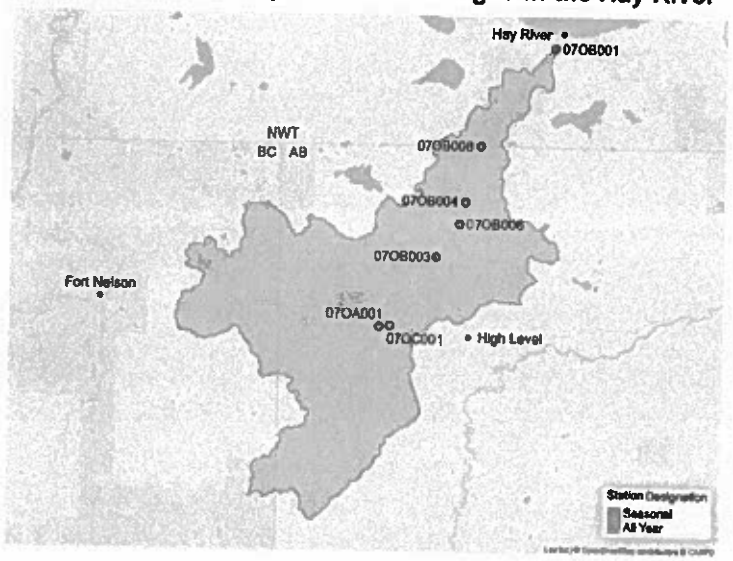
5.1.3. 553 Area

The 553 area was not included on the evacuation alert or order for Riverfront areas. No evacuation alert or order was provided for the 553 area of Hay River until the community-wide evacuation order was sent at 12:33am on Thursday May 12. Between 1030pm and 11pm on May 11 soon after the river began moving again an ice jam in the west channel caused the flooding in the 553 area with very quickly rising waters and a large amount of debris, including large ice chunks, trees and other debris. The quickly rising water and large amount of debris made it very difficult for some residents to evacuate their homes. Some were able to drive out before the water got too high but as the waters rose there was several vehicles that were flooded and stalled out. Many people left their homes on foot carrying a few bags, their children and pets through the water and debris. Some also waited for first responders who came around in boats and/or heavy equipment.

5.1.4. Hydrology Data

The Water Survey of Canada (WSC) operates water level and flow gauges all across Canada. There are 7 WSC gauges in the Hay River Basin, 4 are operated seasonally and 3 are operated all year.

Figure 5- Water Survey of Canada Gauges in the Hay River



All of the water level and flow data for these gauges is available publicly. The links for the data for the stations is provided below

- CHINCHAGA RIVER NEAR HIGH LEVEL (07OC001)
  https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=07OC001&fbclid=IwAR0qarpJ85lPRSV3uFJUaF5Ks_Q1ivG6H9M5eorvOG2CAHqqSiE-6R9uuWg
- •SOUSA CREEK NEAR HIGH LEVEL (07OA001) [AB]
  https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=07OA001&fbclid=IwAR0lQt5SFRB0rZzuO5nD8PQXFnOaAF3KyXkDg3UgvVVvJExc5xfJWUsM644
- •LUTOSE CREEK NEAR STEEN RIVER (07OB006) [AB]
  https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=07OB006&fbclid=IwAR24H5JD2GG0nAq9xTmJuacJ6IQX2RzcKxFCjx9mrsPZvFuEdZ3DmEDpLtg
- •STEEN RIVER NEAR STEEN RIVER (07OB004) [AB]
  https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=07OB004&fbclid=IwAR2VCgEbX4vtuChGu4U2LF0jQxyfRVej-aOM-2BKycmw319mVvuhpjMPJsA
- •HAY RIVER NEAR ALTA/NWT BOUNDARY (07OB008) [NT]
  https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=07OB008&fbclid=IwAR3Fi8pEJF1d3zjRGcePJ1gDpNgFXpDgcFCyr5t6cb1wFbrG7lnWVEel1es
- •HAY RIVER NEAR HAY RIVER (07OB001) [NT]
  https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=07OB001&fbclid=IwAR2HomBgzuprKr3CW_SBGMl6-WswM6kn6ynnYypZWyGemkE-FA6h_LKcEQ0

A large precipitation event occurred over the Hay River Basin on the weekend of May 7 and 8, 2022, consisting of a large amount of rain in the southern end of the basin and snow in the northern end. The ground was still frozen at this time of year meaning infiltration was minimal and the majority of the precipitation ended up as runoff into the Hay River. Before the flooding occurred in the Hay River area flooding occurred in several areas upstream which resulted in several road closures and a full evacuation of the community of Chateh in Northern Alberta. Historically high-water levels on the Great Slave Lake and Hay River combined with very deep ice on the Hay River and Great Slave Lake to create high risk conditions for ice jam flooding. These conditions combined the increased flows from the southern part of the basin to create the unprecedented flooding that occurred.

"Ice Jams and Flood Forecasting, Hay River, N.W.T." (Gerard and Stanley, 1988) estimated a "approximately two-day travel time of flow between the WSC station at the Alberta-NWT border and Hay River" (Gerard and Stanley, 1988). It also stated that "only 6% of the Hay River

catchment lies below WSC station at the Alberta-NWT border and most of this area is flat and covered with muskeg and so adds little runoff. Consequently, discharge at the border station should be almost the same as the discharge in Hay River some two days later." (Gerard and Stanley, 1988).

All of the hydrological factors mentioned in Section 5.1.4 were not properly employed in the evacuation alerts and orders for the Hay River flood in 2022 outlined in Section 5.1.1-3. Water elevations and ice levels were at unprecedented levels and an unprecedented precipitation event occurred in the basin right during the river break up (with WSC gauges upstream all still rising) yet the approach to evacuation orders and alerts did not properly employ this hydrological information which led to the unsafe evacuations outlined above.

Conclusion

- **No evacuation alert was provided for Paradise Gardens and surrounding areas prior to the evacuation order to allow residents time to pack for evacuations, prepare their homes, farms and business for flooding;**
- **The evacuation order for Paradise Gardens and Riverview Drive was sent after flash flood waters began flooding homes and roads which did not provide sufficient time for a safe evacuation;**
- **Although the lower part of the 553 area was heavily impacted by the flooding this area never received an evacuation alert or order until approximately 2 hours after it had been flooded when the community wide evacuation order was issued which was not sufficient for a safe evacuation; and**
- **The evacuation orders and alerts did not properly employ all of the hydrological factors and available data such as upstream flow and water levels.**

5.2. Mitigation 1A- Flood Inundation Mapping

Flood mapping is a key tool used by government organizations across the world to model, forecast and plan for flooding events. The difference between flood inundation and flood hazard/risk mapping are as follows:

Flood Inundation Mapping- These are maps that show the floodwater extent of real flood events, or that show potential floodwater coverage for flood events of different magnitudes and water elevations (Government of Canada, 2022). They are key tool in emergency preparedness plans for communities in floodplains and flood hazard zones (Government of Canada, 2022). **An important distinction of flood inundation mapping is that it is based on land surface and water elevation only; there is no hydrologic or hydraulic modeling required for this type of mapping.**

Flood Hazard/Risk Mapping- These are maps that show results of hydrologic and hydraulic investigations and modeling and illustrate areas of potential flooding in different flow or flood scenarios. (Government of Canada, 2022). These maps are engineering maps, often used as regulatory maps for land use planning or to demonstrate potential negative consequences that communities may face during a flood scenario (Government of Canada, 2022). **Flood hazard/risk mapping is based on hydrologic and hydraulic modeling to illustrate areas of potential flooding in different flow or flood scenarios.**

Figure 6- An Example of a Flood Inundation Mapping for the Toronto Islands (Government of Canada, 2022).

Figure 7- An Example of a Flood Hazard/Risk Mapping for New Hamburg, Ontario (Government of Canada, 2022).

Flood warning levels

Flood emergency officials have developed a warning system that is based on the rate of flow of water in the Nith River during floods. Water flows are measured in "cubic metres per second" (m^3/s). That is the amount of water flowing past a fixed spot in one second.

Residents should locate their property on the map to see how it is affected at various warning levels.

Normal summer low flow: 1.5 m^3/s (cubic metres per second)

Warning Level 1: 142 - 175 m^3/s

Warning Level 2: 175 - 300 m^3/s

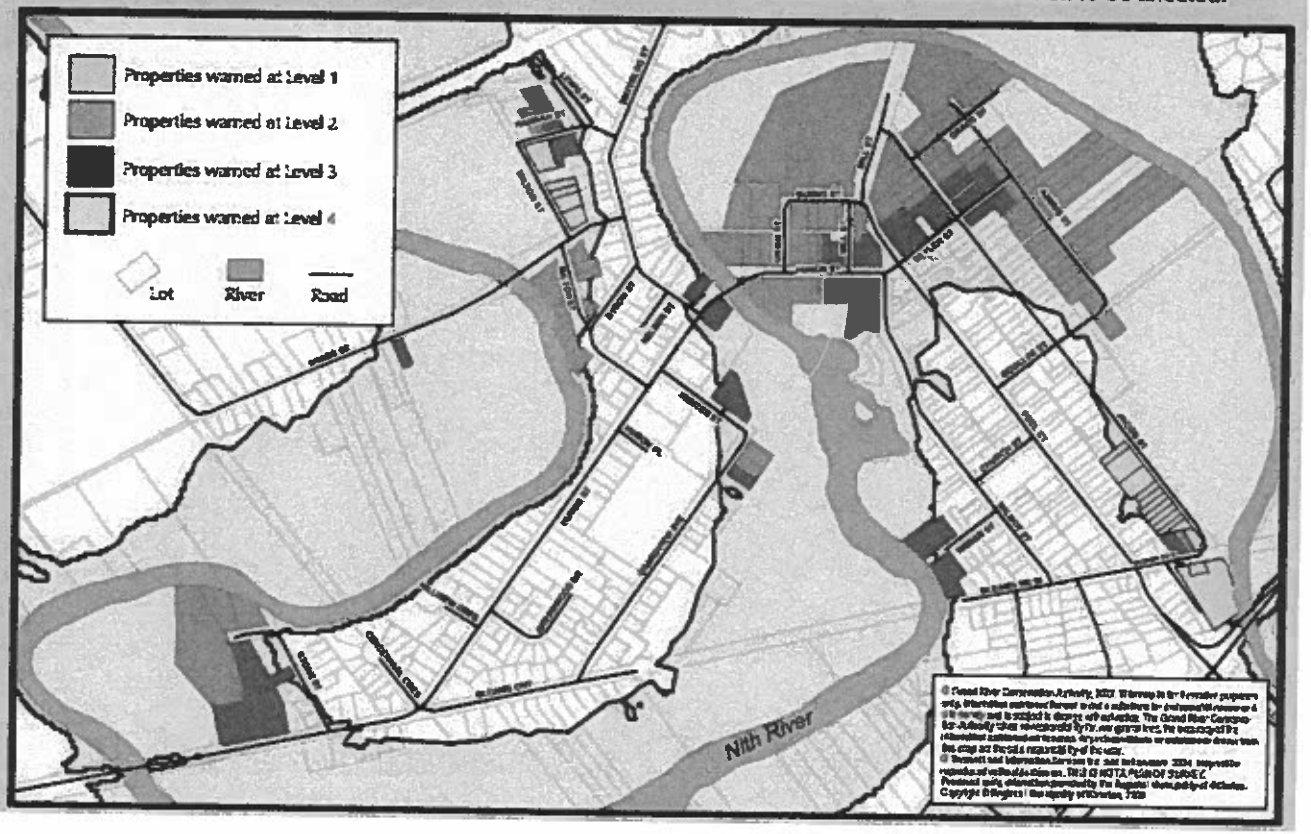
Warning Level 3: 300 - 500 m^3/s

Warning Level 4: more than 500 m^3/s
Warning Level 4 includes the land that would be flooded if a huge storm, the size of Hurricane Hazel in 1954, were centred directly over New Hamburg. The flows would be about 1,000 m^3/s. This is known as the "regulatory flood" and is used to determine the parts of New Hamburg where construction and new development is restricted. Anyone considering building, grading or other construction activity in this area must consult the Resource Planning department of the GRCA. More information is available in the "Planning and Regulations" section of the GRCA website.

Ice jams: Ice jams can develop quickly and can cause flooding at any flow level or make flooding worse than under ice-free conditions. The GRCA's water level monitoring gauges can sometimes detect sudden changes in water level caused by ice jams.

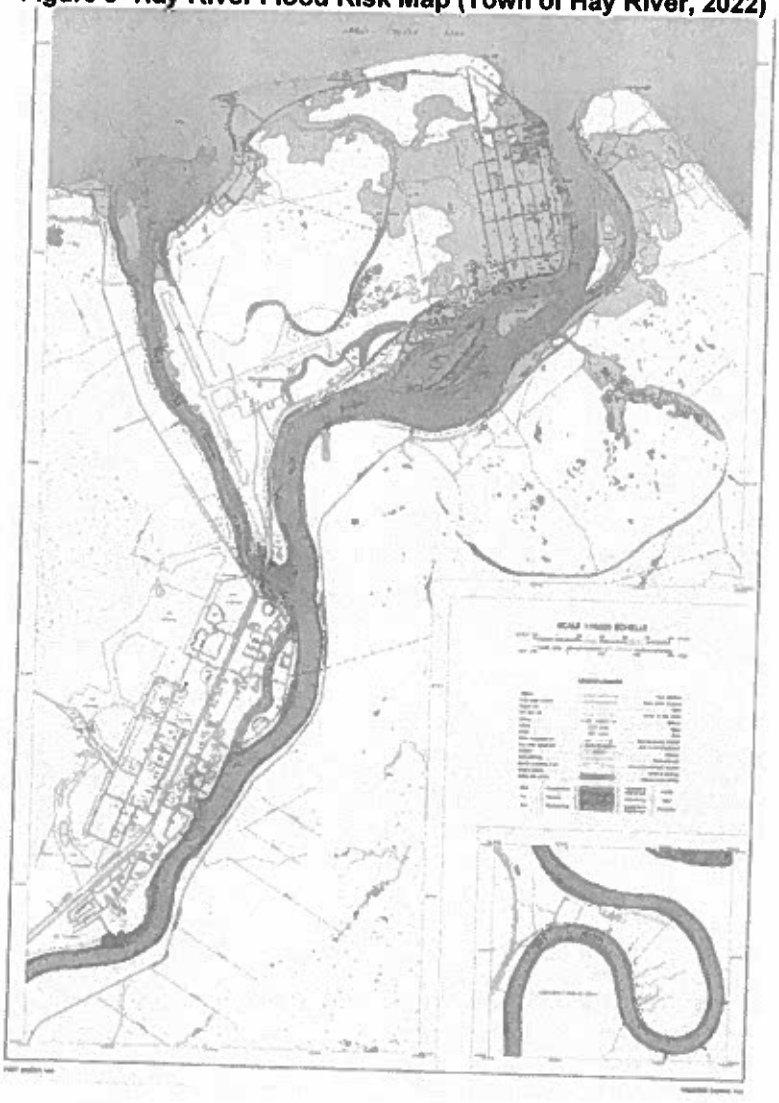
New Hamburg properties warned in the event of Nith River flooding

If flooding is about to occur, the police will warn households and businesses within the area to be affected.



The current flood risk map listed on the Town of Hay Rivers website is from 1984 and is over 35 years old. Given the changes in the climate of the region, new development and infrastructure constructed within the community, and upgrades in hydrologic modeling, GIS software and topographic mapping since 1984 the flood risk map that is being referenced for Hay River is so outdated that it is essentially unusable for flood mitigation and planning.

Figure 8- Hay River Flood Risk Map (Town of Hay River, 2022)



The National Floodplain Mapping Assessment (MMM Group, 2014). states that floodplain maps were completed for nine NWT communities in the Mackenzie River Basin through the Flood Damage Reduction Program (FDRP), which was administered from 1976 to 1997 (MMM Group, 2014). Given the changes throughout the NWT in climate since 1997 and the updates in GIS and DEM software these existing floodplain maps are very outdated. Through a search of publicly available data, it was also difficult to locate any of the floodplain maps for NWT communities with the exception of the Hay River map which was listed on the Town of Hay River's website.

As discussed above ice jam floods are very difficult to accurately model. As such an important first step for the NWT would be to create updated ***flood inundation maps*** for the communities throughout the territory which are high risk for flooding. This will be a more effective approach to begin with as flood inundation maps are relatively simple and cheap to make as they are based on topography, elevation data and water level only and require no hydrologic or hydraulic modeling.

Flood risk maps may be then developed at a later date but they will require significantly more investment and time to model, create and verify as they are based on hydrological or hydraulic modeling along with elevation data.

The nine communities which were listed as high flood risk areas in the *2014 Northwest Territories Hazard Identification Risk Assessment* (Vanguard, 2014) were:

- Hay River;
- Fort Simpson;
- Fort Liard;
- Nahanni Butte;
- Tulita;
- Fort Good Hope;
- Fort McPherson;
- Aklavik; and
- Tuktoyaktuk
- (Jean Marie River should also be added to this list given the flooding in 2021)

Updated **flood inundation maps** could be used in conjunction with real-time water level data prior to and during flooding events to improve the safety of future evacuation alerts and orders in the NWT. This mapping could also help develop more conservative evacuation thresholds to avoid the unsafe evacuations that occurred in Paradise Gardens, Riverview and 553 in Hay River. For example, if an area is at an elevation of 200m and the water level of the river is 198m they will know they have 2m of clearance in this location. Evacuation thresholds can be developed that work with the flood inundation mapping, i.e. areas within 4m of the river elevation are on evacuation alert, areas within 2m are on evacuation order. Using these evacuation thresholds zones can be developed that will be alerted and evacuated as water levels rise. These maps should be shared with public so all residents know which zone they are in. A great example of a flood map with evacuation zones is provided in Figure 7.

Inundation maps should just not map where historical floods have gone as climate change is leading to unprecedented flooding where areas that have never flooded historically were flooded, also the ice could jam differently in the future causing flooding in different locations; as **such the maps should be based off of elevation and related to real-time water level monitoring discussed below.**

Mitigation 1A Summary

- **In advance of completing formal floodplain risk/hazard mapping "Flood Inundation Maps" should be developed for all high-risk communities in the NWT to improve the safety of future evacuations in the short term. These flood inundation maps should:**
  - **Include entire communities;**
  - **Follow the Federal Floodplain Mapping Guidelines;**

- **Work in conjunction with the water levels from local water monitoring stations;**
- **Define zones and properties at risk in relation to water levels based on elevation;**
- **Be publicly available to all residents;**
- **Be developed in conjunction with local communities needs and priorities; and**
- **Include flood water elevations higher than historical flooding as climate change is leading to unprecedented flooding.**

5.3. Mitigation 1B- Use of Real-time Monitoring Data and Increased Monitoring for High-Risk Areas

The flood inundation maps mentioned above depend on real-time monitoring data to be effective. The Water Survey of Canada maintains water and flow gauges all across the territory and country. Most of the at-risk communities for flooding have a WSC gauge in or near the community.

In some cases, additional water monitoring stations may be required as the current locations of monitoring stations are not sufficient to cover local areas. Ice jam floods can occur locally and as such water level gauges need to be relatively close to residents to be useful (Alberta, 2018). In the Hay River area, some locations that could have additional water level gauges installed include: Paradise Gardens, Delancey area, main channel downtown and or the west channel. These additional water level gauges could be operated by the WSC on a seasonal basis during spring break up using territorial/federal climate change adaptation funding. The GNWT could also operate these gauges. There are hundreds if not thousands of water level and water flow gauges across the territory operated by government organizations and private companies. Given the high risk of flooding and the availability of climate change adaptation funding the installation and operation of some additional water level gauges to improve public safety during future flooding events is an easily implemented mitigation measure.

Mitigation 1B Summary

- **Install additional water level gauges where required for areas within or outside high-risk communities where no water level gauge exists; and**
- **Use real-time water level and flow data with the flood inundation maps to develop clearly defined evacuation procedures and zones for high-risk communities.**

5.4. Mitigation 1C- Ensure Flood Evacuation Alerts and Orders are issued by Subject Matter Experts

The communities of the NWT are small, from a population of 36 (Kakisa) to 3823 (Hay River) and as such have small community governments with minimal funding, technical capacity and resources in comparison to larger communities in Southern Canada. These small Municipal and Indigenous governments are staffed by dedicated individuals but most of the smaller communities in the NWT, if not all of them, do not have a water resource engineer or hydrologist on staff. These community governments do not currently have the water resource expertise to develop detailed flood response plans, flood inundation mapping, evacuation thresholds or the ability to, interpret complex hydrology and hydraulic models and data and install water monitoring stations.

The GNWT Environment and Natural Resources division has a Waters division that is staffed with hydrologists with a solid understanding of the unique hydrology, climate and environments of the NWT. Currently the GNWT ENR Waters division issues information packages to stakeholders across the NWT during spring break up. These *NWT Water Monitoring Bulletins* contain information on water levels, precipitation and flow across the territory for break up. The May 11 NWT Water Monitoring Bulletins is located here: NWT Water Monitoring Bulletin – May 11, 2022 | Environment and Natural Resources (gov.nt.ca). These bulletins do not provide evacuation alerts or orders only information on water levels which the majority of community governments do not have the capacity to properly process and implement into evacuation planning.

As discussed in the Deficiency 1 section using real-time flow and water level data is of upmost importance to ensure evacuation alerts and orders correspond to upstream water levels and other hydrologic factors. If the communities of the NWT do not currently have the technical resources to develop detailed flood response plans, flood inundation mapping, evacuation thresholds or the ability to interpret complex hydrology and hydraulic models and data and install water monitoring stations and the GNWT does would it not be more cost effective and safer if these responsibilities were held at the GNWT level where the technical capacity exists. Also, flooding is a regional issue and to develop stand-alone standards and mapping at the community level may result in different standards and approaches. Completing this work at the territorial level will be more cost efficient and ensure standards are congruent across the territory.

If the GNWT were to increase its responsibility for developing detailed flood response plans, flood inundation mapping, evacuation thresholds and be the responsible party for issuing evacuation alerts and orders this would mitigate the current risks due to lack of capacity at the community level. Forest Fire experts within the GNWT are responsible for evacuations related to forest fires, public health experts are responsible for public health measures and policies across the territory, why are water resource and hydrology experts not responsible for flood warnings and evacuations for the communities of the NWT?

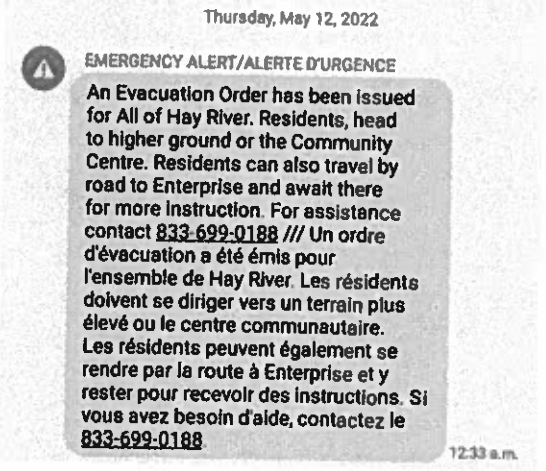
Mitigation 1C Summary

- **Ensure real-time WSC water level and flow data is used in developing future flood evacuation alerts and orders;**
- **Qualified water resource engineers and/or hydrologists should be the party responsible for issuing evacuation alerts and orders for flooding;**
- **Transfer the responsibility for developing detailed flood inundation mapping and evacuation thresholds to qualified water resource engineers and/or hydrologists in the GNWT;**
    - **This will be more a more efficient, cheaper and more standardized approach if completed at the territorial level for all communities;**
    - **GNWT will need to engage with communities to ensure the plans meet the community/indigenous governments needs and expectations.**

6. Deficiency 2- Evacuation Destination

The community wide evacuation order directed residents to evacuate to the Hay River community center and or the Hamlet of Enterprise and await further instructions.

Figure 9- Community Wide Evacuation Order



The community of Enterprise is very small with few facilities and services and did not have sufficient infrastructure to accommodate the approximately 3500 residents of Hay River. The fact that Enterprise did not have capacity to accommodate all evacuees led to a few things:

- Some residents did not evacuate as they knew Enterprise did not have enough facilities or accommodation and services;
- Some residents that did go to Enterprise waited overnight in their vehicles or in some of the facilities or businesses that were graciously opened for people to rest in overnight before returning to Hay River in the morning or moving on to a larger community;
- Some residents evacuated directly to larger communities across the NWT or Northern Alberta;
    - Anyone who attempted to travel to High Level in Northern Alberta had to drive through water covered highways and was unable to stay in the community as all hotels and facilities were already at capacity from the evacuations from flooding in northern Alberta;
    - The lack of direction resulted in an evacuation time of 5-24 hours and evacuees spread areas across a radius of 1400km throughout various communities in the NWT and northern Alberta.

The closest major center with health and lodging facilities for evacuees with high-risk individuals such as young children, seniors or anyone with mobility or health issues was Yellowknife or Manning, AB (High Level, AB was full) both of which were a 5-hour drive away from Hay River. Evacuees that travelled to communities within the territory, specifically Yellowknife, could access GNWT government services that evacuees in Alberta could not.

Conclusion:

- **Directing the community-wide evacuation to Enterprise, a community that does not have sufficient lodging, healthcare and/or grocery services to accommodate the approximately 3500 residents of Hay River, resulted in:**
    - **Residents not evacuating;**

- **Residents spending the night in vehicles/local centers or businesses before returning to Hay River or moving to another community and/or;**
- **Residents evacuating directly to communities spread areas across a radius of 1400km in the NWT and northern Alberta with an evacuation time of 5-24 hours depending on circumstances.**

6.1. Mitigation 2A- Evacuation Destination with Sufficient Services and Accommodation for Evacuees

A community wide evacuation needs to direct residents to the closest community that has sufficient healthcare, food and lodging capacity to accommodate evacuees. For a community wide evacuation of Hay River this would normally be Yellowknife and or High Level, however in this case High Level did not have capacity due to evacuees from flooding in Northern Alberta. Community wide evacuation plans should also have scenarios and options if routes are blocked or flooded or for high-risk individuals, etc.

Mitigation 2A Summary

- **Evacuation plans during flooding events should be reviewed for NWT communities and updated to ensure a community wide evacuation directs residents to the closest community that has sufficient healthcare, food and lodging capacity to accommodate evacuees and includes additional scenarios for blocked routes, high risk individuals, etc.**

6.2. Mitigation 2B- Increasing Territorial Responsibility for Community Wide Evacuations

The communities of the NWT are small, from a population of 36 (Kakisa) to 3823 (Hay River) and as such have small community governments with minimal funding, technical capacity and resources in comparison to larger communities in Southern Canada. These small Municipal and Indigenous governments are staffed by dedicated individuals but do not have the capacity to properly develop and implement community wide evacuation plans given the scale, speed and destructive power of ice jam flooding events, the isolation and huge distances required for evacuation and the lack of infrastructure and technical capacity at the community level.

Once a community wide evacuation is issued the evacuees leave the community and become very dependent on territorial resources, such as highways and health centers (operated by GNWT departments) and resources of adjacent communities, which would need territorial coordination to mobilize. If this is the case it would be much more efficient and safer for the GNWT to take responsibility for community wide evacuations for flooding. Evacuations for forest fires are led by the GNWT, if flooding is in the same risk category why would the GNWT not be responsible for flood evacuations as well?

Mitigation 2B Summary

- **Transfer the responsibility for developing and implementing community-wide evacuation plans for flooding events to the GNWT and use technical experts from various departments to coordinate the plans on a regional level while also engaging with communities to ensure the plans meet the community/indigenous governments needs and expectations.**

7. Deficiency 3- Safety of Evacuation Route

During the 2022 town wide evacuation there was water overtopping the road in several places along NWT Highway 1 from the NWT/Alberta border to Enterprise and in Northern Alberta. During the Hay River Evacuation the NWT Highway 1 closed from the NWT/Alberta border to Enterprise to all traffic midday on May 15 until midday May 16 at which point the highway opened but with single lane traffic and large works crews and pumps working in several areas where water was overtopping the road. These closures and delays impacted evacuees trying to return to Hay River and delayed the delivery of supplies, equipment, materials and work crews that were mobilizing from Alberta to support the flood response.

In the spring and summer of 2021 there was also several road closures and washout along NWT highways including a major washout at Swede Creek which closed NWT Highway 1 from the NWT/Alberta border to Enterprise.

There are two highway routes into the North Slave, South Slave and Dehcho regions of the NWT; Highway 1 from Alberta and Highway 7 from B.C. A large majority of the freight, materials, food and supplies that support NWT highway/winter road accessible communities and/or mines in these regions comes into the territory through Highway 1. Road washouts not only result in a disruption to supply chains but also present a safety hazard during community wide evacuations, similar to those that occurred in the spring of 2021 and 2022 due to flooding. Given that the high-water conditions that cause road washouts and community evacuations due to floods often occur at the same or similar times there is a risk that a future major road washout could restrict future evacuations. For example:

- If the 2022 highway washouts occurred overnight on May 11/12 when the evacuations occurred evacuees heading south to Alberta could have encountered highway washouts blocking the route south during their overnight evacuation;
- If the 2021 washouts on Highway 5 occurred during the evacuations of Jean Maire River or Fort Simpson evacuees would have not been able to make it to Yellowknife, Hay River or Alberta and would have had to go down Highway 7 to Fort Nelson B.C. for the next major service community.

These washouts are not only a safety risk but financially wasteful. The cost of mobilizing crews, pumps, equipment and materials on an emergency short term basis and working around the clock are very high and all of these costs are placed on the government's shoulders.

Conclusion:

- **The NWT highway system is prone to overtopping and washout during flood events which results in:**
  - **Public safety risks during community evacuations;**
  - **Costly disruptions to the supply chain of the NWT; and**
  - **Emergency repairs which are very costly and financially wasteful.**

7.1. Mitigation 3A- Additional Preventative Maintenance

Throughout the winter and spring thaw culverts can often get plugged by debris or blocked by animals such as beavers and muskrats. Additional preventative maintenance during spring break-up, and before freshet during high water years could help reduce the amount of highway overtopping that occurs.

Additional patrols and maintenance to clear debris to ensure all culverts are flowing at full capacity in the spring of year could help to avoid highway overtopping. When a flood risk is present and community wide evacuations may occur, such as those for Fort Simpson and Jean Marie River in 2021 and those for Hay River and KFN in 2022, the major highway routes that could be used for evacuations should be patrolled and maintained to ensure all culverts are flowing at full capacity and to flag any potential problem areas before they overtop the highway.

Mitigation 3A Summary

- **Implement additional preventative maintenance during spring break up, and before freshet during high water years for territorial highway culverts and crossings to ensure culverts and bridges are flowing at full capacity and problem areas are flagged before they overtop the highway.**

7.2. Mitigation 3B- Implementation of Territorial Highway Drainage Design Standards

The NWT currently has no standard drainage design specifications for highway culverts based on the hydrology, or drainage area and flow, for the crossing. In Division 4 of the Standard Specifications for Highway Construction – 2021 (combined standard specification for highway construction 20210331.pdf (gov.nt.ca)) there are no standards for sizing culverts based on the drainage area or flow through culvert to avoid overtopping and/or washouts which result in public risk, supply chain distributions and additional costs to repair.

If the NWT developed and implemented drainage requirements to ensure culverts that are installed are able to pass flows from the area they drain this would significantly reduce the amount of washouts that occur on NWT highways.

The Ontario Ministry of Transportation has developed, implemented and updated the *Highway Drainage Design Standards* which is a comprehensive set of standards and specifications for any highway drainage project in Ontario. These standards are located here: Design Floods (gov.on.ca). Table 4 provides an overview for the return periods for the flows that crossings for various classifications of roads must be able to pass from the Ontario standards. For example, a freeway on a major drainage system must be able to pass the flow from a 1 in 100-year storm through the culvert, bridge or crossing. The British Columbia Government has also established similar standards through the *Forest and Range Practices Act*. Table 5 provides an overview for the return periods for the flows that crossings for various classifications of roads must be able to pass for the B.C. standards. There is also a Canadian Standards Association (CSA) standard for drainage planning in northern Canada. This standard is more suited for communities, but definitely worth referencing in the development of NWT drainage standards. These standards can be located here: https://www.csagroup.org/store/product/2703783.

Similar standards and policies exist for many jurisdictions in Canada; Ontario and B.C. standards are presented for context but policies from other jurisdictions should be referenced as well.

Table 4- Ontario Ministry of Transportation- Highway Drainage Design Standards

1.1 Design Flows

Design Flows for the Minor and Major highway drainage systems are as follows:

Design Flow for Minor System and Major System		
Functional Road Classifications	**Drainage System Type**	**Design Flow**
Freeway Arterial (Urban)	Minor System	10-Year
	Major System	100- Year
Arterial (Rural) Collector (Urban and Rural)	Minor System	10-Year
	Major System	100-Year
Local Road (Urban and Rural)	Minor System	5-Year
	Major System	-
Depressed Roadways (see SD-7)	Minor System	25-Year
	Major System	100-Year

Table 5- B.C. Forest and Range Practices Act Standards

Peak flow

74 (1) A person who builds a bridge across a stream or installs a culvert in a stream for the purpose of constructing or maintaining a road must ensure that the bridge or culvert is designed to pass the highest peak flow of the stream that can reasonably be expected within the return periods specified below for the length of time it is anticipated the bridge or culvert will remain on the site:

Anticipated period the bridge or culvert will remain on the site	Peak flow return period
For a bridge or culvert that will remain on site for up to 3 years	10 years
For a bridge that will remain on site from 3 to 15 years	50 years
For a bridge that will remain on site for over 15 years	100 years
For a culvert that will remain on site for over 3 years	100 years
For a bridge or culvert within a community watershed that will remain on site for over 3 years	100 years

Both of these standards provide design flows that road crossings must be able to convey to avoid road overtopping and flooding. B.C. and Ontario have far more highways and roads than the NWT and to develop regulations and standards of the same detail for the N.W.T. would not be realistic or required.

However, given that there are currently no drainage requirements for highway crossings in the NWT the amount of future overtopping of highways could be significantly reduced by implementing drainage standards developed specifically for the NWT climate and highway system that takes the area upstream of a culvert and/or bridge into account when sizing it.

Mitigation 3B Summary

- **The NWT could significantly reduce the risk of future highway overtopping by developing and implementing highway drainage standards for all NWT highways that take the upstream drainage area and peak flow into account when sizing culverts and bridges similar to other jurisdictions in Canada;**
- **These standards should be developed specifically for the NWT climate and highway system and be scoped for implementation in the NWT.**

8. Conclusion

The conclusions, decencies and potential mitigations for regional flood risk planning and evacuation procedures and policies following the unprecedented flooding that occurred in May 2022 on the Hay River, NWT and the corresponding community wide evacuations that took place for the communities of Hay River, KFN and surrounding areas are presented in Section 1.

Thank you for taking the time to review this memo.

9. References'

Auld, H. (2007). Climate Change in the Northwest Territories. Adaptation and Impacts Research Section, Environment Canada. 2007. 26 (Auld)

Brundiers K, Eakin HC. (2018). Leveraging Post-Disaster Windows of Opportunities for Change towards Sustainability: A Framework. Sustainability. 2018; 10(5):1390. https://doi.org/10.3390/su10051390

Conservation Ontario (2022). History of Conservation Authorities. Available at https://conservationontario.ca/conservation-authorities/about-conservation-authorities/history-of-conservation-authorities

Gerard and Stanley (1988). Ice Jams and Flood Forecasting, Hay River, N.W.T. Available at https://publications.gc.ca/collections/collection_2021/eccc/En36-535-88-6-eng.pdf

Government of Alberta (2108). Ice Jam Flooding. Available at https://open.alberta.ca/dataset/bc810165-232e-4408-aa92-36759b5207a3/resource/f94a9ce2-84e6-4635-a835-5d1d237ba8c2/download/aep-rfc-factsheet-ice-jam-flooding.pdf

Government of Canada (2022). Flood mapping types and process. Available at https://www.nrcan.gc.ca/science-and-data/science-and-research/natural-hazards/flood-mapping-types-and-process/24264

Government of Northwest Territories Department of Infrastructure (2021). Standard Specifications for Highway Construction. Available at https://www.inf.gov.nt.ca/sites/inf/files/resources/combined_standard_specification_for_highway_construction_20210331.pdf

MMM, Group Limited (2014). National Floodplain Mapping Assessment- Final Report. Available at https://www.slideshare.net/glennmcgillivray/national-floodplain-mapping-assessment?fbclid=IwAR0NIAJ7VLiPdEVXE7pEgTqndQyEU-QPR1jpNuJUQ5Azy5FIUcGgdU9H_fY

NWT Bureau of Statistics (2021). Population Estimates by Community. Available at https://www.statsnwt.ca/population/population-estimates/bycommunity.php

Ontario Ministry of Transportation (2008). Highway Drainage Design Standards. Available at https://tcp.mto.gov.on.ca/sites/default/files/2021-09/ctyd%20-%20Highway%20Drainage%20Design%20Standards-January%202008-Revised%20Feb%202008.pdf

Queens Printer (2022). Forest and Range Practices Act- Forest Planning and Practice Regulation. Available at https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/14_2004#section74

The Geneva Association (2020). Flood Risk Management in Canada- Building flood resilience in a changing climate. Available at https://www.genevaassociation.org/sites/default/files/research-topics-document-

type/pdf_public/frm_canada_web.pdf?fbclid=IwAR0NIAJ7VLiPdEVXE7pEgTqndQyEU-QPR1jpNuJUQ5Azy5FIUcGgdU9H_fY

Town of Hay River (2022). Flood Risk Map. Available at https://hayriver.com/wp-content/uploads/2022/04/HayRiver-FloodRiskMap.pdf

Vanguard EMC Inc. (2014). Northwest Territories Department of Municipal and Community Affairs Northwest Territories Hazard Identification Risk Assessment. Available at https://www.maca.gov.nt.ca/sites/maca/files/resources/nwt-hira-final.pdf

WSP Canada Inc (2021). Government of Northwest Territories Department of Municipal and Community Affairs Assessment of Climate Change Impacts on Infrastructure in all NWT Communities. Available at https://www.maca.gov.nt.ca/sites/maca/files/resources/gnwt_pievc_report_final_released.pdf