GUIDELINES FOR

SAFE ICE CONSTRUCTION 2015

Northwest Territories Transportation

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SAFE ICE CONSTRUCTION

Department of Transportation
February 2015

This document is produced by the Department of Transportation of the Government of the Northwest Territories.

It is published in booklet form to provide a comprehensive and easy to carry reference for field staff involved in the construction and maintenance of winter roads, ice roads, and ice bridges.

The bearing capacity guidance contained within is not appropriate to be used for stationary loads on ice covers (e.g. drill pads, semi-permanent structures).

The Department of Transportation would like to acknowledge NOR-EX Ice Engineering Inc. for their assistance in preparing this guide.

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1.0 INTRODUCTION

The Department of Transportation's (DOT) highest priority is safety. Consequently, the Department is committed to:

- encouraging the joint efforts of management, employees, and contractors to establish and maintain safe and healthy working conditions for all employees
- providing employees with safe and proper equipment, materials, and construction practices
- providing effective training in safe work practices
- encouraging employee and contractor's participation in the development and support of safety programs

All stakeholders in turn have a responsibility to perform their work in a safe and responsible manner, to follow guidelines established to ensure their safety, to advise their supervisor or clients of unsafe practices or conditions, and to promote safety amongst their co-workers.

AUTHORITY

This guide is issued under the authority of the Government of the Northwest Territories Department of Transportation.

SCOPE

This booklet was developed to provide guidance to Department of Transportation staff and contractors involved in the construction and maintenance of winter roads, ice roads, and ice bridges. It outlines work practices and procedures intended to increase the safety of those working or traveling on winter roads and ice surfaces.

It is not possible to anticipate every circumstance that may arise in the field or all of the factors that might affect one's response to ice construction challenges. This document is intended to guide decision making for supervisors when they encounter circumstances not explicitly provided for by DOT procedures. Common sense and good judgment, in conjunction with the best practices outlined within this document, are important to ensure that winter roads and ice roads are safely constructed and maintained.

All GNWT and contractors' employees involved in ice and winter road construction and maintenance will be provided with a copy of **"Guidelines for Safe Ice Construction"**. Please read this guide and talk with your supervisor immediately or at any of the regularly scheduled safety meetings if you require clarification or have any questions.

General Safety Procedures

Annually before the beginning of winter or ice road construction season, your supervisor must organize a meeting with all ice and winter road construction employees to review and discuss the safety procedures for ice road construction presented in this guide. A written record of this training must be maintained.

The GNWT supervisor should attend the contractor's information meeting to ensure that the procedures presented in this guide are clearly understood by all staff and workers on ice and winter road construction.

The GNWT supervisor and contractor's supervisor must have regular safety meetings with all ice and winter road employees during the construction and maintenance phase. Minutes of the meeting must be produced and a copy provided to the GNWT Regional Superintendent within five working days following each meeting.

All ice and winter road workers are responsible for following the guidelines contained in this guide. The GNWT supervisor must ensure that GNWT employees and contractors follow the procedures and practices of this guide through periodic worksite inspections and the review of health and safety documentation.

Figure 1.1

SAFETY IS EVERYONE'S RESPONSIBILITY

2.0 DEFINITIONS

2.1 Types of Ice

Natural ice[1]

Ice that grows below the layer of surface ice under calm conditions. It usually forms in vertical, columnar crystals that contain few air bubbles.

Figure 2.1

Natural Overflow Ice

Overflow ice, caused by natural water overflow onto the ice surface, usually contains high air content and should not be relied upon in calculating effective ice thickness.

Constructed Flood Ice

Ice constructed by pumping water directly on the surface of a bare ice sheet to build ice on the top of the ice sheet. Uniformity and quality depend on construction practices.

If ice is constructed using sound construction practices, then this ice, once completely frozen and inspected, can be considered as having similar strength to natural ice.

River Jam Ice

This is ice cover that is formed irregularly on rivers, normally due to the higher flow rate present on rivers. Often, large pans of ice stack atop one another and freeze in place during early season conditions. When fully frozen, this ice can be considered of good quality, however the ice thickness will be highly variable and extra caution is required in determining the minimum ice thickness for load bearing.

Spray Ice

Ice constructed by spraying water high into the air and using the ambient air temperature to cool the water and form a wet slush layer on the surface of a bare ice sheet. Uniformity and quality depend on construction practices.

If spray ice is constructed using sound construction practices, then this ice, once completely frozen and inspected, can be considered as having similar strength to Natural ice.

Effective Ice Thickness

The thickness of good quality, well-bonded, ice that is used to calculate the bearing capacity of the ice cover. Unless otherwise stated, the minimum ice

[1] *Alberta Best Practices Guide to Working Safely on Ice*

thickness measured at a particular test point on an ice cover will be used as the effective ice thickness. The thickness of poor quality or poorly bonded ice should not be included when measuring ice thickness.

Freeboard

The difference between the height of the water level and the top of the ice surface in a hole drilled through the ice cover. Usually the water level is below the ice surface because ice is less dense than water and it floats.

Flooding

The pumping of water onto the surface of an area of ice that is free from snow to fill cracks or to increase the ice thickness (once frozen). When conducted by experienced crews, this will result in well-bonded ice that is free from significant air voids, and can be considered to have strength equivalent to that of natural ice.

Figure 2.2

Gross Vehicle Weight (GVW)

For the purpose of this Guide, this is the total weight of a vehicle when loaded, i.e., includes the weight of the vehicle itself plus fuel, freight, passengers, attachments and equipment. Experience has shown that weighing the fully loaded vehicle on a scale is the most accurate way to determine the GVW. When determining allowable GVW for an ice cover, highway legal axle weights should not be exeeded.

Ice Bridge

A seasonal crossing over a frozen river for the purposes of transportation.

Ice Cover

The portion of an ice surface that is floating (buoyant) on a river, lake, pond or peatland and that is capable of carrying an external load.

Ice Profiling

Technique used to measure the thickness of floating ice. The standard for ice profiling within DOT is to use Ground Penetrating Radar (GPR). When GPR is used for profiling, regular calibration using manually drilled holes is required.

Ice Road

A seasonal road built over frozen lakes or along rivers for the purpose of transportation. It usually consists of floating ice and ice that is frozen to the ground.

Manual Ice Measurements

Technique used to measure the thickness of floating or grounded ice by drilling holes through the ice and taking direct physical measurements of the ice thickness.

Professional Engineer (P. Eng.)

An engineer licensed to practice in the Northwest Territories and registered with the Northwest Territories and Nunavut Association of Professional Engineers and Geoscientists (NAPEG).

Tare Weight

The empty weight of a vehicle or piece of equipment.

Operational Tare Weight

The scaled operating weight of a vehicle or piece of equipment used for construction on ice. This scaled weight will include the combined weight of the equipment, associated attachments, operator and full load of fuel.

2.2 Phases of DOT Operations

Pre-Construction Phase. The planning and action taken on ice to determine if it is safe to deploy construction equipment.

Construction Phase. The phase of operations that begins with the safe deployment of construction equipment. This covers all activities prior to the opening of the ice covers for public use.

Operations Phase. The phase of operations from initial opening of the ice cover to the public through to the permanent closing of the road for the season.

2.3 DOT Operating Conditions

Routine Construction. Routine Construction is an operating condition that describes the minimum level of control measures and design parameters that will govern the initial construction of ice crossings and ice roads. This level of construction is expected to be the most common level used on DOT ice covers and is based on more conservative design parameters. Unless otherwise directed by the Regional Superintendent, construction crews will follow Routine Construction guidelines that are outlined in Section 5 of this guide.

Enhanced Construction. Enhanced Construction is an operating condition that can be used for construction when operational or environmental conditions do not favour the efficient use of Routine Construction practices.

The Enhanced Construction operating level incorporates a less conservative load bearing determination and requires an increase in monitoring and control measures that must be in place prior to authorizing loading. The decision to adopt an Enhanced Construction level shall be reserved by the Regional Superintendent within each of the DOT regions.

Routine Operations. Routine Operations is an operating practice that describes the minimum level of control measures and design parameters that govern the normal operations of ice crossings and ice roads when they are opened for the public use. This level of operations is expected to be the most common level used on DOT ice covers and represents the most conservative level of design and monitoring practices outlined within this guide. Unless otherwise directed by the Regional Superintendent, all operations on ice covers will follow Routine Construction guidelines that are outlined in Section 5 of this guide.

Enhanced Operations. Enhanced Operations is an operating condition that can be used when operational or environmental conditions do not favour the efficient use of Routine Operation procedures. The Enhanced Operations level incorporates a less conservative load bearing determination and requires an increase in monitoring and control measures that must be in place prior to authorizing loading. The decision to adopt an Enhanced Operations level shall be reserved by the Regional Superintendent within each of the DOT regions.

Acute Operations. Acute Operations is an operating condition that can be used when operational or environmental conditions do not favour the efficient use of Enhanced Operation procedures or when unusually heavy loads need to cross an ice surface. As an example, this operating condition could be used for small numbers of non-standard loads that exceed the normal operating criteria. The Acute Operations level incorporates stress analysis as the method for determining allowable ice loading and requires an increase in monitoring and control measures that must be in place prior to authorizing loading. This analysis will be conducted by a Professional Engineer with experience in ice construction and engineering. The decision to adopt an Acute Operations level shall be reserved by the Regional Superintendent within each of the DOT regions.

3.0 ICE BEHAVIOR UNDER LOADING

Nature of Ice Covers

Ice covers that form on rivers and lakes are capable of supporting loads within the limits of load bearing capacity. Natural ice is buoyant and floats on water because it is 8 to 10% less dense than water. It is this buoyancy that helps support the weight of loads placed on the ice.

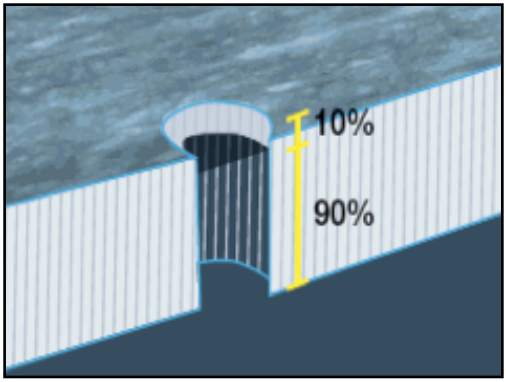

Figure 3.1: Example of Positive Freeboard on an Ice Cover (JV, TCWR Driver Orientation, 2014)

As the ice cover itself bends under this load, it displaces a volume of water equal to the weight of the load (Archimedes principle). In theory the size of the ice sheet and the volume of the lake have to be large enough to support the load on the ice sheet. However, in practice most bodies of water are large enough in relation to the load that checking for buoyancy rarely needs to be undertaken. Instead the critical issue is whether the ice cover is strong enough to resist temporary bending caused by the load.

Although an ice cover may appear to be rigid it will bend under loading. The amount of bending will depend on the flexibility of the ice and magnitude of the load. The ice flexibility (elasticity) depends on its temperature. Heavier loads will cause more bending and displacement. For acceptable loads, the ice covers will rebound and return to the original position when the load is removed or moves away. In these cases the ice cover deforms and distributes the load over a larger area. The depression underneath the load is often described as the deflection bowl.

Bending of the ice generates flexural stresses—tensile stresses at the bottom and compressive stresses at the top. When excessive loads are placed on ice covers, the ice will bend to the point where the flexural stresses in the ice exceed the flexural strength at the bottom of the ice. Cracking occurs in these situations and these reduce the bearing capacity of the ice cover. Under the extreme load circumstances these cracks can grow, merge and cause the ice to collapse and allow the load to break through the ice.

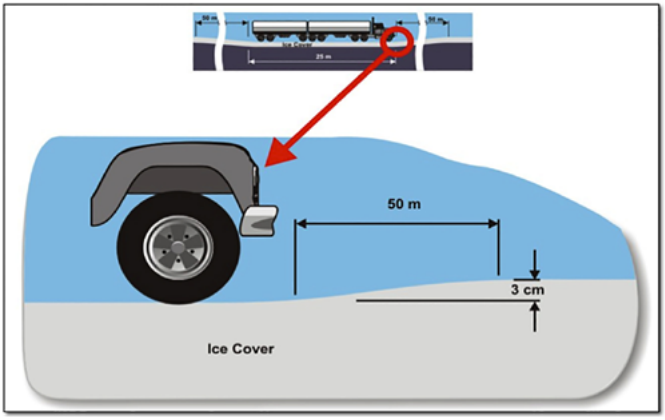

Figure 3.2: Illustration of ice deflection under a moving load

Ice covers can fail for a variety of reasons. Some of the more common reasons for failure are the following:

- Loading of ice that has poor ice quality
- Overloading of good quality ice
- Overstressing ice by operating at unsafe speeds
- Unintended stationary load on ice

Types of Loads

Temporary Loads.

Temporary loads are defined as loads that are expected to be in one location for no more than two hours. These are often moving loads that will travel across an ice road or ice crossing. Recommended bearing capacity of temporary loads will be discussed later in this document.

Stationary/Long Term Loads.

Stationary or long term loads are loads that are intended to remain in place for longer than six hours. A common example is drilling equipment that is operating on a constructed ice pad. A greater ice thickness is required for stationary loads as compared to temporary loads.

Over a period of time, the ice begins to show signs of plastic or creep failure. This mechanism for failure is significantly different; therefore the standard load calculations do not apply. For this reason, parking of vehicles or equipment on ice that is near ice bearing capacity limits must be avoided.

Determining the bearing capacity of ice under long term stationary loads is beyond the scope of this document. Advice should be sought from a Professional Engineer for such loadings.

[2] *Best Practices for Building and Working Safely on Ice Covers*

Moving Loads

A moving load deflects the ice sheet and creates a deflection bowl that travels at the speed of the vehicle. As the vehicle speeds up, the deflection bowl deepens and becomes narrower and the vehicle gradually lags behind the trough of the deflection bowl. With further increases in the vehicle speed the deflection bowl reaches its maximum depth where the bending stresses attain their highest level. This speed is known as the critical speed and it can potentially overstress the ice and cause failure. The ice stresses reach a peak because a series of waves are trapped underneath the vehicle at critical speed. Theoretical studies show that the stresses can be increased by 50% compared to a vehicle travelling below the ice critical speed.

The critical speed of a vehicle travelling on the ice depends on the water depth, ice thickness and ice stiffness and also on underwater obstacles, such as rock outcrops. The critical speed increases with water depth. Consequently, over very deep water, the critical speed of the ice is usually higher than a typical vehicle speed. However, as a vehicle approaches a shoreline and the water depth becomes shallow, the critical speed limit of the ice decreases.

Figure 3.3: A slow moving vehicle causes the ice road to bend and forms a deflection bowl under the vehicle [2]

Figure 3.4: A fast moving vehicle causes the ice to bend and creates dynamic waves in the ice ahead and behind the vehicle. [3]

The critical speed of a vehicle travelling on ice should be viewed as the natural speed limit for the ice—A vehicle travelling at the critical speed can potentially damage the ice and endanger the following traffic. Consequently speed limits are established for ice crossings to protect operators from ice damage caused by excessive vehicle speeds.

When a vehicle approaches a shoreline, ice waves can reflect off the shoreline back to the vehicle. Reflected waves are greatest when a vehicle approaches a shoreline at a right angle. Where possible, approaches should be built to meet

[3] *TCWR JV Driver Orientation*

the shoreline at a 45° angle. These reflected waves become more critical when the vehicle weight is close to the load-bearing limit of the ice.

Drivers must obey the posted speed limit at all times and especially when a road meets the shoreline at a 90° angle and when a vehicle's weight is close to a maximum load limit for the ice.

Two Way Traffic

When two vehicles are approaching each other from opposite directions, the deflection in the ice sheet will increase and stresses may be amplified. In order to minimize the increase in stress on the ice sheet, both vehicles should slow to a speed of 10 kph and they should maintain a minimum of 10m lateral spacing while passing by each other.

Multiple Loads

Two or more moving vehicles increase deflection and stress as they approach one another or travel close together. In these instances, their ice deflection bowls can overlap thereby increasing the bending stresses in the ice. If either or both vehicles are travelling at critical speed, the stresses in the ice sheet can be even greater. Therefore drivers should decrease speed when approaching another moving or stationary vehicle to reduce the possibility of overstressing the ice through a combination of overlapping loads and speed related stresses. When travelling in the same direction, vehicles should maintain a spacing of:

- 200 m for light vehicles (<5000 kg)
- 500 m for medium and large trucks (>5000 kg).

The increase in the size of the deflection bowl is greatest when you have two vehicles in close proximity where each vehicle is operating at the maximum allowable range of loading for the ice cover. When one of the vehicles is only lightly loaded (<30% of the allowable GVW for the ice cover), then reductions in speed may not be required to control ice deflection. However, a reduction in speed may be required for operational and traffic safety, depending on the width of the road and the size of the vehicles in question.

Frequently Repeated Loads

As ice covers undergo a growing number of loads, they may suffer damage such as rutting, potholes, and cracking. If this damage progresses it can threaten the integrity of the ice sheet and its load bearing capacity. Routine maintenance and flooding of damaged areas is an important control measure in maintaining a safe ice cover throughout the season. Once cracks or damaged areas have been sufficiently flooded and have re-frozen, they can be considered repaired and load limits may be maintained. Constructing the ice cover wide enough to allow for re-routing of traffic around damaged and flooded areas is important in maintaining the serviceability of the ice cover.

4.0 HAZARDS AND HAZARD CONTROLS

There are a variety of hazards related to operating on ice covers. The primary ice cover hazards are:

- operating on an ice cover that has been damaged or where the integrity of the ice cover has been compromised, this damage could be localized or widespread
- overloading an ice cover beyond its capacity to support a load
- operating on undetected areas of thin ice

These hazards can be controlled through a variety of engineering and administrative controls that will provide operators overall confidence in:

- the integrity of the ice cover
- the knowledge of the load that is to be placed on the ice cover
- the minimum ice thickness present

With confidence in these three elements, operations on ice can be carried out very safely.

Ice Integrity Hazards and Controls

Any ice cover can develop cracks by thermal contraction, ice movement or frequent loading on the ice cover. Minor cracks do not necessarily indicate a loss in the load-bearing capacity of the ice. However, during spring thaw or in areas subject to excessive damage, the load bearing capacity of the ice may be negatively impacted. The main features affecting ice integrity are:

- dry cracks
- wet cracks
- snowbanks
- thermal contraction cracks
- thermal expansion cracks
- warming ice
- high winds
- water level changes

Dry Cracks (Figure 4.1)

Dry cracks are cracks that are visible on the ice surface and extend partially through the ice thickness. Dry cracks are a result of stresses on the ice sheet and can compromise the integrity and bearing capacity of the ice cover.

In zones where a number of intersecting dry cracks over 10 cm wide are observed, the area should be repaired by filling them with water and allowing them time to freeze fully. Alternatively, a reduction in the maximum load limit should be considered. The decision to reduce the load limit will be based on the frequency, width, depth, and intersection of the cracks.

Figure 4.1

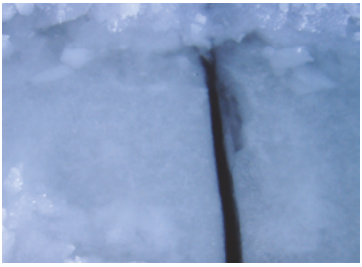

Figure 4.2

Wet Cracks (Figure 4.2)

Wet cracks are those that have propagated through the entire thickness of the ice sheet. The presence of wet cracks will reduce the capability of the ice sheet to safely support a load.

It is good practice to either divert traffic or temporarily suspend the loading of any ice cover when wet cracks are present. Wet cracks should be flooded if necessary and allowed to freeze back before allowing traffic back in these areas. If the wet cracks are limited to a localized area only, it may be possible to route traffic around the damaged area provided sufficient ice thickness and integrity is available in the area where loading occurs.

Once a wet crack completely refreezes, the ice can be considered as strong as the original. However, the conditions which led to the localized ice sheet failure should be examined and considered before permitting the same level of loading that may have led to the wet crack. A healed wet crack should be tested with an auger to gauge the depth of healing.

Cracks along Snowbanks

For ice covers that have been cleared of snow, it is normal to have extensive cracking and natural flooding occur along the edges of cleared areas where snowbanks are present. This cracking develops over time and represents a significant hazard. Although the visible flooding on the ice cover will freeze, there often are deep and un-healed cracks underneath the snowbanks that can remain open for the duration of the season.

Figure 4.3

Figure 4.4

For this reason, ice pads and ice roads should be designed and constructed so that normal operations do not occur within 3m to 5m of the edge of the cleared area. Once the ice has been cleared to full width and the snowbanks have been established, efforts should not be taken to move snowbanks, as placing equipment onto established snowbanks can be a severe hazard. During the planning phase of any operation, the size of the work area should be determined with consideration that snowbanks should not be moved back after initial clearing. It is good practice to leave a "buffer zone" between the edge of your designed operating area and the edge of the cleared area.

Thermal Contraction of Ice

Thermal contraction of ice can cause cracks when ice shrinks due to significant cooling. These cracks are usually distributed randomly over the ice and spaced well apart. Snow removal tends to promote thermal contraction cracks because it exposes the surface to rapidly falling air temperatures.

Thermal contraction cracks are usually dry and do not significantly reduce the ice bearing capacity. Thermal cracks should be monitored and repaired because they can develop into wet cracks when subjected to further contraction or heavy loads.

Thermal Expansion of Ice

Thermal expansion of ice occurs if there is a rapid warming of the ice. Thermal expansion can lead to pressure ridges - upward movements (up to 3 m) of ice at weak (thin) locations in the ice sheet, potentially extending for hundreds of meters (Figure 4.5). These tend to form on larger lakes and oceans (several kilometers across) where the thermal expansion effect can accumulate over large distances. Pressure ridges are significant hazards because they can be areas of reduced bearing capacity, sources of water, or be difficult to cross.

Figure 4.5: Pressure ridge about two metres high and several hundred metres long that formed adjacent to a road over lake ice.

Pressure ridges can recur over several years and local knowledge may help in identifying potential pressure ridge locations. Avoid constructing roads across pressure ridges where possible.

Sudden and Extreme Air Temperature Changes

Sudden drops in temperature can thermally shock the ice causing deep cracking that weakens the ice cover. In some cases it can open cracks that then fill with water. The ice cover should be checked for cracks when the air temperature experiences a drop of more than 20° C over a 24 hour period. This may require GVW load reductions or suspending operations until an inspection has taken place to verify whether ice conditions meet quality requirements.

Sudden rises in temperature will contribute to thermal expansion of the ice cover. This may cause or aggravate the formation of pressure ridges, particularly early in the season.

Warming of the Ice

A warm period when the air temperature remains above freezing for 24 hours or more allows the ice to warm rapidly from the surface down. These effects are greatest on bare ice and are reduced by increasing depths of snow cover. Even though the ice may have adequate thickness, ice strength can be substantially reduced the longer it is exposed to sunlight and above freezing temperatures. *(Ashton 1986)*

If the average air temperature exceeds 0° C for more than 48 hours, the following steps should be taken:

- Determine the minimum ice thickness.
- Monitor ice conditions for signs of decay, cracking and water.
- Re-evaluate the allowable weight if the average air temperature remains above 0° Celsius for more than 24 hours and the ice conditions meet the requirements for strength and cracking.

Ice bearing capacity can reduce rapidly if the ice cover is subjected to warm air temperatures in combination with the longer daylight conditions associated with spring-like weather.

Safety Note: ***Any time there are sudden and extreme temperature changes, the ice cover should be checked for cracks or other features that can compromise the load capacity.***

High Winds

High winds can cause blowing snow and reduced visibility for traffic, often making it difficult to see the limits of the safe travel way on the road. In extreme cases, very high winds could aggravate existing cracks and cause severe damage to the ice cover. The barren lands above the treeline are especially prone to blowing snow, snow drifting across the road, and poor visibility due to whiteouts.

Figure 4.6

In areas where high winds are common, enhanced marking of the road edges can improve visibility. Appropriate marking for overland sections of winter roads is also important above the tree line to properly delineate the travel section of the road in conditions of reduced visibility.

When travelling in areas above the treeline, increased vigilance is required. Operators should make regular checks of the weather to identify potential storms and whiteout conditions in advance. Road closures during these periods may be necessary.

Finally, individual drivers should be equipped with appropriate survival equipment in the event that they are stranded for an extended period of time in whiteout conditions. A Risk Assessment should be completed at all levels prior to operations to identify, eliminate, or mitigate associated risks.

Water Level Change Cracks

Changes in water levels can cause cracks. These usually occur in rivers but can also occur in other bodies of water where levels change, particularly waterways that are influenced by dams or other man-made influences. Cracks can frequently occur in rivers and lakes downstream of dams that control water levels. These cracks are almost always wet, tend to follow the shoreline, and occur around grounded ice features.

Changes in water levels may produce cracks near and generally parallel to the shoreline where the floating ice drops or rises while the ground fast ice remains fixed. This can create hanging ice where the ice cover can separate completely and form a significant drop (Figure 4.7).

Figure 4.7: Cracking along the shoreline of a lake following significant drop in water level.

It is best to avoid areas of grounded ice features that have water level change cracks around them. These cracks should be checked before permitting loads to cross them and repaired as necessary. If these cracks are wet, loads should be routed to avoid these areas or traffic temporarily suspended until proper repairs are completed. With extreme differences in the level, bridging repair or flooding may be necessary.

The following table summarizes specific remedial actions for dealing with features affecting the integrity of the ice cover. By implementing a quality control program that identifies and mitigates these hazards, the overall safety of the ice program will be greatly enhanced.

Table 1: MODIFICATION OF ICE LOADING AND REMEDIAL ACTION FOR VARIOUS TYPES OF CRACKS

Type of Crack	Modification of Ice Loads	Remedial Action
Hairline Cracks	None required	None
Refrozen Cracks	None required	Flooding of local area should be considered
Moderate Non-Intersecting Dry Cracks	No weight reduction is normally required, however this is a sign of degradation of ice integrity. Immediate repair action should be taken.	Flood affected area extensively and Detour around affected area, until repairs are completed.
Large, Intersecting Dry Cracks penetrating 50% or more of ice thickness	Weight reduction to 75% of allowable load should be considered based on frequency, width and intersection of cracks. Adjust traffic flow as required.	
Wet Cracks	Wet cracks are indicative of a failure in the ice sheet. The impacted area should be cordoned off from traffic and traffic re-routed. If traffic cannot be re-routed, operations should be suspended until repairs can be made.	Cordon off affected area from traffic. Detour around affected area until repairs are complete, or Suspend operations temporarily until repairs are made.

Overloading Hazard and Control

The next major cause of ice failure is the overloading of an ice cover. This can occur when operations either have poor controls over the weight placed upon an ice cover, when they have a poor understanding of the ice thickness, or where there is inadequate delineation of tested ice areas.

Loading Controls

It is important that operators understand the load that they are applying onto the ice. Though it may not be feasible to weigh all loads or load combinations, it is usually feasible to have individual pieces of equipment weighed to determine their actual weight, and then aggregate the individual loads to determine an overall ice load.

Ideally, weighing of equipment should occur with the maximum payload that can be carried by the equipment. Manufacturer weights can be misleading as they do not always include payload, nor will they reflect any equipment modifications or additions that may have taken place. Planning weights should also take into consideration fuel loads, operator weight, as well as any additional equipment being carried. Scaling and aggregating the weights of individual pieces of equipment will give you the greatest confidence in the overall load.

For DOT operations, all construction equipment used during the Construction and Operations Phases requires both Operational Tare weight and GVW to be clearly posted on both the exterior driver's side and in a place that is easily visible to the operator inside the cab. The Operational Tare weight of the equipment is the value that will be used to compute the allowable load in accordance with Chapter 5. This control measure will also be a requirement for all contractors constructing or operating roads on behalf of DOT.

Measuring Ice Thickness

Construction of ice bridges and ice roads has unique safety hazards because of the danger of ice failure. To reduce this risk for those working on the road as well as for the travelling public, strict attention must be paid to ice thickness measurements for load capacity analysis. The following section provides guidelines for measuring ice thickness and for selecting the ice thickness to be used to determine the capacity of the ice to carry loads.

Experience in ice profiling has shown that the ice thickness within a natural ice sheet can vary by as much as 70% of its average thickness over just a few hundred metres. Consequently it is very important to gather sufficient information about the thickness of an ice road to determine its load capacity or delineate thin ice areas. The number (density) of ice thickness

measurements is a key factor in determining the confidence level in the overall ice thickness to be used to calculate allowable loads.

A historic method for determining ice thickness is to manually drill holes at prescribed intervals in the ice sheet and use the measured minimum ice thickness to determine bearing capacity. This method provides a low density of coverage and is normally acceptable when the ice thickness comfortably exceeds that required to support the specified load.

Newer technology supports Ground Penetrating Radar (GPR) ice profiling, which provides significantly more ice thickness measurements compared to manual drill holes. This method provides a very high density of coverage and consequently provides a much higher level of confidence that thin ice zones over a given area have been detected. The level of confidence in the ice thickness is an important consideration in calculating the allowable bearing capacity of the ice.

Currently GPR is the primary method for ice thickness measurements within DOT. Where it is not feasible to use GPR profiling, Table 2 on page 20 outlines the minimum spacing requirements for test holes when conducting manual measurements for ice thickness.

Safety Note: *The ice thickness that should be used to calculate the associated bearing capacity of the ice cover is the minimum operational ice thickness measured, using either GPR equipment or from manual measurements. See Appendix M for more detail in determining the minimum operational ice thickness.*

Figure 4.8: Measuring ice thickness with GPR unit.

TABLE 2: TEST HOLE SPACING FOR ICE ROADS AND BRIDGES

	Preconstruction	Construction	Operation and Maintenance
	Initial test run	**From start of construction until road is opened to traffic**	**This may overlap with construction activities at lower load levels**
Rivers	If GPR is used, test holes are only required for calibration and for mapping of thin areas 30 meters between test holes along centre line	If GPR is used, test holes are only required for calibration and for mapping of thin areas 30 meters between test holes along alternate edges	If GPR is used, test holes are only required for calibration and for mapping of thin areas 30 meters between test holes along alternate edges Look for thin areas caused by river current
Lakes	If GPR is used, test holes are only required for calibration If within 250 metres of shore: 30 meters between test holes along centre line If more than 250 metres from shore: 250 metres between test holes along centre line	If GPR is used, test holes are only required for calibration If within 250 metres of shore: 30 metres between test holes along alternate edges If more than 250 metres from shore: 250 metres between test holes along alternate edges	If GPR is used, test holes are only required for calibration and for mapping of thin areas 250 metres between test holes along alternate edges
Mackenzie Delta	If GPR is used, test holes are only required for calibration 250 metres between test holes along centre line	If GPR is used, test holes are only required for calibration 250 metres between test holes along alternate edges	If GPR is used, test holes are only required for calibration and for mapping of thin areas

Note: Table 2 indicates normal test frequency and hole spacing. Good judgement based on field experience must be used when varying from this table. In thin areas the suggested spacing should be reduced to determine their extent and severity.

A safe operating procedure for determining minimum ice thickness using either method is provided in Appendix H, Safe Work Procedure –Initial Ice Measurements online at www.dot.gov.nt.ca.

Recording And Reporting Ice Thickness Measurements

All ice thickness test data must be recorded in the ICE THICKNESS log book (bound book) or recorded electronically to enable review by supervisors if required. The records will be filed as part of the permanent record and will be made available to senior department officials. These records will be held on file for a minimum of 5 years. It is very important that the log book is filled out accurately and in a professional manner. In addition to the distances and thicknesses, the following information must also be recorded:

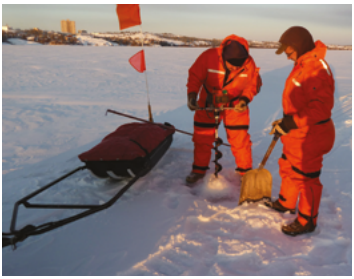

Figure 4.9

- date of test
- time of start and finish
- names of testing crew
- air temperature during testing
- the presence of wide, wet cracks and other significant cracking
- details of load reductions and/or traffic detours
- location, i.e., Peel, Mackenzie at Arctic Red, Tsiighetchic Branch at Mackenzie, Liard River, Aklavik, Tuktoyaktuk, etc.
- general ice and road conditions
- printed name and signature

For GPR profiling results, -- all electronic files shall be saved for a minimum of 4 years.

Appendix J contains a sample Ice Cover Inspection form that can be used for recording the results of visual inspections of the ice.

5.0 DETERMINING SAFE ICE BEARING CAPACITY

INTRODUCTION

The risk management and associated quality control involved in engineering, construction and operations on ice continues to evolve. Poor quality control can lead to unwanted tragic but preventable losses. The DOT has adopted a systems approach to the design, construction and operations of ice programs [4] as it relates to safety and risk management. This approach acknowledges and considers the interdependency among the design parameters used, the experience level of the construction contractors in working on ice, and the number and nature of control measures in place to mitigate and manage risk. In many recent incidents involving ice failures in Canada, the root causes of failure were not lack of understanding of ice thickness. The causes of failure were rooted in lack of quality assurance in loading conditions, contractor procedures, control measures and ice inspection procedures.

5.1 DOT Operating Levels

The Department of Transportation has established a series of Operating Levels for the Pre-Construction Phase, the Construction Phase, and the Operations Phase. These Operating Levels prescribe the allowable ice bearing capacity to be used as well as the minimum level of control measures and quality control elements applicable to each level.

These Operating Levels have been identified as:

- **ROUTINE**
- **ENHANCED**
- **ACUTE**

Within DOT, Regional Superintendents will be responsible to issue written direction on the Operating Level to be used for each region, or for specific projects within their respective regions.

[4] *NOR-EX Ice Engineering Inc., Fitzgerald and Proskin, 2014*

The following factors should be considered when determining the appropriate Operating Level to be used:

- projected frequency and volume of traffic
- maximum projected vehicle weight that will use the road
- control of public and private access to the road
- ice Profiling capabilities and frequency
- active and passive control measures regarding
    - vehicle weights
    - vehicle speed
    - ice condition monitoring
- construction equipment available

In general terms, the Operating Level selected should be as conservative as is necessary to support the maximum vehicle weight and configuration that is anticipated.

This concept is illustrated in Figure 5.1.

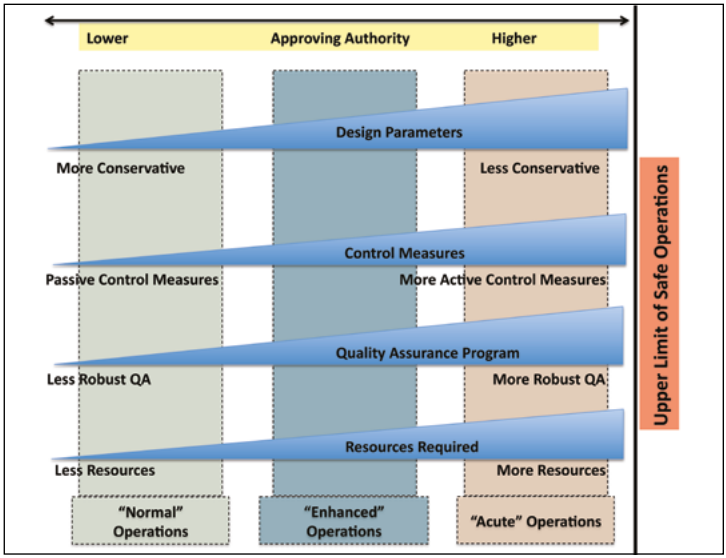

Figure 5.1: Illustration of variable Safe Operating Conditions and escalating effort of diligence and resources required. (Fitzgerald and Proskin, 2014)

Gold's Formula

Gold's Formula provides an estimate of the ice bearing capacity for a particular ice thickness. It is a reliable measure of the bearing capacity of an ice sheet when combined with a strong quality control program including field observations of ice integrity and strong loading controls.

Gold's Formula will be the only method used to calculate the bearing capacity of the ice cover in **ROUTINE** and **ENHANCED** operating levels. If the use of the **ACUTE** operating level for road operations is required, then stress analysis methods conducted by a Professional Engineer will be used in determining the allowable loading of the ice cover.

Gold's Formula: $P=Ah^2$ where:

- P = allowable Gross Vehicle Weight (GVW) load in kilograms
- A = the value assigned dependent on the DOT operating level selected
- h = minimum ice thickness of good quality ice in centimeters

The ROUTINE operating level will be the most common operating level used by DOT. Construction or Operations that take place at levels higher than ROUTINE require the commitment of additional resources and control measures to implement.

Appendices A, B and C contain guidance on allowable loading based on the use of Gold's Formula with A Values utilized within DOT operations.

Risk Management Framework

ROUTINE or ENHANCED operating levels may be used for construction of ice crossings and ice roads. ROUTINE, ENHANCED or ACUTE operating levels may be used for actual operations of ice crossings and ice roads. Each of these prescribed operating levels is based on a comprehensive series of control measures and loading parameters. Each Operating Level prescribes a maximum ice bearing capacity based on Gold's Formula, as well as associated minimum requirements regarding profiling, profiling equipment, visual inspections, loading controls, and inspections.

Tables 3 through 6 describe the risk management framework that DOT and their contractors shall follow when constructing and operating on ice covers. It should be emphasized that all elements within this table are interdependent and must be implemented comprehensively, depending on the Phase of Operation, and Operating Level selected.

TABLE 3: Ice Bearing Capacity and Quality Control - Pre-Construction and Construction Phases
This table is a summary of the DOT allowable load bearing capacity guidance combined with the minimum level of control measures required for each. **This table must be used in conjuction with Appendices E and F to this Guide, which outline the applicable Safe Operating Procedures to be followed.**

			Routine	**Enhanced**	**Acute**
Pre-construction	Load Determination		Gold's formula with an **A value = 4**	Not applicable	Not applicable
Procedures prior to decision to deploy profiling vehicle	Ice Measurements		Manual		
	Visual Inspections		Conducted by operators in accordance with Appendix E		
	Loading Controls		Scaled weights, Amphibious or semi-amphibious vehicle preferred.		
Construction	Load Determination		Gold's formula with an **A value = 4**	Gold's formula with an **A value = 5**	
Procedures prior to decision to deploy construction equipment	Frequency of Ice Measurements		Most current ice profile data to be used to determine allowable load for construction equipment.	Most current ice profile data to be used to determine allowable load for construction equipment.	
	Method/Density of Ice Measurements				
		GPR	Minimum 2 lines at **maximum 12m** spacing by qualified* profile operator. If road width is greater than 20m, then 3 parallel lines of GPR measurements are required. Minimum 1 measurement per .5 meter.	Minimum 3 lines at **maximum 10m** spacing by qualified* profile operator. Minimum 1 measurement per .5 meter.	
		Manual	Manual in accordance with Table 2, page 20	**GPR Profiling Mandatory**	
	Frequency of visual inspections		Continual during snow clearing activities	Continual during snow clearing activities	
	Loading Controls		Construction equipment to be scaled.	Construction equipment to be scaled.	
	Enforcement		Active enforcement of procedures by supervisor	Active enforcement of procedures by supervisor	

TABLE 4: Ice Bearing Capacity and Quality Control - Operations Phase - Ice Crossings on Rivers			
This table is a summary of the DOT allowable load bearing capacity guidance combined with the minimum level of control measures required for each. **This table must be used in conjuction with Appendices E and F to this Guide, which outline the applicable Safe Operating Procedures to be followed.**			
River Crossing	**Routine**	**Enhanced**	**Acute**
Determining Allowable Load	Gold's Formula with an **A value = 4**	Gold's Formula with an **A value = 6**	Detailed stress analysis conducted by a Professional Engineer to recommend required ice thickness. Not using Gold's equation approach.
Frequency of Ice Measurements	Supervisors to use the most recent ice measurements conducted when setting allowable load limits. Confirmation profiling to be conducted prior to each load increase until maximum operating thickness is reached. Then minimum 10-14 days between ice thickness measurements. Circumstances may require more frequent measurements.	Ice measurements must be conducted within 48 hours prior to decision to increase allowable weights under the "Enhanced" operating level. Confirmation profiling to be conducted every 3 days as a minimum while operating at Enhanced Level. Circumstances may require more frequent measurements.	Ice measurements must be conducted within 48 hours prior to decision to increase allowable weights under the "Acute" operating level. Confirmation profiling to be conducted every 2 days as a minimum while operating at the Acute Level. Circumstances may require more frequent measurements.
Method/Density of Ice Measurements	Manual or GPR profiling acceptable	**GPR Profiling Mandatory when operating at the Enhanced Operation Level**	**GPR Profiling Mandatory when operating at the Acute Operation Level**
GPR	Two equally spaced lines of GPR coverage. Maximum spacing for profile lines is 20m. Minimum 1 measurement per .5m distance.	Three equally spaced lines of GPR coverage. Maximum spacing for profile lines is 15m. Minimum 1 measurement every 0.5 m.	Three equally spaced lines of GPR coverage. Maximum spacing for profile lines is 15m. Minimum 1 measurement every 0.5 m.
Manual	In accordance with Table 2, page 20		
Frequency of Visual Inspections	Inspection by qualified supervisor at least once every 3 – 5 days	Daily visual inspection by qualified supervisor.	Daily visual inspection by qualified supervisor.
Loading Controls	Maximum allowable GVW posted at road entrances	Vehicles operating under this permitting condition to produce scale ticket confirming axle group weights and overall GVW.	Vehicles operating under this permitting condition to submit tractor and trailer configuration including axle group spacing and axle group weights for analysis. Scale ticket confirming axle group weights and overall GVW required prior to departure
Enforcement	Passive enforcement through signage and public awarenes campaign.	Active enforcement through use of Safety Officer or Highway Enforcement Officer.	Active enforcement through use of Safety Officer or Highway Enforcement Officer.

TABLE 5: Ice Bearing Capacity and Quality Control - Operations Phase - Ice Roads on Lakes			
This table is a summary of the DOT allowable load bearing capacity guidance combined with the minimum level of control measures required for each. **This table must be used in conjuction with Appendices E and F to this Guide, which outline the applicable Safe Operating Procedures to be followed.**			
Roads on Lakes	**Routine**	**Enhanced**	**Acute**
Determining Allowable Load	Gold's Formula with an **A value = 4**	Gold's Formula with an **A value = 6**	Detailed stress analysis conducted by a Professional Engineer to recommend required ice thickness.
Frequency of Ice Measurements	Supervisors to use the most recent ice measurements conducted when setting allowable load limits. Confirmation profiling to be conducted prior to each load increase until maximum operating thickness is reached. Then minimum 10-14 days between ice thickness measurements. Circumstances may require more frequent measurements.	Ice measurements conducted within 48 hours prior to decision to increase allowable weights. Confirmation profiling to be conducted every 3-5 days as a minimum while operating at the Enhanced Level. Circumstances may require more frequent measurements.	Ice measurements conducted within 48 hours prior to decision to increase allowable weights. Confirmation profiling to be conducted every 3-4 days as a minimum while operating at the Acute Level. Circumstances may require more frequent measurements.
Method/Density of Ice Measurements	Manual or GPR profiling acceptable	**GPR Profiling Mandatory when operating at the Enhanced Operation Level**	**GPR Profiling Mandatory when operating at the Acute Operation Level**
GPR	Two equally spaced lines of GPR coverage. Maximum spacing for profile lines is 20m. Minimum 1 measurement per .5m distance.	Three equally spaced lines of GPR coverage. Maximum spacing for profile lines is 15m. Minimum 1 measurement every 0.5 m.	Three equally spaced lines of GPR coverage. Maximum spacing for profile lines is 15m. Minimum 1 measurement every 0.5 m.
Manual	In accordance with Table 2, page 20		
Frequency of Visual Inspections	Inspection by qualified supervisor at least once every 7-10 days or as warranted by site, loading or weather conditions.	Daily visual inspection by qualified supervisor.	Daily visual inspection by qualified supervisor.
Loading Controls	Maximum allowable GVW posted at road entrances.	Vehicles operating under this permitting condition to produce scale ticket confirming axle group weights and overall GVW.	Vehicles operating under this permitting condition to submit tractor and trailer configuration including axle group spacing and axle group weights for analysis. Scale ticket confirming axle group weights and overall GVW required prior to departure.
Enforcement	Passive enforcement through signage and public awarenes campaign (posting on website).	Active enforcement through use of Safety Officer or Highway Enforcement Officer.	Active enforcement through use of Safety Officer or Highway Enforcement Officer.

TABLE 6: Ice Bearing Capacity and Quality Control - Operations Phase - Ice Roads along Rivers			
This table is a summary of the DOT allowable load bearing capacity guidance combined with the minimum level of control measures required for each. **This table must be used in conjuction with Appendices E and F to this Guide, which outline the applicable Safe Operating Procedures to be followed.**			
Roads Along Rivers	**Routine**	**Enhanced**	**Acute**
Determining Allowable Load	Gold's Formula with an **A value = 4**	Gold's Formula with an **A value = 6**	Detailed stress analysis conducted by a Professional Engineer to recommend required ice thickness.
Frequency of Ice Measurements	Supervisors to use the most recent ice measurements conducted when setting allowable load limits. Confirmation profiling to be conducted prior to each load increase until maximum operating thickness is reached. Then minimum 10-14 days between ice thickness measurements. Circumstances may require more frequent measurements.	Ice measurements conducted within 48 hours prior to decision to increase allowable weights. Confirmation profiling to be conducted every 2 - 3 days as a minimum while operating at the Enhanced Level. Circumstances may require more frequent measurements.	Ice measurements conducted within 48 hours prior to decision to increase allowable weights. Confirmation profiling to be conducted every 2 days as a minimum while operating at the Acute Level. Circumstances may require more frequent measurements.
Method/Density of Ice Measurements	Manual or GPR profiling acceptable	**GPR Profiling Mandatory when operating at the Enhanced Operation Level**	**GPR Profiling Mandatory when operating at the Acute Operation Level**
GPR	Two equally spaced lines of GPR coverage. Maximum spacing for profile lines is 20m. Minimum 1 measurement per 2m distance.	Three equally spaced lines of GPR coverage. Maximum spacing for profile lines is 15m. Minimum 1 measurement every 0.5 m.	Three equally spaced lines of GPR coverage. Maximum spacing for profile lines is 15m. Minimum 1 measurement every 0.5 m.
Manual	In accordance with Table 2, page 20		
Frequency of Visual Inspections	Inspection by qualified supervisor at least once every 3 days	Daily visual inspection by qualified supervisor.	Daily visual inspection by qualified supervisor.
Loading Controls	Maximum allowable GVW posted at road entrances.	Vehicles operating under this permitting condition to produce scale ticket confirming axle group weights and overall GVW.	Vehicles operating under this permitting condition to submit tractor and trailer configuration including axle group spacing and axle group weights for analysis. Scale ticket confirming axle group weights and overall GVW required prior to departure.
Enforcement	Passive enforcement through signage and public awarenes campaign.	Active enforcement through use of Safety Officer or Highway Enforcement Officer.	Active enforcement through use of Safety Officer or Highway Enforcement Officer.

6.0 ICE COVER MANAGEMENT

6.1 Introduction

All GNWT Department of Transportation employees involved in ice road construction and maintenance are responsible for monitoring road conditions, in addition to their regular duties. If an employee sees a situation that is a danger to the public, they have the authority and responsibility to take immediate action to correct the problem.

6.2 Speed Limits and Spacing on Ice Covers

Loads operating at excessive speeds can increase the risk of damage to the ice cover, particularly when the load is operating at the higher end of the allowable loading for the ice cover. This potential damage can lead to a reduction in the capability of the ice cover to safely support the load for which it has been designed. It is therefore necessary to control the speed of vehicles operating on ice covers.

- Vehicles operating at the upper end of the allowable load limit of an ice cover should travel at a maximum of 25 km/h.
- As the season progresses and the ice cover thickens, light vehicles may be permitted to travel at higher speeds, provided road surface conditions allow for safe operations at the designated speed.
- Vehicles weighing more than 12,500kg should maintain a minimum spacing of 500m between vehicles to avoid exceeding allowable stress limits on the ice cover by inadvertently overloading the ice sheet.
- Where loaded vehicles are required to pass each other in opposite directions, vehicles should reduce their speed to 10 km/h.
- A loaded vehicle should not be permitted to pass another loaded vehicle moving in the same direction. If necessary to do so, the lead vehicle should come to a temporary stop on the ice cover and the passing vehicle should reduce their speed to 10 km/h until it has passed the stationary vehicle.

Signs identifying allowable speed limits for traffic will be posted at the entrance to all ice covers and periodically throughout the length of the crossing as required.

6.3 Winter Road Inspections

While all personnel have a responsibility to identify potential hazards, this is a major part of the activities of supervisors, foremen, and superintendents. Regular road patrols are carried out during both the construction and maintenance phases of the winter road season. Once identified, problems must be either corrected or isolated from the traffic. The travelling public must also be promptly advised of changes to road conditions that might affect their ability to complete a trip.

When conducting road inspections, inspector should

- Look for snow drifting, overflow, wet or dry cracks, and icing. If a hazard is discovered, place warning devices such as flags, delineators, or flares. If possible, remedial action should begin at once. Warning signs must be set if the repair will take some time to complete.
- Check for missing or damaged traffic signs and make immediate repairs or replacements.
- Check for and remove debris from the roadway.
- Report the unauthorized erection of signs or the construction of accesses to the Regional Highway Superintendent.
- Help stranded motorists.
- Report abandoned vehicles to your supervisor.
- Check for and report spills of oil or dangerous goods.

The minimum frequency of routine inspections required for ice covers varies with the Phase of Construction and the Operating Level in place. Details can be found in Section 5 (Tables 3 - 6). The guidance contained in Section 5 is the minimum required inspection frequency only, additional inspections should be performed if warranted and deemed necessary by the supervisor.

Appendix J which can be found online at www.dot.gov.nt.ca provides an inspection template for use by supervisors and others conducting routine ice cover inspections.

6.4 Traffic Enforcement – Highway Traffic Offences and RCMP

Traffic Enforcement Officers are responsible for ensuring that all vehicles comply with the Motor Vehicles Act and its regulations. Inspections of transport trucks are especially important when the load limits on the ice roads are not yet up to those set for the all-weather highway system. A truck that is legally loaded for the primary highway system may exceed the load limit for an ice road or crossing and cause an ice failure.

Planned loads that exceed the allowable loading limits on ice roads or crossings will require special approval through the DOT permitting process.

If construction/maintenance personnel believe that trucks are operating in excess of an ice crossing load limit, they should notify Department of Transportation personnel of the need for spot inspections.

6.5 Signs and Barricades

Winter road traffic signs are used to declare the road open or closed, to direct traffic to destinations along the road, to post maximum GVW load limits, speed limits, and to warn motorists of potential hazards. The standards of signing are somewhat different from those on permanent all-weather roads because conditions on seasonal roads are more subject to change. Traffic signs must be adjusted to meet these changing road conditions. Recommended winter road signage information can be found in the GNWT Highway Maintenance Manual.

During Construction

While the winter road is under construction and not yet open to the public, barricades and signs will be posted at the entrance to the winter road stating that it is closed. Regular checks and patrols will be conducted to ensure that all barricades are in place at all times. If barricades have been moved or vandalized, your supervisor should be notified.

At the end of the season the signs and barricades should be reinstalled and the closure monitored and enforced.

Figure 6.1

Entry Signs

Signs must be posted at each major river crossing and at the entrance to all winter roads on the NWT Highway System, which clearly indicates whether the road or crossing is open or closed, the maximum allowable GVW weight, and the phone number to call for road information.

At the entrance to winter roads, signs must also be posted that advise motorists to carry chains and survival gear if required and indicate if there are services available.

Figure 6.2

At the entrance to major ice bridges motorists will be advised to maintain a distance of 500 metres from other vehicles and a maximum speed of 20 kph.

Regulatory and Advisory Signs

Speed limit signs should be posted as required taking into account the type of road surface.

Signs should also be posted to indicate the distance from the next community. These signs and the speed limit signs should at minimum be posted at 50 kilometre intervals, near communities and at intersecting roads.

Standard traffic and warning signs should be used where required. See Highways Operations Manual for recommended signage requirements.

On short detours, traffic cones or drums may be sufficient.

Barricade lights may be installed in an emergency to attract attention to a sign message or to identify a particular hazard or obstruction. Lighting devices should be positioned so as not to blind traffic with their glare. Flashing devices do not provide good illumination and should not be used by themselves to channel traffic.

More detail is contained within the approved winter road signage charts provided in the DOT Highways Maintenance Manual.

6.6 Temporary Road Closure

Section 23 of the Public Highways Act authorizes the closure of portions of a highway for the purpose of construction or maintenance. The Department routinely closes sections of highway if snowstorms or drifting snow reduce visibility to the extent that travel is hazardous.

When a road is closed, proper signs must be installed to inform the public. The same standards apply to temporary and permanent road closures.

6.7 Public Information and Communications

The Department makes regular public announcements on current road conditions through public service announcements on local radio stations, messages on a toll free telephone line, 1-800-661-0750, on the GNWT website (www.dot.gov.nt.ca/_live/pages/wpPages/Travel_Alerts.aspx) and communication with major transportation companies. Any changes in road conditions must be promptly communicated to the Department's Regional Superintendent, to ensure that information provided to the public is up to date and accurate.

6.8 Training

Minimum levels of training for Supervisors, equipment operators, and profile operators have been outlined in Appendix G, Training Guidelines, which can be found online at www.dot.gov.nt.ca.

Regional Superintendents are responsible to ensure that all personnel working on ice covers have received the appropriate training annually prior to commencement of working on the ice.

6.9 Monitoring and Reporting

A key component of any operation on ice cover is the frequency and nature of inspections that are required for Quality Control. Section 5 of this guide outlines the minimum frequency and nature of inspections required.

This section identifies in detail the requirements for reporting of ice thickness measurements, visual inspections, road opening dates, weight increases, and other advisories.

The following reports are to be completed regularly and retained at Regional offices:

- ice condition / thickness log book
- ice thickness reports from manual ice measurements
- GPR Ice Profile raw data and electronic files including any ancillary information used for analysis/decision support (e.g. core information, start/end position).
- ice cover inspection reports
- road opening and crossing opening and closing announcements
- allowable load increase announcements
- guidance amending the authorized operating level of specific roads or crossings.
- other road advisories issued by regions

7.0 END OF SEASON GUIDELINES

Proper quality control and monitoring measures will extend the safe operating life of most roads and ice crossings. While there is a limit to how long an ice cover can remain safe and serviceable, there are steps that can be taken to extend the safe operating season.

Although the Department of Transportation (DOT) aims at keeping winter roads open as long as possible, roads must be closed when public safety and the environment are being compromised. The environmental impacts of winter roads must be minimized by following accepted best practices for winter road management and DOT's own policy on environmental stewardship. This responsibility requires a road to be closed when the land and crossings within the right-of-way become vulnerable to harm from continuing its use.

Generally speaking, most ice covers will be forced to close as a result of deteriorating running surface or operating surface, long before the ice integrity of the cover is jeopardized. Some common surface degradation that may result in the closing of ice covers include:

- melting of overland or portage ice cover, resulting in extensive rutting and generally untrafficable conditions
- the accumulation of excessive water on the surface of roads or ice crossings from surface melt
- the softening of the upper portion of the ice sheet to a degree that inhibits travel for most vehicles

In late winter, the energy of the sun is strong enough to cause the melting of the ice surface, even when ambient temperatures remain below 0 degrees Celsius.

Dark surfaces from sand, gravel, and other debris that is carried onto the ice cover will absorb energy from the sun and can cause localized melting in areas where there is a large concentration of dark sand/gravel. Maintenance crews can extend the length of the season by scraping these areas clean on a regular basis.

Eventually, the ice will continue to degrade and the crossing or ice road will need to be closed. While it is impractical at this time to provide precise conditions outlining when an ice cover is unsafe to operate, the following guidelines are recommended to supervisors when exercising their judgement on when a crossing should be closed.

Figure 7.1: Water from surface melt on an ice cover in Spring.

Crossings can continue to be operated safely for as long as supervisors can maintain confidence in the **minimum ice thickness** present, the **overall integrity of the ice**, and the **accuracy of loading conditions**. When the presence of surface melt on the ice cover prevents the ability to maintain confidence in ice thickness and/or ice integrity, the crossing should be closed.

More details regarding the closure of winter roads can be found in Appendix L– Winter Road Closing Protocol, which can be found online at www.dot.gov.nt.ca.

Figure 7.2: Water flooding a large area in spring.

APPENDIX A

GOLD'S FORMULA A=4 LOAD CHARTS

Appendix A - Gold's Formula A=4 Load Charts

This chart is to be used for Pre-Construction and Routine Construction in accordance with Table 3 page 25

Gold's Formula P = 4 h^2 **A Factor 4**	**P** = Load in Kilograms **h** = Minimum Ice Thickness of Good Quality Ice in centimeters

h (Centimeters)	Load (Kilograms)	h (Centimeters)	Load (Kilograms)	h (Centimeters)	Load (Kilograms)
20	1,600	56	12,544	92	33,856
21	1,764	57	12,996	93	34,596
22	1,936	58	13,456	94	35,344
23	2,116	59	13,924	95	36,100
24	2,304	60	14,400	96	36,864
25	2,500	61	14,884	97	37,636
26	2,704	62	15,376	98	38,416
27	2,916	63	15,876	99	39,204
28	3,136	64	16,384	100	40,000
29	3,364	65	16,900	101	40,804
30	3,600	66	17,424	102	41,616
31	3,844	67	17,956	103	42,436
32	4,096	68	18,496	104	43,264
33	4,356	69	19,044	105	44,100
34	4,624	70	19,600	106	44,944
35	4,900	71	20,164	107	45,796
36	5,184	72	20,736	108	46,656
37	5,476	73	21,316	109	47,524
38	5,776	74	21,904	110	48,400
39	6,084	75	22,500	111	49,284
40	6,400	76	23,104	112	50,176
41	6,724	77	23,716	113	51,076
42	7,056	78	24,336	114	51,984
43	7,396	79	24,964	115	52,900
44	7,744	80	25,600	116	53,824
45	8,100	81	26,244	117	54,756
46	8,464	82	26,896	118	55,696
47	8,836	83	27,556	119	56,644
48	9,216	84	28,224	120	57,600
49	9,604	85	28,900	121	58,564
50	10,000	86	29,584	122	59,536
51	10,404	87	30,276	123	60,516
52	10,816	88	30,976	124	61,504
53	11,236	89	31,684	125	62,500
54	11,664	90	32,400	126	63,500
55	12,100	91	33,124		

APPENDIX B

GOLD'S FORMULA A=5 LOAD CHARTS

Appendix B - Gold's Formula A=5 Load Charts

This chart is to be used for the Enhanced Construction Phase in conjunction with the Additional Control Measures outlined in Table 3 page 25

Gold's Formula P = 5 h^2 **A Factor 5**	**P** = Load in Kilograms **h** = Minimum Ice Thickness of Good Quality Ice in centimeters

h (Centimeters)	**Load** (Kilograms)	**h** (Centimeters)	**Load** (Kilograms)	**h** (Centimeters)	**Load** (Kilograms)
20	2,000	52	13,520	84	35,280
21	2,205	53	14,045	85	36,125
22	2,420	54	14,580	86	36,980
23	2,645	55	15,125	87	37,845
24	2,880	56	15,680	88	38,720
25	3,125	57	16,245	89	39,605
26	3,380	58	16,820	90	40,500
27	3,645	59	17,405	91	41,405
28	3,920	60	18,000	92	42,320
29	4,205	61	18,605	93	43,245
30	4,500	62	19,220	94	44,180
31	4,805	63	19,845	95	45,125
32	5,120	64	20,480	96	46,080
33	5,445	65	21,125	97	47,045
34	5,780	66	21,780	98	48,020
35	6,125	67	22,445	99	49,005
36	6,480	68	23,120	100	50,000
37	6,845	69	23,805	101	51,005
38	7,220	70	24,500	102	52,020
39	7,605	71	25,205	103	53,045
40	8,000	72	25,920	104	54,080
41	8,405	73	26,645	105	55,125
42	8,820	74	27,380	106	56,180
43	9,245	75	28,125	107	57,245
44	9,680	76	28,880	108	58,320
45	10,125	77	29,645	109	59,405
46	10,580	78	30,420	110	60,500
47	11,045	79	31,205	111	61,605
48	11,520	80	32,000	112	62,720
49	12,005	81	32,805	113	63,500
50	12,500	82	33,620		
51	13,005	83	34,445		

APPENDIX C

GOLD'S FORMULA A=6 LOAD CHARTS

Appendix C - Gold's Formula A=6 Load Charts

This chart is to be used for Enhanced Operations Phase and in conjunction with the Additional Control Measures outlined in Tables 4, 5 and 6 in this guide, pages 26 - 28

Gold's Formula P = 6 h^2 **A Factor 6**	**P** = Load in Kilograms **h** = Minimum Ice Thickness of Good Quality Ice in centimeters

h (Centimeters)	Load (Kilograms)	h (Centimeters)	Load (Kilograms)	h (Centimeters)	Load (Kilograms)
20	2,400	48	13,824	76	34,656
21	2,646	49	14,406	77	35,574
22	2,904	50	15,000	78	36,504
23	3,174	51	15,606	79	37,446
24	3,456	52	16,224	80	38,400
25	3,750	53	16,854	81	39,366
26	4,056	54	17,496	82	40,344
27	4,374	55	18,150	83	41,334
28	4,704	56	18,816	84	42,336
29	5,046	57	19,494	85	43,350
30	5,400	58	20,184	86	44,376
31	5,766	59	20,886	87	45,414
32	6,144	60	21,600	88	46,464
33	6,534	61	22,326	89	47,526
34	6,936	62	23,064	90	48,600
35	7,350	63	23,814	91	49,686
36	7,776	64	24,576	92	50,784
37	8,214	65	25,350	93	51,894
38	8,664	66	26,136	94	53,016
39	9,126	67	26,934	95	54,150
40	9,600	68	27,744	96	55,296
41	10,086	69	28,566	97	56,454
42	10,584	70	29,400	98	57,624
43	11,094	71	30,246	99	58,806
44	11,616	72	31,104	100	60,000
45	12,150	73	31,974	101	61,206
46	12,696	74	32,856	102	62,424
47	13,254	75	33,750	103	63,654

The following Appendices can be found online at www.dot.gov.nt.ca

Appendix D	Safety Act Excerpt
Appendix E	Guidelines for Working in a Cold Environment
Appendix F	Worker Safety Guidelines
Appendix G	Training Guidelines
Appendix H	Safe Work Procedure – Initial Ice Measurements
Appendix I	Safe Work Procedure – Initial Snow Clearing
Appendix J	Ice Cover Inspection Form
Appendix K	Accident Reporting
Appendix L	Winter Road Closing Protocol (March 2014)
Appendix M	GPR Information