Contents

5 Hazard Narratives

5.1 Guiding Principles

Emergency managers need to have a basic understanding of their community's hazard exposure and be aware of the potential effects of extreme events in order to be fully prepared.

The following hazard narratives:

- Define and classify the hazard;
- Explain the hazard including the type of events included within the hazard type;
- Describe the relevant circumstances surrounding the hazard;
- Report on the history of this hazard in the NWT including, where relevant, near misses and lower impact events that support consideration;
- Include both qualitative and quantitative information; and
- Include scientific information and local knowledge.

5.2 Very High Hazard

5.2.1 Fire/Explosion

Figure 5: Wood Buffalo Park Wild Fire - June 2013 (Source: GNWT, MACA)

Definition	**Class**
Uncontrolled burning and/or a sudden, violent release of gas under pressure which causes or threatens loss of life and property and environmental damage	Natural and Human-induced

NWT greatest impacts to date
Fatalities 2
Evacuated 950
Cost $12,044,118

Climate Change
Projected to increase both frequency and consequence

Type	Cause/Explanation
explosion	Ignition of a flammable substance resulting in instantaneous combustion.
forest fire, grass, bush and brush fire	Uncontrolled burning in relatively unpopulated grassland, brush or woodlands.
wild land/urban interface fire	Fires that have encroached on a developed and populated area.
urban fire	An uncontrolled fire in an urban area affecting residential or commercial properties.
peat fire	Wildfire in bogs or fens (muskeg) (can smolder beneath ground for long periods of time and create smoke hazards to surrounding populations).
fuel tank explosion	An explosion resulting from the leak, in the presence of an ignition source, of fuel from a storage container.

Vulnerability	Description
People	High injury and fatality potential from the immediate threat of the fire and the blast as well as an increased mortality rate and respiratory symptoms due to smoke.
Infrastructure	Total loss or damage to most infrastructure including public buildings, roadways, rail-lines, power facilities and water treatment plants. Smoke can impede evacuation of remote communities by air.
Communications	Any existing power lines can be damaged and destroyed by fire/explosion cutting off communication links. The same holds true for microwave towers in regions without in-place power lines.

NWT Exposure/History

Table 3: Wildfires and Urban Fires with Losses of $500,000 and Over

Where	When	Impact
Port Radium	1951	Urban fire – Mine. Estimated Total Cost $4,000,000
Inuvik	1968	Wildfire – Fire guards built around town, 35,120 HA burnt ($160,000 of timber in 1968$). Communication to CFB was cut due to destruction of poles and CFB communications tower, roads closed. Estimated Total Cost $54,000 in labour and equipment.
Fort Smith, Pine Point, and Hay River	1982	Wildfire - Highway closed and Hay River prepared for evacuation.
Norman Wells	1993	Wildfire - Community threatened.
Sahtu region of the NWT (Fort Norman (in the Hamlet of Tulita), Norman Wells, Yellowknife and Déljne)	June 6-15, 1995	Wildfire - Damage was incurred by provincial, municipal and private property. Fort Norman was evacuated on June 6, and Norman Wells was evacuated on June 9. Norman Wells was under a State of Emergency from June 8-14. Evacuated 950 Estimated Total Cost $3,432,310
Fort McPherson	Jan 1996	Urban fire – School. Estimated Total Cost $7,000,000
Norman Wells	March 1996	Urban fire – Dormitory. Estimated Total Cost $1,000,000
Fort Resolution	March 1997	Urban fire. Injured 1 Estimated Total Cost $700,000
Yellowknife	Aug 1997	Urban fire - Department store. Estimated Total Cost $1,050,000
Tibbitt Lake	July 22-31, 1998	Wildfire - State of Emergency declared and the area closed to traffic and residents. Reached 140000 HA in size. Destroyed three vacation cabins. Evacuated 5 Estimated Total Cost $12,044,118
Fort McPherson	April 1998	Urban fire – Hotel. Estimated Total Cost $1,200,000
Déljne	May 1998	Urban fire – Store. Estimated Total Cost $1,400,000
Tsiigehtchic	1999	Wildfire - Town threatened, highway closed.

Where	When	Impact
Behchokǫ̀(Edzo)	1999	Wildfire - Community evacuated.
Fort Providence	2002	Urban fire - Big River Service Restaurant Estimated Total Cost $500,000
Norman Wells	July 21, 2003	Wildfire - Declared a state of emergency. About 100 people were evacuated due to thick smoke. Estimated Total Cost $121,846
Yellowknife	March 2005	Urban fire - Old Airport Road hardware store. Fatalities 2
Tulita	Oct 2007	Urban fire - Chief Albert Wright school. Estimated Total Cost over $500,000
Inuvik	Nov 2010	Urban fire – A hangar and three planes, King Air, B99 and Twin Otter.
Yellowknife	May 2010	Urban fire - Coast Fraser Tower blaze significantly damaged two apartments on the 14th floor, and units on the 12th and 13th floors had smoke and water damage.
Déljne	2011	Wildfire - Community Evacuation. Evacuated 103
Inuvik	2012	Urban fire - Lions Club loss of building.
Wrigley	2013	Wildfire - Community Evacuation. Evacuated 40
Inuvik	Aug 2013	Urban fire - Building that houses the NWT Housing Corporation offices, Inuvik Gas, and the Inuvialuit Development Corporation offices. Estimated Total Cost between $500,000 and $750,000

Table 4: Urban Fire Losses in NWT 1999-2007 (Source: Council of Canadian Fire Marshals and Fire Commissioners)

Year	Number of Fires	Deaths	Injuries	Losses
1999	97	0	3	$3,206,808
2000	116	1	7	$1,754,097
2001	85	1	5	$2,137,285
2002	148	0	9	$2,780,735
2003	111	2	8	$1,269,887
2004	73	1	0	$1,464,140
2005	158	2	3	$1,954,580
2006	81	1	1	$1,818,345
2007	57	1	0	$2,327,895

Wildfire

Lightning activity over the Mackenzie Basin region is short but intense, with a strong peak in cloud-to-ground lightning during July. The maximum area of lightning activity is influenced by local moisture sources and by topography. Lightning causes up to 80% of the forest fires in the NWT (Black, et al. 2010, Annex). In a ten-year period from 2002 to 2011, there were 250 wildfires within a 10 kilometre radius of Yellowknife. The following communities throughout the NWT have a wildfire FireSmart hazard of High or Extreme:

Table 5: FireSmart Hazard Areas of High or Extreme in NWT According to Community CWPP

Community	Development Area	FireSmart Hazard
Fort McPherson	East Cabins	High-Extreme
Inuvik	Shell Lake	Moderate-Extreme
	Airport Lake Remote Cabins	Extreme
Déljne	Proposed Residential Area	Extreme
Fort Good Hope	High potential fire behaviour within the community interface and the vast areas of similar fire behaviour immediately west of the community. High wildfire risk.	
Norman Wells	Moderate to high for wildfire.	
Tulita	New residential subdivision	Extreme
	North and east perimeter developments in the main townsite area	High to Extreme
Behchokǫ̀	Eastern residential area of Rae	Extreme
	Western residential area of Edzo	Extreme
	Sah Naji Kwe Lodge	High
Dettah	Deton'Cho Training Centre and along the north perimeter of the main community	Extreme
Łutselk'e	Łutselk'e East	High
	Fishing Lodge	Extreme
Whatì	Whatì East	High
Yellowknife	Engel Industrial/DND FOS	Moderate-High
	Yellowknife Bay East	High-Extreme
Enterprise	High risk of wild fires.	
Fort Providence	Very low to High risk of wildfires.	
Fort Resolution	Fort Resolution South-End	High Extreme
	Little Buffalo River Village Area East-end	High Extreme
	Little Buffalo River Village Area Det'an Cho (Eagle) Tourist Camp	High
Fort Smith	Town East	High - Extreme
	Town West	High - Extreme

Community	Development Area	FireSmart Hazard
	Towering Pines	High - Extreme
	Bell Rock	Extreme
Hay River	Smith's Road	Moderate - High
	Delancy Estates	Extreme
	Kelly's Lane	Extreme
	West Point	Low - Extreme
	Hay River Indian Reserve Rural Developments	High - Extreme
	Hay River Indian Reserve Main Townsite	Moderate - High
	Riverwoods CR Subdivision	Extreme
Fort Liard	New Subdivision	Moderate - High
	Beaver Enterprises – Hwy 7 (bulk fuel tank site)	High
Fort Simpson	Wildrose Acres	High - Extreme
	Nogha Heights	High - Extreme
	Bannock Land	Moderate - High
Jean Marie River	Moderate to High risk to wildfire.	
Wrigley	New subdivisions on the south-end and for scattered structures on the east perimeter of the town site	High

Many of the industrial activities in the NWT have a high or moderate forest fire risk classification including land clearing, timber harvesting, timber processing, mechanical site preparations and other silviculture treatments, gas or oil well operations, mining, highway maintenance and construction, engineering operations, plant harvesting, manufacturing, milling, railroad operations, trenching, and the use of explosives.

Peat Fire

The NWT has the largest deposit of peat in Canada with 250,000 km/2 of peat (Lappalainen, 1996).

Explosion

Many communities have large fuel tanks needed to prepare for the winter months. This large fuel load can result in an explosion if an ignition source is presented nearby. Nearby forests increase the fire load and the risks to the communities.

Figure 6: Tulita Fire - 1995 (Source: GNWT, MACA)

Climate Change Impacts

Over the next fifteen years, due to climate change, the NWT may experience a 46% percentage increase in the total number of fires (Wotton, 2010). Climate change could mean:

- The melting of permafrost and more droughts which suggest peat fires will be more common (Flannigan, 2009).
- Warmer temperatures, changes in precipitation, atmospheric moisture, wind, and cloudiness could increase the number and size of wildfires.
- Longer fire season (Black, et al. 2010, Annex).
- Shorter ice road availabilities could mean more fuel stored in communities.

The area burned by forest fires has been growing along with average temperatures. The length of the fire season in the NWT is expected to increase by up to 50 days this century (Black, et al. 2010, Annex).

Increasing threats of forest fires, especially in the Mackenzie basin require action by forest agencies to reduce risks, and preparedness by emergency managers in communities that may be in the potential path of major fires (Black, et al. 2010, Annex).

Community Feedback from Meetings

Summers are becoming hotter and drier. The isolated nature of the many NWT communities, lack of adequate fire-fighting resources and bulk fuel storage in or close to the community increases the fire risk. Bulk storage of fuels could lead to explosions which would have disastrous effects on many communities throughout the NWT. In many cases, bulk fuel storage containers are very close to, or within the community. Urban fires in isolated communities with volunteer firefighters can lead to the loss of critical infrastructure. Explosives are stored very near the community of Norman Wells and any accident involving these supplies could impact the community.

Key Risk Analysis Considerations

- Potential to spontaneously cause multiple deaths and injuries (especially explosion);
- Smoke can complicate evacuation by air;
- Current and historical experience in the NWT;
- High damage potential if near or in a community;
- Potential to affect any community in the NWT;
- Isolation of communities; and
- Difficulties training and retaining firefighting resources.

5.2.2 Flood

Figure 7: Nahanni Butte Flood - June 2012 (Source: GNWT, MACA)

Definition	**Class**
An overflow or surge of water which causes or threatens loss of life and property and environmental damage	Natural Hazard

NWT greatest impacts to date

300 Evacuated

Estimated Total Cost $3,500,000

Climate Change

Projected to increase both frequency and consequence

Type	Cause/Explanation
local flood	Local flooding is an increase in water level associated with an extreme hydrological event, such as record rainfall or poor / blocked drainage.
seiche	Rhythmic oscillation of water in a lake or a partially enclosed coastal inlet, such as a bay, gulf, or harbour which may be caused by the ground shaking in an earthquake or local changes in atmospheric pressure.
rain storm	A flood caused by heavy or excessive rainfall in a short period of time, generally less than 6 hours.
snow melt	River floods can also be caused by snow melts (freshets) which cause significant elevations in river levels.
ice jam	Accumulation of ice fragments in a waterway that builds up and restricts the flow of water causing a temporary obstruction.
storm surge	Strong wind stress on the water surface that creates a strong net displacement of water pushing lake or ocean water up onto the land.
lake burst	Rapid accumulation of water in glacial lakes can result in a sudden discharge of large volumes of water and debris and causing flooding in the downstream.

Vulnerability	Description
People	Evacuation of communities due to flood events is common. Deaths and injury due to flooding can occur during heavy rainstorm events which can interfere with evacuation attempts. Deaths in the NWT due to flooding are rare.
Infrastructure	Personal property damage can be extensive. Contamination by floodwaters, structural damage, and mold can destroy buildings. Roads can be damaged or washed away. Damage to infrastructure can be extensive. Flooding can also negatively affect utilities and critical infrastructure. Utilities such as wastewater treatment, electricity and gas

Vulnerability	Description
	may be disrupted in the event of a flood. Emergency ground vehicles may be unable to respond if roads and bridges are flooded, washed out or covered by debris.
Communications	Communication towers can be damaged by flooding events.

NWT Exposure/History

When	Where	Impact
1937	Aklavik	Flooding.
1944	Tuktoyaktuk	Storm Surge 3 m above MSL.
1961	Aklavik	Flooding.
May 3, 1963	Hay River Township	Major flooding caused by ice jamming required evacuation of the community of Hay River. Evacuated 1800
Sept 1970	Tuktoyaktuk	Storm Surge 3 m above MSL.
May 2, 1974	Hay River Township	Flooding caused by ice jamming required evacuation of West Channel residents.
Jan 1, 1982	Hay River	Flooding. Estimated Total Cost $572,824
1982	Aklavik	Spring runoff and ice jams cause flooding and extensive damage. Estimated Total Cost $141,412
May 3, 1985	Hay River Township	Record high flows of the Hay River and ice jams caused serious flooding, requiring the evacuation of West Channel residents. Ice jams, spring runoff, minor damages, one injury. Estimated Total Cost $1.1 million
June 29 - July 3 and July 11-15, 1988	Norman Wells	Two severe flood events occurred in the Liard and Mackenzie River Basins of southwestern NWT.
May 1-9, 1989	Liard River	Severe ice jams near 3 Mile Island, flooded the community of Fort Liard. A local State of Emergency was declared. Fort Simpson was also damaged. Personal, municipal and territorial property was damaged and riverbanks were eroded. Over 50 homes were affected by the flooding. Evacuated 125 Estimated Total Cost $1,094,778
1992	Aklavik	Flooding.
April 25, 1992	Hay River	Hay River flooding caused by a 10-kilometre-deep ice jam. Evacuated 100

When	Where	Impact
Sept 22, 1993	Tuktoyaktuk and Mackenzie Delta	A severe storm with winds from the northwest of up to 96 km/h generated a 1.68 m surge and raised water levels to 2.2 m above chart datum. Coincident with approximately 90% open water offshore, waves were relatively powerful and, together with the high water levels, resulted in damage to or destruction of about half the shore protection at Tuktoyaktuk, and flooding in the community and parts of the Mackenzie Delta.
2003	Hay River	An ice blockage at the mouth of the Hay River where it enters Great Slave Lake caused localized flooding in the community of Hay River and Hay River Reserve. A number of residences in both communities had to be evacuated due to the floodwaters. Estimated Total Cost $100,000
May 11-14, 2005	Fort Good Hope	Jackfish Creek and Rabbitskin River rose to the point that 50 people were evacuated from Fort Good Hope. A state of emergency was declared. Estimated Total Cost $920,000
May 27, 2006	Aklavik	Infrastructure was damaged after the Peel River Channel overflowed its banks swamping the town under several feet of water. Evacuated 300 Estimated Total Cost $3,500,000
May 5 and 6, 2008	Hay River	Overland flooding due to snow melt and the spring backup of Hay River resulted in damages to public and private property. Estimated Total Cost $460,000
June 9 2012	Nahanni Butte	The South Nahanni River flooded low-lying parts of the community. The flood caused extensive damage to a number of buildings including the band office, the community's store and the community gymnasium. Evacuated 72

In the NWT, ice jam is the main type of flooding. Rivers break up much earlier than lakes and these bottlenecks can cause ice jams. In the Mackenzie Delta, the risk is higher as the larger channels maintain year-round flow but smaller channels may freeze to the bottom. Spring flooding occurs within the Mackenzie Delta, at the horseshoe bend on the middle channel at Tununuk and in the channel junctions north of Aklavik, Hay River, as it nears the shores of Great Slave Lake and the Mackenzie River, in the Fort Simpson area. High spring flows and major ice jams in the Middle Channel of the Mackenzie Delta can cause widespread flooding, affecting the community of Aklavik. As much as 95% of the delta can be covered by water in some years (e.g., 1961, 1982 and 1992). Environment Canada field staff advises and assists local flood watch committees in Hay River, Fort Simpson, and Aklavik (Environment Canada, 2013).

In Norman Wells, overtopping of islands in the Mackenzie River (used as production bases for ESSO Resources Canada Ltd. oilfields) by ice and water necessitates the shutdown of wells during breakup. This is to prevent wellhead damage and oil spills. The community itself is not flood prone (Environment Canada, 2013).

In the mountainous areas of the west, rainstorms or glacier melt waters cause major summer floods. The most extreme summer floods often exceed spring runoff flows, and sometimes exceed the maximum breakup water levels observed on area rivers and the mainstream of the Mackenzie River (Environment Canada, 2013).

During the late summer and fall when the pack ice retreats 100 km or more from the shore, Beaufort Sea storm surges cause flooding in Tuktoyaktuk (Environment Canada, 2013).

A majority of the NWT population is located on a body of water.

Nine communities are designated flood risk areas:

- Hay River;
- Fort Simpson;
- Fort Liard;
- Nahanni Butte;
- Tulita;
- Fort Good Hope;
- Fort McPherson;
- Aklavik; and
- Tuktoyaktuk

Climate Change Impact

- All models and scenarios project that Arctic rain and snowfall will increase (AMAP, 2012) leading to more frequent and severe flooding events.
- Greatest relative increases in rain or snowfall will be in winter and autumn, and the smallest in summer (AMAP, 2012).
- A 10-25% increase in precipitation by 2050 (40% increase in snowfall) (IBC, 2012).
- Changing precipitation already linked to flooding in Aklavik and Fort Good Hope (NWT CC. 2008 p. 10).
- Increased frequency of flash flooding, with a combination of snowmelt and intense rain in the spring (Auld, 2007).
- Potential increases in flooding, flash flooding require review of drainage systems, and may also increase demands on emergency response (Auld, 2007).
- Increasing snowmelt, rain runoff and flooding risks will potentially increase disaster risks, resulting in a need for greater emergency response capacity (Auld, 2007).

Community Meeting Feedback

This issue was discussed at all meetings except Yellowknife. Virtually every community in the Dehcho has been affected by flooding as have many in the South Slave and Sahtu. In the Inuvik

Region, Aklavik has an issue with seasonal flooding. Fort McPherson and Tsiigehtchic have been threatened as well.

Key Risk Analysis Considerations

- 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.

5.3 High Hazard

5.3.1 Weather – Winter Storm

Figure 8: Blizzard Damage to Inuvik Airport Roof - January 2012 (Source: GNWT, MACA)

Definition	**Class**
Strong weather characterized by ice, snow and freezing rain	Natural Hazard

NWT greatest impacts to date

- Infrastructure damage (power failure, airport damage)
- Property damage

Climate Change

Projected to increase both frequency and consequence

Type	Cause/Explanation
polar low	An intense storm system that usually forms in polar regions during outbreaks of very cold air, over relatively warmer ocean waters. Typically spanning from 400 to 800 kilometres across, and usually existing for only one or two days, polar lows can result in severe blizzard-like conditions, with heavy snow and gale force winds over affected marine areas.
snow storm	The accumulation of several centimeters to meters of snow that covers roads and infrastructure.
ice fog and ice storm	An ice storm combines high wind, freezing temperature and freezing rain or drizzle.
freezing rain	Freezing rain occurs when the air in an upper–air layer has an above – freezing temperature, passes through a layer of cold air and the temperature at the surface is below freezing.
blizzard	Combines low temperatures, blowing snow and wind speeds ranging from 90 to 130 km/hour. Conditions are most severe in open or deforested areas where there are no trees or structures to act as wind breaks.

Vulnerability	Description
People	Heavy winds and cold temperatures can combine with power loss to cause injury and death that could be extensive. Blowing snow creates hazardous driving and working conditions (see Transportation hazard).
Infrastructure	Heavy winds and snow can cause damage to buildings, loss of power and water and sewage systems. Snow build-up on roofs can cause collapse (see Snow-load hazard).
Communications	Snow and heavy winds can knock out communications systems.

NWT Exposure/History

Winter storms render millions of dollars of lost or delayed revenue due to shut down of operations and slow transportation of goods and services every year. The increased frequency of snowstorms has had an impact on roadway safety. More snow removal is necessary to allow for safe travel, and the transportation of goods (Pryor, 2007 p.18).

Recent Blizzard Events

When	Where	Impact
March 5, 2003	Norman Wells	Prior to that Norman Wells had not had a blizzard in 20 years.
March 11, 2003	Norman Wells	This blizzard also stranded nine northern residents on the Tuktoyaktuk ice road in the Mackenzie Delta.
Jan 2005	Tuktoyaktuk	Temperatures dipped below -30°C and winds topped 117 km/h. Some homes lost power for 5 days, and water and sewage services were unavailable. Five houses froze solid, likely with burst pipes and ruined pumps.
March 2011	Inuvik	Winds reached 70 km/h. The blizzard also knocked out the internet, cell-phone service, bank machines, Interact card service and any calls other than local calls for three-and-a-half days.
Jan 17 and 18, 2012	Inuvik, Norman Wells	Winds at Inuvik peaked at 100 km/h, while more isolating blizzard conditions endured for over 24 hours. At Norman Wells it was an even longer 38 hours, blowing any previous records for blizzard duration by 7 to 21 hours respectively. Winds took off several roofs, including one at the Inuvik Airport, and lifted and shifted other items all around the region.

Climate Change Impact

- More intense and frequent winter storms, and greater unpredictability (Pryor & Cobb, 2007).
- Significant further increases in snowfall (IBC, 2012 p.53).
- Increases snowpack, earlier melting, and rain on snow are prevalent with climate change
- Increase in precipitation of 25 to 35 % in the high Artic since the 1950s. A mixture of snow and rain, increasing snow loading on buildings (CSA, 2010) (See Snow load hazard).
- More freezing rain is expected (Pryor & Cobb, 2007).
- Increased snowpacks, earlier melting, warmer winter temperatures, rain on snow, are all prevalent in the North with climate change (Auld, 2011).

- Approximately one fifth of buildings in the NWT are under watch or renovation for increased snow loads (Auld, 2011) (See Snow Load Hazard).
- Accumulated snow increases spring run-off and lead to wash-outs (NWT, 2008. p.10).

Community Meeting Feedback

There was a general consensus amongst participants at all meetings that while the NWT was experiencing milder winters on the whole, the winter weather was becoming more extreme in terms of storms and temperature variance.

Key Risk Analysis Considerations

- Annual economic loss;
- Potential to spontaneously cause multiple deaths and injuries;
- Potential loss of communications and air support can leave communities isolated;
- Current and historical experience in the NWT;
- High damage potential;
- Potential to effect any community in the NWT; and
- NWT communities particularly resilient to winter storms.

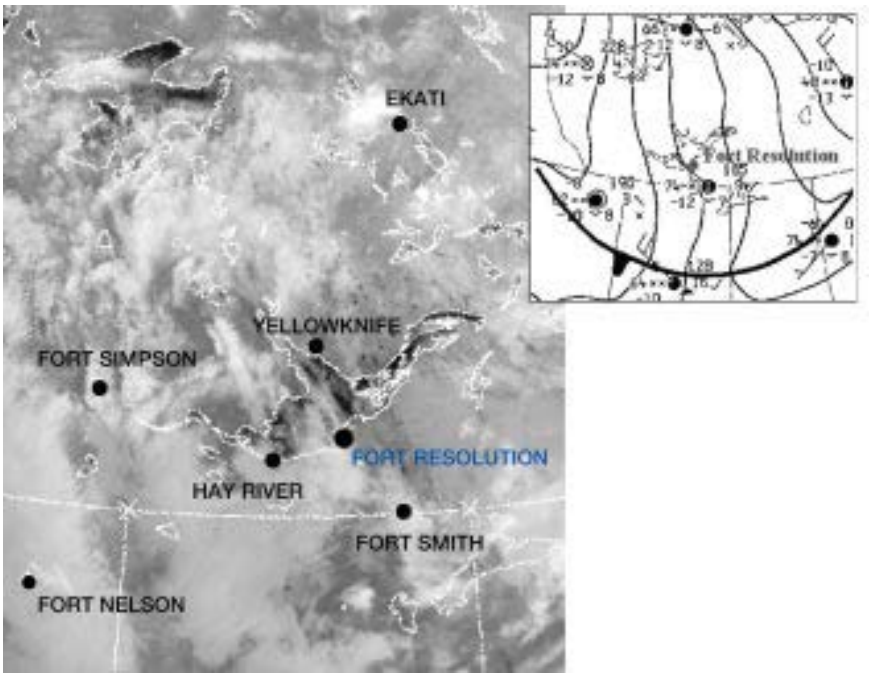

Figure 9: About 40 centimetres of snow fell on Fort Resolution overnight 9 into 10 November 1998. (Source: NAV CANADA, Satellite photo 1229 UTC 10 November 1998)

5.3.2 Transportation Accidents

Figure 10: Highway 3 Accident - February 2013 (Source: GNWT, MACA)

Definition
All vehicle accidents which involve large loss of life and property damage

Class
Human-induced Hazard

NWT greatest impacts to date

- Fatalities 32
- Infrastructure damage (power failure, airport damage)
- Property damage

Climate Change
Projected to increase both frequency and consequence

Type	Cause/Explanation
ice roads accidents	Ice road accidents occur when a vehicle collides with another vehicle, pedestrian, animal, road debris, or other stationary obstruction, such as a tree or utility pole. Speeding on ice roads over water can produce waves which can be strong enough to force its way up, blowing a hole through the ice. Truckers travel at 15 miles per hour, potentially for up to 30 hours, over frozen lakes.
aircraft accident	An aircraft accident where a person is fatally or seriously injured, the aircraft sustains damage or structural failure or the aircraft is missing or is completely inaccessible.
motor vehicle accident (including bison collisions)	When a vehicle collides with another vehicle, pedestrian, animal, road debris, or other stationary obstruction, such as a tree or utility pole. Traffic collisions may result in injury, death, vehicle damage, and property damage.
marine accident	Any incident on water which involves a collision, fire/explosion, grounding or foundering of a vessel.
sonic boom	A loud explosive noise caused by the shock wave from an aircraft or other object travelling faster than the speed of sound.
dangerous goods transportation	The movement of dangerous goods by vehicle, train, vessel or aircraft. Dangerous goods are solids, liquids or gasses that can harm people, other living organisms, property, or the environment.
Vulnerability	**Description**
People	Accidents, specifically motor vehicle accidents, are one of the highest causes of death and injury to Canadians every year. Amongst young Canadians (below age 25) vehicular accidents are the number one cause

Vulnerability	Description
	of death in the country. Largest loss of life in one accident usually occurs on passenger flight accidents.
Infrastructure	Any accident which occurs on a roadway has the ability to damage the roadway and therefore leave already isolated areas without any road access. The same holds true for aircraft accidents which may close down an airport making it virtually impossible to gain access to several communities in the NWT.
Communications	Given that communication hubs are serviced by a single communication line, especially in the southern NWT, any accident may cut these lines leading to loss of communications.

NWT Exposure/History

When	Where	Impact
Oct 30, 1974	Rae Point	A Pan-Arctic Oils Lockheed Electra crashed. Fatalities 32
Jan 12, 2000	Near Fort Providence	A Northbound Super-B-Train truck hauling diesel fuel crashed through the Mackenzie River ice crossing. Driver was treated for hypothermia.
Jan 3, 2007	From Yellowknife,	3 fishing lodge employees died when a bush plane went down in restricted weather. A fourth person survived the crash. His survival was aided by temperatures of -16°C, mild for that time of year in the North.
Feb 20, 2007	Parry Peninsula	A hunter went adrift on an Arctic ice floe when winds caused his land tether to break. A Canadian Forces helicopter search and rescue team made a daring jump onto the ice floe and stayed with the stranded hunter overnight. It was below -50°C with the wind chill.
July 24, 2008	North of Inuvik	Members of three generations of an Inuvik family, on their way to take part in a traditional beluga whale harvest, perished after their six-metre boat capsized in the Mackenzie River. Fatalities 4
Dec 8, 2010	20 kilometers north of Enterprise	Two transport trucks collided head-on near McNally Creek. The highway was closed for four hours until the accident site could be cleaned up and traffic allowed to safely pass. Fatalities – 1 Injuries – 2
Sept 23, 2011	Yellowknife	An Arctic Sunwest Twin Otter float plane crashed in a parking lot after unsuccessfully attempting to land at the float base near Latham Island. The plane attempted to abort the landing but was unable to gain sufficient altitude before clipping power lines and spiraling nose first into the empty lot between two buildings. Nobody on the ground or in the buildings was injured in the accident. Fatalities–2 Injuries–7
Oct 7, 2011	Pethei Peninsula	An Air Tindi Cessna 208B crashed into a cliff. Fatalities – 2 Injuries – 2

When	Where	Impact
	along the coast of Great Slave Lake	
Sept 9, 2013	McClure Strait north of Banks Island on the opposite side of the island from Sachs Harbour	Helicopter operating with the Canadian Coast Guard research icebreaker Amundsen crashed into the Arctic Ocean. Fatalities 3

NWT transportation infrastructure includes a network of roads, ports and airports and a rail connection to Hay River.

Motor vehicle accident / Ice roads accidents

Overall, the NWT has 2,200 kilometers of all-weather roads complemented by 2,100 kilometers of ice roads. As may be expected, the areas with the heaviest traffic and the largest populations (e.g., Yellowknife) have the highest number of accidents. Accidents in the Inuvik and Fort Simpson areas are more likely to end in injury or death than those of North and South Slave Regions. Highway Rescue units are only available in the North and South Slave regions. This is most likely the reason that they have a lower percentage of accidents that end in injury or death.

Winter access roads are open in winter, usually from about mid-December to late March, but may vary with weather conditions and locations. Some of them are privately operated and maintained, and offer no services, emergency or otherwise. Unleaded gas, diesel and propane are available in most communities on the highway system, with repair facilities in larger towns. Distances between these services may be significant, however, and hours of operation limited.

Figure 11: Fuel Truck Broke Through Ice Near Aklavik NWT – April 2012 (Source: CBC News, Francis Gruben)

To improve on safety, all trucks on ice roads must be equipped with two way radios and drivers must report as they approach the numbered portages to alert each other of their presence on the same portage.

Each year, collisions with wildlife, particularly bison, cause vehicle damage and injuries on NWT highways. Most incidents occur along Highways 3 and 5. Bison can also be found on and alongside Highway 7.

Marine Accident

There is also a well-developed marine freight route along the Mackenzie River to the Arctic Ocean. Within the Mackenzie watershed there are five sectors: the Mackenzie River from Hay River to Tuktoyaktuk, including the Peel River; the western Arctic coast (Beaufort Sea area); the Athabasca River and Lake Athabasca system; Great Slave Lake; and the Liard River and Fort Nelson River System. Navigation problems on the Mackenzie River include a short shipping season (beginning of June to mid-October), ice conditions, low water levels (especially in the fall), four sets of rapids and decreasing daylight in the fall. Because of the rapids, barge tows must stop and each barge must be carefully moved through a channel to protect the cargo.

Aircraft Accident

Statistically, approximately 30% of aviation accidents are weather related and up to 75% of delays are due to weather (NAV, 2005). The NWT experiences a number of aviation weather hazards including icing, poor visibility, wind shear and turbulence, weather fronts and thunderstorms. Aging infrastructure at some airports increases the community hazard exposure.

Climate Change Impacts

- Infrastructure associated with transportation is expected to be affected by climate change (see 5.3.4 Critical Infrastructure Failure – Other).
- There could be a shift in means of travel, for instance from driving to flying, with reduction in the availability of ice roads and bridges.
- Accidents can be expected with thinning ice conditions on ice roads and ice bridges, which could result in the need for more search and rescues.
- More intense and frequent snowstorms impact the transportation of goods and services in the region increasing vulnerability to other hazards and leading to economic loss (Pryor and Cobb, 2007 p. 2).
- Increased Arctic shipping in the Northwest Passage (Lemmen and Warren, 2004 p.135).

Community Meeting Feedback

The issue of transportation accidents was raised at several of the meetings held throughout the NWT. There is concern for poor highway infrastructure and the transportation of dangerous goods. The issue of aircraft accidents has been front and center in the NWT over the past few years with several accidents involving the loss of life over the past two years.

Key Risk Analysis Considerations

- Potential to spontaneously cause multiple deaths and injuries;
- Current and historical experience in the NWT;
- High damage potential if near or in a community; and
- Potential to affect any community in the NWT.

5.3.3 Critical Infrastructure Failure – Energy Crisis

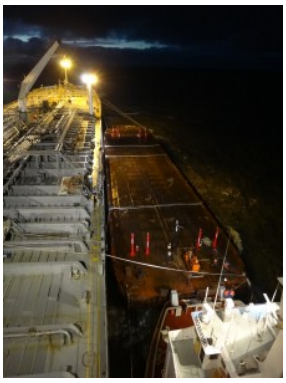

Figure 12: Fuel Barge from Hay River (Source: 2014 Northern Transportation Company Ltd. Shane Sadoway)

Definition	**Class**
Failure to provide energy required to meet basic human needs, sustain the economy, and protect public safety and security	Human-induced Hazard

NWT greatest impacts to date

Declared state of emergency

Climate Change

Projected to increase both frequency and consequence

Type	Cause/Explanation
energy emergency	A situation where energy supplies are insufficient to maintain minimal levels of service to an area or region.
oil and natural gas shortage	Oil and natural gas are an energy source used for heating, cooking, and electricity generation.

Vulnerability	Description
People	Given the severe weather in the north, the population relies on a steady and safe supply of energy to provide heating in the winter. Most areas of the NWT are extremely isolated and the health hazards of being left without energy/power are both physical and mental.
Infrastructure	Water lines and sewage lines can freeze and break in severe winter weather without heat or flowing water. Loss of power can cause a situation where pipes burst in the colder temperatures.
Communications	Loss of electrical power can cause disruption to communication systems such as radio and television which people rely on for information.

NWT Exposure/History

When	Where	Impact
May 31, 2011	Norman Wells	Due to an Enbridge pipeline malfunction, the town nearly ran out of natural gas. There are 268 households and over 100 businesses which would be directly impacted by the shortage. A determination was made that, if necessary, supply would be cut-off to commercial users first in order to preserve as much gas as possible for the households.
Jan 28, 2013	Norman Wells	The town of declared a state of emergency as gas shortages became acute.

In the NWT, there are three main energy sources used to generate electricity: natural gas, diesel fuel and hydro resources. Hydroelectric generation is used in eight communities in the Great Slave Lake area, while natural gas-fired power plants provide electricity to the community of Norman Wells. The remaining 24 communities have electricity provided by diesel-fired power plants. Alternative Energy Programs are being put in place such as a waste-heat recovery system in Holman, wind turbines in Sachs Harbour and a solar wall in Fort Smith. Fuel must be shipped into the communities by road, pipeline, barge, ice road or air. A shorter ice road season, barge or pipeline disruption, or prolonged extreme weather events can lead to shortages of fuel in communities.

Since 1999, residents and businesses in the Town of Inuvik have had their energy provided by two natural gas wells at the Ikhil site. In November 2010, one of the two wells had an unexpected inflow of water, resulting in the well no longer being able to produce natural gas. Efforts to repair the well (K-35) were unsuccessful (Inuvialuit Petroleum Corporation, 2007). It is no longer in operation. The second well (J-35) currently provides part of the town's energy supply, although an independent reserve report confirmed that the recoverable reserves are significantly less than previously estimated (Inuvialuit Petroleum Corporation, 2007). As a result, Ikhil can no longer provide a long-term natural gas supply. As an interim measure, the town of Inuvik is using a mix of propane and air, referred to as synthetic natural gas (SNG), which is now being injected into the gas distribution system for customers.

In November of 2013, Inuvik, was cut off from new shipments of propane because the ferry was not operating and ice roads had not opened yet. The town was able to switch from propane to natural gas from the Ikhil Natural Gas Facility but this option will not be available in the future.

Climate Change Impact

- Shortened ice road seasons could reduce the time available for transportation of fuel leading to shortages.
- Energy transportation systems (roads and pipelines) built in or on permafrost could be damaged due to climate change.
- Climate change caused drought could strand or limit the passage of fuel barges on the Mackenzie River.

Community Meeting Feedback

This issue was addressed at each community meeting. In most cases the concern was the remoteness of much of the NWT and the difficulty in ensuring reliable energy infrastructure was in place. Residents in the South Slave spoke of the "single" supply of fibre optic cables and power lines and the fact that an accident, fire or storm could severely impact the region. The issue was most acutely felt in the Beaufort Delta where Inuvik has dealt with gas shortages in the past few years. Inuvik is introducing the transportation of liquefied natural gas this coming year as a way to alleviate their reliance on the natural gas pipeline. Residents confirmed that Norman Wells was close to declaring a state of emergency due to gas shortages in 2011 and 2013.

Key Risk Analysis Considerations

- Potential to spontaneously cause multiple deaths if complicated by weather (shortage combined with blizzard or extreme cold);
- Current and historical experience in the NWT; and
- Potential to affect many communities in the NWT.

5.3.4 Critical Infrastructure Failure - Other

Figure 13: Bluefish Dam (Source: NWT Power Corp)

Definition

Failure of services that meet basic human needs, sustain the economy, and protect public safety and security

Class

Human-induced Hazard

NWT greatest impacts to date

- Power failures
- Road Damages

Climate Change

Projected to increase both frequency and consequence

Type	Cause/Explanation
airport	Incidents such as accidents, weather and systems failure could be the cause of an airport shut down.
sewage	Collapse of sewage facilities could lead to water contamination and bacterial concerns.
telephone	Disruption to land line or cell phone (where available) service would further isolate communities which would then have to rely on satellite phone service.
satellite	Satellite failure could lead to a loss of telecommunications links.
microwave towers	Microwave towers are used to relay phone and internet signals in remote areas where cables and fibre optics do not exist.
dam failure	Dam failure can disrupt power supply to those areas of the NWT which rely on this source of power.
structural collapse	Building collapse is a concern throughout the NWT where buildings are situated on pilings, some of which are showing serious deterioration causing the buildings to shift.
ice road collapse	Many communities are serviced by ice roads during the winter season. These roads allow necessary materials to be transported to isolated areas at a more affordable cost than is usual with air transportation. Warmer winters directly impact the length of time these roads are open.
bridge collapse	Bridge collapse would isolate communities with little to no alternative travel routes.
road sluffing	Due to shifting ground many roads are “sluffing” or collapsing.
low water levels limiting barges ability to reach community	Many communities rely on summer barge supplies to restock for long winters. Low water levels make it difficult, if not impossible in some cases, for barges to unload their cargo of material and fuels to many communities. This leaves the communities dangerously exposed in the winter without adequate supplies of fuel in particular.

Vulnerability	Description
People	People in the NWT live rely on infrastructure to keep them supplied and in touch with other communities. Any infrastructure collapse could be catastrophic given the harsh nature of most areas where people live.
Infrastructure	Airports are subject to closure regularly in the winter, ice roads rely on a consistent pattern of cold weather and all weather roads are also subject to closure during winter season. Any infrastructure collapse is also exacerbated by the fact that the isolated nature of these communities makes it extremely difficult to repair failed infrastructure. Given the isolated nature of most of the communities within the NWT, any incident which closes down an airport could be severe.
Communications	Communications break downs are common throughout the north as severe weather can shut down facilities and “power bumps” often hamper effective communications. Again, given the isolated nature of the area, repair of these systems is often extremely difficult.

NWT Exposure/History

When	Where	Impact
Jan 2003	NWT-wide	Mid-winter temperatures ranging from -1°C in Yellowknife to an incredible 7°C in Fort Smith. The mild El Nino weather put winter road and ice bridge construction behind schedule by a few weeks and created problems for mining and oil and gas industries, which rely on the frozen roadways to transport yearly supplies.
Oct 16, 2009	Yellowknife	The Mackenzie Valley Land and Water Board granted an emergency exemption to the NWT Power Corporation (NTPC) to replace the failing Bluefish dam. Evidence provided by the corporation and EBA Engineering Consultants Ltd. indicated that the dam was in a critical condition. Leakage from the dam's walls had increased almost 400 per cent in two years and accelerated the decay of the dam's timber spillway and crib.
Oct 2011	Wekweètì	Days of dense fog meant flights couldn't land. Effectively cut the community off from groceries, supplies and travel for a week and stranded other community members in Yellowknife until the fog cleared. Many airports, like the one in Wekweètì, don’t have GPS help on approach. Instead, pilots must be able to see the runway in order to land.
Oct 6, 2011	10 communities	Telesat’s Anik F2 satellite suddenly ceased operating. Remote northern locations were the most affected, with 10 of 33 NWT communities served by NorthwesTel seeing disruptions from the outage. First Air airline cancelled 48 flights, stranding about 1,000 passengers just before the Thanksgiving long weekend.

When	Where	Impact
Feb 14, 2012	Yellowknife	A Canadian Armed Forces Griffin helicopter struck a power line on its way to Yellowknife airport causing power outages to the city. The power outage lasted over an hour and the city relied on diesel generators to get the city powered up. The damage caused was significant and Northland Utilities warned of rotating outages for the next day while asking commercial users with backup generators to use those to lessen power needs.
Jan 30, 2013	Behchokǫ̀	Malfunction of a piece of equipment out at the Snare Hydro substation caused 200 to 250 homes in Behchokǫ̀, and 8,200 homes in Yellowknife to lose power for up to 12 hours. Caused property damage due to frozen pipes.
Sept 18, 2013	Dehcho Region	A damaged NorthwesTel fibre optic cable cut off long-distance calling and Internet services. People had to deal with paying only by cash, having no cellphone access and no Internet. Using cash was the sole method of payment accepted at Fort Simpson's Northern Store during a region-wide Internet and long-distance phone disruption. A melted fibre terminal caused by a forest fire at the Morrisey Microwave Site was the reason for the disruption, the company confirmed.

Consequences Classification for the failure of the Duncan and Bluefish dams is considered to be low - no increase in loss of life; low social, economic and/or environmental losses.

Climate Change Impact

- The safe travel season on winter roads is shortening (IPCC, 2013 p.5).
- Overuse of ice roads due to a shortening of the ice road season could lead to dangerous conditions.
- Ice roads provide necessary infrastructure for shipment of food that is not produced locally (Infrastructure Canada, 2006 p.13).
- Increases in the number of freeze-thaw cycles could have major impacts on roads, bridges and other infrastructure in the north.
- Delayed freeze-up in the fall, thinner ice and an earlier spring melt, result in a shorter winter road season despite improved technology and more time and effort being applied to construct and maintain roads (NWT MENR, 2008 p.9).

Community Meeting Feedback

The issue of infrastructure failure was discussed at all of the regional meetings. The biggest concern commented upon was the present state of the highways and roads throughout the NWT and the reliance on seasonal roads. The span of time these seasonal roads could be accessed was believed to be directly affected by climate change according to many residents. The reliance on air transportation and the implications of an airport closure anywhere in the Territories was also commented upon. At the South Slave regional meeting there was also

mention of the fact that any infrastructure failure in Alberta, be it road or airport, would also have an immediate impact on the NWT as the Territory relies on Alberta for supplies and also for emergency response in some areas.

Key Risk Analysis Considerations

- Potential to spontaneously cause multiple deaths and injuries (especially structural collapse);
- Current and historical experience in the NWT;
- Potential to affect any community in the NWT;
- Aging infrastructure;
- Rapid structural deterioration of critical infrastructure in the extreme environment; and
- Lack of options and “backups” in services.

5.3.5 Critical Infrastructure Failure - Water Contamination

Figure 14: Water Treatment Plant – Łutselk'e, September 2012 (Source: GNWT, MACA)

Definition	**Class**
Serious contamination of drinking water or loss of supply, that presents a danger to the general health of the public	Human-induced Hazard
NWT greatest impacts to date Boil water advisories	
Climate Change Projected to increase both frequency and consequence	

Cause/Explanation

Water contamination is a result of biological or chemical contamination of the community water system.

Vulnerability	Description
People	The levels of contaminants in drinking water are seldom high enough to cause acute (immediate) health effects. Examples of acute health effects are nausea, lung irritation, skin rash, vomiting, dizziness, and even death.
Infrastructure	Disasters that destroy infrastructure may result in water contamination by sewage. Chloride ions, usually found in seawater or acid rain, increase the conductivity of water and accelerate corrosion. Chloride can penetrate and deteriorate concrete on bridge decking and parking garage structures, and damage reinforcing rods, compromising structural integrity. It damages vehicle parts such as brake linings, frames, bumpers, and other areas of body corrosion. It impacts railroad crossing warning equipment and power line utilities by conducting electrical current leaks across the insulator that may lead to loss of current, shorting of transmission lines, and wooden pole fires.
Communications	Chloride ions from acid rain significantly aggravate the conditions for pitting corrosion of most metals by enhancing the formation and growth of the pits through a process which weakens them over time.

NWT Exposure/History

The responsibility for ensuring safe drinking water is vested with the Government of the NWT, which has passed specific public health legislation designed to ensure the safety of drinking water supplies. The Department of Health and Social Services is the regulator and is responsible for enforcing the *Public Health Act*, *Water Supply System Regulations*, and *General Sanitation Regulations* as well as ensuring the *Guidelines for Canadian Drinking Water Quality* are met.

Community governments have the authority and responsibility to provide safe potable water to their residents. In communities where the community government is the owner and operator of the water treatment facilities, the community government is responsible for the treatment and safety of the water supply in those operations. Responsibilities include treatment of water to meet the *Guidelines for Canadian Drinking Water Quality*, the submitting of water samples to a laboratory for bacteriological and chemical analysis, and maintaining records of raw water quality, finished water quality and the amounts of chemicals used in treatment.

NWT Exposure/History

When	Where	Impact
2004	Colville Lake	Had no operating water treatment plant. The community has been under a boil water advisory since 2004. The boil water advisor will remain in place until the EHO is satisfied with the regulatory sampling regime.
Spring 2006	Tulita	A precautionary boil water advisory issued because of problems with the filters at the WTP. No bacteria was found in the treated water. The advisory was lifted when the filters were fixed.
2007	Hay River	Boil water advisory during spring break up due to high turbidity.
	Wekweètì	Boil water advisory due to broken chlorine pump.
	Paulatuk	Boil water advisory due to positive bacteriological sample.
2008	Hay River	Boil water advisory during spring break up due to high turbidity.
July 2008 to March 2009	Sachs Harbour	The community spent more than eight months under a boil water advisory after chlorination pumps failed at the local water treatment plant.
2009	Hay River	Boil water advisory during spring break up due to high turbidity.
	Tulita	Boil water advisory during spring break up due to high turbidity.
May 2009	Most of the NWT communities	Oil sands development in the Wood Buffalo Region threatens the water supply to most of the NWT 33 communities which are located on water directly downstream from the oil sands. The main area of concern is that contaminants may be getting into the water system which would directly affect the drinking water of virtually all residents of the NWT.
June to Nov 2011	Sachs Harbour	Boil water advisory for five months due to problems with the hamlet's water treatment plant. No related illnesses were reported.
July 13, 2012	Town of Inuvik	Boil water advisory. There were no illnesses associated with drinking water reported.

Climate Change Impact

- Climate change is expected to result in increased siltation in water systems (Pryor and Cobb, 2007, p. 34) and increased water volumes due to precipitation. This will require adjustment in capacity of water treatment and sewer systems to handle the volume.
- The structural aspects of water systems could be affected by climate change impacting permafrost (Auld, 2007 p. 26).
- Literature indicates that greater bio accumulation of contaminants is expected with climate change, particularly POPs and mercury.

Community Meeting Feedback

The issue of water contamination and the need for clean sources of water was brought up at all community meetings, save those held in Yellowknife. South Slave residents are concerned with what is being put in the water in Northern Alberta by industry as these waters feed the rivers of the South Slave region. Also raised was the contamination of water in the Hay River area by waste from the NTCL yard as well as a chicken barn which is located south of town directly on the Hay River. Throughout the South Slave and Dehcho regions issues were raised over how the placement of sewage lagoons and poor sewage infrastructure could affect the quality of drinking water. In some cases, such as Fort Resolution, the sewage lagoon was built above the water supply which means that any seepage could directly impact the community's water supply.

Oil spill contamination was a concern in Fort Good Hope where the water supply was located directly adjacent the Enbridge pipeline. Any incident with the pipeline would have an immediate impact on the water supply. Tulita and other communities in the Sahtu Region have to boil water each and every spring as hazardous materials are left on the ice during the winter and fall into the water during spring break-up.

Residents of the Beaufort Delta spoke of the isolated nature of their water supply and the need for an improvement to the local infrastructure in order to ensure a safe supply of water.

Key Risk Analysis Considerations

- Potential to spontaneously cause multiple deaths and injuries;
- Current and historical experience in the NWT; and
- Potential to affect any community in the NWT.

5.3.6 Weather – Other Extreme

Figure 15: Radiation fog, Inuvik airport tower from weather instrument site, September 2001 (Source: NAV Canada, Ken Kehler)

Definition

All weather related hazards excluding wind storm and cold weather storms

Class

Natural Hazard

NWT greatest impacts to date

- Power failures
- Road Damages

Climate Change

Projected to increase both frequency and consequence

Type	Cause/Explanation
extreme cold	Temperatures of -40 or lower for a period of at least seven days.
frost	A deposit of ice crystals that forms through a process called sublimation.
drought	Abnormal shortage of water, typically occurring throughout the summer months over an extended period of time.
fog	A cloud based at the earth's surface, consisting of tiny water droplets, or under very cold conditions, ice crystals or ice fog found in calm or low wind conditions.
geomagnetic storm	Disturbances in the geomagnetic field caused by gusts in the solar wind that blows by Earth. Energetic particles thrown out from the sun interact with the earth's magnetic field producing magnetic disturbances and increased ionization in the ionosphere, 100 to 1000 km above the earth.
heat wave	Significant rise in ambient temperature above the mean for an extended period of time, or by a combination of high humidity and lack of air motion.
lake effect storm	Lake-effect storms occur along the lake shore caused by the modification of cold, subfreezing air by the relatively warmer lake water.
lightning and thunder storm	Ascending moisture laden unstable air leads to the formation of thunderclouds which transmit electrical charges of up to 100 million volts of electricity from cloud to cloud or ground.
hail storm	Precipitation in the form of ice balls of five millimeters or more in diameter.
Vulnerability	**Description**
People	Extreme cold temperatures can cause injury and death. Temperatures of -55 and colder have an extremely high risk of causing injury as exposed skin can freeze in less than 2 minutes. Temperatures of -48 to -54 have a very high risk of causing injury as exposed skin can freeze in 2 to 5 minutes. Temperatures -40 to -47 have a high risk of causing injury as

Vulnerability	Description
	exposed skin can freeze in 5 to 10 minutes. Under foggy conditions, visibility is reduced to less than 1 kilometre and vehicle accidents can result (see Transportation Accidents Hazard). Ocean and lakes areas, and in particular the large lakes such as Great Bear Lake and Great Slave Lake, are cloud and fog prone through the fall until they freeze over completely (see Transportation Accidents Hazard).
Infrastructure	Extreme cold temperatures can cause significant property damage, mechanical malfunctions and burst pipes. Drought can cause crop failure, depletion of municipal water sources, increase in forest fire risk (see Fire/Explosion Hazard) and insufficient water flow through waterways. Lighting storms can lead to fires (see Fire/Explosion Hazard). Combining heat wave with the dry climate of the Arctic creates ideal conditions for wildfires (see Fire/Explosion Hazard).
Communications	A geomagnetic storm can knock out communications and have a variety of effects on technology. Radio waves used for satellite communications or GPS navigation are affected by the increased ionization with disruption of the communication or navigation systems. The high energy particles affect satellites causing failure or equipment damage. The magnetic disturbances directly affect operations that use the magnetic field, such as magnetic surveys, directional drilling, or compass use. Magnetic disturbances also induce electric currents in long conductors such as power lines and pipelines causing power system outages or pipeline corrosion.

NWT Exposure/History

When	Where	Impact
January 2008	Yellowknife, Norman Wells and Fort Simpson	Cold snap of nine straight days of -40°C temperatures. Lingering ice fog obscured entire neighbourhoods, caused several flight disruptions, lengthened work commutes, and halted mail delivery. The -50°C wind chill and freezing fog caused a 90 minute power failure and impelled the homeless to fill emergency shelters. Schools were closed.
July 20, 2008	Yellowknife	An intense 20-minute storm dumped enough hail and rain to flood streets and grounds in a metre of water in some areas. Drains were unable to keep up with the hail-chocked flow and backed up. During the peak of the storm, residents were seen canoeing across some streets. The golf-ball size hail forced construction workers and others to flee for cover.
January 2013	Behchokǫ̀	Cold weather was blamed for a power outage in Behchokǫ̀ which resulted in half the community without power for about 12 hours. That was the second major power outage in the territory that week. That same week , Norman Wells prepared to evacuate the town as its natural gas service failed, leaving about half of that community without heat in cold temperatures.

Climate Change Impact

- A decrease in extreme cold events is projected. Mean temperature will rise by 4-8 ^{o}C by 2050, and an increase in heat waves are likely.
- Little change in frost events projected to 2050 (Bruce et al, 1992).
- Increase in intensity and frequency of rain events, 5 to 10% increase (of 10mm events) to 2050.
- Increase fog events, with increased humidity.
- Increase in lake affect storms.
- Temperature increases are likely to increase lightning.

Community Meeting Feedback

There was much discussion amongst residents at all meetings regarding the increase in extreme weather. This mostly included higher temperatures in the summer months and a shifting in seasons. Whereas in the past summer weather deteriorated in late August, recent years have seen warmer weather lasting into late September. There was also a general agreement that, although the NWT is not as consistently cold has it has been in the past, there are wilder swings and more extreme storms than in the past.

Key Risk Analysis Considerations

- Potential to spontaneously cause multiple deaths and injuries (especially lightening and extreme cold);
- Current and historical experience in the NWT; and
- Potential to affect any community in the NWT.

5.4 Moderate Hazard

5.4.1 Industrial Emergency

Figure 16: Diavik Diamond Mine Site (Source: Photo Courtesy of the Diavik Diamond Mine, www.diavik.ca)

Definition	**Class**
Emergencies involving businesses that handle dangerous goods, hazardous wastes or chemicals or engage in potentially hazardous activities	Human-induced Hazard

NWT greatest impacts to date

Environmental Damage

Climate Change

Projected to increase both frequency and consequence

Type	**Cause/Explanation**
mine emergency	A situation involving an accident or incident at a mine site which causes potential threat to health, environment or property. Can include explosions/fire, cave-in's, or personal injury.
oil spill	The release of a liquid petroleum hydrocarbon into the environment, especially marine areas, due to human activity, and is a form of pollution.
gas leak	A leak of natural gasses from a pipe or other containment, into a living area or any other area where the gas should not be.
contamination	The improper presence of a harmful substance in the natural environment, or at a workplace.
hazardous material spill	A spill involving any material which can be hazardous to the people or the environment.
radiological emergency	An emergency where radioactive material in significant concentrations escapes into the environment. If the concentrations of the materials are high enough, they could be dangerous to health.
Vulnerability	**Description**
People	Industrial accidents have an enormous impact on the health of workers and on the economy in general, which is reflected in the death, disability and personal suffering of workers on one hand, and in absence from work, loss of productivity and health costs on the other.
Infrastructure	Industrial accidents can have a dramatic negative affect on physical and virtual systems which are considered critical. This would include fires or explosions, oil spills which could impact water treatment and dam failure which could impact power supply.
Communications	Communications hubs in small communities could be damaged by an industrial accident in the community.

NWT Exposure/History

Mining and oil and gas industries are the most common hazardous industries in the NWT. In mining, traumatic injury remains a significant problem. Common causes of fatal injury include rock fall, fires, explosions, mobile equipment accidents, falls from height, entrapment and electrocution. Less common but recognized causes of fatal injury include flooding of underground workings, wet-fill release from collapsed bulkheads and air blast from block caving failure. The systematic application of risk management techniques has contributed to a substantial decline in injury frequency rates (Donoghue, 2004).

When	Where	Impact
From 1943 to 1945	Norman Wells, NWT, to Whitehorse, Yukon Territory	CANOL Crude Oil Pipeline No. 1 lost approximately 17,838,500 L of oil through spills and 9,864,400 L was left in the line and storage tanks. Although some burning was done during salvage operations, most residual oil was drained onto the soil surface.
April 06, 1975	High Arctic Islands	Pan-Arctic Oils, Jet/Turbine Oil, Drake D-73 Well Site - 22,817 Gallons (Hazardous Materials Spill Database).
Sept 18, 1985	Beaufort Sea	Esso, Diesel Fuel/ Heating Oil, Esso Rig #7, W. of Pelly Island - 103,000 Gallons Spill (Hazardous Materials Spill Database).
Sept 07, 1986	Norman Wells	Esso Resources Canada Ltd. Crude Oil, Imperial Oil Tank #53 Mainland, Sahtu Region - 21,136 Gallons.
Aug 20, 1991	Unknown	Production Processing Facility, Esso Resources Canada Ltd. Crude Oil, Imperial Oil Tank #53, Mainland Facility - tank leak and equipment damage 16,800 Gallons (Hazardous Materials Spill Database).
May 04, 1992	Norman Wells	Interprovincial Pipelines, Crude Oil, Norman Wells Pipeline, 25 km N of Ft Simpson - 26,420 Gallons (Hazardous Materials Spill Database).
May 05, 1997	Norman Wells	Imperial Oil, Crude Oil Transfer line, CPF to tank 401 - 63,000 Gallons (Hazardous Materials Spill Database).
April 02, 2003	300 kilometres northeast of Yellowknife	BHP Diamonds Inc. NSL-Fox Fuel Tank Farm – 62,500 L Diesel Fuel (Hazardous Materials Spill Database).
May 10, 2011	North of Fort Simpson	An Enbridge pipeline leaked oil into the environment near Willowlake River. Approximately 1500 barrels of oil were spilled.
2012	Norman Wells	Imperial Oil Resources NWT Ltd. Norman Wells – 80,000 L Oil Emulsion (Hazardous Materials Spill Database).

Other Hazard Specific Information

The Radiation Protection Bureau of Health Canada operates a network of radiological air monitoring stations across Canada. Each site is equipped with a high-volume air sampler, a precipitation collector, and a thermo-luminescent dosimeter for gamma radiation measurements. The Yellowknife site has equipment for the measurement of radioxenon.

There are several abandoned and decommissioned uranium mines in the NWT. A number of shipping points along the Northern Transportation Route were contaminated with low levels of natural radionuclides from the loading and unloading of uranium ores (AMAP Assessment, 2009).

Climate Change Impact

- Permafrost melting could cause mine tailing ponds to degrade (Auld, 2007) or lead to the failure of mine water retention dams.
- Industrial activity is expected to increase with easier access to natural resources afforded by climate change.
- May alter table impacts of frozen arsenic encapsulation at a decommissioned gold mine (Pryor and Cobb, 2007, p.34).

Community Meeting Feedback

During the community meetings there was little in the way of information received regarding industrial accidents. Community members in the South Slave region discussed the need for clean-up at the Northern Transportation Company Ltd. (NTCL) yard in Hay River. Residents of the Sahtu and Beaufort Delta also spoke of their concerns with the oil and gas industry which operates in those regions. Much of the discussion centered on prior industry and what was buried or left in dumps throughout all of the regions. Included in this discussion were arsenic in the Yellowknife area and contaminated materials buried or stored throughout the Sahtu and Beaufort Delta.

Also discussed at length at each of the meetings was the transportation of dangerous goods throughout all regions and the lack of knowledge among residents as to what was actually being transported through their community.

Key Risk Analysis Considerations

- Potential to spontaneously cause multiple deaths and injuries;
- Current and historical experience in the NWT;
- High damage potential if near or in a community;
- High environmental potential impact; and
- Potential to affect any community in the NWT but mainly the industrial mining and oil and gas operations.

5.4.2 Weather – Wind Storm

Figure 17: Microburst Damage to Trees in Fort Smith, September 2012 (Source: Northern News Services)

Definition	**Class**
Strong weather characterized by damaging movement of air	Natural Hazard

NWT greatest impacts to date

- Property Damage (drill rig)
- Infrastructure (transmission tower)

Climate Change

Projected to increase both frequency and consequence

Type	**Cause/Explanation**
wind storm	Weather event that includes wind speeds that exceed what is expected for a particular area.
hurricane/cyclone	Large storms with winds of greater than 110 kilometres per hour.
tornado and water spout	A funnel cloud of rapidly rotating air, with an intense low pressure of rising air at the centre.
dust and sand storms	When blowing dust covers a large area, the event is termed a dust storm.
microburst	Pattern of intense wind that descends from rain clouds, hit the ground, and fan out horizontally.

Vulnerability	**Description**
People	All wind storms have the potential to cause injury or death due to structural damage, flying debris or storm surges. Hurricanes also can cause flooding (see Flood Hazard). Tornados can cause many injuries and death but are very rare across the NWT.
Infrastructure	Heavy winds can cause great damage to buildings and infrastructure, and knock out power across large areas. Tornados can cause heavy damages but are very rare across the NWT.
Communications	Heavy winds are often responsible for damage to communications towers.

NWT Exposure/History

When	Where	Impact
July 30, 1978	Near Yellowknife and near Behchokǫ̀	A tornado toppled a tower near Yellowknife and then ripped up a transmission tower near Behchokǫ̀. It was the third tornado reported in the NWT since 1960.
1985	Beaufort Sea	An Oil rig on the Minuk I-53 sacrificial beach island was lost during a severe storm in the Beaufort Sea. The drill rig, modules, camp and ancillary equipment were destroyed.
Sept 14, 2012	South of Fort Smith	A thunderstorm was accompanied by both windshear and micro-bursts. The wind event affected a vast area, including Pine Lake, 60 km in Wood Buffalo National Park, where thousands of trees were downed, with a few damaging cottages (LADIK, 2012).
Aug 2012	Beaufort Sea	A very strong cyclone developed over eastern Siberia and strengthened rapidly over the central Arctic Ocean north of Alaska. It reached near-hurricane wind speeds and, at its peak on August 6, covered two-thirds of the Arctic Ocean. The storm brought warm winds and in the end was likely responsible for a very rapid loss of ice in the western Arctic. On three consecutive days, sea ice extent dropped by nearly 200,000 square km per day.

On July 19, 2012 at 9:30 p.m. photographic evidence from a cell phone was taken of a funnel cloud near the Inuvik Airport. This was one of the most northern sightings of a funnel cloud anywhere in the world. It did not touch down.

Climate Change Impact

- Tornado activity is expected to move further north, with warming temperatures.
- Observations show strengthening of storms and strong winds over time.
- Strengthening of cyclone activity in the Artic has occurred and is expected to continue (CSA, 2010).

Arctic cyclone activity has increased during the second half of the twentieth century (NASA/Goddard Space Flight Center, 2008). Warming temperatures could bring more tornado activity further north. Low-pressure systems from mid-latitudes are moving further North, particularly in the noted time period from 1950 to 2006 (Cassano et al., 2006; Hakkinen et al., 2008). From a risk management perspective, the assumption should be made that there will be more frequent windstorm and tornado events in the future (IBC, 2012).

Community Meeting Feedback

There was agreement among the residents of all meetings that the NWT was seeing more extreme windstorms in recent years. Residents of the South Slave spoke of seeing an increase in micro-bursts over the past few years.

Key Risk analysis considerations

- Potential to spontaneously cause multiple deaths and injuries;
- Some historical experience in the NWT;
- High damage potential if in a community; and
- Potential to affect any community in the NWT.

5.4.3 Human Disease

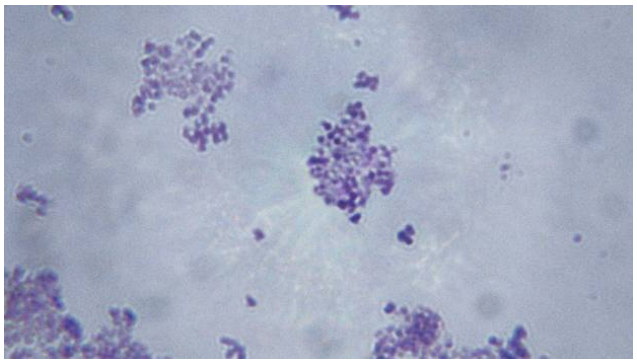

Figure 18: Staphylococcus aureus (Source: Canadian Press, 12 Oct 2012)

Definition	**Class**
A grave or widespread illness that presents a danger to people's health	Natural Hazard

NWT greatest impacts to date

Fatalities 600

Climate Change

Projected to increase both frequency and consequence

Type	**Cause/Explanation**
epidemic	An epidemic is a situation where a disease affects many people in a given area, resulting in illness and potential death. Yearly epidemics cause serious illness and death, especially among those who have weakened immune systems due to age or underlying medical conditions.
pandemic	A pandemic refers to an epidemic that spans a large geographic area and can become a global health emergency.
anthrax	Anthrax is a disease resulting from inhalation of the naturally occurring bacteria of the same name. It is endemic in northern bison, with periodic outbreaks that have killed at least 2,196 bison since the first confirmed outbreak in 1962. Risk of exposure to the disease by humans is most likely to occur through direct contact with infected animals, carcasses or animal parts (e.g. meat, hide, hair, etc.).
Vulnerability	**Description**
People	Injury and death from human disease can severely impact an isolated community where continual medical care is limited.
Infrastructure	While human diseases do not impact infrastructure directly, some disruption in critical services could occur when enough of the population is affected. Support services to remote communities could be cut off during a pandemic or severe epidemic.
Communications	N/A

NWT Exposure/History

When	**Where**	**Impact**
Between 1890 and 1910	Tuktoyaktuk	Between 1890 and 1910 the population was destroyed by influenza.

When	Where	Impact
1902	Fort Resolution, Behchokǫ̀	Measles epidemic killed 60 people in Behchokǫ̀,and 66 in Fort Resolution.
1928	Mackenzie District	Influenza epidemic sweeps through the Mackenzie District, killing about 600 people. Approximately 10 to 15% of the population of each village.
1952	Wood Buffalo National Park	Cutaneous anthrax was retrospectively diagnosed in two wardens who developed skin lesions after they handled a bison carcass. Both responded to antibiotic therapy.
Summer 1962	Hook Lake	Two people working with infected bison carcasses during the Hook Lake outbreak contracted anthrax. One was exposed while performing a necropsy without the use of appropriate safety precautions, and the second was exposed while working on heavy equipment that had been used in the outbreak response. Both individuals received prompt medical attention.
Since 2008	NWT wide	Methicillin-Resistant Staphylococcus Aureus (MRSA) infections. 55 hospitalizations (5 of them had to be flown south for treatment). Fatalities 2
Nov 2009	NWT wide	H1N1 - 45 hospitalizations. Fatalities 1

Pandemic

Worst case scenario in the GNWT Pandemic plan – each community may be completely isolated and little or no extra resources (human or material) will be available from the Region, Territory, or Nation during the Pandemic period.

Climate Change Impact

- Potential for increasing levels of infectious disease, malnutrition and pandemics.
- In the past diseases might not have survived in the cold temperatures and the ice of the Arctic but as the region warms new diseases could be introduced.

Community Meeting Feedback

Residents believe there is a higher risk of a pandemic hitting the North Slave region due to the influx of travellers and tourists to the city of Yellowknife. There was also concern for the lack of formal coordination for medical evacuation.

Key Risk Analysis Considerations

- Potential to spontaneously cause multiple deaths;
- Pandemic can impact evacuation or treatment;
- Current and historical experience in the NWT; and
- Potential to affect any community in the NWT.

5.4.4 Ice Hazard

Figure 19: Mackenzie River Breakup near Tulita (Source: GNWT, MACA)

Definition	**Class**
Formations or movements of ice which cause loss of life, property and/or environmental damage	Natural Hazard

NWT greatest impacts to date

- Property Damage (houses)
- Infrastructure (roads)

Climate Change

Projected to decline

Type	Cause/Explanation
seabed gouging by ice, strudel scours	Occurs when floating ice features (typically an iceberg or sea ice) drift into shallower waters and their keel comes into contact with the seabed.
ice override (ivu)	An ice shove, Ivu, or shoreline ice pileup is a surge of ice from an ocean or large lake onto the shore.
ice flow, iceberg, ice island, sea ice	Sea ice is any form of ice found at sea which has originated from the freezing of water and can pose a hazard due to its growth, decay and drift. An iceberg is a piece of glacial ice which has broken off and become free-floating. Ice islands are large tabular icebergs with thicknesses ranging up to 60 meters and lateral dimensions ranging upward to approximately 40 x 40 km. Because of their relatively great thickness, they have often been observed grounded at water depths greater than 20 meters, and may represent the strongest variety of ice in the Arctic Ocean.

Vulnerability	Description
People	Injury and loss of life can occur when oil rigs, boats or ships are damaged or sunk by ice (see Transportation Hazards).
Infrastructure	Icebergs still threaten offshore oil rigs, fishing boats and ships. Ice shoves can damage buildings that are near to a body of water. Seabed gouging or strudel scour can damage off shore oil rigs or pipelines (see Industrial Hazards).
Communications	None

NWT Exposure/History

When	Where	Impact
Jan 12, 2000	Near Fort Providence	A Northbound Super-B-Train truck hauling diesel fuel crashed through the Mackenzie River ice crossing. Driver

When	Where	Impact
		was treated for hypothermia.
Feb 20, 2007	Parry Peninsula	A hunter went adrift on an Arctic ice floe when winds caused his land tether to break. A Canadian Forces helicopter search and rescue team made a daring jump onto the ice floe and stayed with the stranded hunter overnight. It was below -50°C with the wind chill.

Elders and hunters have developed a detailed understanding of the ocean and weather conditions that may cause sudden changes in ice conditions, and generally try to avoid unnecessary risks when traveling on the sea ice. The sea ice can be dangerous to navigate because it is constantly shifting and can be a hazard to offshore structures. It can be either fast ice, which stays close to shore, or drift ice, which moves around and grinds together with great force to form ridges.

Icebergs can represent a serious threat to shipping, because they are difficult to see and avoid. Historically, numerous ships were lost due to iceberg collisions. In the modern era, ships avoid bergs by taking advantage of tracking data about especially large icebergs, along with utilizing technology, which can be used to identify upcoming bergs in the path of a ship.

Climate Change Impact

- A decline sea ice cover is associated with climate change (IPCC, 2013).
- Navigation and shipping is more risky with sea ice becoming less predictable.
- Opening of areas previously covered with sea ice, brings security issues, and makes passage or access to natural resources easier.

Community Meeting Feedback

The issue of ice hazards was mentioned specifically during the regional meeting held in the Sahtu. There have been incidents where ice has damaged pipes along the shore of the river which are intended to off-load fuel from barges. The same commentary was also heard from residents of the South Slave. There have also been occurrences in Tulita where ice has moved on-shore during break-up causing considerable damage to houses and roads. The other impact of ice has been felt in the span of time seasonal roads can be used. Climate change shortening the winter road season would have a dramatic effect upon many NWT communities.

Key Risk Analysis Considerations

- Potential to spontaneously cause multiple deaths and injuries (especially to watercraft);
- Current and historical experience in the NWT; and
- Potential to affect some communities in the NWT.

5.4.5 Snow Load Hazard

Figure 20: Municipal Garage Roof Collapse in Enterprise, January 28, 2013 (Source: Paul Bickford/NNSL Photo)

Definition	**Class**
Potential collapse of buildings due to the weight of build-up or drifting of snow	Natural Class

NWT greatest impacts to date

Property Damage (Roofs)

Climate Change

Projected to increase both frequency and consequence

Cause/Explanation

Structures are built using historical snow load standards. When the snow load exceeds the standards, due to wetter, heavier, more frequent or drifting snow, structures can collapse.

Vulnerability	Description
People	High numbers of injuries or deaths could occur if an occupied community building or school were to collapse.
Infrastructure	Loss of the building and contents plus loss of the use of this building until repairs or a new structure can occur.
Communications	Potential collapse of microwave towers due to snow load could impact the community's communications.

NWT Exposure/History

When	Where	Impact
May 5, 2004	Inuvik	Samuel Hearne Secondary School roof of the foyer collapse caused by a record-breaking build-up of snow. Due to the timing of the event, no one was hurt in the collapse.
Jan 28, 2013	Enterprise	The roof of an Enterprise municipal garage collapsed under the weight of snow.

Other Hazard Specific Information

Studies show that approximately one fifth of public buildings (22%) in the NWT are at risk of collapse due to changing/increasing snow loads. Public buildings at risk include schools, hospitals, community centers and medical centres. Of those buildings at risk, about 10% have been retrofitted since 2004, and another 12% are under a snow load watch status. While studies are being completed on snow loads in the NWT, an adjustment of required snow load

calculation for new buildings has increased by 20% over the National Building Code of Canada, now a Territorial Building Code requirement (Auld and Klaassen, 2010).

Public Works and Services/GNWT has issued a roof snow overload risk estimation checklist that can be used to identify which GNWT structures are potentially at risk of developing snow overloading during any one winter, applicable to every community in the NWT. Ten NWT communities, located in the Dehcho and Sahtu Region, have a high Community Snow Load Risk Factor.

Climate Change Impact

- Change in precipitation patterns.
- Since the 1950s, precipitation has increased by 25 to 35% (Zhang et al., 2000: updated in 2005; CSA, 2010).
- Increase in the days per year of snowfall and a rise in the number of heavy snowfall events (Vincent and Mekis, 2006: updated in 2008).
- The snow/rain mix is changing due to warmer temperatures, and results in a heavier wetter snow thus higher snow loads (Pryor, 2007 p.2).

Community Meeting Feedback

Response amongst participants at regional meetings was mixed on this issue. While many residents agreed that weather was, in general, becoming more extreme, with higher temperatures and more intense winds, there was no agreement on snow loads. Residents of the South Slave spoke of the increased amount of snow they were seeing and the fact that it was heavier and wetter than in the past. Residents of Yellowknife and Dehcho spoke of the decrease in the snow load and residents in the Beaufort Delta were split. The representative of Sachs Harbour spoke of the large amount of snow they received last winter while the representative of Ulukhaktok commented that they received so little snow it was extremely hard to get out for the spring hunt.

Key Risk Analysis Considerations

- Potential to spontaneously cause multiple deaths and injuries;
- Current and historical experience in the NWT;
- High property damage potential; and
- Potential to affect any community in the NWT.

5.4.6 Earth Movement – Permafrost Degradation

Figure 21: Permafrost degradation of highway (Source: NWT Climate Change Impacts and Adaptation Report, 2008)

Definition	**Class**
Movement of the ground causing wide spread damage caused by loss of permafrost	Natural Hazard

NWT greatest impacts to date

- Power failures
- Road Damages

Climate Change

Projected to increase both frequency and consequence

Cause/Explanation

Permafrost is frozen soil, sediment, or rock that remains at or below 0° Celsius for at least two years. Frozen soils lose strength as they warm, and ice loses all its strength when it thaws. This change in land strength increases the risk of mass movements of land, such as erosion, landslide and riverbank collapse. The flow of water in karst topography due to permafrost melting increases the risk of sink holes. Permafrost thawing may result from natural processes and related environmental disturbance such as wild fire, human activity (such as the clearing of vegetation), extreme climatic events or ongoing climate change (CSA, 2010).

Vulnerability	Description
People	Injury and death could result from the unexpected collapse of land or a building.
Infrastructure	Permafrost has always figured heavily into Arctic infrastructure design, construction, and maintenance (NRTEE, 2009; CSA, 2010). Infrastructure systems in permafrost have depended on the stability of permafrost as a foundation material. Permafrost erosion along streams and rivers is threatening dikes, bridges and culverts.
Communications	Some damage to communication towers possible.

NWT Exposure/History

Ground movement caused by melting permafrost has resulted in the cracking or sloping of building walls and foundations. It has also resulted in heaving, slope failure, sinkholes and potholes, affecting all forms of infrastructure. An example of the effect of permafrost degradation is the roadway buckling on Franklin Avenue hill in Yellowknife. This road was rebuilt after only 3 years in service due to excessive buckling. The cause was a subsurface with variable degrees of support along the length and width of the road (Pryor & Cobb, 2007 p.17).

Permafrost erosion along streams and rivers is threatening dikes, bridges and culverts. Slope failures, in communities such as Sachs Harbour, are becoming unmistakable.

A mixture of different types of permafrost is found under all of the NWT including: continuous, extensive discontinuous and sporadic discontinuous permafrost. In Inuvik (continuous), 40-75% of the existing buildings are likely to incur foundation damage during the buildings' lifetime due to permafrost melting (CSA, 2010). Inuvik, because of its size and location, has been identified as particularly vulnerable. The Factor of Safety (actual or design strength / required strength or loaded stress) has dropped from 1.5 to 1.0 in Inuvik since ground temperatures started increasing. For the widespread discontinuous permafrost zone (where communities of Norman Wells and Tulita are located), the ground temperatures could increase sufficiently to cause fairly strong impacts on building foundations. In Norman Wells, 14-26% of existing buildings could incur foundation damage due to permafrost degradation while the projected impacts on Tulita's buildings were found to be somewhat less severe. (Couture, et al, 2000) Communities in the sporadic permafrost zone are the least vulnerable as most buildings there are not founded on permafrost.

Climate Change Impact

- Thawing of permafrost expected with climate change, top two to three meters will have thawed by 16-20% by 2100 (AMAP, 2012. p.45).
- Planning should include expecting this trend of changes in permafrost to continue in the future. This applies to construction (and thus building codes) and shoreline setback on developments.

Infrastructure adaptation is occurring in the NWT. The Yellowknife airport runway required extensive restoration after the permafrost below began to thaw. A new insulating liner was installed four metres beneath a 100 metre section of the runway. Portions of the Canadian northern highway from Yellowknife to Fort Providence have been abandoned and rebuilt over more stable permafrost.

Community Meeting Feedback

The issue of permafrost degradation was brought up in all meetings held. There was specific mention from Norman Wells in the Sahtu regarding the need to relocate certain buildings which had begun to shift dramatically due to this issue. The same commentary was made in regards to Inuvik. Residents of the South Slave and the Dehcho spoke of the degradation of the permafrost from the point of view that trees and grass were drier during the summer possibly leading to increase fire risk.

Key Risk Analysis Considerations

- Potential to spontaneously cause multiple deaths and injuries (due to building collapse);
- Current and historical experience in the NWT;
- Spontaneous property damage potential (although likely to be gradual); and
- Potential to affect most communities in the NWT.

Figure 22: Permafrost Zones (Source: Atlas of Canada Permafrost Map)

5.4.7 Civil Unrest

Figure 23: Idle No More protesters at the Dehcho Bridge near Fort Providence, NWT, 5 Jan 2013 (Source: Randall McKenzie/CBC)

Definition	**Class**
People breaking the law in order to bring attention to their cause	Human-induced Hazard

NWT greatest impacts to date

- Fatalities 9
- Property Damage (Mine)

Climate Change

Projected to increase both frequency and consequence

Type	**Cause/Explanation**
arctic security	Establishing Canadian sovereignty in the arctic region guarding against the illegal use of Canadian lands, water and resources in the region.
terrorism	The use of violent acts to frighten people in an area as a way of trying to achieve political goals. The systematic use of terror to create a climate of fear in a population.
riot	A situation in which a large group of people behave in a violent and uncontrolled manner. A public tumult or disorder involving violence.
demonstration	An event in which people gather together in order to show that they support or oppose something or someone. A public display of group feelings towards a person or cause.
rampage	To act in a wild and usually destructive way.
Vulnerability	**Description**
People	Civil unrest can directly impact the safety and security of individuals or groups of persons whether or not they are targeted by the unrest. There is also a threat of injury to public responders and those persons involved in the unrest.
Infrastructure	Damage to public and private property is almost always a staple of civil unrest. Acts of terrorism are often targeted against utilities which regulate a society, such as power installations or communication facilities. There is also an increase in cyber terrorism which targets computer systems which control defense establishments as well as public utilities.
Communications	Acts of civil unrest or terrorism can impact communications which disrupt public authorities' ability to deal with the unrest.

NWT Exposure/History

When	Where	Impact
Sept 18, 1992	Yellowknife	A rail car in the Giant Yellowknife gold mine, 230 metres below ground, was destroyed by an explosion. RCMP investigators said a deliberately-planted home-made bomb caused the blast. During the strike there had been picket line violence, deliberately set fires and at least two earlier, non-fatal, explosions. Fatalities 9
Dec 21, 2012	Yellowknife	Idle No More rally - more than 200 people gathered and proceeded to march to a downtown intersection where a ceremony was held. Traffic was disrupted for approximately an hour but there were no incidents.
Jan 05, 2013	Fort Providence	About 150 Idle No More activists blocked traffic across the NWT's Dehcho Bridge Saturday afternoon for about 40 minutes.

Climate Change Impact

Any changes that are predicted to occur due to climate change (all hazards) may be viewed by the public or groups as needing attention, leading to civil unrest.

Community Meeting Feedback

None.

Key Risk Analysis Considerations

- Potential to spontaneously cause multiple deaths and injuries (especially explosion);
- Current and historical experience in the NWT;
- High damage potential if near or in a community; and
- Potential to affect any community in the NWT.

5.4.8 Earth Movement - Other

Figure 24: Sinkhole near Fort Resolution, 24 Jul 2012 (Source: CBC News/Carol Collins)

Definition

Movement of the ground causing wide spread damage not involving permafrost degradation or earthquake

Class

Natural Hazard

NWT greatest impacts to date

- Fatalities 1
- Property damage $1,000,000
- Infrastructure (Police detachment)

Climate Change

Projected to increase both frequency and consequence

Type	Cause/Explanation
submarine slide	The underwater down slope movement of slope materials under the influence of gravity.
mass movements, landslide, debris avalanche, debris flow and torrent, riverbank collapse	Mass movement or mass wasting of masses of bodies of soil, bed rock, rock debris, soil, or mud which usually occur along steep-sided hills and mountains because of the pull of gravity. This slipping of large amounts of rock and soil is seen in landslides, mud slides, and avalanches. The influence of forest fires appear to be significant in landslide triggering. It has been observed that more active layer detachments occur in areas impacted by forest fires (Dyke 2004).
snow avalanche	Gravitational movement of snow and ice down a sloped surface that commonly results from dense, wet snow falling on dry, loosely packed snow. Ambient temperature and wind conditions are also critical factors.
erosion	“The wearing away and removal of soil particles by running water, waves, currents, moving, ice or wind…” (Maine, The Hazards We Face, p. 17, 2001). Erosion is an ongoing natural process and is only considered to be a hazard when it threatens humans, property or the environment.
expansive soils	Certain clay soils are able to take on water and subsequently expand when they come into contact with it.
land subsidence and sink holes,	The sudden sinking or gradual downward settling of land with little or no horizontal motion, caused by a loss of subsurface support. The risk level for land subsidence depends on several factors: the type of soil and/or rock (areas with carbonate karst are more susceptible), the natural and human induced fluctuations of groundwater, underground human mining activities and the natural processing of rock.

volcano/falling ash	Tephra (volcanic ash) fallout from a large eruption composed of pulverized rock, accompanied by a number of gases, sulphuric acid, and hydrochloric acid. It can be carried by wind for many hundreds or thousands of kilometres.
Vulnerability	**Description**
People	Injuries or even death could occur from riverbank collapse or sinkholes.
Infrastructure	Damage to buildings, roads and other infrastructure has and is being caused by these earth movements including erosion, riverbank collapse and sinkholes. Also increase in maintenance costs associated with landslides and avalanches, even where no infrastructure damage occurs.
Communications	Falling ash from Alaska could impact communications or air travel.

NWT Exposure/History

When	Where	Impact
1908	Fort Smith	A riverbank collapse caused many of the oldest buildings to be dragged down in the mud. Riverside docking facilities were battered and a warehouse burned to the ground.
1950's	Aklavik	Erosion was partially responsible for the relocation of government and businesses from Aklavik (for further information see Flood Hazard).
Aug 9, 1968	Fort Smith	A landslide some 3,300 by 990 ft (1,000 by 300 m) broke away from the riverbank causing property damage and killing one person. It destroyed four homes. Estimated Cost $1,000,000
1982	Tuktoyaktuk	Caused the relocation of an RCMP detachment, the undermining and destruction of a curling rink and the abandonment of an elementary school, which was dismantled in 1996.
May 11, 2008	164 kilometres from Fort Smith, near the Nyarling River	A large section of the road collapsed. Officials with the Transportation Department described the collapsed area as a crater-like hole about six metres wide and six metres deep — large enough to swallow a car. No injuries.
July 24, 2012	Near Fort Resolution	An entire cabin vanished into a massive sinkhole. No injuries.

Across the NWT, people have experienced losses from various earth movement hazards.

Coastal erosion has been severe on Territorial north-western shores, especially near Tuktoyaktuk. This is due to sea level rise, increased storminess with less protective shore ice, land subsidence and permafrost thaw, which are all likely to continue. Erosion has been a long term problem in Tuktoyaktuk.

In Tsiigehtchic, riverbank erosion is threatening two churches and a cemetery. If either church is occupied when further earth movement occurs, there is a high risk of property damage, injury or even loss of life.

Landslides also pose a threat in the NWT. In the Mackenzie Valley, there is an average of one landslide per 5 km. The dominant landslide types are retrogressive thaw flows (28%) and active layer detachments (26%) and about 47% of all landslides took place in moraine deposits (Couture, 2004).

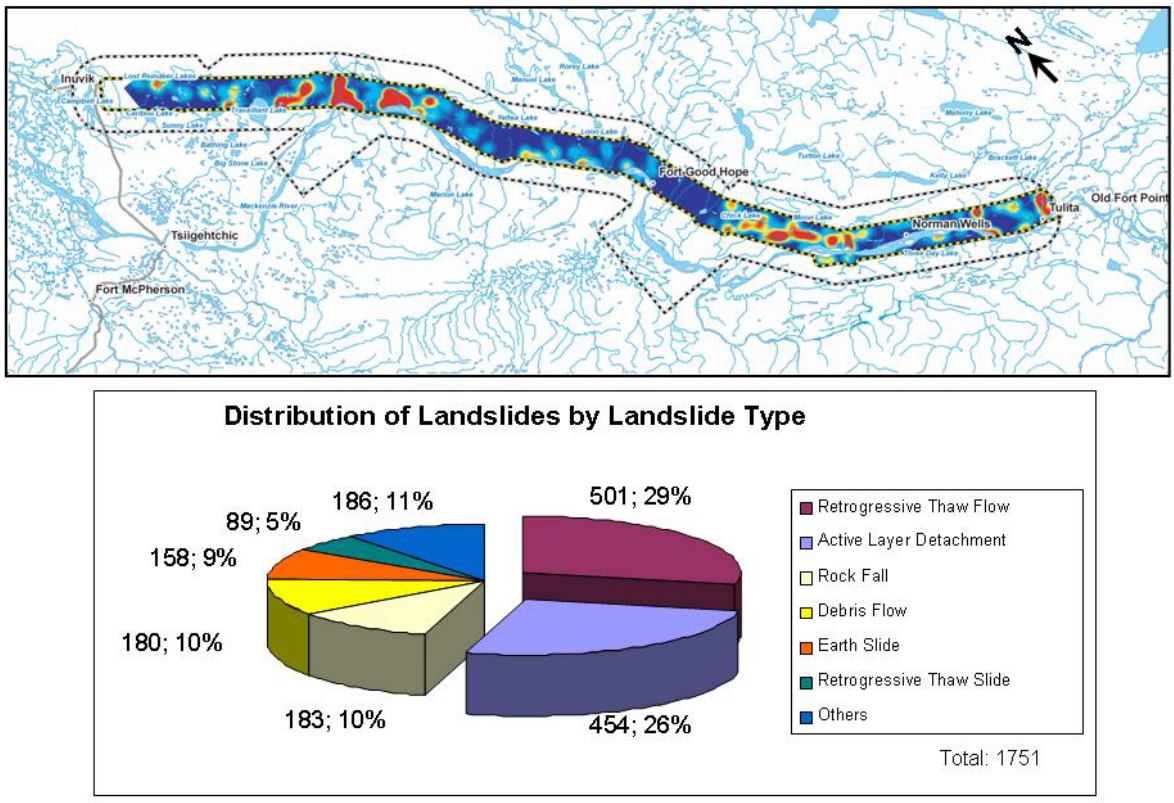

Figure 25: Upper figure—Landslide density map along the proposed pipeline corridor with some "hot spots" of higher density of landslides. These are situated near Travaillant Lake, Thunder River, between Fort Good Hope and Norman Wells, and in the vicinity of Tulita

Lower figure: Distribution of landslide types in the study area (Source: Couture et al., 2007).

Climate Change Impact

- Increased landslides are expected, with thawing of permafrost, reducing soil strength (CIER, 2010).
- Increased avalanches associated with increases in temperature and precipitation (CIER, 2010).
- Warming along with unstable snowpack can lead to more avalanches.
- Excess water draining as permafrost thaws can also lead to subsidence, and excess water creating ponds or draining away (CSA, 2010 p.26).

- Disappearing ice and sea level rise, associated with climate change, is leading to more coastal erosion (Auld, 2011).

Community Meeting Feedback

Residents at several regional meetings spoke of sink holes and slumping as being issues which were affecting road infrastructure.

Key Risk Analysis Considerations

- Potential to spontaneously cause multiple deaths and injuries;
- Current and historical experience in the NWT;
- High damage potential when near or in a community; and
- Potential to affect many communities in the NWT.

5.5 Low Hazard

5.5.1 Earth Movement – Earthquake/Tsunami

Figure 26: Rock avalanche triggered by October 5, 1985 Nahanni earthquake (Source: Geoscience Canada, 2009/R Horner)

Definition	**Class**
A slip along a fault in the earth causing the ground to shake and/or the large wave caused by it	Natural Hazard

NWT greatest impacts to date

Minor Property damage 1985

Climate Change

Could increase impact

Type	**Cause/Explanation**
Earthquake	Violent shaking of the earth's surface accompanying movement along a fault rupture. Seismic energy traveling in waves may cause damage to structures, generate tsunamis, trigger landslides, liquefaction or other geologic events. There are three types of damaging seismic categories: • Crustal Earthquakes -typically low magnitude ground movement occurring along faults at an average depth of 10 – 20 km; • Sub-crustal Earthquakes - occur at a depth of 30 – 70 km are produced by fracturing and frictional slipping of pre-existing faults along a tectonic plate; and • Subduction Earthquakes - the most powerful type of earthquake, these occur when there is a massive shift at the junction of multiple tectonic plates.

Tsunami	Large wave events generated by water surface impacts or when the floor of a water body moves suddenly, displacing the water above it. Tsunamis can be classified into three categories: • Telegenic Tsunami - a distant, underwater earthquake induced wave which can originate along subduction zones. These events are rare and often cause little or no damage; • Local Marine Tsunami - typically a very large wave induced by a local tsunamigenic earthquake along shallow offshore fault zones; and • Local Terrestrial Tsunami - a large wave induced by a terrestrial and submarine landslide in oceanic and freshwater regions. The impact of the land mass in the water creates the water movement.

Vulnerability	Description
People	Some injury and possible death may occur due to landslide or structural collapse caused by a major earthquake in the western part of the territory or a tsunami in the Arctic ocean.
Infrastructure	Structural damage to buildings and infrastructure could be caused by a major earthquake in the western part of the territory or a tsunami in the Arctic ocean.
Communications	Communications could be disrupted by a major earthquake in the western part of the territory or a tsunami in the Arctic ocean.

NWT Exposure/History

When	Where	Impact
October 5, 1985	Mountains west of Fort Simpson	A magnitude 6.6 earthquake. No injuries or damage was reported.
December 23, 1985	Mountains west of Fort Simpson	The largest earthquake recorded in the NWT was a magnitude 6.9 event. No injuries or damage was reported. Wrigley, Fort Simpson, Nahanni Butte and Fort Liard experienced this earthquake. Vehicles bounced on the road and trees and power lines whipped back and forth. Sections of the banks of the Mackenzie River slumped into the water. Inside homes, furniture moved, dishes fell from cupboards, unsupported shelves toppled over, liquids slopped out of containers, doors swung open and shut and walls flexed in and out.

The northern Rocky Mountain region is a seismically active area. Communities in the west of the NWT experience minor earthquakes each year which are rarely felt.

Large tremors do occur. In 1985, a tremor shook the mountains west of Fort Simpson. The lack of serious damage can be attributed to the sparse population and type buildings near the epicentre.

The town of Inuvik has a short-period hazard designated as the “stable Canada” region. There is a low-probability of moderate-sized earthquakes (Halchuk and Adams, 2004). For example, in January 2008, a 5.8 magnitude earthquake shook buildings but did not cause real damage. This earthquake actually took place in the northern Richardson Mountain range, about 40 kilometres northwest of Fort McPherson. Earthquakes can be felt in Inuvik about once every two years. Inuvik could see earthquakes approaching magnitude 7 at a distance of about 150 km (Halchuk and Adams, 2004).

A small risk of tsunami on the Arctic Ocean exists.

Climate Change Impact

- No direct correlation between climate change and an increase in the number of earthquakes (ICLR, 2010 p.5).
- Sea ice breakage (calving of glaciers and ice shelves) could cause Arctic tsunami-type waves, and, with less sea ice, these could have a larger, visible impact.
- Increase in sea level would increase potential damage during a tsunami.
- Increased impact of an earthquake on warmer permafrost soil and frozen soil can lead to greater damages due to soil liquefaction (Hazirbaba and Hulsey, 2009).

Community Meeting Feedback

None

Key Risk Analysis Considerations

- Small potential to spontaneously cause multiple deaths and injuries;
- Little historical experience in the NWT;
- High damage potential if near or in a community;
- Potential to affect some communities in the NWT; and
- Because of very low population density, around the Canadian Arctic, at present, there is no priority for a tsunami warning system for Arctic Canada.

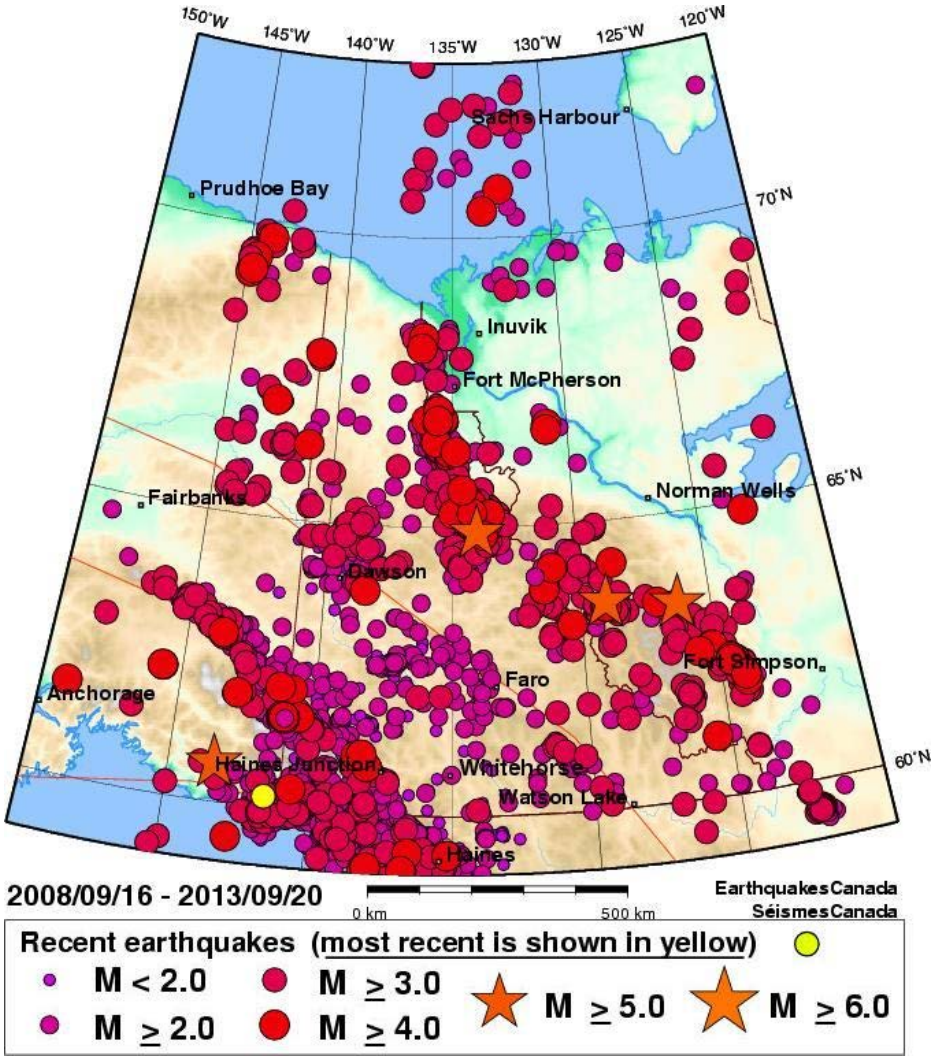

Figure 27: Earthquakes 2008-2013 (Source: Earthquakes Canada)

5.5.2 War and International Incident

Figure 28: Joint Task Force (North) Headquarters Yellowknife (Source: Wikipedia)

Definition	**Class**
An action or clash that results in a wider dispute between two or more nation-states.	Human-induced Hazard

NWT greatest impacts to date

N/A

Climate Change

Projected to increase in frequency

Cause/Explanation

War Emergency: a real or imminent war or other armed conflict that involves Canada or any of its allies that is of sufficient magnitude to be a national emergency.

Vulnerability	Description
People	The main effects of war on people are poverty due to destruction of properties and business, death and property destruction. War can also cause a dramatic impact on civilian health, because of the weapons which may be highly radioactive.
Infrastructure	The most commonly held thoughts on war's effect on infrastructure is the destruction of roadways, railways and bridges to hamper an enemy's ability to move freely and accumulate forces at a given point. In recent wars there have been specific examples of water and power plants being targeted in order to dramatically impact the ability of a populace to survive in a given area.
Communications	Communication facilities are likely the first to be targeted in any war or act of war or terrorism. Without communications authorities will be unable to respond to threats coherently and the loss of information can lead to a general state of panic amongst a population.

NWT Exposure/History

The number of military naval vessels traversing the Arctic Ocean is believed to be on the rise, given the strategic importance of the region.

Climate Change Impact

- Opening of artic sea waters and access to natural resources could lead to an international incident.
- Increased foreign military presence in Arctic.

Community Meeting Feedback

While there was no specific mention of this issue at the meetings, there was some discussion centering on the activities of the Canadian Military in the North. Most of this discussion revolved around the impact any exercises in the area may have on local wildlife and resources. There was specific mention of an incident near Yellowknife when a Canadian Armed Forces helicopter knocked out power to Yellowknife after striking a power line. However, there was no discussion regarding issues such as Canadian sovereignty in the far north.

Key Risk Analysis Considerations

- Potential to spontaneously cause multiple deaths and injuries;
- No historical experience in the NWT;
- High damage potential; and
- Low potential to affect any community in the NWT.

5.5.3 Food and Agricultural Emergency

Figure 29: Community Freezer Project Dehcho (Source: Arctic Energy Alliance)

Definition	**Class**
Any emergency which affects food security, food quality or food safety for many people	Natural Hazard

NWT greatest impacts to date

- Food recall

Climate Change

Projected to increase both frequency and consequence

Type	**Cause/Explanation**
animal disease	Three types: non-infectious, infectious and parasitic diseases with the potential to spread between animals and sometimes to humans.
food contamination	Food contamination refers to the presence in food of harmful chemicals and microorganisms which can cause consumer illness.
pest infestation (including rodents)	Large number of pests can cause damage, danger, discomfort or threat to food supply including foliage or root feeding insects that damage plants.
plant disease and infestation	Any plant makes an ideal habitat for insects and may lead to an infestation. A series of harmful physiological processes caused by irritation of the plant by some invading agent.
Vulnerability	**Description**
People	Humans are reliant on a well regulated safe supply of food and agricultural processes. Any emergency caused by a failure of this system can impact on the immediate and long term health of anyone affected.
Infrastructure	N/A
Communications	N/A

NWT Exposure/History

When	**Where**	**Impact**
Feb 12, 2012	All Co-op grocery Stores in the NWT	A brand of frozen hamburgers manufactured in Ontario was recalled as it may have been contaminated with E. coli. Consumption of food which contains this strain of virus can cause life-threatening illness.

Climate Change Impact

- Wildlife species migration is altered by climate change which could affect hunting.
- Changes in insect populations (number, type and seasonal peaks) could affect the food chain (Pryor and Cobb, 2007 p.18).
- Increased vulnerability to other hazards due to more dependence on transported food with a reduction of hunting and fishing.

Community Meeting Feedback

Stakeholders at the meetings raised little concern over agriculture as very little occurs in the NWT. Concerns were expressed during the meetings in the Dehcho, Sahtu and Beaufort Delta over the storage of food and spoilage. There was also discussion amongst residents of the South Slave over how climate change was affecting growing seasons.

Key Risk Analysis Considerations

- Some potential to spontaneously cause multiple deaths;
- Little historical experience in the NWT; and
- Potential to affect any community in the NWT.

5.5.4 Falling Debris

Figure 30: First piece of debris found from the crashed Cosmos-954 Soviet satellite, 1978. (Source: Wikipedia)

Definition	**Class**
Any object (such as a satellite) which survives its passage through the Earth's atmosphere and impacts Earth	Natural Hazard

NWT greatest impacts to date

Environmental

Climate Change

N/A

Type	**Cause/Explanation**
natural space object crash	Comets and asteroids have impacted the earth in the past and will continue to do so in the future. However, in general large impacts are rare. It is estimated that an object greater than 50 m in diameter impacts the earth's surface approximately every 100 years.
human made space object crash	An earth orbiting human-made object (such as a satellite) which survives atmospheric re-entry to impact earth.
Vulnerability	**Description**
People	Any object falling to earth from space will be of concern in terms of public safety and there will always be a worry of people being injured or killed by falling debris. Given the low population of the NWT and rare occurrence of these events there is a low likelihood of this happening.
Infrastructure	Damage to buildings, roads and other infrastructure would be a concern in the event of falling debris.
Communications	An object which falls from space may impact a communications satellite or microwave tower which could directly impact communications in a region.

NWT Exposure/History

When	**Where**	**Impact**
445 million yrs	Near Fort Smith	Pilot Crater is an impact crater 6 kilometers in diameter.
400 million yrs	Nicholson Crater lake	Nicholson Crater is a meteorite crater 12.5 kilometers in diameter.
130 million yrs	Victoria Island	Prince Albert Crater is an impact crater measuring 25 kilometers in diameter.
January 24, 1978	Near Great Slave Lake	A soviet satellite, Cosmos 954, crashed to earth scattering radioactive waste across 124,000 square kilometers of the NWT, Alberta and Saskatchewan. The clean-up operation continued into October 1978.

Climate Change Impact

None

Community Meeting Feedback

None

Key Risk Analysis Considerations

- Very low frequency;
- Potential to spontaneously cause multiple deaths and injuries;
- Current and historical experience in the NWT;
- Damage potential if near or in a community; and
- Potential to affect any community in the NWT.