Nunavut Fibre Optic Feasibility Study

Prepared for the Nunavut Broadband Development Corporation (NBDC)
March, 2012



Salter Global Consulting Incorporated SGC

LEDCOR GROUP

Imaituk

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Section 1 - Executive Summary

This Nunavut Fibre Optic Feasibility Study report was commissioned by the Nunavut Broadband Development Corporation (NBDC) and subsequently executed by QINIQ INC (on behalf of NBDC) and Salter Global Consulting INC (SGC). In turn, SGC engaged Ledcor Infrastructure Services and Imaituk Inc. as sub contractors.

The principal requirements of the study were:

1. To review current and anticipated fibre optic technologies and make recommendations for suitable deployment in Nunavut.
2. Review the status of arctic fibre network infrastructure, including proposed expansion initiatives up to 2020.
3. Review a minimum of 3 possible landing points in Nunavut.
4. To review the possible impact of fibre systems on service parity in Nunavut. This review is also to include the socioeconomic impact of a mixed telecommunications network in Nunavut, including possible overland distribution alternatives.
5. Provide recommendations for initiating and financing a fibre network in Nunavut, including Private Public Partnership (PPP, P3) alternatives.

Review of Fibre Optic Technologies

From a strictly technical point of view, the report concludes that existing fibre optic technologies (with some modifications to adapt to northern environments and local conditions) would permit the installation and operation of a fibre optic network in Nunavut. However, this is not without risk, and the report has indentified key risk areas, possible risk mitigation strategies, and the need for further "on the ground" survey work before the detailed final configuration and scheduling aspects of a fibre network can be recommended. Key issues are:

- The need for accurate bathymetry information, up to date nautical charts, geological information, tidal information and local ice condition forecasts (including possible iceberg tracks) in order to determine optimum undersea cable routings and landing approaches.
- Environmental review processes and permitting information, both for marine aspects of any proposed fibre system, and also for landings and any proposed land crossings.
- The limited installation window and the unpredictability of changing ice conditions.
- The need for a long term maintenance and repair strategy that identifies alternative backup systems in the event of a prolonged system outage. This is particularly important given the potential inaccessibility of undersea cables for extended periods of time.

The installation of fibre optic cables in Nunavut could be accomplished using three existing technologies (these techniques may need to be modified to meet local conditions):

- Horizontal drilling from landing points to deeper water, to reduce the possibility of cable damage close to the shore.

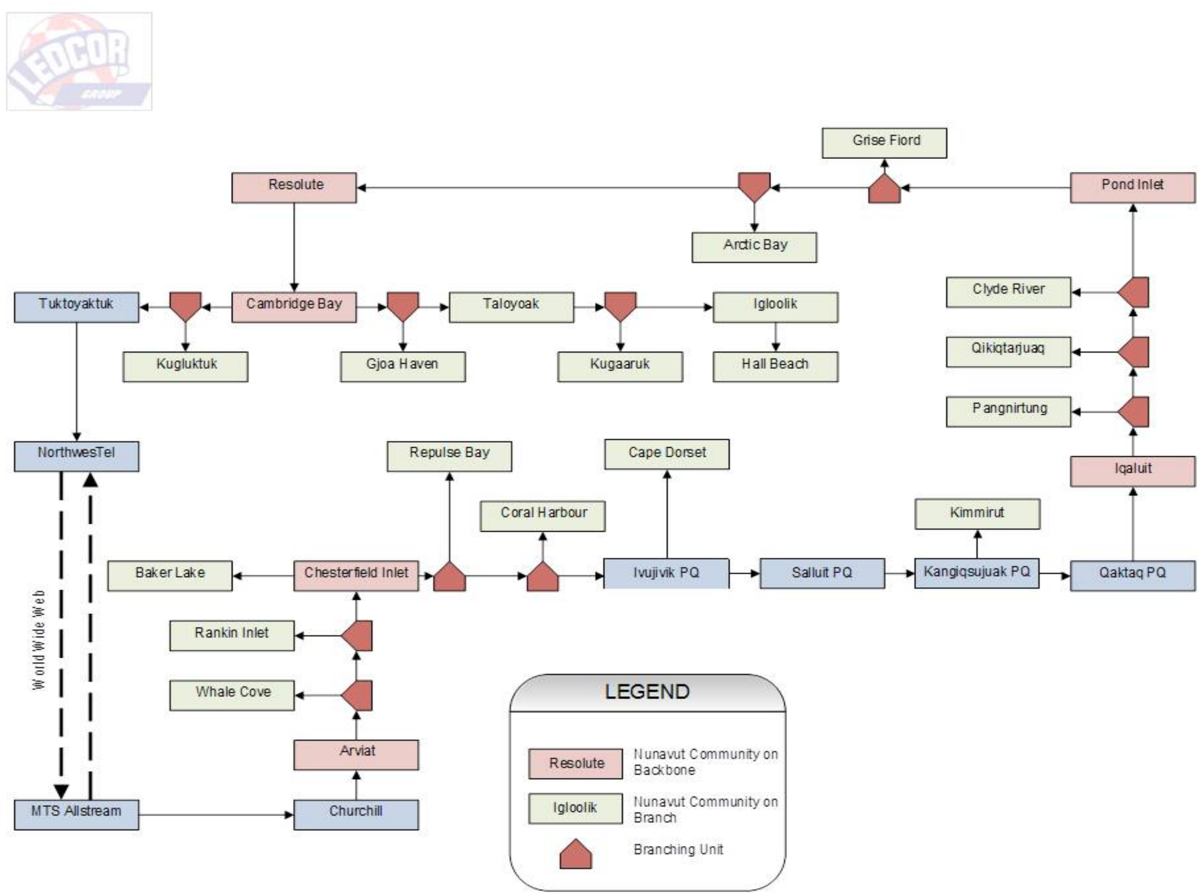
- Undersea plowing of the cable directly into the sea bed for the approaches to landing areas and in shallower water.
- Laying the cable directly on the sea bed in deep water.

<u>Fibre Optic Network Considerations</u>

Fibre optic systems are inherently reliable, but overall system reliability and availability can be significantly improved using three techniques:

- Network fibre "ring" architectures – traffic in these systems can flow in either direction, giving the system improved resilient to a single break. Overall reliability can be further improved by having a "ring within a ring" configuration and multiple ring entry points.
- Route diversity – this technique requires a parallel, but independent routing.
- Use of "branching units" – in this architecture, local feeds to communities along the route are provided by spurs off the main cable. This means that, in the event of a failure along the spur route, the mainline cable system is unaffected.
- Alternative technologies as backup (satellite and/or digital radio).

<u>Proposed network to provide fibre service to communities in Nunavut</u> (- in this model, it is assumed that Sanikiluak could be most economically served from a Nunavik network).



The cable distance for this architecture is 10, 782 km (this distance could be increased marginally following detailed marine and geological surveys).

The "Rough Order of Magnitude" (ROM) capital cost estimate to realize this network is $750M. If a typical Government of Canada style risk analysis is performed on the project, and recognizing that the ROM estimate is based on a desk top study without any physical surveys, the "risk premium" that could be then allocated to a project at this stage of consideration could increase the estimated project cost to $1,050M.

A second network alternative was considered, that provides fibre service to the Regional Centres of Iqaluit, Rankin Inlet and Cambridge Bay, with an extension to Resolute Bay.

The baseline ROM cost estimate for this alternative is $244M (this includes links from Cambridge Bay to Tuktoyaktuk, Iqaluit to Nuuk, Greenland, and Rankin Inlet to Churchill, Manitoba. Using the same "risk premium" analysis as in the first network model, the cost estimate would increase to $342M.

A long term expansion of the Nunavut fibre ring model is proposed that connects communities in Hudson's Bay (including communities in Nunavik). This long term network model is characterized by a two ring network model, with four entry points: Tuktoyaktuk (connecting to the southern NWT system); Churchill, Manitoba; Radisson (or Chisasibi) Quebec; and Iqaluit (connecting to Nuuk, Greenland or Milton, Newfoundland). This network architecture provides a potential long term template for a robust "pan arctic" fibre optic network.

Landing Point Analysis

The report provides a preliminary "desk top" analysis of four landing points using publicly available nautical charts. The locations are Iqaluit, Rankin Inlet, Cambridge Bay and Resolute Bay:

- For Iqaluit, two diverse cable routing paths are proposed. It is also proposed that cable be buried for a distance of at least 7 km to minimize the potential for damage by ice, fishing activities and anchorages.
- For Rankin Inlet, it is proposed to use a branching unit located in deeper water and have a spur feed to the community. From a technical point of view, we have proposed Chesterfield Inlet as a preferable regeneration point for the system, which could be equipped with two diverse shore landings.
- For Resolute Bay, two diverse cable paths are proposed, with separate feeds from Pond Inlet and Cambridge Bay.
- For Cambridge Bay, two diverse routings are proposed. The first, through the bay and into Dease Straight towards Kugluktuk, and the second into Queen Maud Gulf for the routing to Resolute Bay.

Arctic Fibre Optic Systems

Existing fibre optic systems are operating in:

- Northwest Territories and Yukon – NorthwesTel uses a ring fibre optic architecture for its backbone network. An extension of the existing system from Carmacks to Dawson City is planned for 2012.
- TELE Greenland has an undersea system operating from Milton, Newfoundland to Nuuk, Greenland, with a continuing connection to Iceland. A separate network operator is used for the continuation of the system to the Faroe Islands and the UK.
- Two US fibre “ring” systems are operating between Alaska and Washington, and Alaska and Oregon.
- Two 1,400 km marine fibre cables from the Svalbard archipelago, Norway to the Norwegian mainland, operated by Telenor.
- Manitoba Telephone System (MTS) and Manitoba Hydro have a fibre system extending to Churchill, Manitoba.
- A fibre system to Radisson, Quebec that has recently been extended to Chisasibi, Quebec (located on the eastern shore of James Bay).

The following arctic fibre optic systems have been proposed:

- A Mackenzie Valley Fibre Link from near Fort Simpson to Inuvik with an extension to Tuktoyaktuk. This has been identified as one of the top three infrastructure project by the Government of the Northwest Territories.
- Arctic Link has proposed a Europe to Asia system. Two routing options have been discussed; a northerly routing using the McClure Strait, and a southerly routing past Cambridge Bay and then routing north to serve Resolute Bay and communities on the eastern shore of Baffin Island.
- NorthwesTel has proposed a number of system architectures for serving Nunavut communities with marine fibre cable.
- TELE Greenland has proposed a northern domestic fibre route to connect communities on Greenland’s western shore with the Nuuk fibre hub.
- Most recently, Arctic Fibre announced a Europe to Asia proposal using a routing via Tuktoyaktuk, Cambridge Bay, and Gjoa Haven and then using a land crossing across the Boothia Peninsula before continuing on a southerly routing to the south of Baffin Island. In this proposal, a separate fibre cable is proposed to connect Iqaluit with Milton, Newfoundland.
- A northeastern passage routing, connecting England, Japan, China and Russia through cable stations in the cities of Bude (England), Tokyo (Japan), and Russia's Murmansk, Vladivostok, and Anadyr has recently been tendered (January, 2012) by the Russian Optical Trans Arctic Submarine Cable System (ROTACS).

Alternative Telecommunications Technologies

At the same time that fibre optic technology has advanced, alternative telecommunications technologies have also been characterized by significant advances.

Satellite Technology

The report considered three satellite technologies:

- High throughput satellites.
- Low Earth Orbit (LEO) satellite constellations
- The Government of Canada's PolarSat mission proposal, based on a two satellite constellation in highly elliptical polar orbits (Tundra or Molniya orbits).

The report concludes that high throughput satellites provide the best alternative for enhanced satellite broadband coverage in Nunavut. Using the recently launched ViaSat 1 satellite as an example, future expanded high speed broadband coverage is technically possible for all communities in Nunavut.

Digital Microwave

Current digital microwave systems have the capacity to backhaul broadband data at speeds of between 500 Mbit/s and 1 Gbit/s. Typical capital ROM site cost estimates average at between $1M and $1.2M per location (assuming 40 m towers). A typical repeater "skip" distance of between 30km and 40 km has been assumed. In most cases, communities would need to be between 100 km and 140 km distance from a telecommunications fibre hub for a microwave system to be cost effective.

Mixed Telecommunications Network

The Nunavut telecommunications network could evolve in two ways:

- A satellite only configuration, using a combination of existing satellites and, potentially, high throughput satellites.
- A mixed network comprising a backbone fibre network with digital microwave backhaul systems for communities that are relatively close to fibre hubs, and satellite service for outlying communities.

The study indentifies four possible microwave candidates, in addition to a possible digital radio route diversity system from the existing terminal of a microwave system at the Ekati Mine site, NWT, to Cambridge Bay, Nunavut.

Socioeconomic Considerations

Nunavut demographics are unique in the north, with a population spread more evenly throughout the Territory, so it is important that all communities have the opportunity to benefit equally from the provision of broadband services. It is also important in Nunavut to ensure that all communities have similar broadband speeds so that territory wide initiatives that are dependent on broadband will provide benefits to all 31,000 residents.

- The socioeconomic opportunities broadband brings will only be open to a portion of the population if some communities are connected and others are not, creating a political and cultural challenge in Nunavut.
- It is critical that concurrent investment in high throughput satellite will be required to serve non-fibre linked communities, and to provide effective back up in the event of a fibre failure.
- Any serious plan for fibre backbone investment must consider how to mix fibre and satellite so that any difference in service levels can be managed for the socioeconomic growth of the entire territory.

The report makes 4 socioeconomic recommendations:

- Investment in infrastructure must benefit Nunavummiut as it also seeks to benefit Canada.
- Reliability and system redundancy are paramount.
- Strategic concurrent backbone investment is required in satellite.
- Future revenue streams required to maintain and innovate.

Private Public Partnership (PPP or P3) Models

The report considers four types of P3 models:

1. Traditional P3 models, that have been employed by the Government of Canada's (GoC) Federal P3 Agency e.g. Design, Build, Operate Maintain. In this model, the asset has to ultimately be owned by a public body (Territorial Government, Provincial Government, Aboriginal Government, Municipality etc).

2. GoC P3 model that has been used by Industry Canada – In this alternative, the ownership of the asset can ultimately rest with the private sector.

3. "Condominium" Model – In this model, a project sponsor (e.g., a Territorial Government) would own and manage the overall framework infrastructure of the project, but would be able to "sell," "lease," or "rent" capacity to private sector clients at market rates, while maintaining a separate element for public good use (health care, education, social services etc.).

4. IRU (Indefeasible Right of Use) – this is a common form of arrangement within the fibre optic sector. IRUs are commonly used in long haul fibre systems as a way of sharing costs while retaining indefeasible control of an agreed communications channel.

Proposed "Next Steps"

The following next steps are proposed:

1. Local community consultations. Local knowledge with respect to landing approaches, ice conditions and scouring, etc. are important elements in any design.
2. Further assessment of risk mitigation options – this could significantly reduce the "risk premium." These could include:
    a. Completion of a detailed field and marine study, including bathymetry and geological surveys.
    b. Detailed assessment and projected schedule for environmental reviews and permitting.
    c. Sharing and transference of risk to private sector and/or other potential stakeholders.
    d. Business case analysis for the proposed project elements.
    e. Assessment of financing alternatives.
3. Review of long term pan arctic communications alternatives with interested Territorial, Provincial and Aboriginal Governments, together with the Federal Government. This report provides one alternative for a long term pan arctic fibre network infrastructure.
4. Proposed Northwest Passage Private Sector Initiatives – there have been two Europe-Asia fibre optic network proposals. Eventually, one of these proposals (or a similar proposal) could succeed, and it would be important to have the strategy in place to negotiate appropriate branching units and business arrangements, to protect the interests of Nunavut.

Section 2 - Objectives of the Feasibility Study

The Feasibility Study was tasked to address the following issues:

1. A comparative review of current and anticipated fibre networking technologies, with a particular emphasis on the best options suitable for deployment in Nunavut.

2. A review of the status of existing fibre optic systems in the north that could connect with Nunavut either by land or sea. The review was also to include identification of planned fibre optic systems up to 2020.

3. Identification of possible landing points. The study was required to review at least three landing points in Nunavut, and provide budgetary cost estimates for the landings.

4. A review of the possible impact of fibre systems on service parity in Nunavut. This review was also to include the socioeconomic impact of a mixed telecommunications network in Nunavut, including possible overland distribution alternatives.

5. Identification of possible next steps, including the investigation of opportunities for public private partnership and other financing alternatives.

Section 3 – Team Members

The feasibility study was completed by the following team members:

1. Prime contractor - Salter Global Consulting INC. of Ottawa, Ontario.
2. Sub Contractor #1 – Ledcor Infrastructure Services Division with extensive experience in the design and installation of land based and submarine fibre optic systems across Canada and the United States, including NWT, Yukon, Nunavut and Alaska
    a. IT International Telecom Inc., with expertise in subsea fibre optic network integration including design, installation, and maintenance of marine cable systems.
3. Sub Contractor #2 – Imaituk Inc., consultants to northern and aboriginal organizations, with expertise in the delivery of broadband services to remote and underserviced areas, and the socioeconomic implications of alternative telecommunications strategies.

Section 4 – Review of Alternative Fibre Optic Technologies

Overview

The first trial of a submarine fibre optic cable was in 1979, with the first international marine fibre optic system being installed across the English Channel in 1986. In 1988, the first fibre optic transoceanic cable was installed between the United States and Europe.

There is over 1 million route km of fibre optic cable installed worldwide. A total of 91% of the world's international traffic is currently being carried by these systems.

The reliability of these systems is very high (in the order of 99.9999% availability), primarily due to the maturity of the technology, and the use of route diversity. Typically, transoceanic and mainline terrestrial fibre optic systems are configured in "ring" architectures, with traffic flowing in both directions around the ring. These systems are equipped with automatic switching systems so that, in the event of a failure, traffic is automatically routed to avoid the failed section. Further protection is also provided by alternative physical routing of complementary fibre systems that serve similar locations.

Figure 1 shows the current extent of fibre systems worldwide Figure 1.

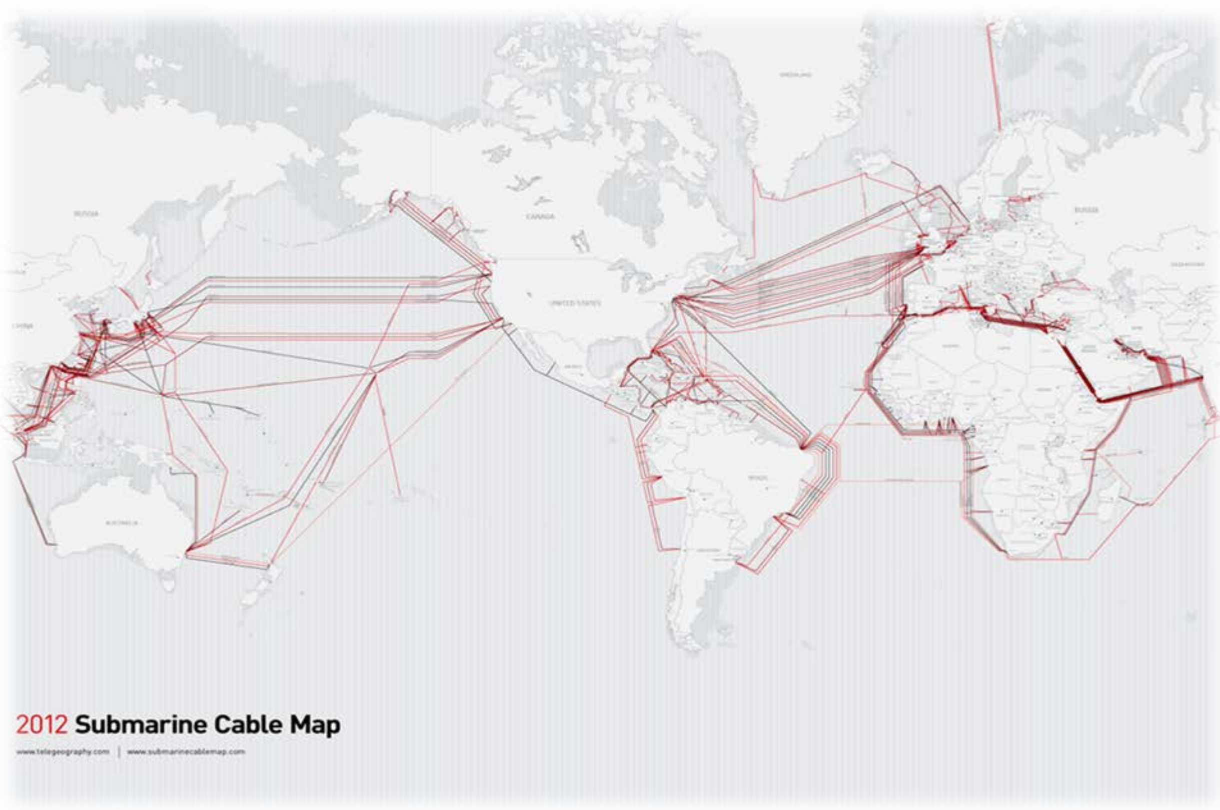


Figure 1 – 2012 Submarine Cable Map

The longest operating fibre system in the world is the "Fiber-Optic Link Around the Globe (FLAG)" system from Japan to Europe, a total of 28,000 km including spurs to India. An extension of the FLAG system connects North America with Europe.

Fibre Optic Systems Capacity - Each fibre optic pair can accommodate up to 128 individual optical channels, each operating at a different optical wavelength. The "stacking" of these channels on a single fibre optic pair is called Dense Wavelength Division Multiplexing (DWDM). Each optical channel can currently support communications up to 40 Gbit/s.

Elements of a Marine Fibre Optic System

The elements that comprise a marine fibre optic system include:

- Optical Fibre Cable
- Terminal Equipment
- Undersea Repeater Equipment
- Land Based Regenerating Stations
- Fibre Branching Units
- Powering Systems (configured both as end to end feeds and intermediate feeds)

The installation of fibre optic cable is typically divided into the following sections:

- Deep sea cable laying
- Near shore and shallow water cable laying
- Cable Landings, and approaches to landing sites

In the determination of the overall fibre optic systems architecture, the following elements are considered:

- The final system configuration, operating at the full design capacity of the system, including locations to be served in future expansion plans.
- The initial system configuration, so that initial system cost is minimized without compromising the expansion to the final system architecture.
- System reliability (including ring architecture, route diversity and alternative backup technology options).
- System maintenance options (including cable repair strategies, and the maintenance of terminal equipment and powering sub systems).

Fibre Optic Cable

Over 70% of damage to optical fibre cables worldwide has occurred close to the shore, or in relatively shallow areas where bottom fishing activity is significant. As a result, a variety of armoured cable types are used close to the shore, with lightweight cable being utilized for deep sea sections.

Figure 2 shows typical cable construction alternatives. Table 1 shows the typical cable depths that are often employed for each cable type.

Figure 2 – Fibre Optic Cable Armouring

Cable Type	Typical Installation Depth
Double Armoured	0 - 400 m
Single Armoured	400 – 1,000 m
Lightweight Armour	1,000 – 1,500 m
Lightweight	Below 1,500 m

Table 1 – Typical Cable Installation Depths

Terminal Fibre Optic Equipment

Terminal equipment is typically housed in a temperature controlled environment at intermediate and end point locations of the fibre optic system. Often, this is close to the landing points, although this is not a technical requirement. Terminal and intermediate electronic equipment is also sometimes located with a "point of presence" (POP) location for connection to a local distribution network.

Redundant standby power equipment is usually provided in the form of backup generators.

Maintenance, system monitoring and fault finding equipment is also typically provided at terminal equipment locations.

The key elements of a terminal equipment site include:

- Dense Wavelength Division Multiplexing (DWDM) equipment, although only one optical channel may be equipped initially.
- Power feed equipment, to feed undersea repeaters and associated equipment.

- Reconfigurable Optical Add Drop Multiplexers (ROADM) equipment. This is an optical add-drop multiplexer that can remotely switch traffic from a DWDM system at the wavelength layer. This allows individual or multiple wavelengths carrying data channels to be added and/or dropped from a transport fibre without the need to convert the signals on all of the WDM channels to electronic signals and back again to optical signals.
- Performance monitoring and fault location equipment. For determining the distance to a break in an optical fibre at a remote location, an Optical Time Domain Reflectometer (OTDR) is used. This is the optical equivalent to an impedance test in a copper cable. An OTDR can locate a break to an accuracy of 0.01% of the actual fibre length.

Figure 3 shows a typical Fibre Optic Terminal Equipment at an intermediate location:

Figure 3 – Fibre Optic Terminal Equipment

<u>Undersea Repeaters</u>

The installation and testing of fibre optic splices together with undersea repeater equipment is typically carried out on board a cable laying ship prior to cable installation. The key elements of undersea repeater equipment include:

- Erbium Doped Fibre Amplifier (EDFA) equipment - this is an optical amplifier that amplifies an optical signal directly, without the need to first convert it to an electrical signal.
- A power source, that is typically provided by current from either a centre conductor in optic fibre cable, or by a copper tube that contains the fibres.
- For improved reliability, redundant electronics are provided in repeaters and powering sub systems.

The typical repeater spacing on a long haul fibre optic system is between 60 km and 100 km and is dependent on the distance between terminal and regeneration locations. The maximum unrepeated span length is in the order of 400km.

Figure 4 shows examples of splicing and repeater housings:

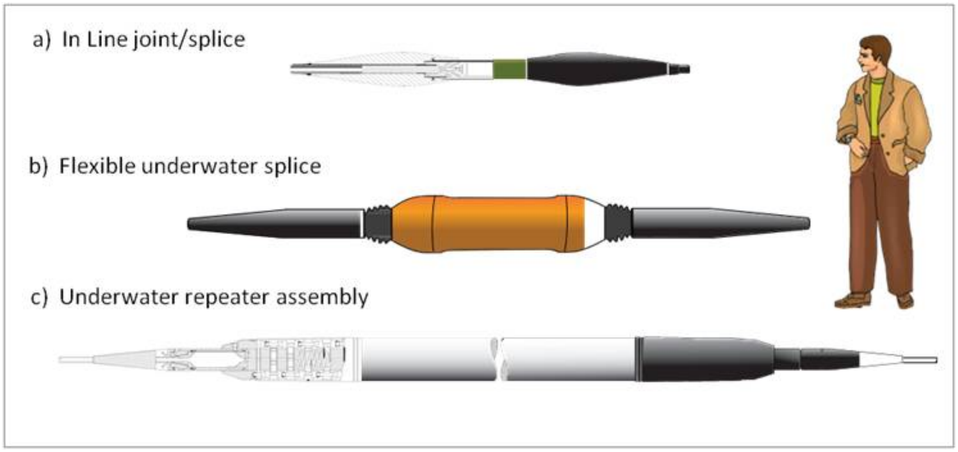
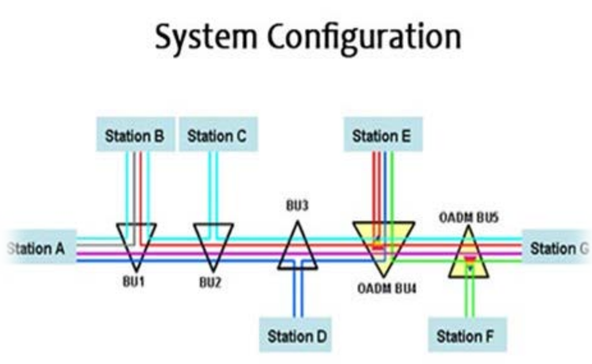


Figure 4 – Undersea Splice and Repeater Housings

<u>Submarine Branching Units</u>

A submarine branching unit allows a fibre optic cable system to split in order to serve more than one destination. For example, one branch might head for a landing point with other feeds providing service for continuation of the backbone route. With one incoming feed, a maximum of three additional feeds are possible. Branching units may be either active or passive, and can utilize either electrical or optical switching equipment.

Figure 5 shows a typical branching network architecture, and Figure 6 shows a schematic example of a branching unit installation.



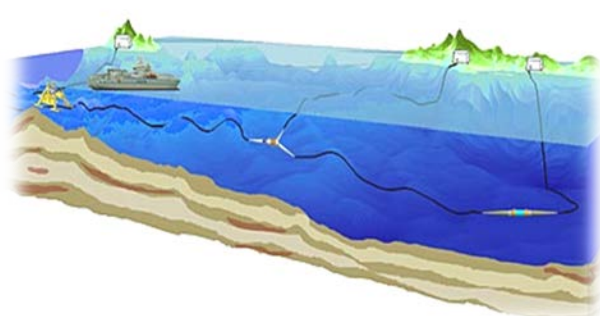


Figure 5 – Branching Unit Architecture **Figure 6 – Branching Unit Installation**

Fibre Optic Cable Installation Techniques

The installation of optical fibre cable uses three basic techniques:

1. Horizontal Drilling – this technique is the most expensive on a per km basis (in the order of $4M to $8M per km, depending on the underlying geology) and is typically used at landing sites. Under normal conditions, the objective is to exit the sea bed at a depth of at least 20 to 25 metres below the low tide level. Figure 7 shows a typical horizontal drill rig.
2. Underwater Plowing Technique – this technique uses a custom designed underwater cable plow (shown in Figure 8) to place the cable in a trench of between 1.2 to 2.0 metres below the sea bed. The plow is towed directly behind a cable ship or, in restricted waters (or waters with exceptionally high tidal races) behind a purpose build cable laying barge that is towed by one or more tug boats. In iceberg-prone areas, a plow technique could be used from the end of the horizontal drill to a water depth of up to 250 metres.
3. Direct laying on the sea bed – this is the most cost effective technique for laying cable in blue water.

Figure 7 – Horizontal Drill Rig

Figure 8 – Underwater Cable Plow

Choosing the Route of the Fibre Optic Cable

A critical technical requirement is that the cable lay directly on the sea bed. If the cable is suspended between sea bottom outcrops, it will chafe and fail. For this reason, the length of the cable route is almost always longer than the direct distance between two repeater or terminal equipment locations.

A key criterion to determine the most appropriate routing for the cable is the availability of accurate and current bathymetry data. This information is usually obtained during the marine survey portion of the project that is conducted before the final design is submitted for approval. Figure 9 shows a schematic of a cable survey ship using a scanning technique to determine the bathymetry of a possible route.

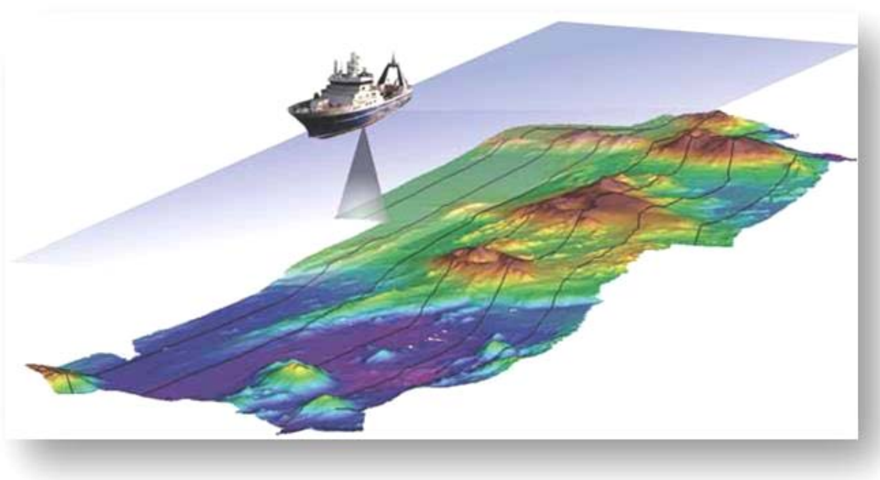


Figure 9 – Hydrographic Survey Schematic

<u>Typical Cable Installation</u>

A typical cable installation is shown in Figure 10.

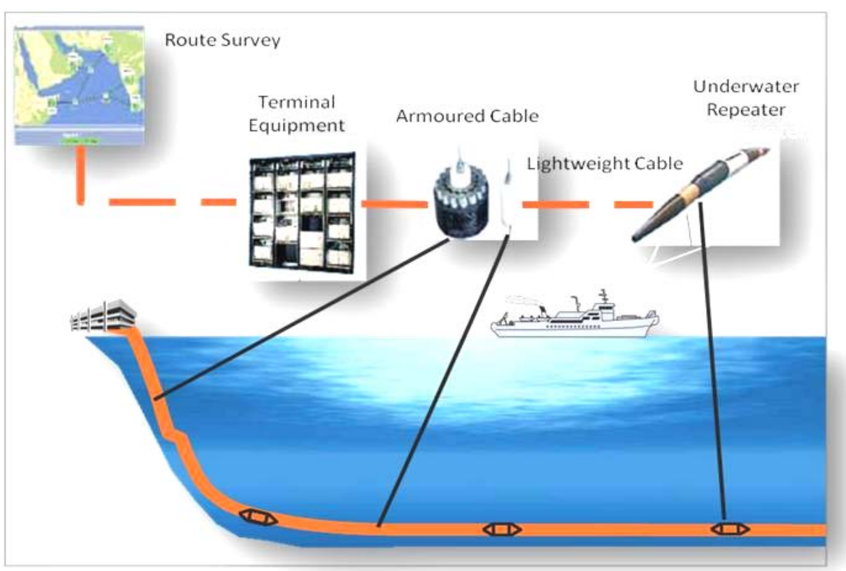


Figure 10 – Typical Fibre Cable Installation

Technical Challenges – Installation of Fibre Optic Network in Nunavut

This section of the report firstly addresses the design and operational challenges that are presented by any new marine fibre optic network, and then addresses the challenges that are unique to the arctic environment in Nunavut.

Network Design Challenges for any New Marine Fibre Optic System

The following design challenges need to be addressed for any new fibre optic cable network:

- A clear understanding of the final configuration of the network, and the final capacity requirements. This network architecture will determine the location of branching points, the configuration of the powering sub system, the location of land based regeneration points, the number (and type) of undersea repeaters etc.

  It is almost always more cost effective to install all of the branching units (often equipped with cable stubs) during the initial installation than later in the life of the system.

  The powering sub system is also designed for the final configuration and final capacity. This includes the future location of additional sites that could be used as alternative intermediate power feeds. This provides power redundancy in the event that a segment of the main powering system fails.

- The design then needs to consider the initial requirements, and the most cost effective expansion strategy as the system grows.
- Both the initial and final design configurations need to consider the interconnection points of the proposed system with either a local distribution network, or other operators systems at the end terminal locations, together with a robust business and administrative operating model.
- Accurate bathymetry data, and up to date nautical charts are then used to generate a "desk top" study to evaluate alternative network configurations. Key evaluation parameters are:
  - Network Reliability – an assessment of alternative routings (sometimes using alternative technologies) in the event of a fibre break. The result of this analysis would be a system performance specification both in term of the availability of the system, and the day to day error rate performance.
  - Performance Monitoring - usually performed on a 24/7 basis at a remote centre.

  - Maintenance Strategy – how to deal with both land and undersea technical failures. This includes estimates of the expected "mean time between failures," access to both the land based equipment and a strategy for dealing with undersea fibre breaks.
- Environmental Review and Permitting – this activity generates a list of all of the reviews and permits that are required to install, commission, and operate the system. An estimate of the cost and scheduling implications is then assigned to each environmental review and permit application.
- Putting all of the above considerations together to generate cost and schedule alternatives.
- The next stage is usually a detailed marine survey to verify the assumptions made in the desk top study. At this point, an engineering report is usually generated for the client's approval, with firm cost and schedule estimates.

Additional Technical Challenges in Nunavut

With the exceptions of the TELE Greenland system from Milton, Newfoundland to Nuuk, Greenland (2050 km), the Telenor system from Harsted, Norway to Svalbard, Norway, (1375 km with 172 km of this buried), the Alaska United fibre optic cable network that connects Anchorage, Fairbanks and Juneau to Seattle (4,988 miles undersea, 982 miles overland), and the Alaska Communications Systems network from Anchorage to Oregon (2,900 km), no other commercial marine fibre optic systems have been installed in the far north.

The key technical challenges in Nunavut revolve around:

- Climatic, ice and tide issues
- The isolated nature of the network and the potential difficulty of access, repair and back up facilities
- Sensitive environmental areas
- The lack of accurate bathymetry and nautical chart information
- The cost of providing a network for a relatively small telecommunications demand profile

On the positive side, the arctic environment has the following advantages:

- Low shipping and bottom fishing activity (this is the principal cause of fibre cable outages)
- Low area of seismic activity
- A cold water (and relatively benign) environment for the undersea electronics and cable

Aside from the business aspects of a fibre network, the Feasibility Study technical team believes that these challenges can be addressed with either existing technologies, or modifications to existing practices based on potential pilot projects to reduce technical risk.

The four key technical issues are cable installation, cable maintenance in the event of a fibre break, environmental review and permitting, and system reliability.

Cable Installation

- Ice conditions - Sea ice cover is an impediment to cable laying activity as well as maintenance and repair. Although ice breakers can extend the construction season somewhat, heavy ice broken by an ice breaker is a threat to the cable since roiling of ice floes in the wake of the laying ship can cause damage to the cable before it is safely below the zone of ice impact.

  A key characteristic of recent climatic change is an increase in the unpredictability of ice conditions. This represents an additional degree of uncertainty with respect to the start and end of a possible cable laying season.

  The shutdown of work after only two or three months at sea is a further complication since marine mobilization costs are very high. Cables may have to be cut and marked for later pickup and splicing in the ocean, and the ship has to transit out of the area before being stranded by the ice. It has to get to a port where it can offload and reload for its next assignment and then be ready to remobilize when conditions permit but there may be delays from the last project. Cable laying ships have been fully booked in recent years and costs have escalated in response to the demand.

- Ice scouring - Polar icebergs can be very large and will scour the ocean floor several kilometres out from land in shallower waters. A cable in the risk zone will very easily be broken by the passing iceberg. Under normal circumstances, the cable ship's on-board plough will be able to bury the cable on the sea bed to a depth of around 2.0m. However, this is not possible in rocky bottoms.
- Tides and currents – Very high tides and currents are characteristic of Frobisher Bay and some other locations. Marine cable installations have been performed in areas of high tides and current, but specialized equipment is needed together with tugs. The Canadian Hydrographic Service has used both modeling techniques, together

with surface and underwater measurements to better understand the characteristics of tidal races.

- Lack of accurate bathymetry data – This risk can be mitigated by a marine survey, either from a specialized marine survey vessel, or be using an Autonomous Underwater Vehicle (AUV). AUV's have been successfully employed by the Canadian Department of Defense under sea ice, and have a range of over 200 km.
- Lack of up to date nautical charts.

Cable Maintenance

- Cable repair in the event of a fibre break - A fleet of repair ships is constantly at work around the globe attending to the repair of submarine cables. Cables can break, undersea repeaters can fail and branching units can take on water. In the arctic, the added complication is obviously the problem of access if the failure occurs when the sea is covered with ice. It may be weeks or months before the cable can be fixed. Cable is normally repaired by grappling the two broken ends in turn and bringing them to the surface to splice in a new length of cable. It may be possible to do this by working through holes in the ice but to the best of our knowledge it has never been done.

Environmental Review and Permitting

A potential Fibre Optic Project would fall under the jurisdiction of several Federal and Territorial Departments in additional to local Municipalities. The following list is based on a preliminary analysis of departments that may have involvement. However, there is no precedent for a fibre cable network in Nunavut.

- **Federal Departments**
    - Fisheries and Oceans
    - Aboriginal Affairs
    - Industry Canada
    - Environment Canada
    - Natural Resources Canada
    - Foreign Affairs
    - Canadian Radio and Telecommunications Commission
- **Nunavut Settlement Area**
    - Responsibility for coordination falls under the authority of the Nunavut Impact review Board (NIRB)

- **Local communities**
  - Proposed land and foreshore route drawings will need to be submitted to the local administration officer of each community for the approval of cable routes, and any associated infrastructure, such as equipment shelters, power equipment etc.
- In addition to the marine environment, individual consideration will need to be given to each proposed landing.

The following maps shows examples of sensitive environmental areas:

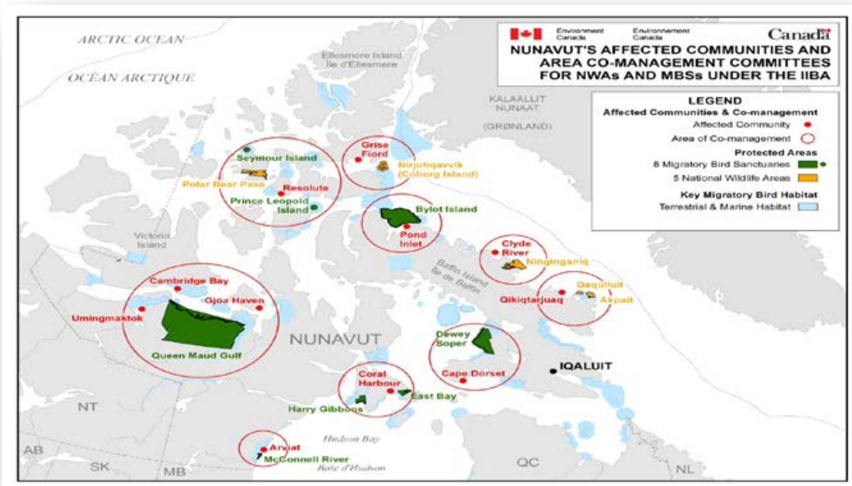


Figure 11 – Environment Canada Map of Designated Habitat Areas

Figure 12 – Parks Canada Proposal for a National Marine Conservation Area

System Reliability

1. Overview of Cable Breaks History.

   There is considerable data on the history of fibre cable breaks worldwide. Figure 13 shows the breakdown of causes of fibre breaks (as of 2009), and Figure 14 shows the compilation of external cable faults from 1959 to 2006. Component and splice failures account for less than 8% of cable outages.

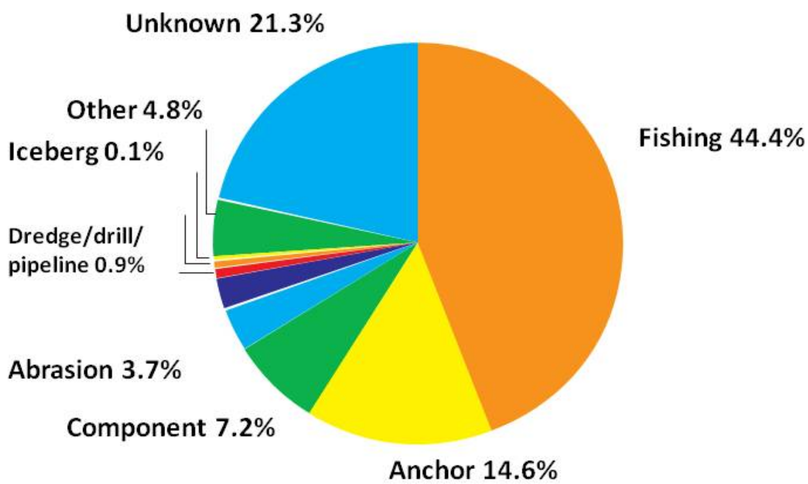


Figure 13 – History of Causes of Fibre Marine Cable Breaks (up to 2009)

Figure 14 – Global Pattern of External Marine Fibre Cable Breaks

2. Recent Northern Fibre Cable Breaks – details of recent cable breaks in the north are shown below:
   - NorthwesTel (for the years when the information is available)

     2009 4 breaks – 3,837 km route length.
     Causes: 2 x road construction
     1 x Environmental Crew doing test boring work
     1 x truck in ditch during spring break up

     2011 4 breaks – approx 6,000 route km

     Typical time to repair – less than 24 hours

   - TELE Greenland – The Milton, Newfoundland to Nuuk Greenland link was implemented in 2009. The system extends to Iceland, with onward connection (with a different network operator) to the Faeroe Islands and the UK.
     - 3 breaks to date, all in the vicinity of Nuuk.
     - All caused by icebergs crossing the cable route at approximately 13 m water depth.
     - TELE Greenland plans to implement a horizontal drilling project this summer (2012) for an extension into the bay to a water depth of 200m.
     - Summary:
       - 3 breaks, 4,598 route km, in three years.
       - Average – 0.22 breaks per 1,000 km, per year.

3. Repair of Marine Cable Breaks

   The typical time to repair an underwater cable break is a minimum of 10 days, assuming that the site of the break is accessible and that a cable repair ship is within 2 days sailing of the break.

   Figure 15 shows an intermediate step in the cable repair process. The location of the break has been identified and the cable has been severed close to the break. One end of the cable has been buoyed and the section of the cable with the fault is in the process of being retrieved. Once repaired, the cable is re-laid either in a trench or on the sea bed.

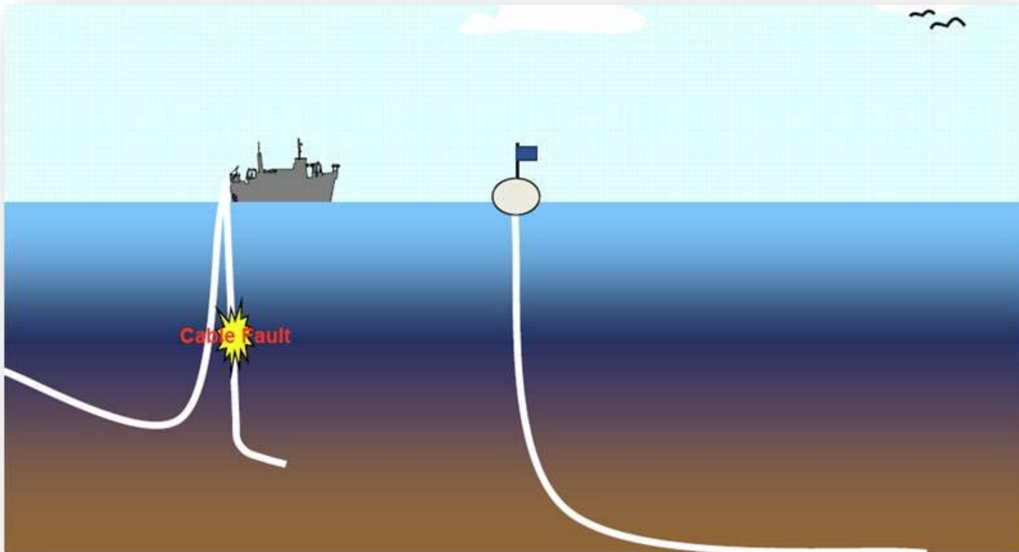


Figure 15 – Repair of an Undersea Cable Fault

4. Network Architecture Considerations – There are four network architecture techniques used to mitigate the risk of a fibre break:
   - Typically, fibre systems are implemented with a long term objective of a network ring architecture to increase the availability of the system in the event of a break. For principal routes in both marine and land based applications, the concept of a ring architecture is often extended to incorporate a "nesting" of ring configurations, with a number of entry ports. This provides for an extremely robust and reliable overall network architecture.
   - In order to connect to the ring, there are two principal network alternatives:
     - A "Festoon" type of connection. In this option, an add drop multiplexer (ADM) is provided on the main fibre ring line at an intermediate location.
     - A Branching Unit – in this option, an undersea branching unit is typically provided to feed an intermediate location. This alternative has the advantage that, in the event of a failure on the individual fibre branch, the main optical fibre line is unaffected.

- Route Diversity – In this alternative, a separate fibre cable in installed on a completely separate route. An automatic switching facility is provided at the end locations so that, in the event of a failure, traffic is automatically switched to the independent system.
- Technological Diversity – available backup systems using independent technical options.

Summary of Risk Mitigation Alternatives

- Fibre Ring Architectures - including the eventual provision of a nested ring structure with multiple entry points.
- Route Diversity – at a systems level, this means the provision of an independent system routing alternative. For local situations, particularly close to landings, where there is significant vulnerability to potential cable breaks, two separate cable routings to separate landing points are often considered.
- Technological Diversity – During the initial construction phase of a network, it is usually impractical and costly to construct redundant systems at the same time. The alternative is to leave in place the former communications system (satellite and/or digital microwave) until the reliability of the fibre system has been demonstrated.
- Branching Networks – means that a failure on a branch connection does not compromise the main fibre link.

Section 5 – Existing and Planned Northern Fibre Optic Networks

This section firstly describes existing northern fibre optic networks that have been installed in Canada (or with a terminal point in Canada). The second part of the section describes plans that have been proposed for future fibre cable networks.

The following northern fibre optic networks have been installed in Canada:

- Northwest Tel – links in the Yukon, Northwest Territories (NWT) and northern British Colombia (BC).
- Manitoba – Link to Churchill, Hudson's Bay. This is a joint Manitoba Hydro/MTS Allsteam link.
- Quebec – Link to Radisson (near Hudson's Bay). This system has recently been extended to the shores of James Bay at Chisasibi, and is part of Quebec's Plan Nord initiative.
- TELE Greenland – Link from Milton, Newfoundland to Nuuk, Greenland.

The Alaska United Fibre Optic Network extends from Fairbanks, Alaska to Seattle, Washington. A second Alaska fibre optic network, operated by Alaska Communications Systems, extends from Alaska to Oregon.

<u>NorthwesTel</u>

NorthwesTel has a combination of "owned" fibre links in Yukon and NWT together with an Indefeasible Right of Use (IRU) for one of two fibre connections to southern Canada.

- NorthwesTel has implemented a fibre ring architecture for improved reliability.
- In most cases, a digital microwave link has been left in place as a backup.
- 2012 plan – to extend the fibre link from Carmacks, Yukon to Dawson City, Yukon.

Figure 16 – Map of Fibre Links in Yukon and NWT

TELE Greenland

TELE Greenland's existing fibre optic link (Greenland Connect) is shown in Figure 17, and is depicted in black:

Figure 17 – TELE Greenland's Existing Fibre Optic Network

Alaska United Fibre Ring Network

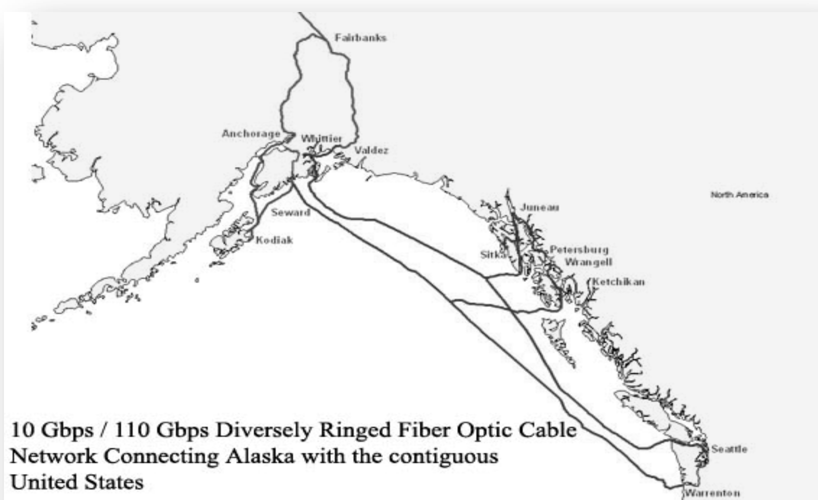


Figure 18 – "Alaska United" Fibre Ring Network

The following fibre optic networks have either been planned, or proposed by a number of different proponents:

- Mackenzie Valley Fibre Link (MVFL) in Northwest Territories linking the southern NWT fibre network with Inuvik, with an extension to Tuktoyaktuk.
- Arctic Link – an Asia-Europe proposal through the Canadian Arctic. Two proposals have been made, one following a northern routing through the McClure Straight and Lancaster Sound, and a subsequent routing following a more southerly route through the Coronation Gulf.
- NorthwesTel has identified two routing alternatives, one leveraging the proposed routing of Arctic Link, and the second serving Nunavut communities using a "Festoon" network architecture.
- Arctic Fibre – a recent proponent using a southern routing with a proposed land crossing across the Boothia Peninsula.
- Extension of the TELE Greenland network to serve domestic communities on Greenland's western coast.
- A northeastern passage routing, connecting England, Japan, China and Russia through cable stations in the cities of Bude (England), Tokyo (Japan), and Russia's Murmansk, Vladivostok, and Anadyr has recently been tendered (January, 2012) by the Russian Optical Trans Arctic Submarine Cable System (ROTACS).

Mackenzie Valley Fibre Link (MVFL)

A Feasibility Study has been completed for this project, and the Government of the Northwest Territories (GNWT) is in the final stage of a Business Case Review.

The GNWT formally adopted the MVFL as a project in March, 2012. The GNWT has identified the MVFL as one its three infrastructure priorities for the 17th Session of the Legislature. The proposal is to use a Public Private Partnership method to fund and execute the project.

The estimated cost of the link from southern NWT to Tuktoyaktuk, including environmental review and permitting is approximately $65M. Approximately two thirds of the route follows an existing Winter Road right of way to Fort Good Hope. The time to complete is estimated to be two years (at least two winters and one summer) from the date that the permits are received.

Figure 19 shows the proposed route of the MVFL:

Figure 19 – Proposed Route of the Mackenzie Valley Fibre Link

<u>Arctic Link Proposals</u>

Arctic Link is an initiative of the Arctic Cable Company LLC and the Great Pacific Cable Company (which, in turn is sponsored by the Kodiak Kenai Cable Co {Alaska} and KnaNNet). The initial proposal was for a northern route, as shown in Figure 20.

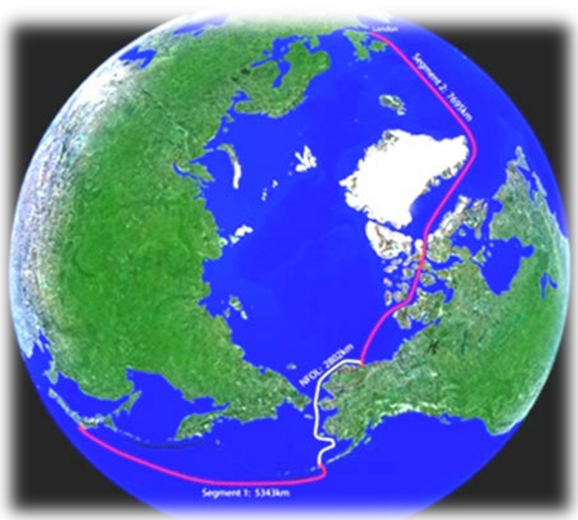


Figure 20 – Northern Route Proposal of Arctic Link

A subsequent proposal utilized a more southern routing, as shown in Figure 21.

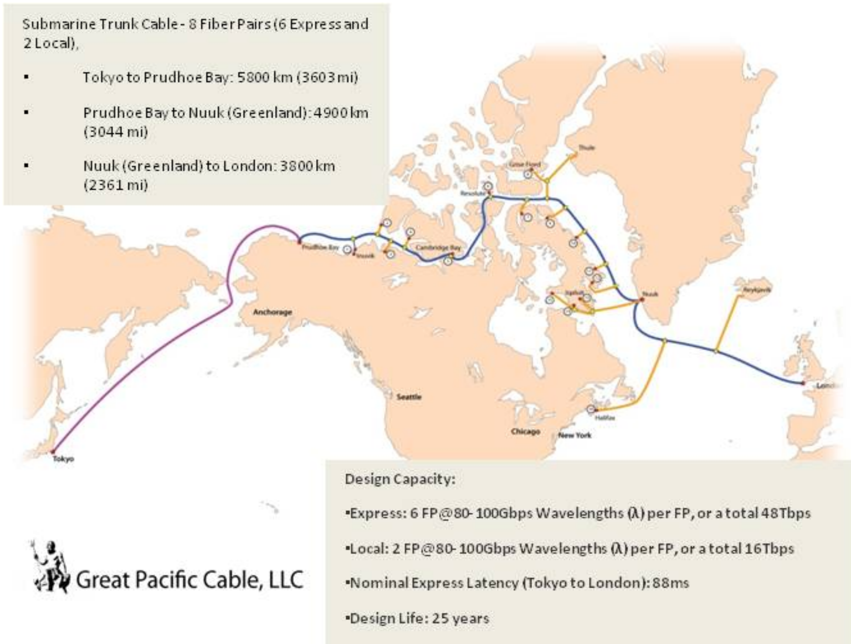


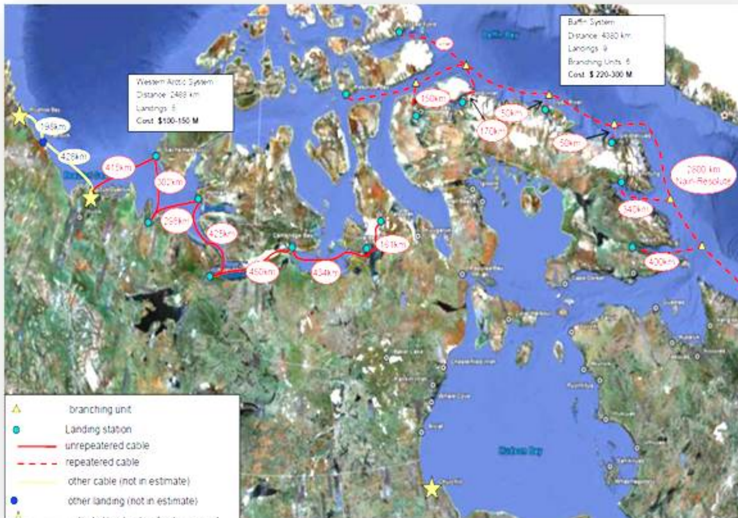
Figure 21 – Southern Route Proposal of Arctic Link

<u>NorthwesTel Network Proposals</u>

The following network alternatives have been identified by NorthwesTel

A system alternative that takes advantage of the northern route option of Arctic Link

Figure 22 - NorthwesTel, Connection to Arctic Link



A proposed "Festoon" system architecture serving northern Nunavut Communities

Figure 23 – NorthwesTel Northern "Festoon" Network Architecture

A network option serving southern Nunavut communities, including those located on Hudson's bay.

Figure 24 – NorthwesTel Southern "Festoon" Network Architecture

<u>Arctic Fibre Proposal</u>

In January 2012, Arctic Fibre announced an Asia to Europe Fibre Optic network proposal that uses a southern route and a short land/lake crossing across the Boothia Peninsula. The estimated end to end system cost, including a regeneration station at Cambridge Bay was $640M. Figure 25 shows the proposed system routing:

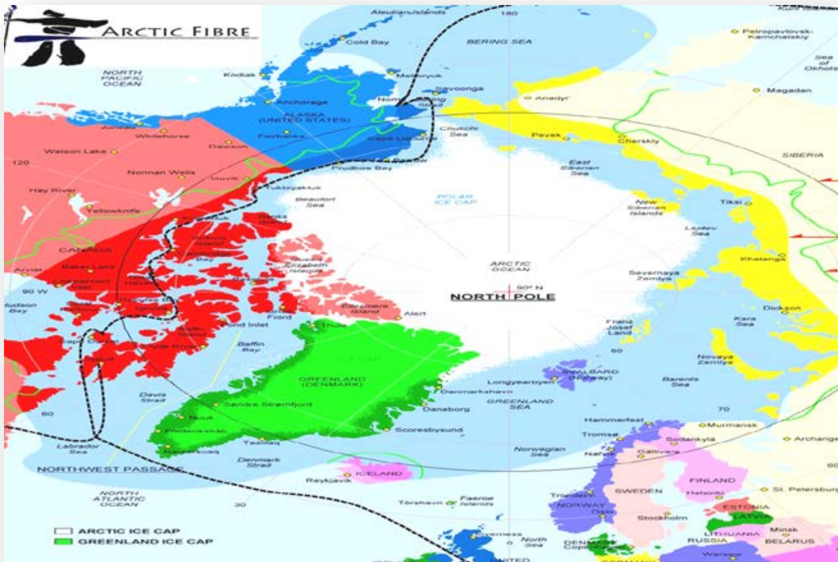


Figure 25 – Arctic Fibre Proposed System Routing

Phase 1 of the Arctic Fibre proposal calls for the installation of a fibre cable from Milton, Newfoundland to Iqaluit, NU. The announced “Ready for Service” date is 4th Quarter 2013.

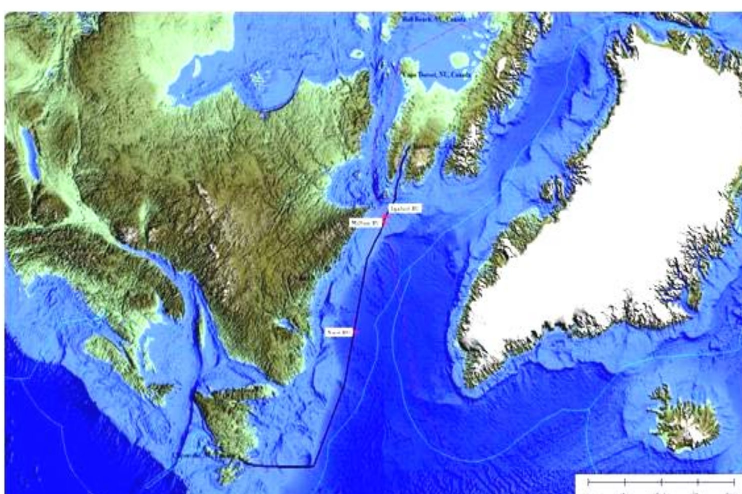


Figure 26 – Phase 1 of Arctic Fibre Proposal

End to end service (Asia to Europe) for the Arctic Fibre proposal has an announced "Ready for Service" date of 4th Quarter, 2014.

Arctic Fibre has also proposed a secondary network, shown in Yellow on Figure 27. Arctic Fibre has indicated that this network addition is contingent on Government support.

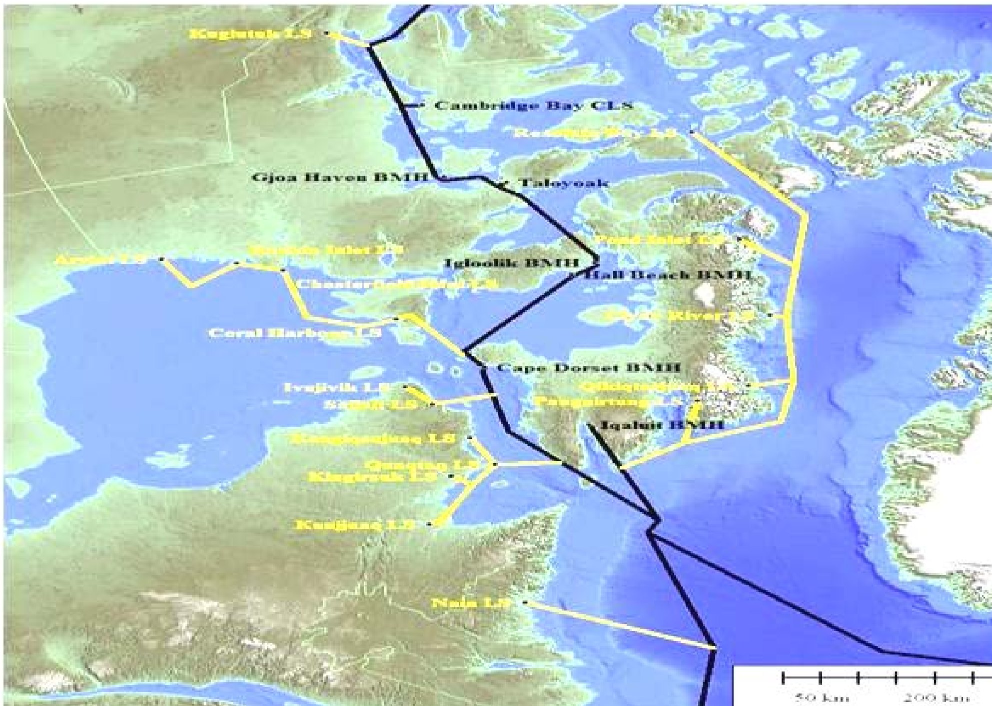
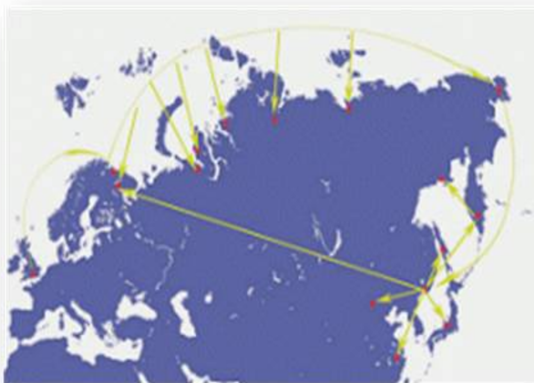


Figure 27 – Arctic Fibre Proposed Primary Canadian Network (in black) and Secondary Canadian Network (in Yellow).

<u>Russian Optical Trans-Arctic Submarine Cable System</u> (ROTACS)

In January, 2012, supply tenders were announced for the Russian Optical Trans Arctic Submarine Cable System (ROTACS) telecommunication project intended to connect Europe and Asia via Murmansk. At the first stage of the project implementation, 6 fibre pairs of an undersea 17,000 km-long cable system are planned to link England, Japan, China and Russia through cable stations in the cities of Bude (England), Tokyo (Japan), and Russia's Murmansk, Vladivostok, and Anadyr. The estimated cost of this phase is $860 million.



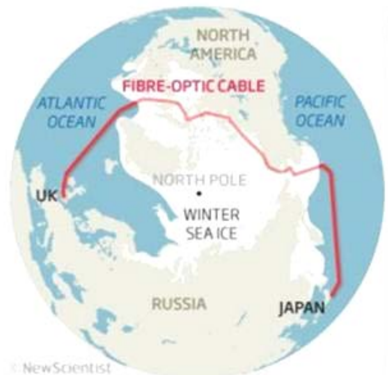


Figure 28 Russian Fibre Optic System

<u>TELE Greenland Expansion Plans</u>

TELE Greenland has announced a domestic expansion of their fibre network as shown in Figure 28:

Figure 29 – TELE Greenland Domestic Expansion Plans

Section 6 – Possible Landing Points

The Feasibility Study has considered four landing point locations:

- Iqaluit
- Rankin Inlet
- Cambridge Bay
- Resolute Bay

Details of the analysis for these landing Points are included in the Feasibility Report Technical Study, shown in Attachment 2.

Iqaluit Landing

Two diverse paths are proposed from the inlet into Iqaluit and the cable would need to be buried in the bed of the inlet for an estimated 7km from Iqaluit to minimize the risk of damage by ice, fishing and anchorages. Two directional drill shots are recommended from the shore into deeper water. The drill on the west side would need to be about 400m long and the east side about 1,000m. The two beach manholes would be linked via terrestrial cables installed to a single point of presence (POP) near the centre of town.

High tidal current and races are an issue near Iqaluit. The range is 11.1m according to the Canadian Hydrographic Service (CHS) with an extreme high water mark (HHWLT) in the island group 60km south of Iqaluit of over 12m above chart datum. CHS have run computer modelling of the flows and estimate that, in the narrowed channels between the island groups, the mean current velocities would reach between 4 and 11 knots depending on the channel.

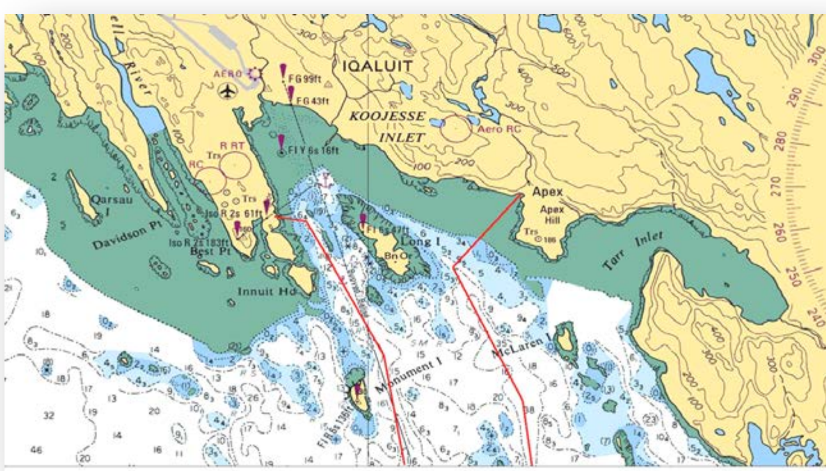


Figure 30 – Proposal for Iqaluit Landing Point (please see note on chart in Attachment 2)

Rankin Inlet

Rankin Inlet is characterized by a relatively shallow depth of water that extents out some 40km to Marble Island in Hudson's Bay. The tidal range is 4m. There is also an issue (common to a number of Nunavut communities) of the changeable nature of the sea bed due to the movement of sediments by currents. There are therefore risks that a deeper channel identified in one year may have moved the next. As a result of the above concerns we have proposed that Rankin Inlet be served by a single cable from a branching unit rather than risk the main ring being lost if the cables coming to shore at this point were to be damaged. We have proposed Chesterfield Inlet as the better location for a regeneration facility equipped with diverse shore landings. It is estimated that a 500m-long drill shot from Fist Point would terminate in approximately 12m of water.

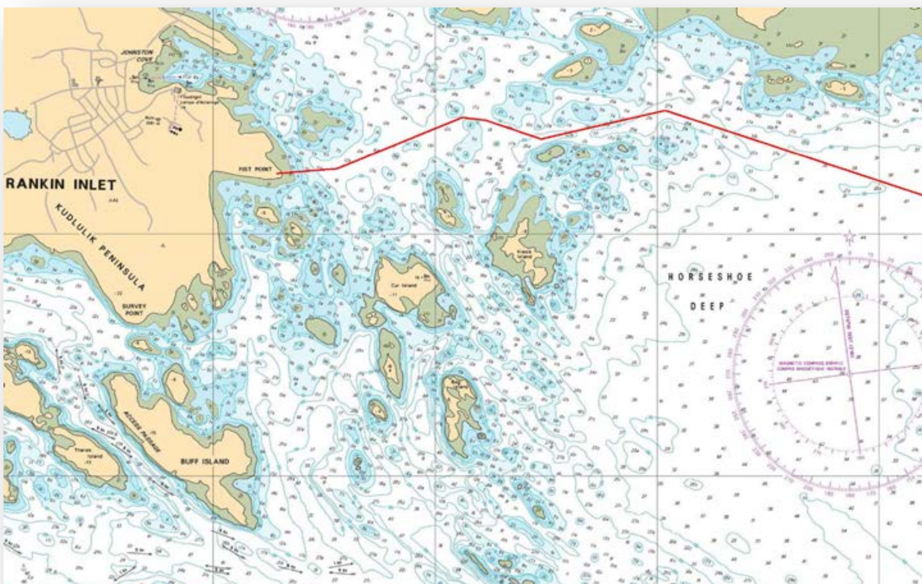


Figure 31 - Rankin Inlet Landing Point
(see note on chart in Attachment 2)

Cambridge Bay

There is a deep water channel that runs into Cambridge Bay itself and it should be possible to accommodate separate east and west cable links from the main backbone ring into a regeneration facility in the community via a terrestrial cable linking the two shore ends. Short drill shots from the shore of perhaps 150 to 250m in length should place the cable into deep water.

The Dease Strait approach to Cambridge Bay is narrow and is characterized by relatively shallow waters and ice build-ups. It may require quite extensive distances of ploughing to properly protect the cable.

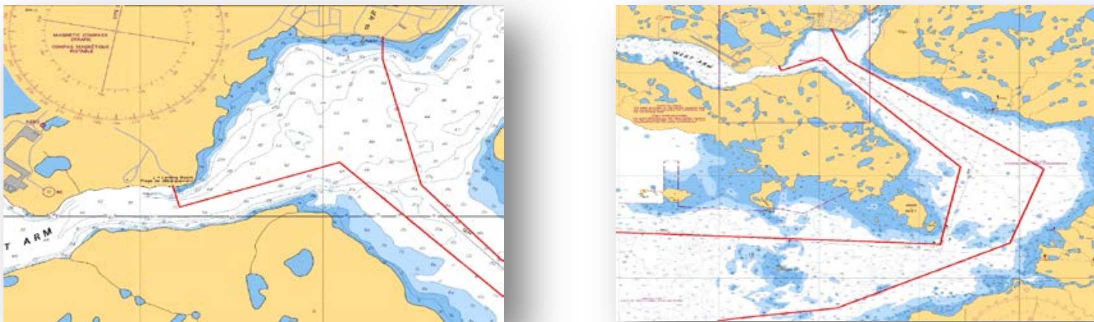


Figure 32 – Cambridge Bay Landing Proposal
(see note on chart in Attachment 2)

<u>Resolute Bay</u>

Two diverse cable paths are proposed to a regeneration site in the hamlet. A cable from Pond Inlet could come ashore due south of the airfield and Resolute Lake. A shore drill shot at this point would need to be about 700m long to reach 20m water depth. A westerly route towards Cambridge Bay could come ashore to the west of the airfield where a 900m directional drill would reach about 20m of water. A further 2 or 3 km of subsea ploughing from the end of either drill shot should reach 100m of water depth.

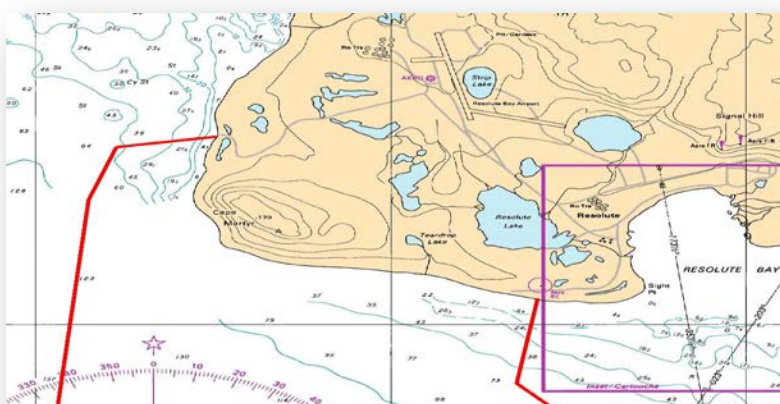


Figure 33 – Resolute Bay Landing Proposal
(see note on chart in Attachment 2)

Section 7 - Review of Possible Fibre Optic Network Configurations for Nunavut

Methodology

The Feasibility Study analysis is based on the requirement to provide a fibre optic connection to all 25 communities in Nunavut.

A number of alternatives can be derived from this baseline analysis. The Feasibility Study then considers a network architecture that provides service to the regional communities of Iqaluit, Rankin Inlet, and Cambridge Bay with an extension to Resolute Bay.

A Rough Order of Magnitude (ROM) costing is derived for both network alternatives, based on the Feasibility Study's "desk top" analysis. It should be noted that this study did not include a marine survey, a geological survey or any visits to potential route locations. Further details of the Technical Analysis are shown in Attachment 2.

In Section 8, a preliminary risk analysis is considered based, in part, on the Government of Canada's "Project Complexity and Risk Assessment Tool." A risk premium is estimated for both network alternatives, and risk mitigation suggestions are made in the Next Steps section of the Feasibility Study to reduce the amount of this risk premium.

Section 9 considers alternative and complementary telecommunications technologies. Advances in satellite technologies (including high throughput satellites) and trends in digital microwave land based systems are reviewed. This leads to the long term possibility of a mixed telecommunications network for Nunavut.

The proposed fibre optic networks for Nunavut are based on the following considerations:

- A desk top study of possible cable routing options, and an assessment of the cost of horizontal drilling, undersea cable plowing and laying the cable directly on the sea bed.
- A proposed Nunavut network "ring" architecture that can be expanded to a "nested ring" configuration with multiple entry and exit ports. In the long term, this will have the potential to provide an extremely robust Pan Arctic fibre optic network architecture.
- Where possible, branching units to provide service to individual communities. This option provides a higher overall network reliability architecture. In most cases, in the event of a failure on the local branch, the mainline fibre system remains unaffected.

Proposed Network Configuration – Option 1

The schematic diagram (Figure 34) shows the proposed network architecture to serve all communities with fibre (assuming that Sanikiluak is more economically served from Nunavik). The proposed ring also includes some communities in Nunavik and Northwest Territories.

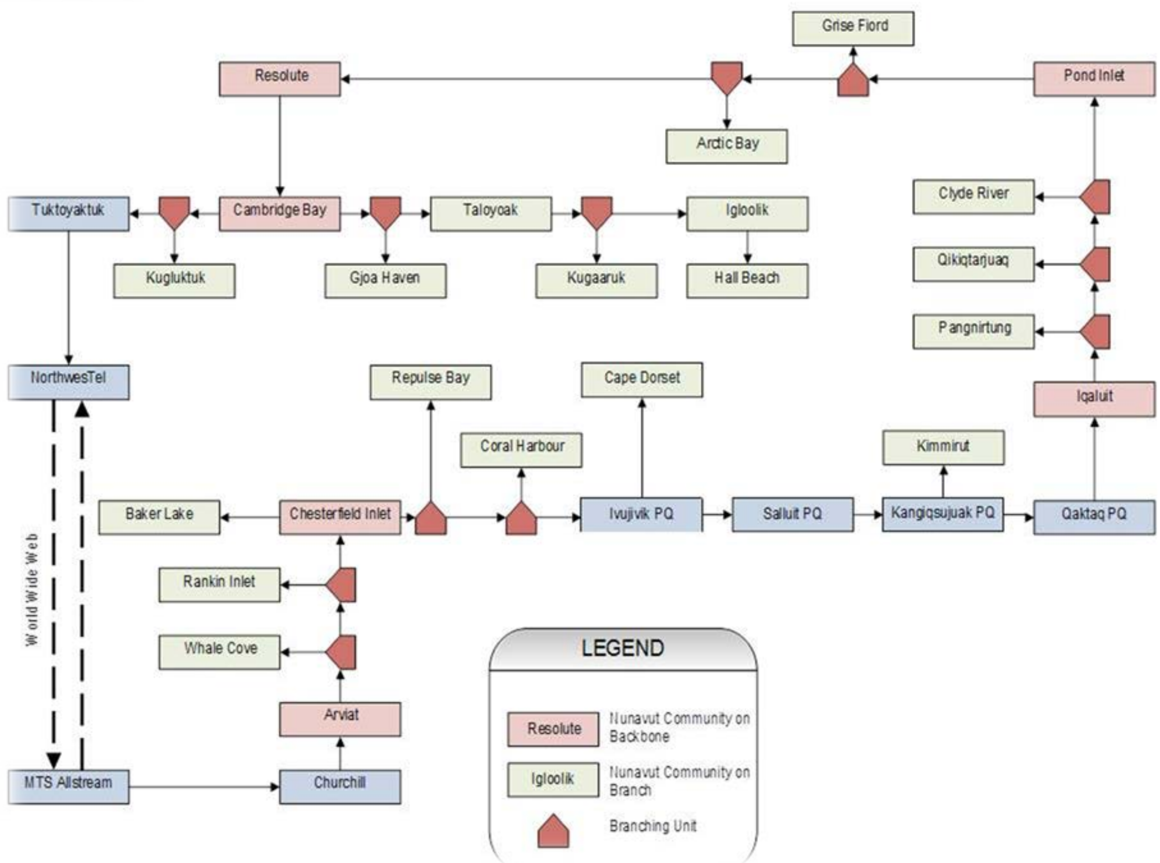


Figure 34 – Schematic of Proposed Network "Ring" Architecture for Nunavut

Three proposed connections to the mainland Canadian high speed fibre network can be made at:

- Churchill, Manitoba – connection to joint MTS/Allstream and Manitoba Hydro fibre link to Thompson.

- Tuktoyaktuk, NWT – the proposed Mackenzie Valley Fibre Link from Tuktoyaktuk to Checkpoint Junction, NWT (near Fort Simpson) for onward connection to the southern Canadian fibre optic network.
- Iqaluit, NU – two connection possibilities:
    - With the proposed Phase 1 of the Arctic Fibre system, from Iqaluit to Milton, Newfoundland.
    - With an alternative high speed fibre link from Iqaluit to Nuuk, Greenland for onward connection to Milton, Newfoundland.

This architecture provides redundancy through a "nested ring" topology, with possible connections to POP locations at High Level, Alberta; Winnipeg, Manitoba; and St John's, Newfoundland.

Geographically, the network is shown in Figure 35:

Figure 35 – Proposed Network "Ring" Architecture for Nunavut.

- The distance of the primary backbone network is 7,268 km
- The network spurs and local branching unit distances total 3,514 km
- The total distance of the proposed network is 10, 782 km

Note: This distance could increase following a detailed marine and geological route survey

Rough Order of Magnitude (ROM) Cost Estimate

We have estimated the construction cost of a backbone ring (Churchill to Tuktoyaktuk) and connections to all the Nunavut communities with the exception of Sanikiluak which we feel would only make economic sense if it were to be included with the Nunavik communities on the Ungava Peninsula of Quebec.

These costs do not include central office space for network monitoring and operations, back-office systems for customer service, provisioning and billing, or a maintenance centre for parts storage and equipment.

The ROM cost estimates includes:

- Marine survey including bathymetry survey, and determination of the conditions suitable for cable underwater plowing.
- Estimated cost for permits and land acquisition
- Shore buildings
- Terminal and intermediate electronic equipment
- Branching units
- Undersea repeaters
- Power equipment
- Fibre Optic cable (double armoured, single armoured, lightweight armoured and lightweight cable, as required)
- Shipping costs
- Installation and commissioning of land based equipment
- Installation of fibre optic cable (including horizontal drilling, undersea plowing and laying the cable directly on the seabed, as required)
- Undersea post installation inspection, using ROV's when required.
- Ice breaker support
- Spares and maintenance package

The total baseline ROM cost estimate for is $750M.

Table 2 shows the ROM cost estimate for the network:

No.	Description	Notes	Quantity	Unit	Rate	Total
1	Route marine survey/bathymetry & burial study	Omits easterly connection from Quebec	10,800	km	$ 3,750.00	$ 40,500,000.00
2	Permits and land acquisition	Allowance	1	LS	$ 10,000,000.00	$ 10,000,000.00
3	Backbone submarine cable lay – ocean going vessel	Placing 4f cable incl splice, test, spare joints	8,100	km	$ 2,000.00	$ 16,200,000.00
4	Laterals to shore - surface laid	Ditto using DP vessel	1,500	km	$ 20,000.00	$ 30,000,000.00
5	Laterals to shore - plowed below sea bed 1.5m deep	Ditto	1,200	km	$ 90,000.00	$ 108,000,000.00
6	Double Armour submarine cable	Assume 4f; one pair lit	8,750	km	$ 16,000.00	$ 140,000,000.00
7	Single Armour submarine cable	Ditto	1,500	km	$ 13,000.00	$ 19,500,000.00
8	Light submarine cable	Ditto	550	km	$ 8,500.00	$ 4,675,000.00
9	Shipping Cable		1	LS	$ 5,400,000.00	$ 5,400,000.00
10	Additional cost to add repeater (one fibre pair)	Includes submarine repeater	84	ea	$ 200,000.00	$ 16,800,000.00
11	Additional cost to add branching unit (BU)	Includes BU but not tail to shore	13	ea	$ 750,000.00	$ 9,750,000.00
12	Icebreaker support		200	days	$ 60,000.00	$ 12,000,000.00
13	Beach landing HDD shot in soft ground - 1 km long	Assume average 1000m shot incl materials	41	ea	$ 800,000.00	$ 32,800,000.00
14	Added allowance for beach landing HDD shot in rock	Assume average 1000m shot incl materials	10	ea	$ 1,800,000.00	$ 18,000,000.00
15	Supply and install (S&I) beach manhole (BM)		41	ea	$ 30,000.00	$ 1,230,000.00
16	S&I BU shore station – prefabricated building	Including genset but excluding SLTE & DC plant	30	ea	$ 1,600,000.00	$ 48,000,000.00
17	S&I Ocean Ground Bed (OGB)	Assuming 7 anodes in soils	41	ea	$ 200,000.00	$ 8,200,000.00
18	S&I OSP from BM to Landing Station and POP	Terrestrial build	50	km	$ 100,000.00	$ 5,000,000.00
19	S&I SLTE equipment (DWDM) - standard & repeatered		38	ea	$ 250,000.00	$ 9,500,000.00
20	S&I SLTE equipment (DWDM) - long span	Includes Raman pumps	5	ea	$ 500,000.00	$ 2,500,000.00
21	S&I DC Power Feed Equipment for repeatered systems		27	ea	$ 750,000.00	$ 20,250,000.00
22	Mobilization/Demob – Cable laying vessel		3	season	$ 2,400,000.00	$ 7,200,000.00
23	Cable Laying Vessel standby cost		100	days	$ 50,000.00	$ 5,000,000.00
24	Allowance for spare equipment		1	LS	$ 2,500,000.00	$ 2,500,000.00
25	Post Lay Inspection and Burial (PLIB)	For ROV	60	days	$ 85,000.00	$ 5,100,000.00
26	Mobilization/Demob – HDD equipment	One setup per community	30	ea	$ 750,000.00	$ 22,500,000.00
27	Shipping materials for Shore Station, OGB, OSP, BM, HDD	One setup per community	30	ea	$ 750,000.00	$ 22,500,000.00
28	Mobilization/Demob – Workforce	One setup per community	30	ea	$ 30,000.00	$ 900,000.00
	TOTAL ESTIMATE					**$ 624,005,000.00**
	Contingency Allowance				20%	$ 124,801,000.00
	BUDGET ALLOWANCE					**$ 748,806,000.00**

Table 2 – Rough Order of Magnitude Cost Estimate for Baseline Nunavut Network

Proposed Long Term Network Expansion Option

This long term expansion option includes the provision of a fibre "ring" network around Hudson's bay, and provides service to Sanikiluak and Nunavik communities.

The proposed expanded system is shown in Figure 36:

Figure 36 – Long Term Nunavut and Nunavik Proposed Network Architecture

This architecture provides:

- A two fibre ring "nested" configuration
- Connection with a fourth mainland fibre entry point at Chisasibi or Radisson, Quebec.

The network model requires an additional 2,166 route km of installed fibre cable.

Nunavut Network Configuration – Option 2

This model serves the regional communities of Iqaluit, Rankin Inlet and Cambridge Bay with an extension to Resolute Bay. The configuration essentially represents a sub set of the more comprehensive architecture.

The cost estimate provides connections to:

- Iqaluit – There are three alternatives for the provision of fibre optic service:
  - Phase 1 of the Arctic Fibre proposal, providing a direct connection to Milton, Newfoundland.
  - A new link to a potential branching unit of the TELE Greenland cable in Baffin Bay.
  - A new link from Iqaluit to Nuuk, Greenland.

  For this study, a separate fibre link to Nuuk has been assumed in the ROM estimate.

- Cambridge Bay – A marine fibre optic link to Tuktoyaktuk is included. Diversity could be accomplished either by improved satellite service, or by an extension of the existing digital microwave system that currently extends from Yellowknife to the Ekati mine site (the cost for this extension has not been included in the current ROM estimate).

- Rankin Inlet – A marine fibre optic link from Churchill, Manitoba.

- Resolute Bay – An extension of the Tuktoyaktuk to Cambridge Bay link.

The baseline ROM cost estimate for Option 2 is $244M

Section 8 – Preliminary Risk Analysis Considerations

A simplified, preliminary risk analysis has been undertaken using the following Government of Canada (GoC) methodologies as a guide:

1. A "Risk Based Heat Map" – Reference, GoC Treasury Board (TB) Guide to Corporate Risk Profiles, 11th July, 2011.
2. Project Complexity and Risk Assessment Tool – Reference, GoC TB Guide to Using the Project Complexity and Risk Assessment Tool, 7th December, 2009. (A description of the risk assessment tool is shown in Attachment 4).
3. A simplified statistical combination of:
    - Assignment of the probability of the occurrence of key risk areas using the basic assessment formula Risk = Probability x Impact
    - An assessment of the potential cost impact of each of the risk elements
    - An evaluation of the total potential cost risk (often called a "risk premium"), and an assessment of a typical cash reserve that could be required.

The following risk elements were considered:

- Environmental Reviews and Permitting
- Project Financing
    - Business Risks
    - Government Policy Change
- Procurement
- Project Management
- Technical
- Northern Environmental Conditions

Risk Management "Heat Map"

An initial assessment of the risk elements puts this project in the moderately high probability of risk, with a corresponding moderately high probability of a significant impact.

From a potential Government funding perspective, this would put the project in a Treasury Board "transformational" category, and would require a senior executive and management team assigned to oversee the project.

Figure 36 shows the corresponding risk "heat map."

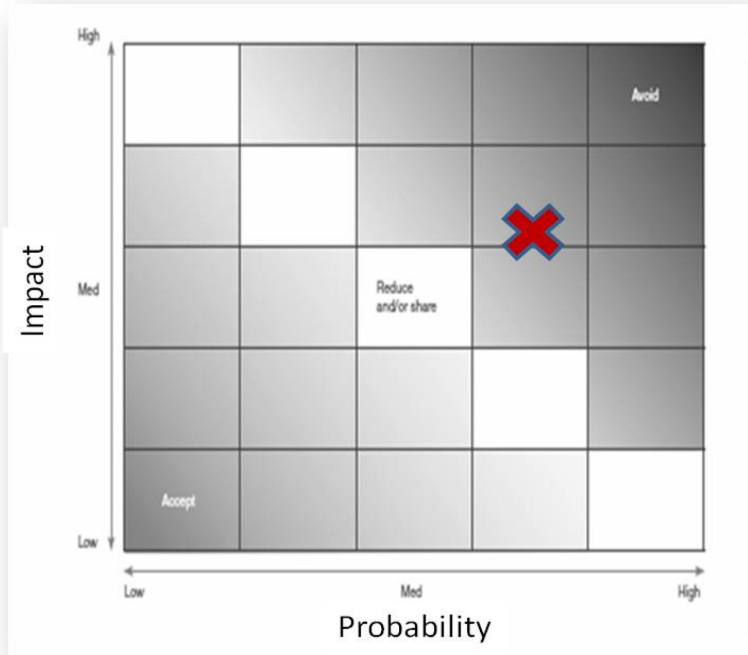


Figure 37 – Risk "Heat Map"

<u>**Risk Analysis – Potential Cost Impact**</u>

The preliminary results of applying a simplified version of the Government of Canada's risk assessment tool, together with a statistical combination of risk versus potential impact factors, indicate that, at this stage of a potential fibre project in Nunavut, the additional risk premium could be in the order of 40%.

This would translate into a project cost assessment (before any additional risk mitigation activities) of:

1. For the comprehensive Nunavut network configuration:

$750M x 1.4 = $1,050M

2. For the network proposal connecting Nunavut Regional Centres plus Resolute Bay:

$244M x 1.4 = $342M

The preliminary risk premium reflects that the Feasibility Study was generated on the basis of a modest desk top study. The premium could be reduced by:

- Transferring risk to the private sector and/or other stakeholders
- Implementing future activities/studies designed to better assess key risk elements, thereby allowing the identification of appropriate risk mitigation strategies.

Section 9 – Review of Alternative Telecommunications Technologies

There have been a number of significant advances in both satellite and digital microwave technologies in the past decade, and improvement in both technology and cost effectiveness are likely to continue.

Although the focus of the Feasibility Study is on fibre optic systems, this section of the report briefly reviews trends in both satellite and digital microwave technologies.

Satellite Technology

History

Satellite technologies have a proven track record in the north. Reliability is typically measured in the % of the amount of time that the service is available (usually this is simply the called system availability).

The measured system availability for the Anik F2 satellite is:

2011 – 99.789%

2010 and 2009 – 100%

2008 – 99.9942%

2007 – 100%

Future Trends

The following satellite technologies have been considered:

- Low Earth Orbit (LEO) “router in the sky” satellites systems, typically used in constellation configurations
- Government of Canada’s proposed PolarSat mission (- two satellites in highly elliptical orbits)
- High Throughput Satellites

Both the LEO satellites and the PolarSat mission were seen as providing either low bandwidth services or premium price specialized services.

We believe that the most promising satellite technology utilizes high throughput satellites. This is recently proven technology with, as an example, the successful launch and commissioning of the ViaSat 1 satellite.

High Throughput Satellites provide:

- 100 times the capacity of Ku Band satellites
- 10 times the throughput of any Ka band satellite
- Significantly reduced in orbit costs per Gbyte, compared to existing satellites
- KA-SAT capacity at 70 Gbps

ViaSat is offering its customers 12 Mbps download capacity (eventually, to over 1M subscribers).

Table 3 shows the possible evolution of broadband technology using satellite:

Evolution of Broadband via Satellite Telesat

		1st Generation	2nd Generation	3rd Generation
Example Systems		Ka-band – e.g. Anik F2/Ka	Ka-band – e.g. Viasat-1	Anik G (proposed) - Ka and V-band
Spot Beam Size		0.8 – 0.9 °	0.4 – 0.5 °	Mix of 0.15 to 0.3° V-band Option 0.4° to 1.0° Ka-band
Coverage		Contiguous	High demand areas only (supplemental capacity)	Small spots for high demand areas with large spots added for contiguous coverage
Service		High speed Internet (at today's user traffic levels)	High speed Internet (at future user traffic levels)	Very High Speed Internet including Internet based media rich services
Service Positioning		Complementary to DSL & cable modem	Complementary to DSL & cable modem	Keeping pace with DSL & Cable and even FTTH
User Speeds	Down	~ 4 Mbps	~ 20 Mbps	100+ Mbps
	Up	~ 1 Mbps	~ 10 Mbps	20+ Mbps

Going forward, 1st, 2nd and 3rd generation systems will co-exist and will serve their targeted markets

Table 3 – Evolution of Broadband via Satellite

In summary, we believe that high throughput satellites have the potential to provide faster and more economical bandwidth to the north.

Digital Microwave Backhaul Technology

Modern digital microwave systems have capacities of between 500Mbit/s and 1 Gbit/s, providing significant broadband capability. The following is a summary of technical and cost considerations for microwave backhaul systems (- details are provided in the Feasibility Study Technical Report, Attachment 2):

Design Considerations

- Path design is extremely important in microwave systems, particularly in flat geographic areas where microwave "ducting" is a possibility, or over significant bodies of water. For this costing exercise, we have assumed a 1 + 1 protection configurations, with antennas at different heights on towers, providing both space and frequency diversity.
- 40M towers are proposed, with antenna sizes between 1.8m and 3.0 m diameter.
- We have assumed skip distances between towers of between 30 km and 40 km.

Cost Considerations

- Typically, each site will have a capital cost of between $1.0M and $1.2M. This includes the construction of the concrete pad, power equipment (diesel generators), equipment shelter, repeater and/or terminal equipment, installation and commissioning, and spares.
- Although not considered in this analysis, ongoing maintenance costs and costs of servicing remote repeater locations can be significant.

Nunavut Example

Using Chesterfield Inlet to Baker Lake as an example (approximately 300 km):

- Based on a preliminary desk study {without a formal path microwave path analysis}, we estimate 9 sites are required comprising 2 terminal sites and 7 intermediate sites.
- Total projected capital cost is between $9M and $10.8M.
- Although not reviewed, ongoing maintenance costs can be significant, with intermediate sites requiring at least one helicopter lift per year to supply fuel for the generators.

In summary, we believe that capital and ongoing maintenance costs of digital microwave backhaul systems typically limit their economic application to between 100 km and 150 km from a fibre hub except in instances where installation of a fibre optic cable is impractical.

Section 10 – Mixed Telecommunications Networks

Most telecommunications network operators use a variety of technologies to provide service (including TELE Greenland, operators in Northwest Territories and Yukon, and in Alaska). Although the business case for fibre optic systems in Nunavut is very challenging, three other factors may affect the ultimate configuration of the long term telecommunications network in Nunavut:

- Strategic considerations by the Government of Canada
- The medium to long term possibility of an Asia to Europe fibre link
- The "market making" capacity of high speed fibre optic systems, particularly in the resource sector

Under these circumstances, the options for a long term network could potentially include satellite, fibre optics and digital radio.

As an example, in the Feasibility Study's option 2 network configuration, with fibre optic connection to Iqaluit, Rankin Inlet and Cambridge Bay with an extension to Resolute Bay, the remaining communities in Nunavut would most likely be served by satellite with the following exceptions, which are candidates for service by digital microwave back haul radio:

- Chesterfield Inlet to Baker Lake
- Repulse Bay from Kugaaruk
- Pangnirtung from Qikiqtarjuak
- Hall Beach from Igloolik
- Kugaaruk from Taloyoak

In the overall management of a mixed network, it would be important to assess the level of service provided by each delivery mechanism, from the perspective of the user and the services that could be delivered.

Section 11 - Impact on Service Parity and Socioeconomic Considerations

The Socioeconomic Component of this report was prepared by Imaituk Inc. and is shown in Attachment 3. The following section outlines the principal considerations in the report and a summary of its conclusions.

Socioeconomic Review of the need for Broadband in Nunavut

- GDP in Nunavut is growing at a rapid pace, largely due to resource development that may or may not benefit the people who live in Nunavut.
- Nunavut communities play an important role as starting points for sovereignty activities, exploration, land management and environmental stewardship.
- Nunavummiut currently score low on socioeconomic indicators, but broadband is seen as a tool to help improve opportunities:
  - *"It is clear that northern economies are very strong and are getting stronger. It is also very clear the challenges the North face are not economic, but social. Broadband-enabled services have a very significant role to play in ensuring a higher quality of life while helping to build and maintain sustainable communities and lessening the digital divide. "*

    ACIA (Arctic Communications Infrastructure Assessment) Report, 2011, page 164.
- People can use broadband connectivity to help build Nunavut businesses, access a wider variety of education, improve health outcomes, support the decentralized government and strengthen language and culture.

Infrastructure Needs from a Socioeconomic Perspective

- Connectivity is now provided via satellite with a point of presence in each of Nunavut's 25 communities, and then distributed to homes, businesses and government with a mix of wireless, copper and fibre.
- Current satellite bandwidth is inadequate to run needed applications over the backbone, as applications increasingly are designed to run on fibre, not satellite.
- All communities are interested in connecting to fibre, as a solution to their bandwidth crisis - as fibre can deliver exponentially faster speeds.
- Hope is high for access to more education, business opportunities and health outcomes so people can work in one of the many jobs created in the future, particularly in the

resource sector - exploding in all corners of Nunavut, not just around the regional centres and military investments.

- There is an imperative in Nunavut to try to ensure all communities have similar speeds so implementation of territory wide initiatives dependant on broadband will actually work, providing benefits to all 31,000 Nunavut residents. Nunavut demographics are unique in the north, with a population spread more evenly throughout, so programs are necessary everywhere - with equal opportunity to benefit (service parity).

The Economic Challenge of Fibre Connectivity from a Socioeconomic Perspective

- While compelling, the socioeconomic needs of Nunavut's population will not provide enough investment incentive for fibre for all communities:
  - at over $1 billion, the estimated cost for installing fibre to each Nunavut POP is almost equal to the Government of Nunavut's entire annual budget
- There are other critical infrastructure investments required in Nunavut, from power to housing, water, schools, airports, health centres, competing for the socioeconomic investment dollar.
- As a territory, GN cannot raise its own royalties and taxes from the expanding resource sector - only the GoC can:
  - Even as the GDP rises, no additional investment in people and infrastructure is possible without the GoC
- Military and sovereignty needs in Cambridge Bay, Resolute, and Nanisivik provide some incentive for investment, but again, are dependent on the Government of Canada.
- Resource sector also needs communications infrastructure, and better infrastructure may assist in attracting even more resource sector investment in Nunavut, that can benefit all of Canada and Nunavut .
- Proposed private sector fibre builds require GoC investment in the form of committed future revenue and usually, capital investment.
- Any economic decision to invest in fibre will be driven by the GoC, as the main investor, bundling the various investment drivers to make a case for investing in backbone.

Mixed Technology Communication Network

- Communications in Nunavut could evolve in two directions:

   - A satellite only network, using improvements in satellite technology and spare capacity in Canadian arctic coverage. This would require less capital expenditure.
   - Use of a mix of technologies. The rationale for this approach would need to be based on more than the demand pull economics of local communities.
      - This mix could eventually comprise of fibre, satellite and, in a limited number of applications, digital microwave backhaul technologies.
- For a mixed network, and considering the second network model (providing fibre service to Iqaluit, Rankin Inlet and Cambridge Bay, with a possible extension to Resolute Bay), the remaining communities in Nunavut would most likely remains with satellite service with the possible exception of the following microwave links.
   - Chesterfield Inlet to Baker Lake
   - Repulse Bay from Kugaaruk
   - Pangnirtung from Qikiqtarjuak
   - Hall Beach from Igloolik
   - Kugaaruk from Taloyoak
- In the management of a mixed network, it would be important to assess the level of service provided by each delivery mechanism, from the perspective of the user and the services that could be delivered.

Implications of a Mixed Network on Service Parity

- The socioeconomic opportunities broadband brings will only be open to a portion of the population if some communities are connected and others are not, creating a political and cultural challenge in Nunavut.
- Applications in government management tools, health, education and business development may not be implemented at all if the majority of communities are not connected, as agencies will have to maintain duplicate processes, so will not invest in the first place.
- As people become more reliant on connectivity for critical tasks, the more important it is that the connectivity is reliable. Fibre connections that can have a single point of failure need satellite back up that can run mission-critical applications immediately in the event of a fibre cut.

- A single fibre pair carries about 600 times more than what Iqaluit expects on satellite. An emergency satellite back up based on the current satellite bandwidth infrastructure will not provide a reliable back up once people start to rely on fibre.
- It is critical that concurrent investment in high throughput satellite will be required to serve non-fibre linked communities, and to provide effective back up in the event of a fibre failure.
- Any serious plan for fibre backbone investment must consider how to mix fibre and satellite so that any difference in service levels as can be managed for the socioeconomic growth of the entire territory.

Socioeconomic Recommendations

- Recommendation 1: Investment in infrastructure must benefit Nunavummiut as it also seeks to benefit Canada:
  - As the Government of Canada invests in communications infrastructure to both meet the needs of sovereignty and attract mining investment, there will need to be rules to ensure this investment also directly benefits community members in all Nunavut communities with opportunities to benefit from increased connectivity to every community.
- Recommendation 2: Reliability and redundancy paramount :
  - Recognize that fibre lines, by the very nature of the Arctic environment, may be at relatively high risk of damage and difficult to repair. Any investment decisions should focus on redundancy either through a robust ringed architecture system, and/or through high throughput satellite for back up. If there is not a robust backup system, then in the event of a failure, the communications failure becomes the emergency.
- Recommendation 3: Strategic concurrent backbone investment required in satellite:
  - Recognize that even with fibre investment, satellite will continue to play a significant role -- both in terms of providing back up to fibre connected communities, as well as providing primary connectivity for others. There must be a strategic balance of investment in both fibre and satellite backbones.
- Recommendation 4: Future revenue streams required to maintain and innovate:
  - After an initial investment into a backbone infrastructure, there must be a system developed for continued investment for maintenance on branch lines,

innovation, quality of service requirements and regulations to ensure the costs to the end user do not creep into the 'cost-prohibitive' category.

Socioeconomic Considerations – Summary

- Broadband access should be an enabler, not a constraining factor in the lives of Nunavummiut
- The real questions of access, equity, opportunity to benefit from broadband have always been closely linked with the thorny challenge of paying for a backbone that far exceeds the territorial and community financial capacity to solve

Section 12 - Review of Private Public Partnership Alternatives and Financing Options

Overview

Historically, Private Public Partnerships (PPP of P3 arrangements) arose as an innovative approach to public procurement from the need to limit public debt, and share risk between Government and the private sector.

- PPP arrangements seek to transfer risk from the public domain to the private sector, with an acknowledgement that the private sector will require a return on investment that is commensurate with the degree of risk they are being asked to assume.
  - The less risk, the less return that is offered, or expected
- Certain PPP arrangements also have the advantage of being reported on Government accounts as operating expense rather than the traditional reporting as a capital expense.
  - This is particularly important for Governments that are operating close to their debt limit.
- PPP's tend to work for large infrastructure projects where the value of the risk transferred is higher than the incremental financing costs.

Outline of PPP Alternatives

There are four basic configurations:

1. A Traditional " Design, Build, Operate Maintain" Approach
   - This type of PPP is the most common, with a number of large private sector companies offering overall project management services.
   - The Government of Canada follows this general outline with projects sponsored under the $1.2B P3 Canada fund, which is managed by PPP Canada (a Federal Agency reporting to the Minister of Finance). For a project to be eligible to receive these funds, the public good element of the project has to be clearly articulated, and the eventual ownership of the asset has to be with a public entity (Territorial Government, Aboriginal Government, Municipally etc).
   - A recent example of this type of project is a Government of Canada $880M building project in Ottawa for Communications Security Establishment Canada.

The contract uses a design, build, operate and maintain model and has an expected lifetime of 30 years.

Figure 37 outlines the various types of traditional PPP arrangements:

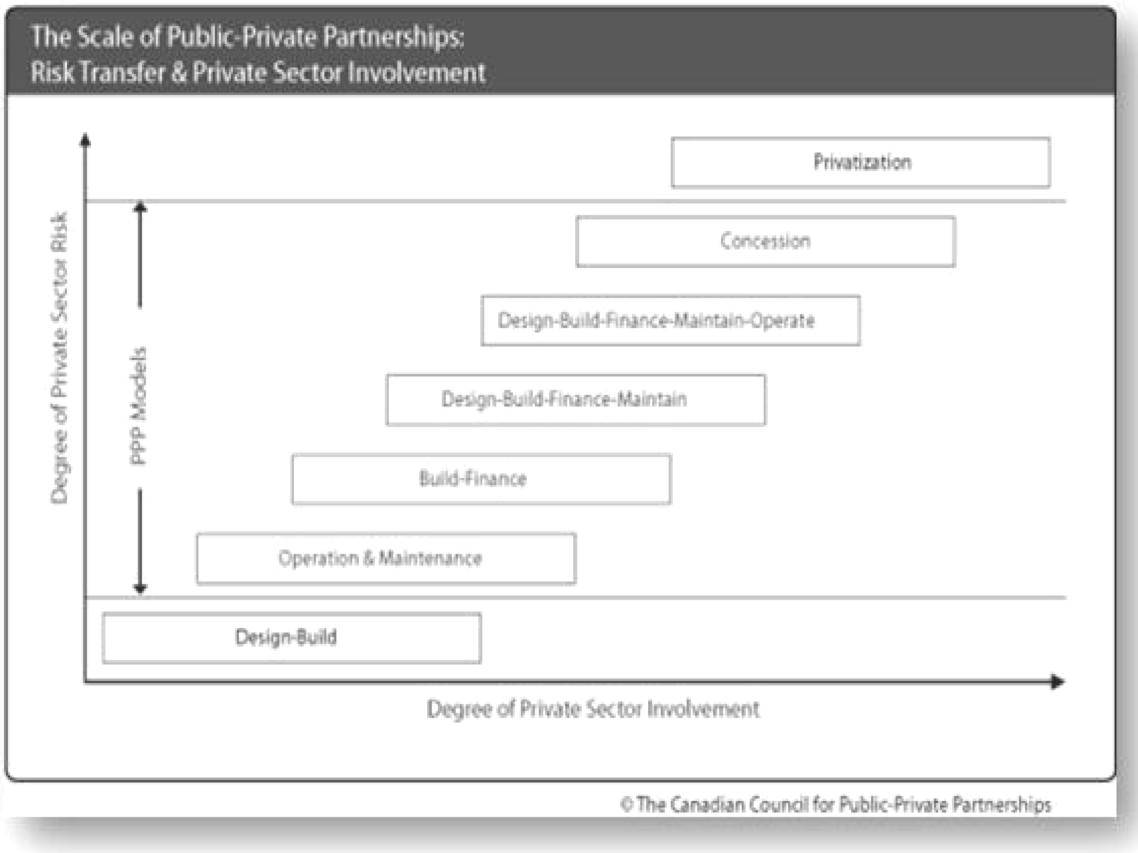


Figure 38 – PPP Model Alternatives

2. Alternative GoC PPP Model – used in certain circumstances by Industry Canada
   - In this model, Government funds are provided to support priority initiatives with the principal difference being that ownership of the asset can eventually rest entirely with the private sector.

3. "Condominium" Model

   - In this alternative, a project sponsor (e.g., a Territorial Government) would own and manage the overall infrastructure framework of the project (i.e. the condominium), but would be able to "sell," "lease," or "rent" capacity to private sector clients at market rates, while maintaining a separate element for public good use (health care, education, social services etc.). Figure 38 shows a Schematic of a "Condominium" PPP Model:

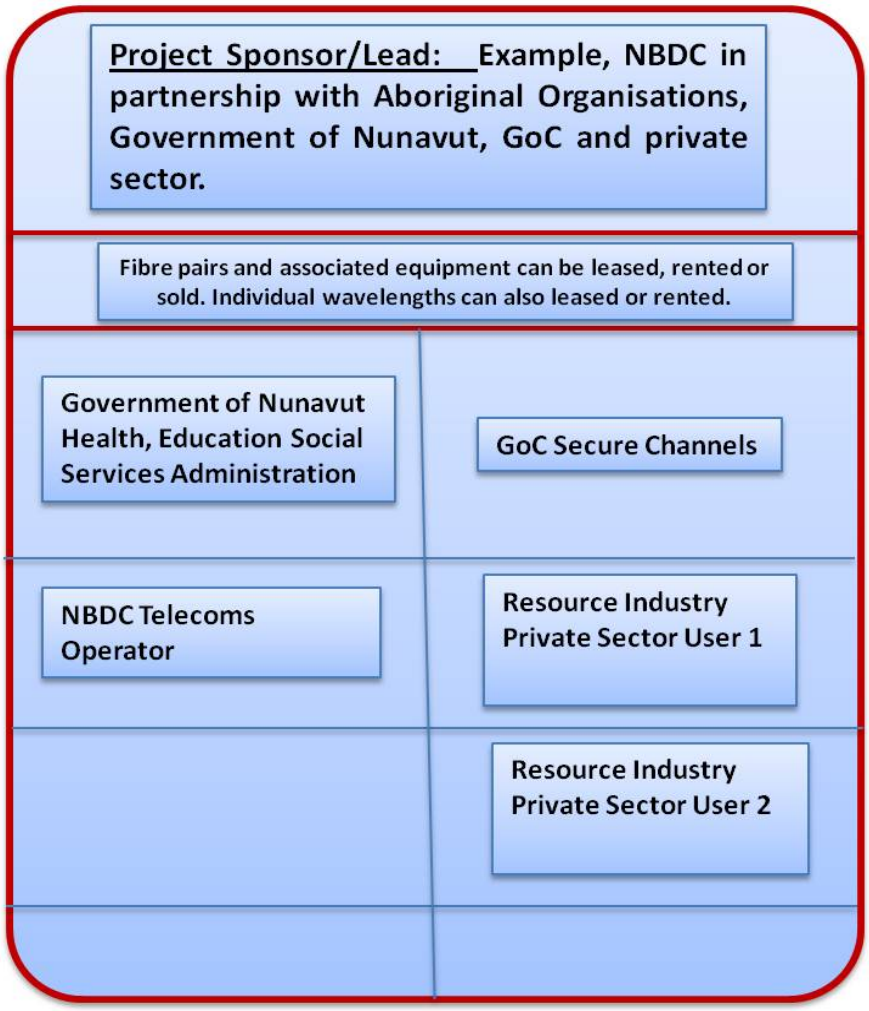


Figure 39 - Schematic of a "Condominium" PPP Model

4. IRU's (Indefeasible Right of Use)

   - IRU's are commonly used in long haul fibre systems as a way of sharing costs while retaining indefeasible control of an agreed communications channel.

Section 13 – Proposed Next Steps

1. Community Consultations

a. SGC believes that this is a vital part of the proposed project. The consultations should be substantive, "in person," and allow for input from local communities from the outset of the project to be considered. Detailed local knowledge and expertise could significantly assist in determination of approached landing point locations and technologies.

2. **Network Growth and Evolution strategies**:

a. In the long term, the Nunavut communications network could evolve using a satellite only technical option (using high throughput capacity satellites) or into a combination of satellite, radio and fibre technologies. From a technical perspective, a network review should include anticipated improvements in satellite broadband technologies as well as digital microwave backhaul systems, to optimize service, and meet the needs of all communities in Nunavut.

b. SGC recommends that further work be considered to further define the potential impact of a Territorial wide mixed technology communication infrastructure, both from a technical, ownership, financing and administration perspective, and also from a broader socioeconomic perspective.

c. SGC recommends that this activity include consultations with NWT, Yukon, Governments of Quebec, Ontario, Manitoba and the Federal Government from the perspective of a potential, cohesive, Pan Arctic communications strategy

3. Proposed Northwest Passage Private Sector initiatives

As identified in the Feasibility Study, a number of initiatives have been proposed.

a. The proposed Asia – Europe systems have the advantage that financing for the end to end link have the effect of potentially subsidizing both the capital and O&M costs of a Canadian Pan Arctic fibre link.

b. The proposals also have an advantage that the private sector will assume a portion of the risk of the system.

5. SGC recommends that these alternatives be seriously considered at least at the level of identification of possible branching units – these units are relatively inexpensive to provide during initial installation, but much more expensive to provision once the

backbone system is installed and operating. It would also be important to have a strategy in place in the event that one or more of these proposals is implemented in order to negotiate appropriate branching units and business arrangements and protect the interests of Nunavut.

4. **Risk Mitigation Approaches.**

The "risk premium" could be reduced by:

a. Completion of a detailed field and marine study.

b. Detailed assessment and projected schedule for environmental review and permitting process.

c. A pilot project assessing the technical options of laying fibre optic cable in selected ice conditions, and under different tidal conditions.

d. A pilot project, using Autonomous Underwater Vehicles (AUV's) to determine bathymetry profiles and possible cable laying options.

e. Sharing, and transference of risk to private sector and/or other potential stakeholders.

f. Business case analysis for the proposed project elements.

5. **Socioeconomic Recommendations**

Nunavut demographics are unique in the north, with a population spread more evenly throughout the Territory, so it is important that all communities have the opportunity to benefit equally from the provision of broadband services. It is also important in Nunavut to ensure that all communities have similar broadband speeds so that territory wide initiatives that are dependent on broadband will provide benefits to all 31,000 residents.

- The socioeconomic opportunities broadband brings will only be open to a portion of the population if some communities are connected and others are not, creating a political and cultural challenge in Nunavut.
- It is critical that concurrent investment in high throughput satellite will be required to serve non-fibre linked communities, and to provide effective back up in the event of a fibre failure.

- Any serious plan for fibre backbone investment must consider how to mix fibre and satellite so that any difference in service levels as can be managed for the socioeconomic growth of the entire territory.
- Reliability and system redundancy are paramount.
- Future revenue streams are required to maintain and innovate.

6. <u>Financing Alternatives</u>

Financing for a Nunavut fibre optic network cannot be based on local demand alone. Strategic considerations, resource industry "market maker" opportunities, and Pan Arctic communication alternatives will all need to be considered.

SGC recommends that the following alternatives be considered, in the context of both a long term strategy for the Nunavut communications network, and also in the context of a Canadian Pan Arctic network:

a. Assessment of Government financing alternatives, together with long term social, business, economic and strategic benefits:

   i. Federal Government Departments.

   ii. Territorial Governments.

   iii. Aboriginal Governments and Organizations.

b. PPP alternative business models, including financing options from:

   i. Development and Export/Import (Exim) Bank loans at both concessionary and consensus rates (in relation to LIBOR rates).

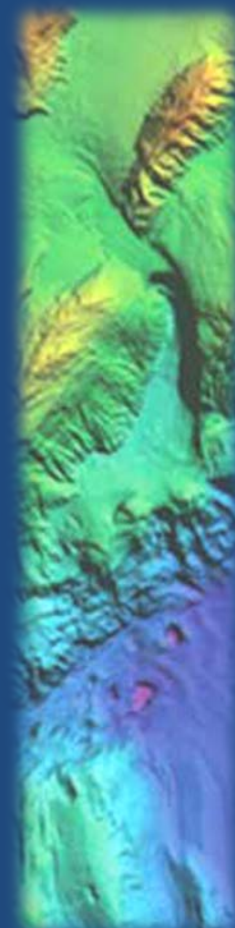
   ii. Domestic and International Private Sector Bank loans.

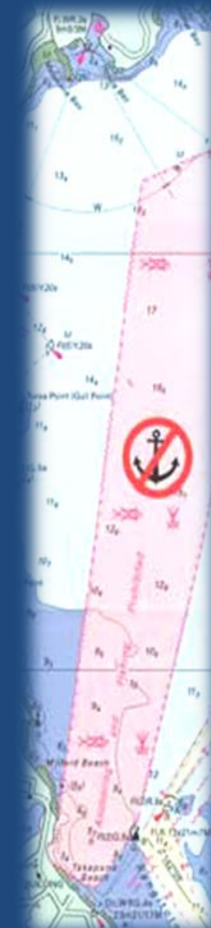
   iii. Pre buying options for capacity – this option consists of conditional purchase orders that convert into firm fixed price contracts in the event that the project proponent delivers the project on time, within budget and to an agreed technical performance and reliability specification. The PO's can usually be converted into cash financing for project construction, with a risk premium being charged on the notes.

Nunavut Fibre Optic Feasibility Study

Presented to Nunavut Broadband Development Corporation

March, 2012





Salter Global Consulting Incorporated SGC

Imaituk

Contract Requirements

1. Overview of Fibre Technologies
2. Status of Arctic Fibre Network
3. Possible Landing Points
4. Impact on Service Parity
5. Next Steps

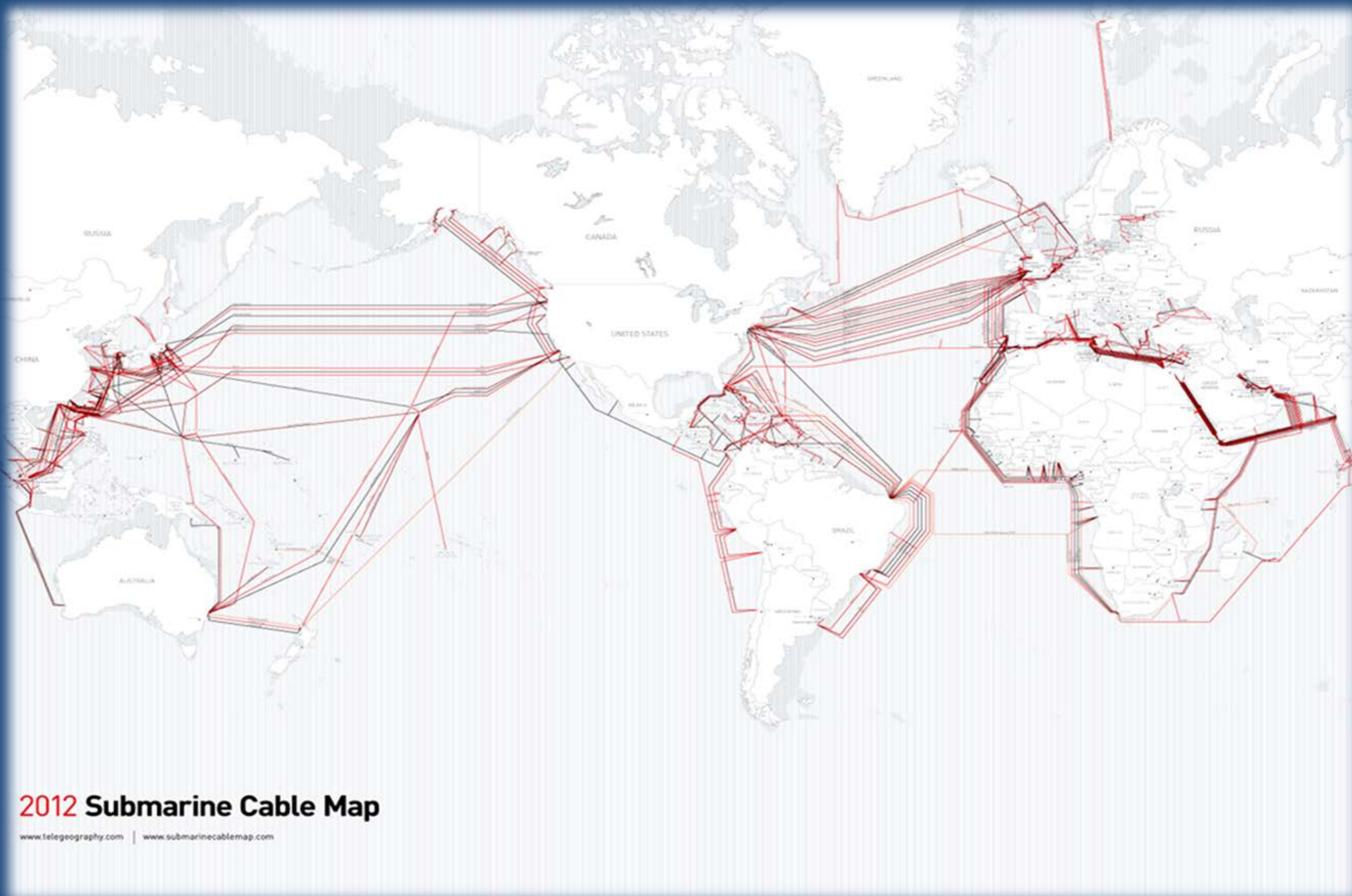
Presentation Outline

- **Review of Alternative Fibre Technologies.**
  - Current marine fibre optic technologies
  - Technical challenges in Nunavut
  - Risk mitigation strategies
- **Existing and Planned Arctic Fibre Networks Infrastructure.**
  - Expansion initiatives to 2020
- **Review of Possible Fibre Optic Network Configurations for Nunavut**
  - Connection for all existing Nunavut communities
  - Leveraging planned Northwest Passage Fibre Optic proposals
  - Connection to Regional Centres
  - Review of risk elements
  - Long term network architecture
- **Possible Landing Points**
- **Review of other Communications Technologies**
  - Satellite
  - Digital Microwave
- **Impact on Service Parity**
- **Next Steps**
  - PPP alternatives
  - Linkages with proposed initiatives

Overview of Fibre Systems

- Over I million km of fibre optic cable installed.
- 91% of international traffic carried by fibre systems.
- Reliability very high when used with fibre ring and other route diversity technologies (over 99.9999% availability)
- High capacity
  - Each fibre pair can accommodate up to 128 channels.
  - Each channels can support up to 40 Gbit/s.
- Longest fibre cable – 28,000 km “Fiber-Optic Link Around the Globe (FLAG)” system from Japan to Europe system.

Global Fibre Networks (2012)



Marine Fibre Systems

- Fibre Network Elements
  - Cable
  - Terminal Equipment
  - Under Sea Repeaters
  - Land based regenerating station
  - Branching Units
- Typical system configuration
- Powering subsystems
  - End to end system feeds.
  - Intermediate feeds.
- Cable Laying
  - Deep sea
  - Near shore techniques
  - Landings
- Cable Maintenance
- Reliability

Fibre Cable Armouring

From shore cable to deep sea cable (left to right)

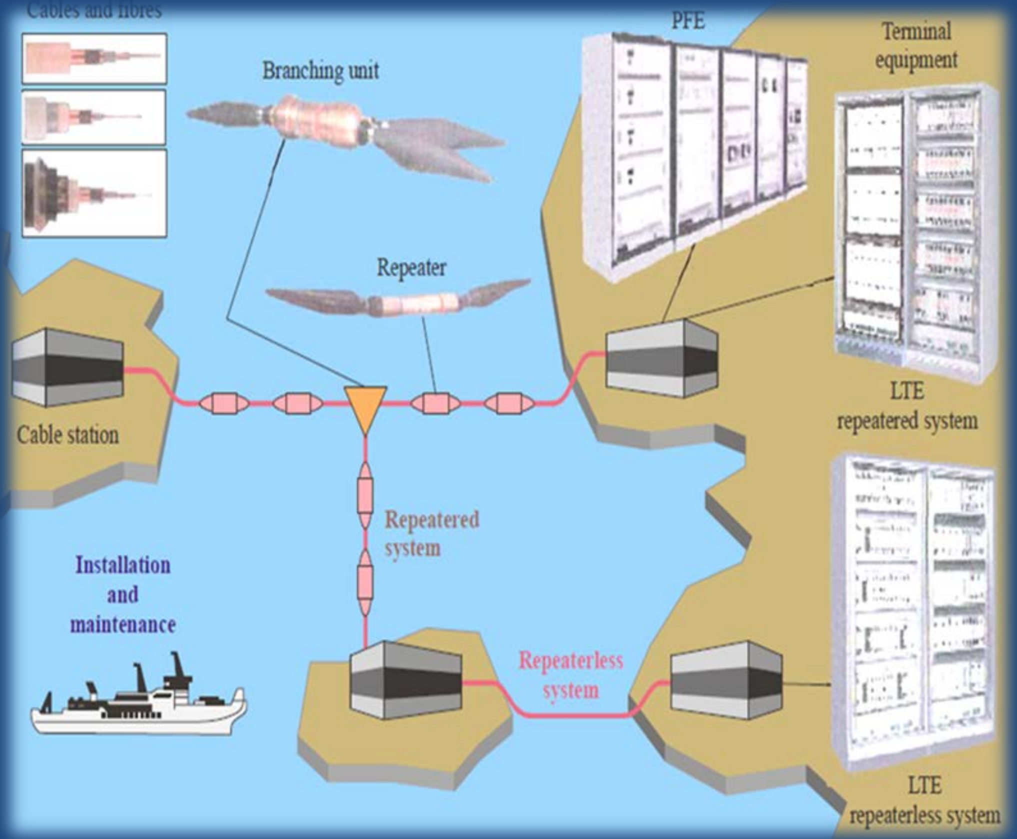
- **Type of fibre cable armouring reflects degree of protection required as the cable is installed from the landing to a deep sea environment.**

Typical Cable Installation Depths

- 0 – 400 metres, double armoured
- 400 – 1,000 metres, single armoured
- 1,000 – 1,500 metres, lightweight armour,
- 1,500 metres and below, lightweight.

Marine Fibre Optic System Network Elements

- Terminal Equipment
- Undersea repeaters
- Branching Units
- Powering and maintenance subsystems

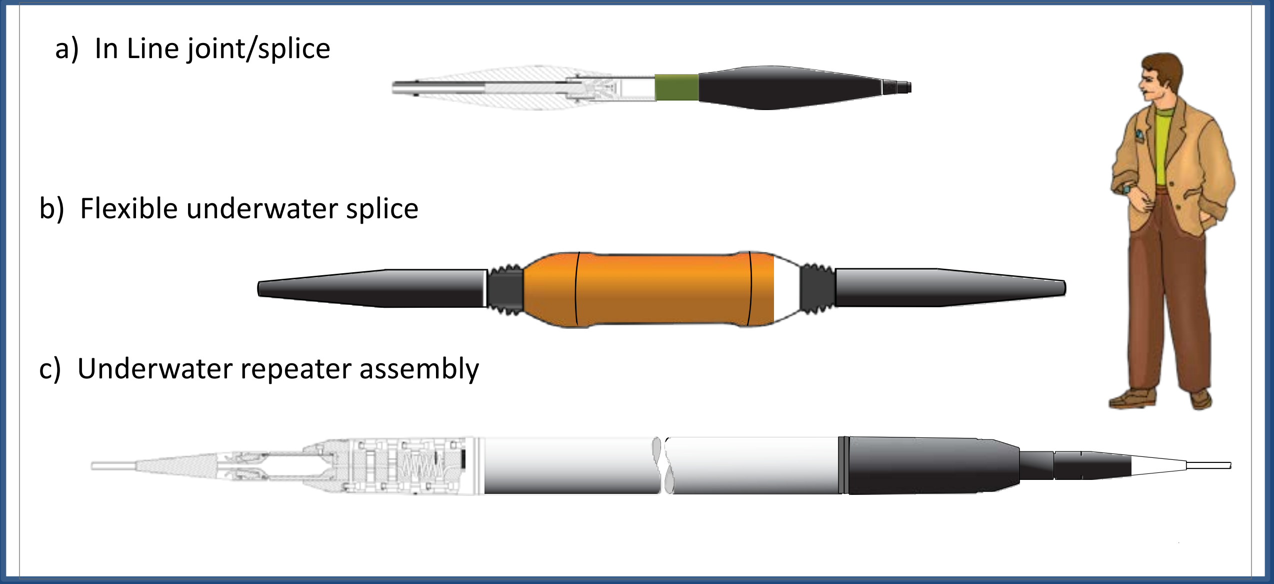


Terminal Equipment

- **Located at Landings**
- **Comprises:**
  - **Dense Wavelength Division Multiplexing (*DWDM*) Fibre Terminal Equipment – initially one wavelength may be used.**
  - **Powering Feed Equipment (PFE)**
  - **Monitoring and fault location equipment**
  - **Standardized electrical cross connection (possible Point of Presence - POP)**
- **At intermediate landing locations, could include Drop/Add Multiplexer equipment (*Remote Optical Drop Add Multiplexer – ROADM*)**

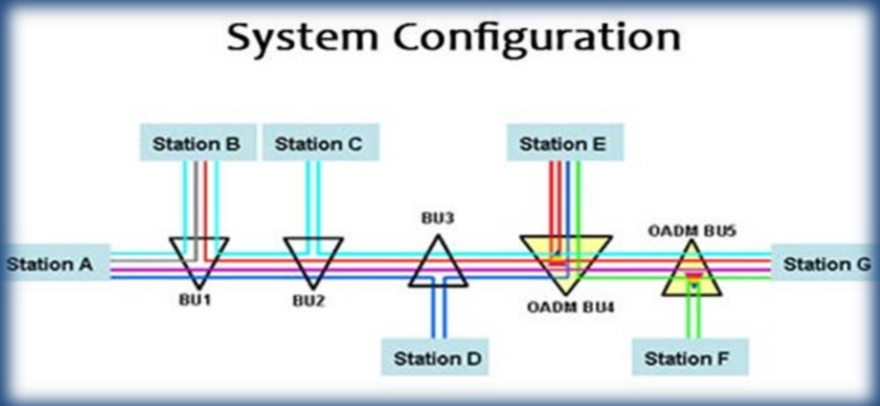
Undersea Repeaters

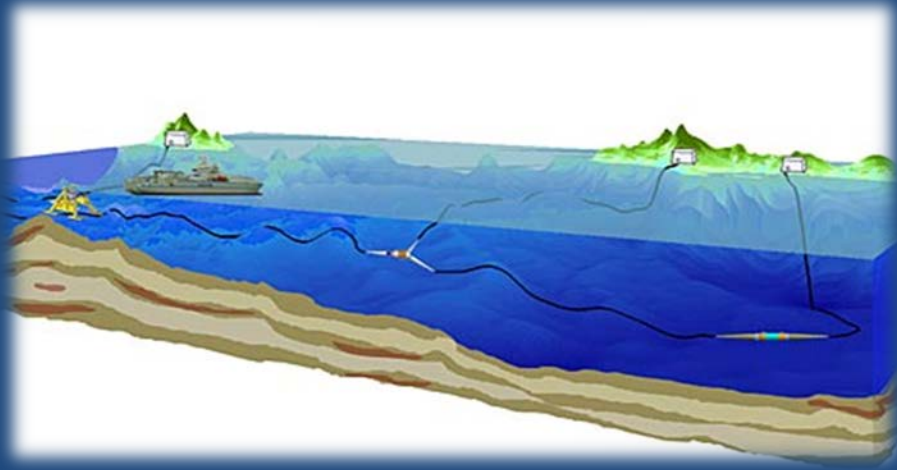
- Use Erbium-Doped Fibre Amplifier technology
- Powered by current down either a centre conductor, or a copper tube containing the optical fibres
- Electronics have redundant components and key subsystem elements for greater reliability
- Typical repeater spacing's between 60 km to 100 km. Maximum unrepeated sections up to 400 km



Branching Units

- Allows cable systems to be spilt into one or more destinations
- With one incoming feed, up to a maximum of 3 additional feeds possible
- Both optical switches and electrical ROADM options possible



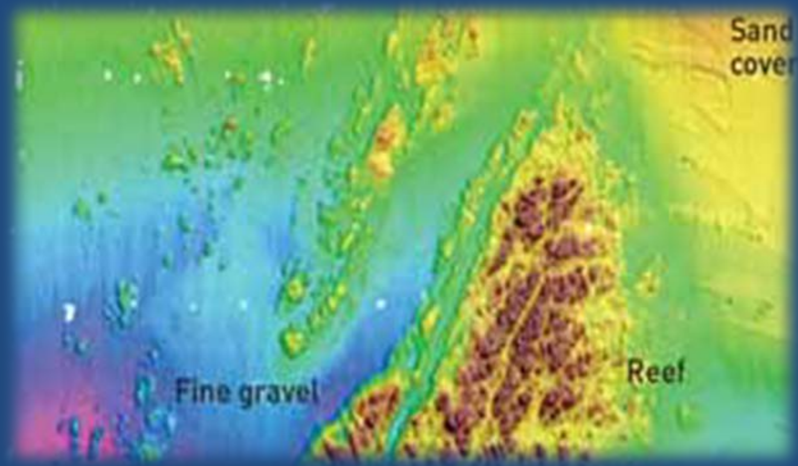


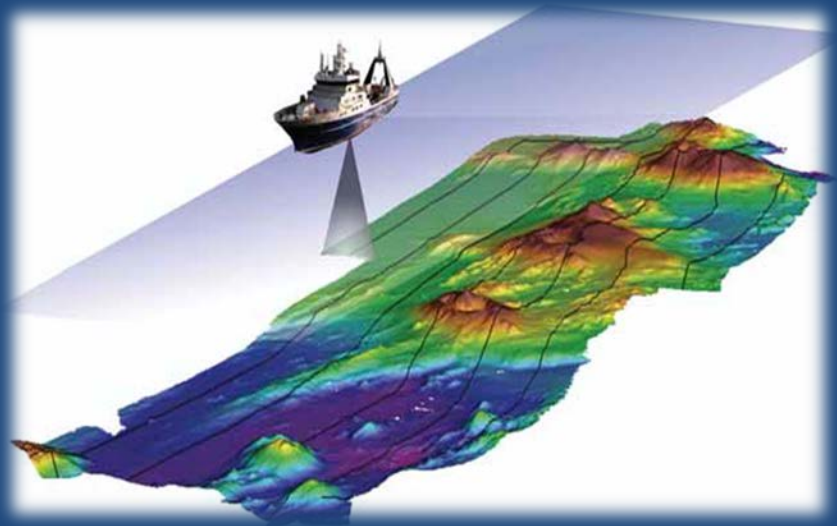
Typical Fibre Cable Installation Techniques

- At landing sites – horizontal drill from shore; ideally to exit the sea bed at least 20-25 metres below low water.
- From the end of the horizontal drill to a depth of up to 250 metres in iceberg-prone areas, direct bury the cable using an underwater plowing technique.
- Below 250 metres, surface lay cable directly on ocean bottom.

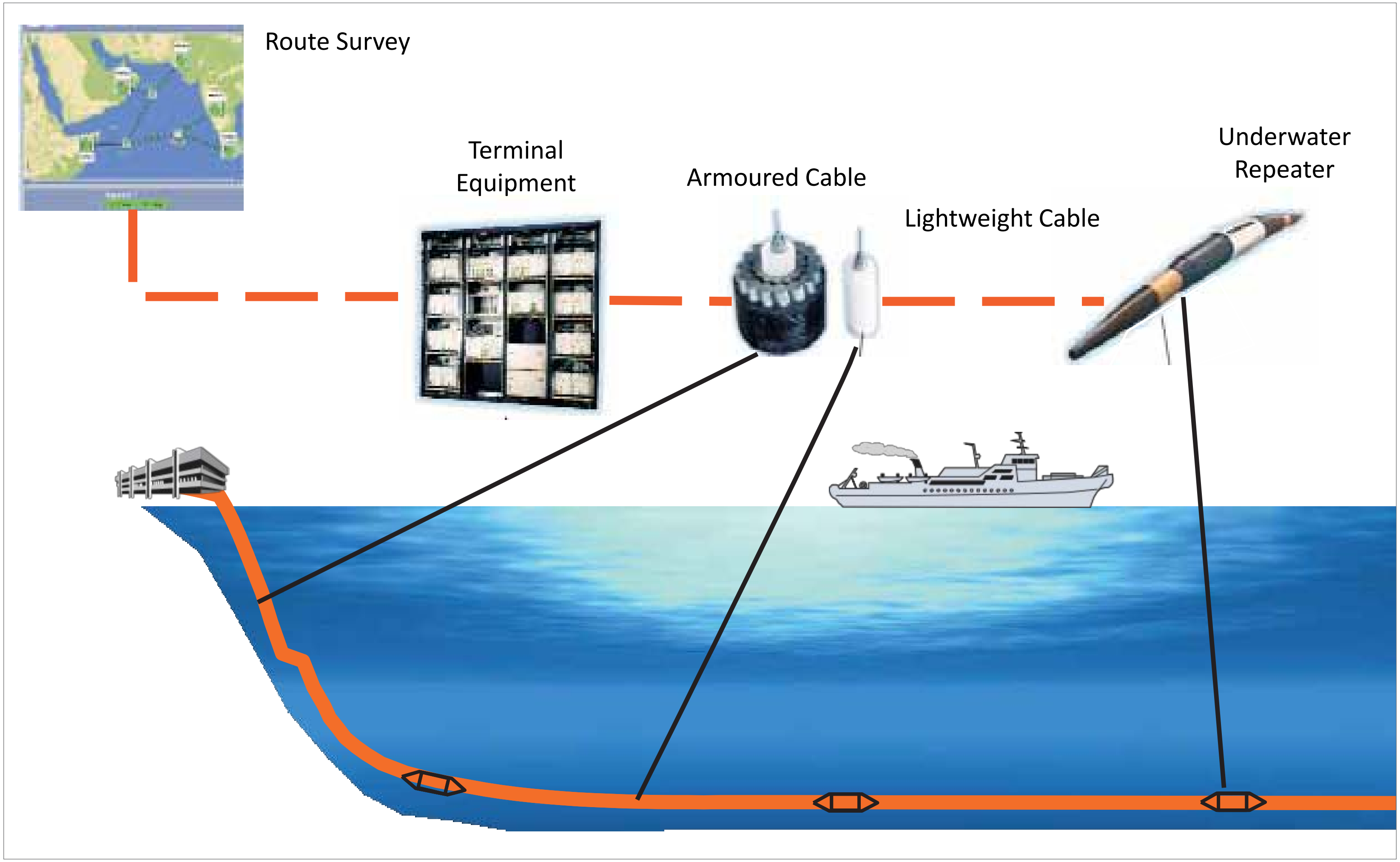
Choosing the cable route

- It is important that the cable lays directly on the bottom – if the cable is suspended, then it will chafe and fail.
- For this reason, the cable route is almost always longer than a direct line between tow location.
- Accurate bathymetry information is usually obtained during a marine survey.
- Landings are critical – this are typically the point of highest vulnerability for the cable.





Typical Cable System Installation



Network Considerations for any Marine Fibre System

- Important to have the final network configuration design before installation commences:
  - Location of land based regeneration stations
  - Location of branching units
    - Identification of those to be used on initial commissioning
    - Identification of those to be used in the future, with appropriate cable stubs attached
  - Design of the powering sub system, including powering alternatives for the connection of future branching unit locations, and for the identification of redundant powering back up systems
- Accurate bathymetry data for the final route design
- Permits
- Environmental reviews
- Long Term Maintenance Strategy

Additional Technical Challenges in Nunavut

In addition to the typical concerns for marine fibre systems, there are the following additional challenges:

- Cable laying
- System reliability
- Cable repair

On the positive side, the following issues are positive from a technical point of view:

- Relatively low ship and fishing activities (particularly, bottom trawling)
- Relatively low area of seismic activity

Cable Laying Issues

- Ice Conditions
  - Increasing variability due to climate change
  - Scouring
  - Icebergs
- Tides and Currents
- Lack of accurate bathymetry data
- Lack of accurate nautical charts

System Reliability

Challenge of repairing a fibre break

- Prolonged service disruption
- Availability of back up facilities and/or alternative fibre routings
- Cable repair in ice conditions

In addition, there is the overarching issue of modest traffic demand (both initial and long term demand).

Environment Reviews and Permitting

- **This project falls under the jurisdiction of many Territorial and Federal Departments in addition to Municipal Authorities**
  - **Federal Departments**
    - **Fisheries and Oceans**
    - **Aboriginal Affairs**
    - **Industry Canada**
    - **Environment Canada**
    - **Natural Resources Canada**
    - **Foreign Affairs**
    - **Canadian Radio and Telecommunications Commission**
  - **Nunavut Settlement Area – responsibility falls under the umbrella of the Nunavut Impact Review Board (NIRB)**
  - **Local communities - route drawings will need to be submitted to the administration officer of each community for approval for the cable routes and any associated infrastructure such as towers, equipment shelters, power feeds, office space, etc**
- **In addition to marine environments, individual consideration needs to be given to each proposed landing, and any land crossings**

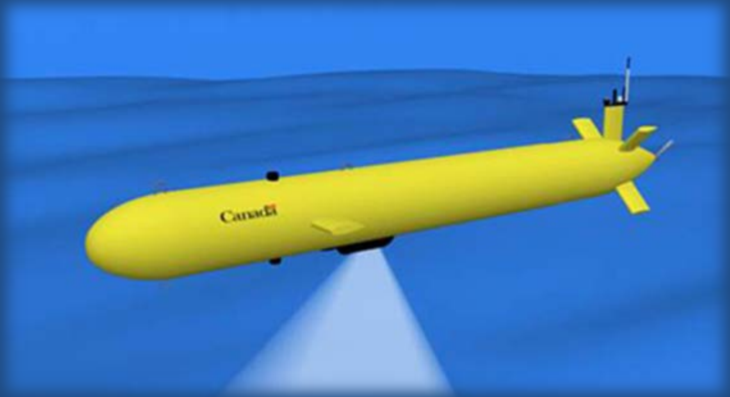
Examples of Sensitive Environmental Areas

Environment Canada Map of Designated Habitat Areas

Parks Canada Proposal for a National Maritime Conservation Area in Lancaster Sound

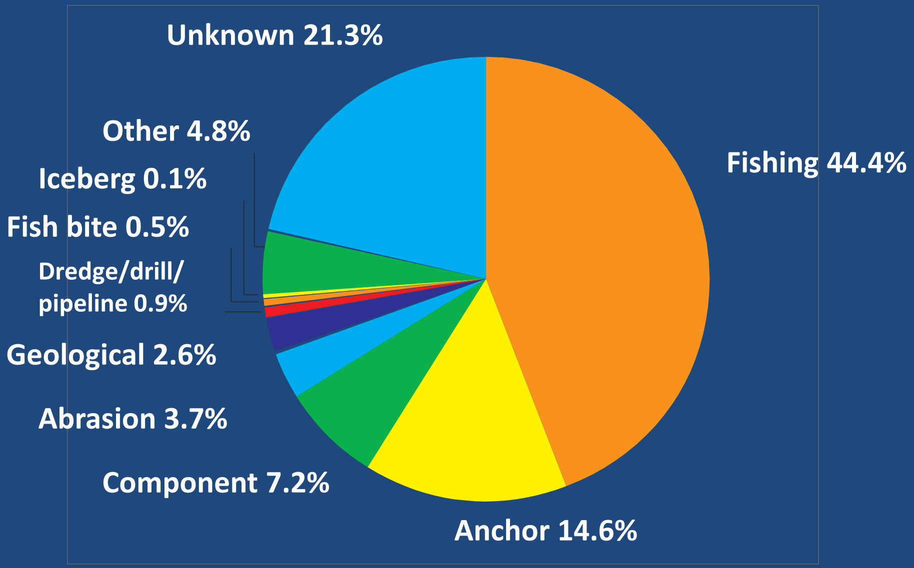
Risk Mitigation Alternatives

- Lack of Bathymetry Data, and accurate Marine Charts
  - Complete detailed marine survey
    - Survey ship
    - Autonomous Underwater Vehicle (AUV)
      - Canada's Dept of Defense has conducted missions using AUV's under ice
      - Range is in the order of 500km
- Tides and Currents
  - Local Knowledge
  - Canadian Hydrological Service (CHS) surface and depth tide and current modeling
  - Use of tugs and cable laying barge in high currents areas
- Changing Ice Conditions
  - Local Knowledge
  - Canadian Ice Service
  - Near Real Time satellite images from Radarsat 2 and TerraSar satellites.



Typical System Reliability - Background Data

- Historical Fibre Cable Breaks (as of 2009)



Global pattern of external aggression cable faults
1959–2006

Component faults less than 8% of total failures

Recent Northern Fibre Break Data

Details of recent fibre breaks in the North:

- Northwest Tel
  - 2009: 4 Fibre breaks - 3,837route km
    Causes: 2 x Road Construction
    1 x Environmental crew doing test boring in ditch
    1 x Truck in ditch during spring break up
  - 2011 4 Fibre breaks - approx 6,000 route km
  - Typical time to repair, less than 1 day

- TELE Greenland – Milton (Newfoundland) to Nuuk link implemented in 2009, system extends to Iceland then (with separate operator) on to the Faeroe Islands and the UK
  - 3 beaks to date, all in the vicinity of Nuuk
  - All caused by icebergs crossing cable route at approx 13 metre water depth
  - TELE Greenland plan to horizontal drill this summer to a depth of 200m.
  - Summary: 3 breaks, route length 4,598 km in three years
    - Average: 0.22 breaks per 1,000 km per year.

System Reliability Mitigation Strategies

- **Fibre Ring Architecture**
  - Used worldwide to mitigate risk of fibre breaks
    - NorthwesTel has implemented fibre ring configurations in NWT and Yukon
  - Signals can travel in either direction
    - In the event of a break, signals can travel in either direction to continue to provide service
- **Route Diversity**
  - Provision of alterative fibre routings
    - Provides protection in the event of two simultaneous failures on a ring network
  - Often used in areas of increased vulnerability e.g. landings, ports and/or near active bottom fishing areas
- **Technology Diversity**
  - Often used during the initial installation phase of networks, prior to the implementation of ring or fibre route diversity networks
  - Typically uses a combination of terrestrial microwave and/or satellite
  - Downside is limited capacity compared to fibre
- **Branching Networks**
  - Provide protection for the principal network in the event of a failure on the branch

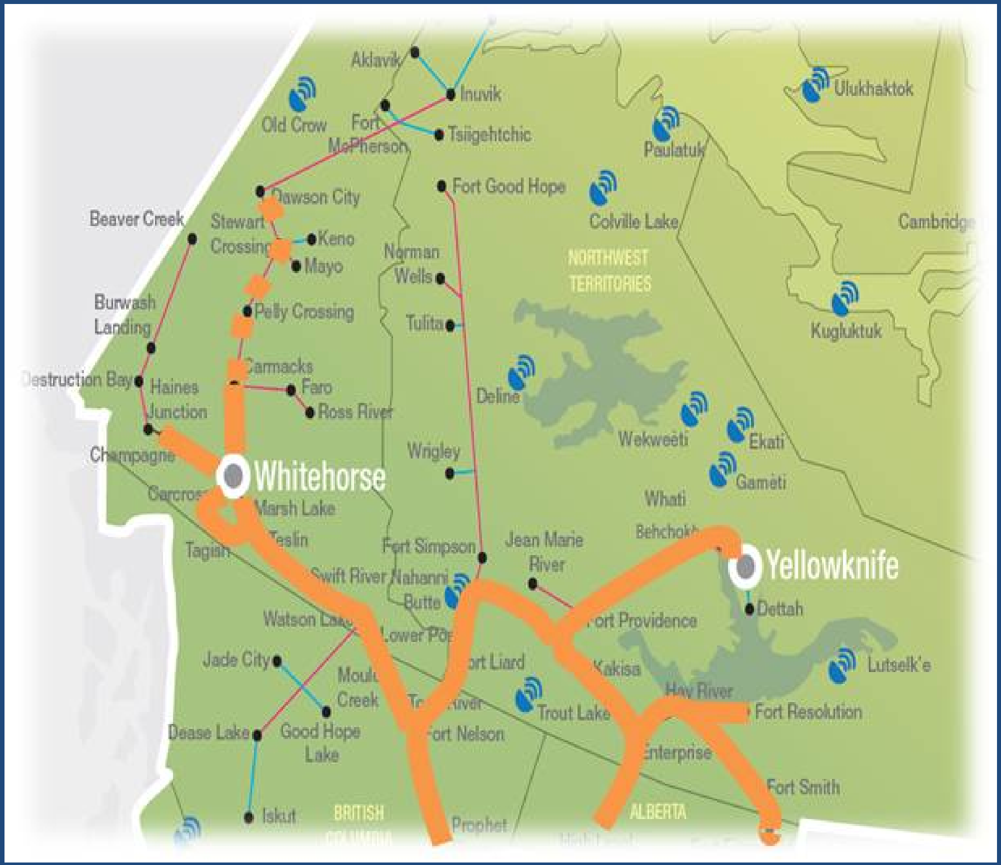
Current Northern Fibre Networks

- **NorthwesTel**
  - Links in NWT and Yukon
- **TELE Greenland**
  - Milton (Newfoundland) to Nuuk(Greenland) with continuation to Iceland
- **Quebec**
  - Link to Radisson, Quebec
- **MTS Allstream**
  - Joint MTS Allstream and Manitoba Hydro link to Churchill; requires refurbishment. MTS planning an asset swap with Manitoba Hydro to have 100% ownership of link to Churchill

NorthwesTel – Existing Fibre and Digital Radio

NorthwesTel has a combination of "owned" fibre links in Yukon and NWT, together with an IRU agreement (Indefeasible Right of Use) for one of two fibre connections to southern Canada network:

- NWTel has implemented a "ring" network topology to improve availability
- In most cases, digital microwave let in place for backup
- 2012 plan – extension of fibre network from Carmacks to Dawson City

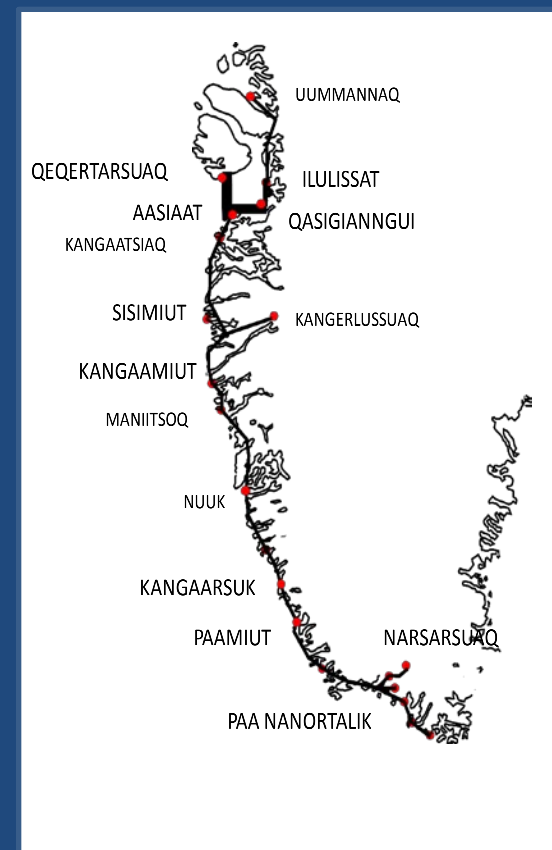


Black – NWTel owned Fibre
Red – Digital Radio

TELE Greenland

Existing Fibre Systems

Planned Extension



TELE Greenland System shown in Black

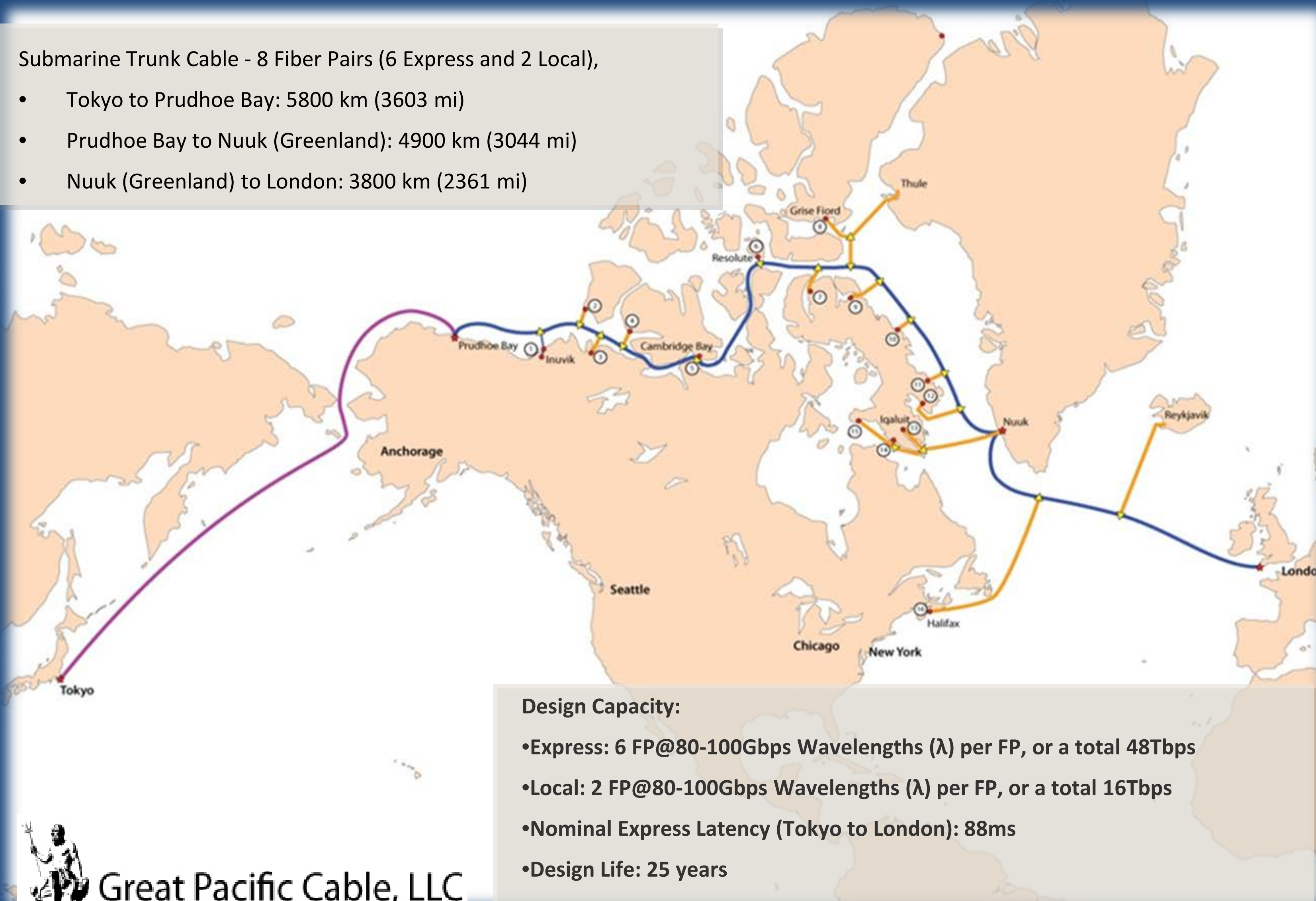
Planned Pan Arctic Systems
- Arctic Link (Initial Proposal)

- **Arctic Link – Initiative of the Arctic Cable Company LLC and the Great Pacific Cable Co (sponsored by the Kodiak Kenai Cable Company {Alaska)}and KhaNNet)**
- **Initial proposal was for a "northern " route traversing the McClure Straight and Lancaster Sound**
- **Summary**
  - Total Route Distance: 15,840 KM
  - Four Fiber Pairs (in addition to 2 NFOL Fiber Pairs)
  - Initial Capacity: 2FP x 8λ x 40Gbps = 640Gbps
  - Ultimate Capacity: 4FP x 40λ x 40Gbps = 6400Gbps or 6.4Tbps
  - 1 Regeneration Site in Alaska
  - Landings: Japan, US, Canada, UK

Planned Pan Arctic Systems
- Arctic Link (Latest Proposal)

Submarine Trunk Cable - 8 Fiber Pairs (6 Express and 2 Local),

- Tokyo to Prudhoe Bay: 5800 km (3603 mi)
- Prudhoe Bay to Nuuk (Greenland): 4900 km (3044 mi)
- Nuuk (Greenland) to London: 3800 km (2361 mi)



Design Capacity:

•Express: 6 FP@80-100Gbps Wavelengths (λ) per FP, or a total 48Tbps

•Local: 2 FP@80-100Gbps Wavelengths (λ) per FP, or a total 16Tbps

•Nominal Express Latency (Tokyo to London): 88ms

•Design Life: 25 years

Great Pacific Cable, LLC

Northwest Tel
- Preliminary System Alternatives

System alternative that takes advantage of the "northern route" option of the Arctic Link proposal

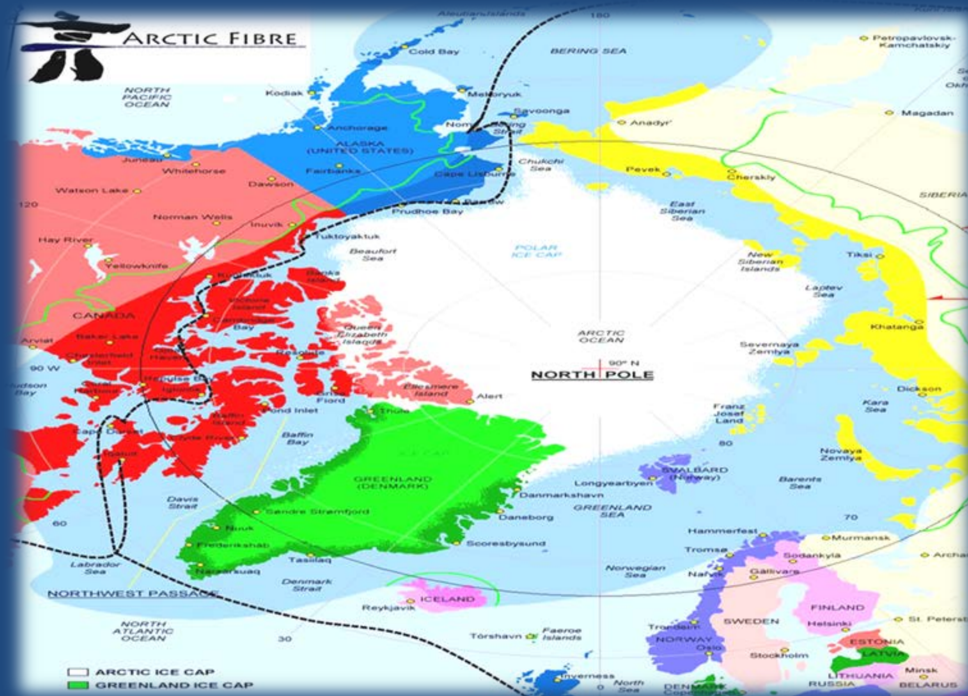
Proposal for a "festoon" system architecture serving northern Nunavut communities

System alternative serving southern Nunavut communities including those located on Hudson's Bay

Planned Pan Arctic Systems
Arctic Fiber (Overview)

Arctic Fibre is a Canadian company that has recently proposed a southern Northwest Passage route to connecting Asia and Europe via the Arctic.

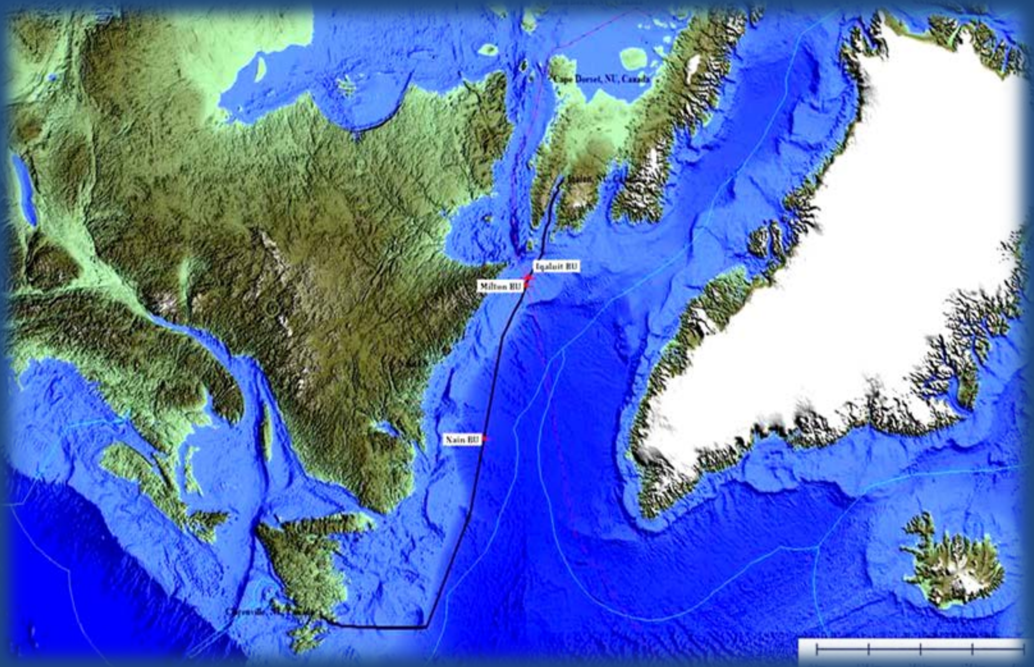
- **Estimated end to end system costs - $640M (includes terminal landings in Asia and Europe plus mid point regeneration station at Cambridge Bay)**



Landing Stations:	Chikura (Tokyo), Japan; Cambridge Bay, NU, Iqaluit, NU, Milton, NF, Canada; and Bude (London) United Kingdom
Landing Points:	Gambell, Nome, Point Hope, Wainwright, Barrow, Prudhoe Bay, AL Tuktoyaktuk, NT, Gjoa Haven, Taloyoak, Igloolik, Hall Beach, and Cape Dorset, NU, Canada
Network Capacity:	Express - Tokyo to London (two pairs @ 80 wavelengths @ 40 Gbps) Express – Tokyo to New York (one pair @ 80 wavelengths @40 Gbps) Festoon- Tokyo to Milton (one pair @ 80 wavelengths@40 Gbps)

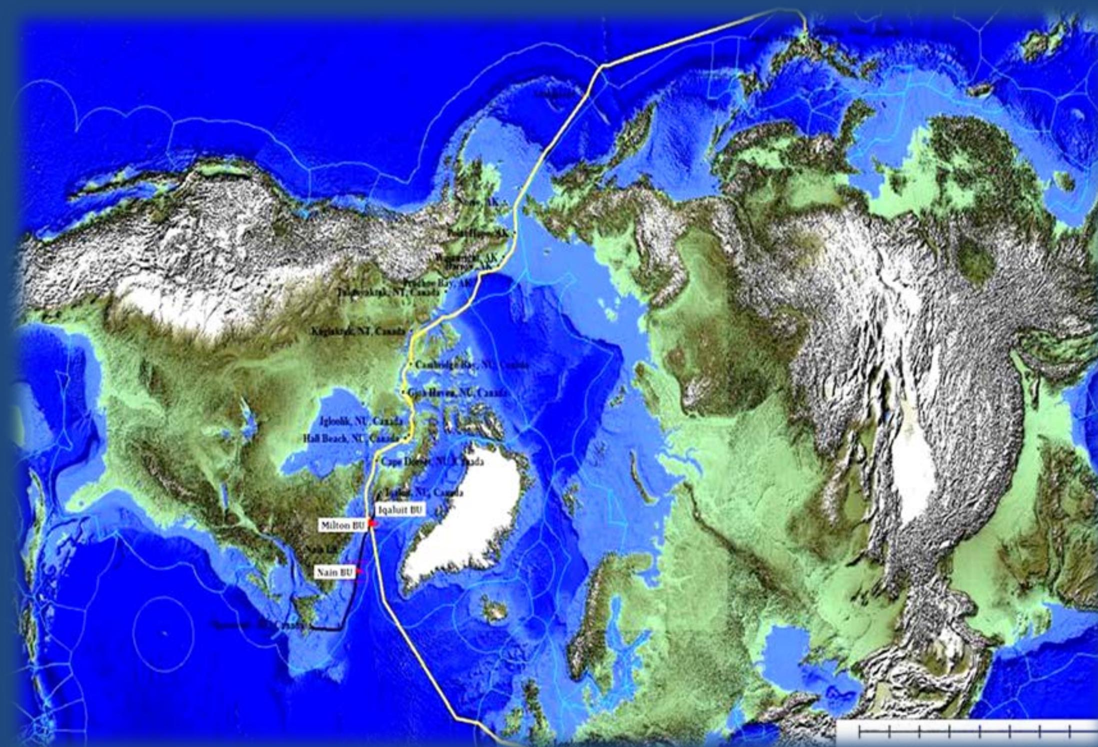
Planned Pan Arctic Systems
Arctic Fiber (Phase 1)

Phase 1 - Iqaluit NU to Milton Newfoundland planned for RFS (Ready for Service) 4th Quarter 2013.



Planned Pan Arctic Systems
Arctic Fiber (Asia to Europe)

End to end Asia to Europe service planned for RFS (Ready for Service) 4^{th} Quarter 2014.



Planned Pan Arctic Systems
Arctic Fiber (Canada)

Secondary network (in Yellow) dependant on availability of Government Funding

Landing Points:	Phase 5 - Nain NL (with microwave to Voisey's Bay) Phase 6 - Quataq, Kangirsuk, Kuujjuaq, Kangiqsujuaq, Salluit, and Ivujivik, QC Phase 7 – Coral Harbour, Chesterfield Inlet (microwave to Baker Lake), Rankin Inlet (microwave to Whale Cove), and Arviat, NU Phase 8 – Pangnirtung, Qikiqtarjuaq, Clyde River, Pond Inlet and Resolute Bay, NU
Inservice Date:	Uncertain; dependent upon government and carrier funding

Proposed Mackenzie Valley Fibre Link

Feasibility and business case review complete:

- **Technologically feasible, using direct buried marine type fibre cable**
- **Cost Estimate - $60M - $65M**
- **Time to complete – 2 years from completion of environmental review and permitting**

Identified as one of the three major infrastructure projects to be implemented by current session of NWT Legislature

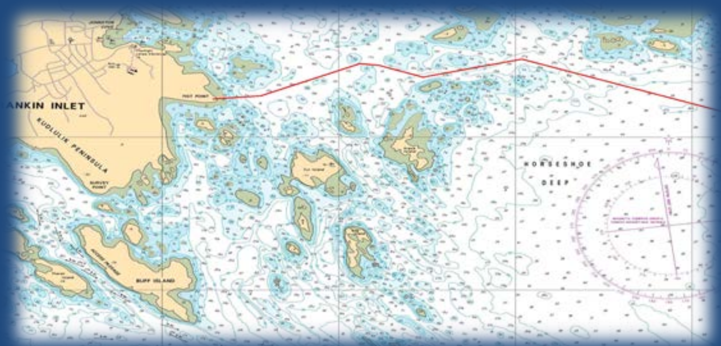
Fibre Feasibility Study Network Proposal Outline and Methodology

- **Generate a network model to serve all of Nunavut's communities with fibre optics, and provide a ROM (Rough Order of Magnitude) cost estimate**
  - Based on desk study, and available local, national and international information.
- **Generate a second network and cost model to provide service to the Regional centre's of Iqaluit, Rankin Inlet and Cambridge Bay (plus Resolute Bay)**
- **Provide a preliminary overview of alternative technologies (satellite and digital radio) as complementary network elements**
- **Provide a desk study for possible landings at Iqaluit, Rankin Inlet, Cambridge Bay and Resolute Bay**
- **Methodology:**
  - Marine Cable, Terminal Equipment, System Integrators and Marine Cable Laying Companies contacted and ROM pricing obtained
  - Network alternatives evaluated. Result is a combination of:
    - Fibre Ring architecture
    - Branching Units
    - “Festoon” architecture
    - Connection to existing and planned links
    - Back up technologies for diversity in the event of fibre cable failure
  - Assessment of Landing Costs
  - Costing and technical models then verified with potential suppliers

Iqaluit, Rankin Inlet and Resolute Bay Landings

Iqaluit - Two diverse paths are proposed from the ocean into Iqaluit and the cable would need to be buried in the bed of the inlet for an estimated 7km from Iqaluit to minimize the risk of damage by ice, fishing and anchorages

Rankin Inlet - Proposal is to serve by a single cable from a branching unit rather than risk the main ring being lost if the cables coming to shore at this point were to be damaged. We have proposed Chesterfield Inlet as the better location for a regeneration facility equipped with diverse shore landings



Resolute Bay - Two diverse cable paths are proposed A cable from Pond Inlet could come ashore due south of the airfield and Resolute Lake. A westerly route towards Cambridge Bay could come ashore to the west of the airfield where a 900m directional drill would reach about 20m of water.

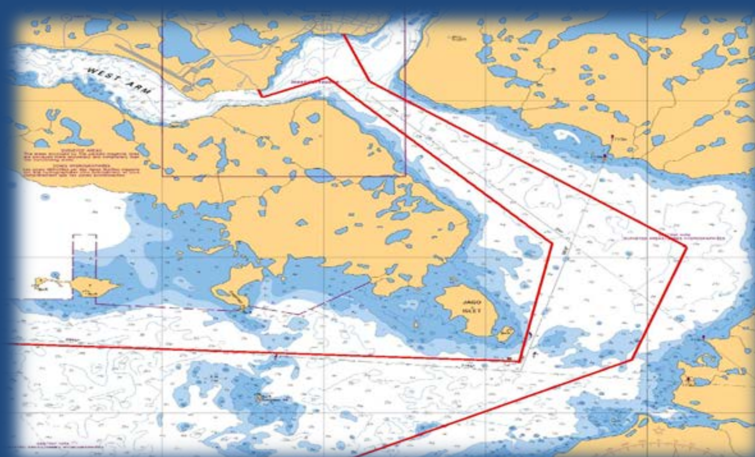
Cambridge Bay Landing

Chart A shows the suggested routes, the easterly feed coming ashore in the main part of the hamlet and the westerly feed coming ashore near the airstrip. Short drill shots from the shore of perhaps 150 to 250m in length should place the cable into deep water.

Chart A

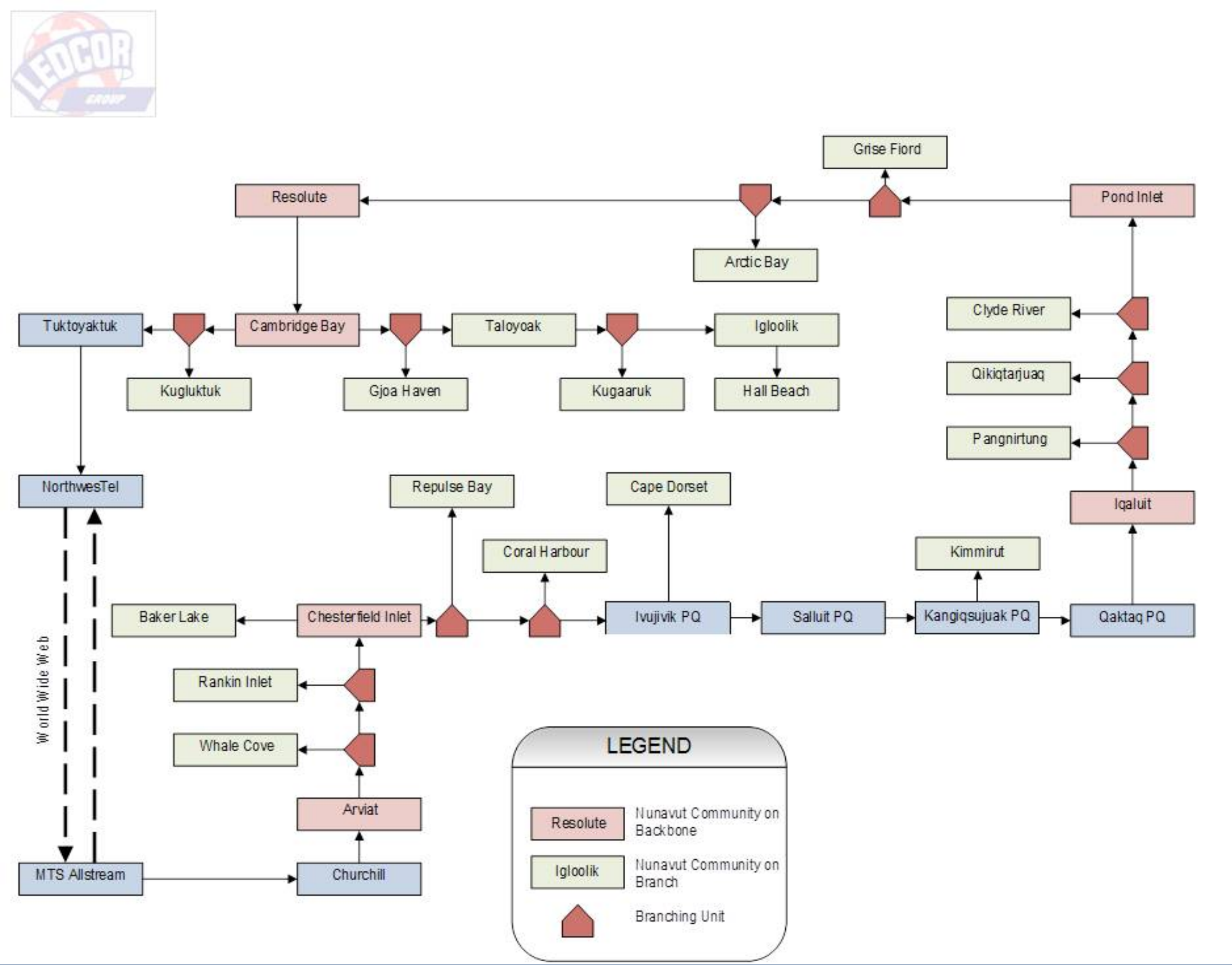
Chart B illustrates the possible routes through the bay into the Dease Strait for the westward traverse towards Kugluktuk, and into Queen Maud Gulf for the east side of the ring towards Resolute.

Chart B



Proposed Schematic to Connect Nunavut Communities (assuming Sanikiluak served from Nunavik)

Combines a fibre ring network architecture, with branching units for increasing system availability



Network to Connect all Communities

Possible External network connections

- Churchill – with MTS AllStream link
- Iqaluit to Nuuk or Milton link.
- Tuktoyaktuk to the Mackenzie Valley link

This architecture provides options for 3 independent links with the southern Canadian network, forming a "nested" ring topology:

- Western Canada to the High Level POP
- Churchill to the Winnipeg POP
- Eastern Canada to the St John's POP

Distances between Nunavut locations

From	Pop.	To	Distance	LOAs	DC Syst
Primary Backbone					
Churchill MB	923	Arviat	**275**	0	0
Arviat	2339	Chesterfield Inlet	**359**	0	0
Chesterfield Inlet	383	Ivujivik PQ	**668**	6	2
Ivujivik PQ	350	Salluit PQ	**158**	0	0
Salluit PQ	1241	Kangiqsujuaq PQ	**273**	0	0
Kangiqsujuaq PQ	620	Qaktaq PQ	**166**	0	0
Qaktaq PQ	307	Iqaluit	**532**	5	2
Iqaluit	7010	Pond Inlet	**1893**	18	2
Pond Inlet	1465	Resolute	**630**	6	2
Resolute	255	Cambridge Bay	**951**	9	2
Cambridge Bay	1626	Tuktoyaktuk NT	**1363**	13	2
Total	16920	Total	**7268**	57	12

From	Pop.	To	**Distance**	LOAs	DC Syst
Spurs and Branching Units					
Whale Cove	400	BU	**46**	0	0
Rankin Inlet	2730	BU	**71**	0	0
Baker Lake	1964	Chesterfield Inlet	**301**	1	1
Repulse Bay	875	BU	**411**	3	1
Coral Harbour	870	BU	**117**	1	1
Cape Dorset	1407	Ivujivik PQ	**233**	0	0
Kimmirut	455	Kangiqsujuaq PQ	**192**	1	1
Pangnirtung	1476		**308**	3	1
Qikiqtarjuaq	534		**93**	1	1
Clyde River	922		**109**	1	1
Grise Fiord	154		**356**	2	1
Arctic Bay	746		**117**	1	1
Taloyoak	891		**249**	3	1
Gjoa Haven	1138		**107**	1	1
Igloolik	1686	Taloyoak	**489**	5	1
Hall Beach	718	Igloolik	**82**	1	1
Kugaaruk	738	BU	**155**	2	1
Kugluktuk	1427	BU	**78**	1	1
Total	19941	Total	**3514**	27	15
		Total for backbone and laterals	**Cable km**	**LOAs**	**DC Syst**
			10,782	**84**	**27**

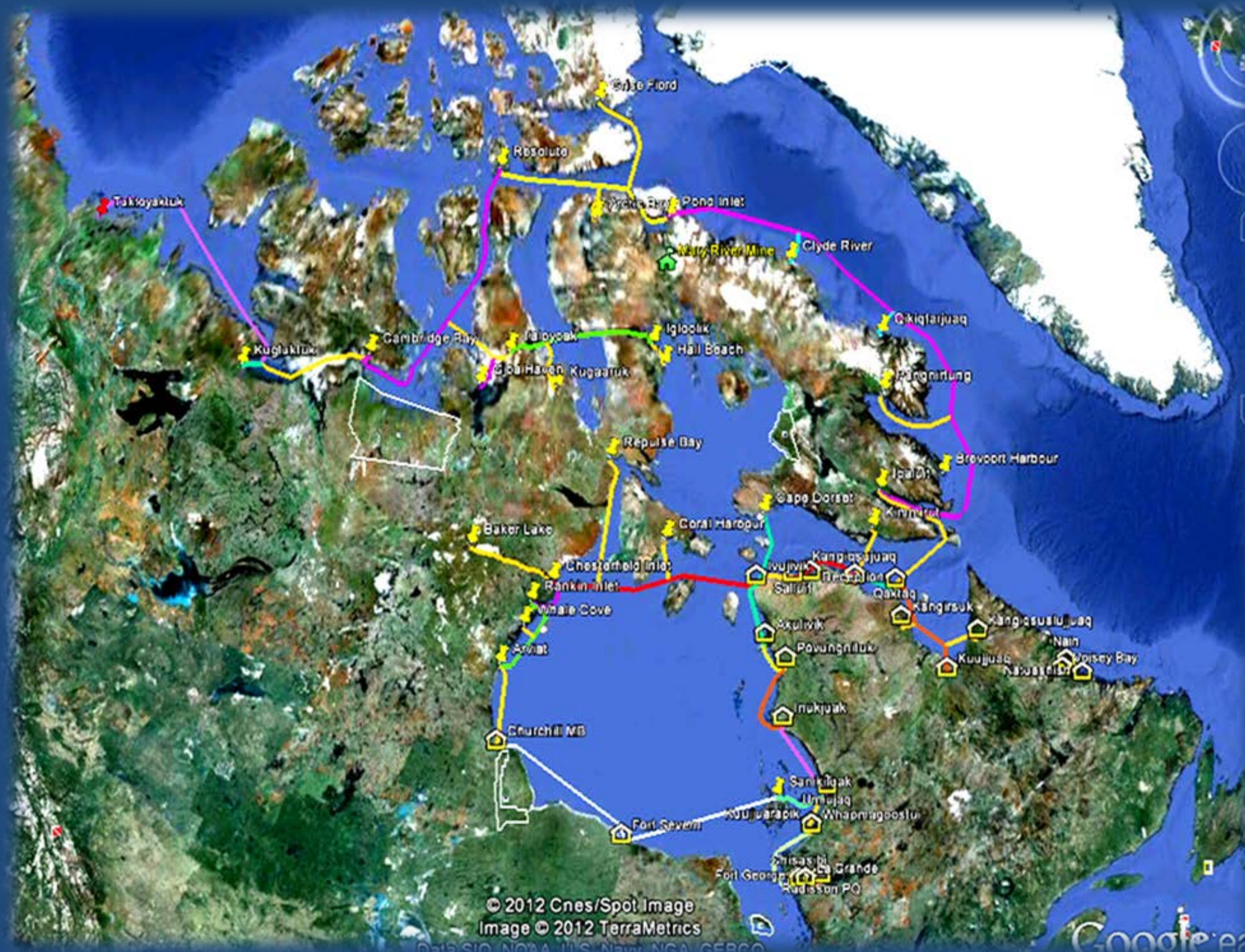
Cost Estimate

- For the proposed network architecture, the ROM cost estimate is $750M (without “risk” allowance), based on assessments of:
  - Horizontal drilling for landings
  - Plowing in shallow areas
  - Direct cable laying in deep waters
  - Appropriate use of double, single, and lightweight armoured cables.

Long Term "Fibre Ring" Architecture

Long term extension network to include a fibre ring around Hudson's Bay. This option would provide:

- Route Diversity with a fourth fibre connection to Southern Canada through Radisson Quebec
- A "two" ring northern network architecture
- Connection to communities in Nunivak



Provides a "robust" long term fibre pan arctic network for the North

Hudson's Bay Fibre Ring (including Communities in Nunavik)

Incremental distances to connect communities in Nunavik

From	Pop.	To	Distance	LOAs	DC Syst
Easterly Connection from Quebec					
Radisson PQ		Fort Georges PQ	99	0	
LG-1 Hydro Dam	0	BU	8	0	
Chisasibi PQ	4000	Drop		0	
Fort Georges PQ	620	Kuujjuarapik PQ	300	0	
Kuujjuarapik PQ	800	Umiujaq PQ	141	0	
Whapmagoostui PQ	500	Drop	0	0	
Umiujaq PQ	362	Sanikiluak	182	2	1
Umiujaq PQ		Inukjuak PQ	275	0	
Inukjuak PQ	1300	Povungnituk PQ	266	0	
Povungnituk PQ	1290	Akulivik PQ	122	0	
Akulivik PQ	510	Ivujivik PQ	202	0	
Kangiqsualujjuaq	620	BU	125	1	1
Kuujjuaq PQ	2132	Qaktaq	397	3	2
Kangirsuk PQ	466	BU	49	0	
Total	12600	Total	2166	6	4
		Total for all legs incl. Quebec	Cable km	LOAs	DC Syst
			12,948	90	31

This easterly leg has been included for the purpose of serving Sanikiluak (Pop 744) and makes sense only as part of a larger scheme to service Nunavik. Until such time, it is likely that Sanikiluak would continue to be served by satellite communications since a microwave service connecting it to the rest of Nunavut does not appear to be a viable option.

Second Nunavut Fibre Network Model

- This model is essentially a sub set of the more comprehensive network architecture, providing connections to:
  - Iqaluit – a proposed link to the TELE Greenland cable, either at a proposed branching unit in Baffin Bay, or a direct link to Nuuk.
  - Cambridge Bay – fibre link served by a link from the proposed Mackenzie Valley System at Tuktoyaktuk (Diversity by a terrestrial link from the Ekati Mine in NWT)
  - Rankin Inlet – fibre link from Churchill, Manitoba
  - Resolute Bay – extension of Tuktoyaktuk to Cambridge Bay link
- ROM Cost Estimate: $ 244M (includes link to Nuuk, but excludes radio diversity link to Ekati Mine) – no allowance has been made for "risk" analysis

Complementary Technologies Look Forward to 2020

- Satellite
  - High throughput satellites
  - LEO (Low Earth Orbit), “Router in the Sky” satellite services
  - GoC PolarSat Mission
- Digital Microwave “Backhaul” Radio
  - High capacity “broadband” systems

Satellite Systems

- Satellite technologies have a proven track record in the North
  - Anik F2's availability record is 99.789% (2011), 100% (2010, 2009 2007) and 99.9942% (2008)
- The most promising satellite technology for the north, that has been tested and verified, uses the latest high throughput satellites
- Reliable service from Low Earth Orbit communication satellites requires a "necklace" of satellites that communicate with each other, and route traffic between satellites. Services from these systems are priced at the high end of the market, and are typically used for military and security communications
- The communication portion of the proposed GoC PolarSat mission is aimed towards providing better communications in the North for ships and aircraft traversing the region

Example of High throughput Satellite Service

- **A High Throughput Satellite(ViaSat 1) was launched and commissioned in late 2012. It provides:**
  - **Economical Internet multimedia capability**
    - **100 times the capacity of Ku-band**
    - **10 times the throughput of any other Ka-band satellite**
    - **In-orbit costs per Gbyte at a fraction of the newest satellites in orbit**
    - **KA-SAT capacity operational now at 70 Gbps**
  - **ViaSat-1 live on January 16, with more capacity than all current North American satellites combined**
  - **Enables service on par with median DSL, and better service than mobile 3G wireless for fixed home use, and many cable systems**
  - **ViaSat-1 will offer 12 Mbps download service packages to approximately 1 million subscribers**

Summary

- **High Throughput Satellites have the potential to provide faster and more economical broadband services to Northern communities**

Possible Evolution of Satellite Technology

Evolution of Broadband via Satellite

Telesat

	1st Generation	2nd Generation	3rd Generation
Example Systems	Ka-band – e.g. Anik F2/Ka	Ka-band – e.g. Viasat-1	Anik G (proposed) - Ka and V-band
Spot Beam Size	0.8 – 0.9 °	0.4 – 0.5 °	Mix of 0.15 to 0.3° V-band Option 0.4° to 1.0° Ka-band
Coverage	Contiguous	High demand areas only (supplemental capacity)	Small spots for high demand areas with large spots added for contiguous coverage
Service	High speed Internet (at today's user traffic levels)	High speed Internet (at future user traffic levels)	Very High Speed Internet including Internet based media rich services
Service Positioning	Complementary to DSL & cable modem	Complementary to DSL & cable modem	Keeping pace with DSL & Cable and even FTTH
User Speeds – Down	~ 4 Mbps	~ 20 Mbps	100+ Mbps
User Speeds – Up	~ 1 Mbps	~ 10 Mbps	20+ Mbps

Going forward, 1st, 2nd and 3rd generation systems will co-exist and will serve their targeted markets

Digital Microwave Backhaul Radio Systems

Modern digital microwave systems have capacity from 500 Mbit/s to 1.0 Gbit/s, providing broadband capability.

- **Design considerations:**
  - Propose a fully protected 1+1 system design
  - RF (Radio Frequency) design - propose space and frequency diversity, with an average of 40 m towers, between 1.8m and 3m dishes resulting in a 30 km and 40 km skip distance between repeater locations
- **Cost considerations:**
  - Typically, between $1.0 and $1.2 million per site
  - Example – for Chesterfield to Baker Lake system (approx 300 km, we estimate 9 sites (two terminal sites and 7 repeaters sites) for a total capital cost of between $9.0M and $10.8M
- **Reliability**
  - Typically in the order of 99.9% in-service time
- **Summary**
  - Except in situations where the installation of fibre cable is not feasible, the capital and maintenance costs of radio systems would typically limit their economic application to communities within 100km to 140 km of a fibre hub

Socioeconomic Overview and Need for Broadband

- **GDP in Nunavut is growing at a rapid pace, largely due to resource development that may or may not benefit the people who live in Nunavut.**
- **Nunavut communities play an important role as starting points for sovereignty activities, exploration, land management and environmental stewardship.**
- **Nunavummiut currently score low on socioeconomic indicators, but broadband is seen as a tool to help improve opportunities:**
  - ***"It is clear that northern economies are very strong and are getting stronger. It is also very clear the challenges the North face are not economic, but social. Broadband-enabled services have a very significant role to play in ensuring a higher quality of life while helping to build and maintain sustainable communities and lessening the digital divide. "*** - ACIA report, pg 164
- **People can use broadband connectivity to help build Nunavut businesses, access a wider variety of education, improve health outcomes, support the decentralized government and strengthen language and culture.**

Socioeconomic Overview - Infrastructure Needs

- Connectivity is now provided via satellite with a point of presence in each of Nunavut's 25 communities, and then distributed to homes, businesses and government with a mix of wireless, copper and fibre.
- Current satellite bandwidth is inadequate to run needed applications over the backbone, as applications increasingly are designed to run on fibre, not satellite.
- All communities are interested in connecting to fibre, as a solution to their bandwidth crisis - as fibre can deliver exponentially faster speeds.
- Hope is high for access to more education, business opportunities and health outcomes so people can work in one of the many jobs created in the future, particularly in the resource sector - exploding in all corners of Nunavut, not just around the regional centres and military investments.
- There is an imperative in Nunavut to try to ensure all communities have similar speeds so implementation of territory wide initiatives dependant on broadband will actually work, providing benefits to all 31,000 Nunavut residents. Nunavut demographics are unique in the north, with a population spread more evenly throughout, so programs are necessary everywhere - with equal opportunity to benefit (service parity).
-

Fibre connectivity - economic challenge from socioeconomic perspective

- While compelling, the socioeconomic needs of Nunavut's population will not provide enough investment incentive for fibre for all communities:
  - at over $1 billion, the estimated cost for installing fibre to each Nunavut POP is almost equal to the Government of Nunavut's entire annual budget
- There are other critical infrastructure investments required in Nunavut, from power to housing, water, schools, airports, health centres, competing for the socioeconomic investment dollar.
- As a territory, GN cannot raise its own royalties and taxes from the expanding resource sector - only the GoC can:
  - Even as the GDP rises, no additional investment in people and infrastructure is possible without the GoC
- Military and sovereignty needs in Cambridge Bay, Resolute, and Nanisivik provide some incentive for investment, but again, are dependant on the Government of Canada.
- Resource sector also needs communications infrastructure, and better infrastructure may assist in attracting even more resource sector investment in Nunavut, that can benefit all of Canada and Nunavut .
- Proposed private sector fibre builds require GoC investment in the form of committed future revenue and usually, capital investment.
- Any economic decision to invest in fibre will be driven by the GoC, as the main investor, bundling the various investment drivers to make a case for investing in backbone.

Mixed Technology Communications Networks

- Communications in Nunavut could evolve in two directions:
  - A satellite only network, using improvements in satellite technology and spare capacity in Canadian arctic coverage. This would require less capital expenditure.
  - Use of a mix of technologies. The rationale for this approach would need to be based on more than the demand pull economics of local communities.
    - This mix could eventually comprise of fibre, satellite and, in a limited number of applications, digital microwave backhaul technologies.
- For a mixed network, and considering the second network model (providing fibre service to Iqaluit, Rankin Inlet and Cambridge Bay, with a possible extension to Resolute Bay), the remaining communities in Nunavut would most likely remains with satellite service with the possible exception of the following microwave links.
  - Chesterfield Inlet to Baker Lake
  - Repulse Bay from Kugaaruk
  - Pangnirtung from Qikiqtarjuak
  - Hall Beach from Igloolik
  - Kugaaruk from Taloyoak
- In the management of a mixed network, it would be important to assess the level of service provided by each delivery mechanism, from the perspective of the user and the services that could be delivered.

Implications of a Mixed Network on Service Parity

- The socioeconomic opportunities broadband brings will only be open to a portion of the population if some communities are connected and others are not, creating a political and cultural challenge in Nunavut.
- Applications in government management tools, health, education and business development may not be implemented at all if the majority of communities are not connected, as agencies will have to maintain duplicate processes, so will not invest in the first place.
- As people become more reliant on connectivity for critical tasks, the more important it is that the connectivity is reliable. Fibre connections that can have a single point of failure need satellite back up that can run mission-critical applications immediately in the event of a fibre cut.
- A single fibre pair carries about 600 times more than what Iqaluit expects on satellite. An emergency satellite back up based on the current satellite bandwidth infrastructure will not provide a reliable back up once people start to rely on fibre.
- It is critical that concurrent investment in high throughput satellite will be required to serve non-fibre linked communities, and to provide effective back up in the event of a fibre failure.
- Any serious plan for fibre backbone investment must consider how to mix fibre and satellite so that any difference in service levels as can be managed for the socioeconomic growth of the entire territory.

Socioeconomic Recommendations

- **Recommendation 1: Investment in infrastructure must benefit Nunavummiut as it also seeks to benefit Canada:**
  - As the Government of Canada invests in communications infrastructure to both meet the needs of sovereignty and attract mining investment, there will need to be rules to ensure this investment also directly benefits community members in all Nunavut communities with opportunities to benefit from increased connectivity to every community.
- **Recommendation 2: Reliability and redundancy paramount :**
  - Recognize that fibre lines, by the very nature of the Arctic environment, may be at relatively high risk of damage and difficult to repair. Any investment decisions should focus on redundancy either through a robust ringed architecture system, and/or through high throughput satellite for back up. If there is not a robust back up system, then in the event of a failure, the communications failure becomes the emergency.
- **Recommendation 3: Strategic concurrent backbone investment required in satellite:**
  - Recognize that even with fibre investment, satellite will continue to play a significant role -- both in terms of providing back up to fibre connected communities, as well as providing primary connectivity for others. There must be a strategic balance of investment in both fibre and satellite backbones.
- **Recommendation 4: Future revenue streams required to maintain and innovate:**
  - After an initial investment into a backbone infrastructure, there must be a system developed for continued investment for maintenance on branch lines, innovation, quality of service requirements and regulations to ensure the costs to the end user do not creep into the ‘cost-prohibitive’ category.

Socioeconomic Considerations - Summary

- Broadband access should be an enabler, not a constraining factor in the lives of Nunavummiut
- The real questions of access, equity, opportunity to benefit from broadband have always been closely linked with the thorny challenge of paying for a backbone that far exceeds the territorial and community financial capacity to solve

Public Private **Partnerships** (PPP or P3)

Four basic alternatives:

1. **Traditional Options e.g. Design, Build, Operate Maintain**
   - Following the GoC P3 Model, the public good element of the project has to be clearly articulated, and the eventual ownership of the asset has to be with a public entity (Territorial Government, Aboriginal Government, Municipally etc)
2. **GoC Industry Canada Model**
   - The difference here is that ownership of the asset can eventually rest entirely with the private sector
3. **“Condominium” Model**
   - A project sponsor (e.g., a Territorial Government) would own and manage the overall framework of the project, but would be able to “sell,” “lease,” “rent” capacity to private sector clients while maintaining a separate element for public good use (health care, education, social services etc.)
4. **IRU’s (Indefeasible Right of Use)**
   - IRU’s are commonly used in long haul fibre systems as a way of sharing costs while retaining control of an agreed communications channel

PPP Basics

- Historically, PPP arrangements arose as an innovative approach to public procurement from the need to limit public debt, and share risk between Government and the private sector.

- PPP arrangements seek to transfer risk from the public domain to the private sector, with an acknowledgement that the private sector will require a return on investment that is commensurate with the degree of risk they are being asked to assume.

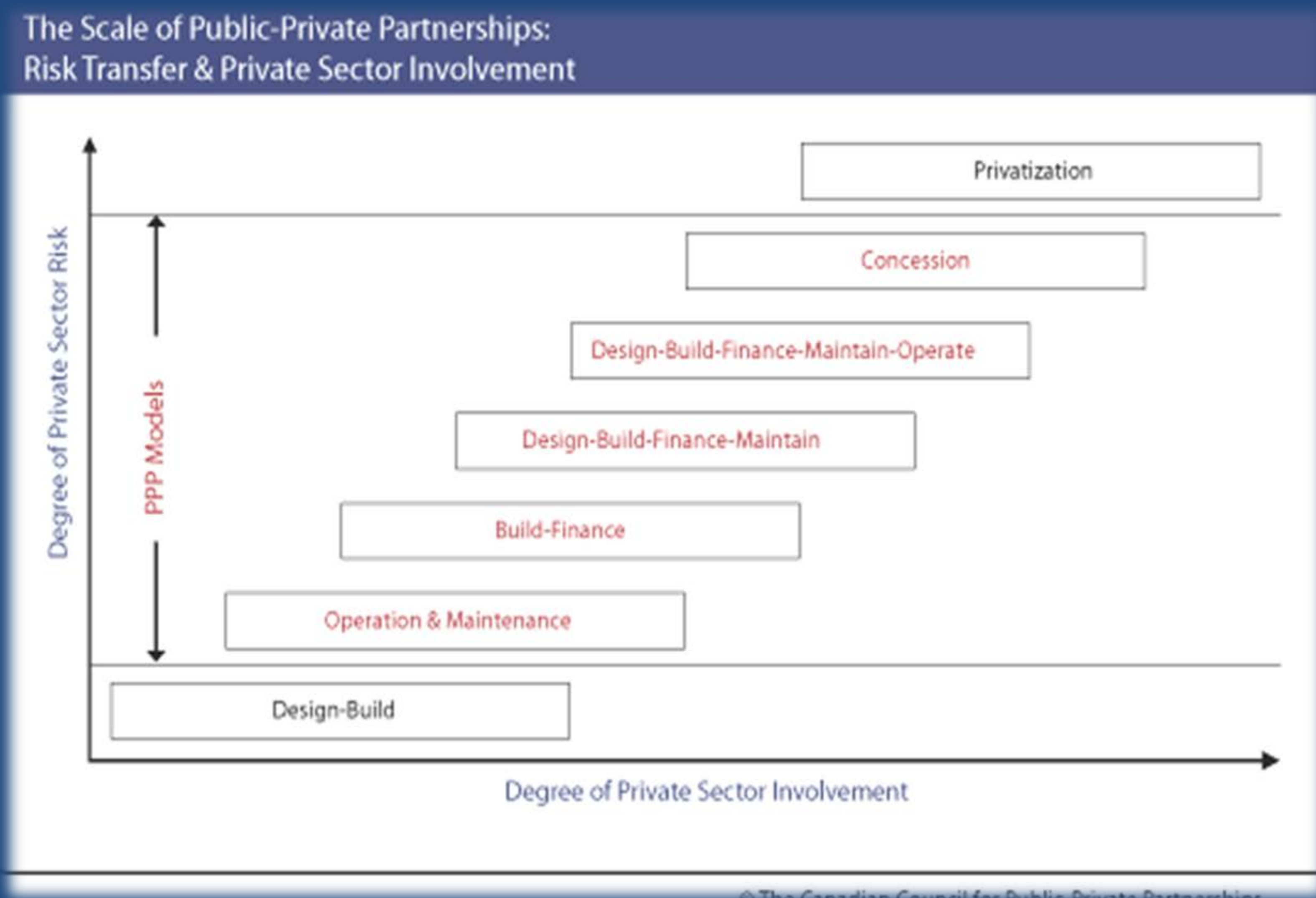
  – The less risk, the less return that is offered, or expected

- Certain PPP arrangements also have the advantage of being reported on Government accounts as operating expense rather than the traditional reporting as a capital expense.

  – This particularly important for Governments that are operating close to their debt limit.

- PPP's tend to work for large infrastructure projects where the value of the risk transferred is higher than the incremental financing costs.

Private Public Partnerships (Traditional Alternatives)



Preliminary Risk Analysis

- A very preliminary risk analysis has been undertaken, using typical GoC methodologies:
  - A risk based "heat map" – Treasury Board
    - TB **Guide to Corporate Risk Profiles, 11th July, 2011**
  - Project Complexity and Risk Assessment Tool – Treasury Board
    - TB **Guide to Using the Project Complexity and Risk Assessment Tool, 7th Dec, 2009**
  - A statistical combination of:
    - Assignment of probability of occurrence of key risk areas using the formula (Risk = Impact x Probability)
    - An assessment of the potential cost impact of each of the risk factors
    - An evaluation of the total potential cost risk, and an assessment of a typical cash reserve that could be required by Treasury Board

Risk Elements Evaluated

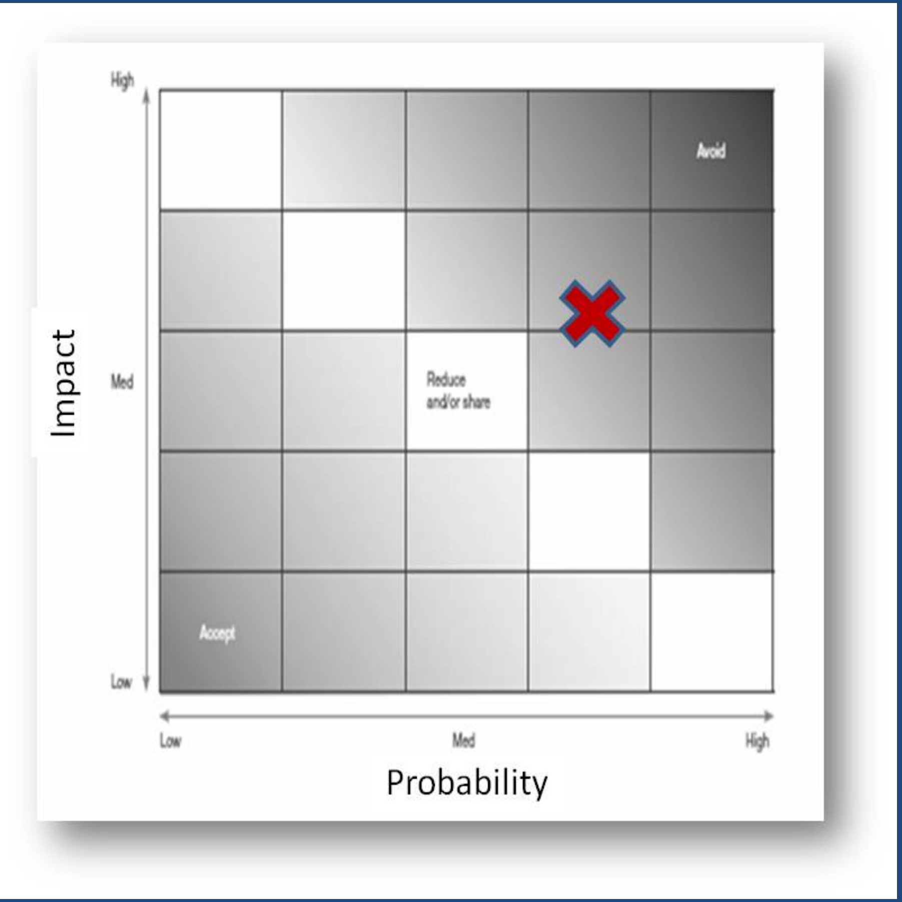
The following elements were considered in the preliminary risk analysis from the perspective of costs and potential impact on scheduling (which, in turn, was translated into a cost)

- Environmental Reviews and Permitting
- Project Financing
  - Business risks
  - Government policy changes
- Procurement
- Project Management
- Technical
- Northern Environmental Conditions

Risk Management "Heat Map."

An initial assessment of the risk elements put this project in the moderately high probability of risk, with a similarly moderately high probability of significant impact

- **From a GoC perspective, together with the Treasury Board (TB) Risk Analysis Tool, this puts the project in the TB "Transformational" category, and would require a senior executive and management team assigned to oversee the project.**



Risk Analysis - Potential Cost Impact

- The preliminary results of the risk analysis, using the GoC risk assessment tool and the statistical combination of risk vs. potential impact would, at this stage of the project, increase the cost (from the perspective of a cash "reserve") by approximately 40%
- This would translate to project costs of:
  - $750M x 1.4 = $1,050M to connect all communities in Nunavut with fibre
  - $244M x 1.4 = $342M to connect Iqaluit, Cambridge Bay, Rankin Inlet and Resolute Bay with fibre
- The "risk premium" reflects that the Feasibility Study was generated on the basis of a "preliminary desk top study. " The premium could be reduced by transferring risk to the private sector or other stakeholders, and/or by future activities designed to better assess the risk, thereby allowing the identification of appropriate risk mitigation alternatives

Next Steps

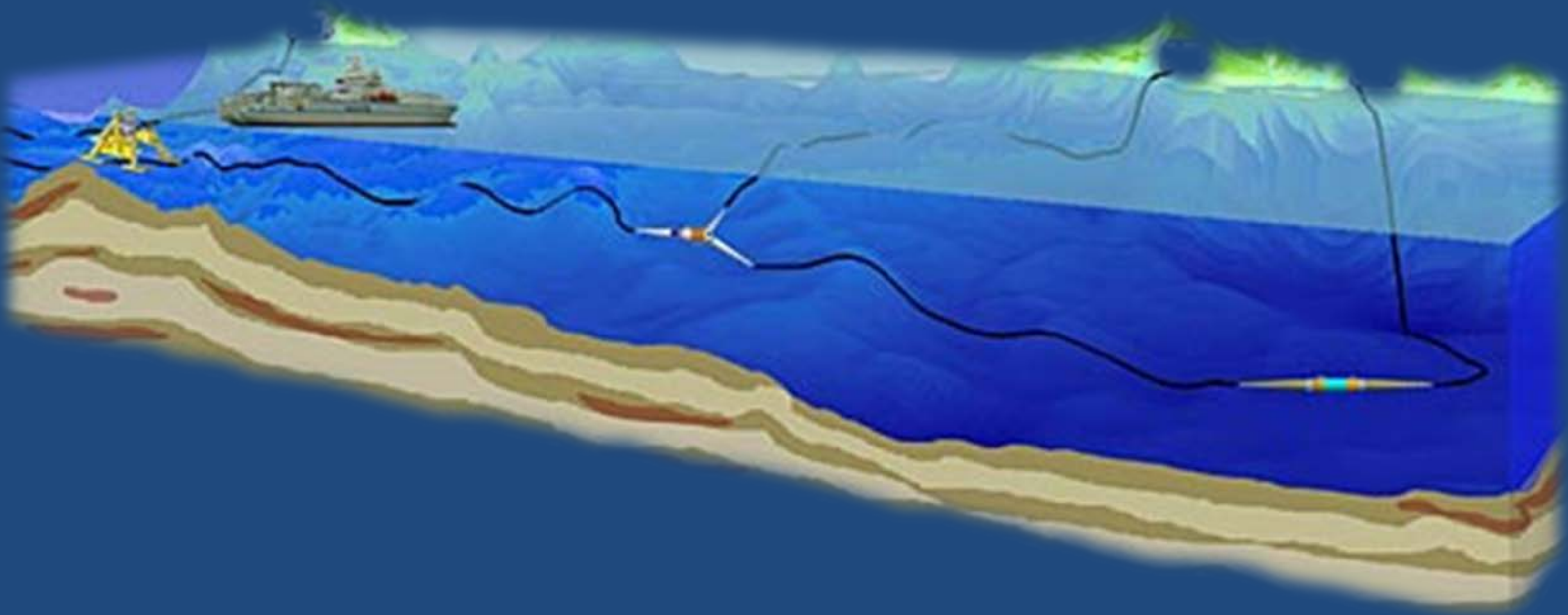
- **Community Consultations**
  - SGC believes that this a vital part of the proposed project. The consultations should be substantive, "in person," and allow for input from local communities from the outset of the project to be considered
- **Communication Network Evolution Strategies:**
  - In the long term, one potential option is that the Nunavut communications network could evolve into a combination of satellite, radio and fibre
  - SGC recommends that further work be considered to define the potential impact of a Territorial wide mixed technology communication infrastructure, both from a technical, ownership, financing and administration perspective, and also from a broader socioeconomic perspective
  - SGC recommends that this activity include consultations with NWT, Yukon, Governments of Quebec, Ontario, Manitoba and the Federal Government from the perspective of a potential, cohesive, Pan Arctic communications strategy
- **Proposed Northwest Passage Private Sector Initiatives**
  - As identified in the Feasibility Study, a number of initiatives have been proposed
  - The proposed Asia – Europe systems have the advantage that financing for the end to end link have the effect of potentially subsidizing both the capital and O&M costs of a Canadian Pan Arctic fibre link
  - The proposals also have an advantage that the private sector will assume a portion of the risk of the system
  - SGC recommends that these alternatives be seriously considered (one of them might be implemented) at least at the level of identification of possible branching units – these units are relatively inexpensive to provide during initial installation, but much more expensive to provision once the backbone system is installed and operating

“Next Steps” - Risk Mitigation Options

The “risk premium” could be reduced by:

- **Completion of a detailed field and marine study**
- **Detailed assessment and projected schedule for environmental review and permitting process**
- **Sharing, and transference of risk to private sector and/or other potential stakeholders**
- **Business case analysis for the proposed project elements**
- **Assessment of financing alternatives**
    - Federal Government Departments
    - Territorial Governments
    - Development and Export/Import (Exim) Bank loans at both concessionary and consensus rates (in relation to LIBOR rates).
    - Domestic and International Private Sector Bank loans (including Aboriginal Banks and Financing Institutions)
    - Pre buying options for capacity – this options consists of conditional purchase orders that convert into firm fixed price contracts in the event that the project proponent delivers the project on time, within budget and to an agreed technical performance and reliability specification. The PO’s can usually be converted into cash financing for project construction, with a risk premium being charged on the notes.

Questions?



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TECHNICAL REPORT

NUNAVUT
FIBRE OPTIC FEASIBILITY STUDY

for

THE NUNAVUT BROADBAND DEVELOPMENT CORPORATION

February 2012

LEDCOR TECHNICAL SERVICES

Table of Contents

A. TECHNICAL ASSESSMENT – FIBRE-OPTIC NETWORK

1.0 Network Architecture

1.1 Ring architecture

A fibre optic network is typically configured as a ring with traffic able to move in either direction. In the event of a cable cut anywhere on the ring, the transmission equipment automatically reconfigures the communication direction away from the cut in a matter of milliseconds. So long as there is not a second cut on the ring, the only potential for service loss to customers is in the immediate vicinity of the cut.

In a system as remote and inaccessible as Nunavut, ring diversity is crucial to operations since it may be weeks or even months before some areas could be accessed for repair.

1.2 Route Options

At this stage in the development of Nunavut a terrestrial cable route option is virtually out of the question. With no road access to any of the 25 primary communities and without construction roads for access, the logistics of installing cable become enormous. Bush has to be cleared; land levelled for vehicle access; rivers and lakes crossed; muskeg, rock and frozen ground dealt with; equipment maintained and repaired; crews rotated, sheltered and provisioned; materials delivered; repeaters and signal regenerators powered and serviced; and the cable accessed for maintenance and repair.

However, with all the 25 communities save Baker Lake on sea coast, it makes good sense to focus on submarine cable options. Not that this is without its own difficulties because of a short construction season; arctic sea ice; problems of access to the communities to construct shore landings; and protection of the cable in shallow waters. All these issues are discussed in the next section.

1.3 Connectivity to (and Diversity for) Existing Carriers

The proposed Nunavut broadband network must have connectivity to the worldwide web through more than one existing or proposed fibre network in order to provide diverse optical paths for proper redundancy.

In addition to establishing secure communications within the territory, the Nunavut network could add value to other existing carriers by providing redundancy for their own systems.

The Nunavut network would have the potential to connect to the following existing or proposed systems:

a) An existing fibre network in Quebec reaches Radisson on the Le Grande Riviere which flows into James Bay via the huge James Bay Hydro-Electric Dams. A westerly extension of this fibre system would reach a number of communities on the east shore of James Bay and could continue as a festoon cable up the east side of Hudson’s Bay picking up Sanikiluak, NU on the way to Hudson Strait.

b) On the west side of Hudson's Bay there is the opportunity to connect to MTS Allstream's fibre-optic network in Manitoba via Churchill. We have spoken to MTS and they own a fibre optic cable which runs south from Churchill to Gillam. From Gillam west to Thompson, they share fibres with Manitoba Hydro along a hydro right-of-way. From Thompson there are diverse cables south to Winnipeg. We understand that the system would require new optronic equipment with additional wavelengths (DWDM) to provide the capacity contemplated for Nunavut but MTS believe this is quite feasible.

c) South of Hudson's Bay, Bell Aliant is in the process of constructing a fibre-optic cable as far as Trout Lake, ON. The work is intended to be completed by 2015. From Trout Lake however, there would over 300km of difficult terrain to cross to reach Fort Severn on the shore of Hudson's Bay.

d) To the west, the proposal would be to connect to a system being proposed to connect Yellowknife with Tuktoyaktuk, NT. This proposal is still in the early planning stages and a completion date has not been set.

e) Internationally, there is the possibility to connect in Nuuk, Greenland, to an undersea cable that runs to Newfoundland.

f) Also international in scope is a transoceanic cable that two organizations are contemplating to run between London, England to Tokyo, Japan via the Northwest Passage. The commercial intent is to reduce the latency of traffic between the financial markets of these two cities –a reduction in transmission time representing a market advantage. The proposed routes of these proposals are different. The Arctic Link cable would border the east coasts of Labrador and Baffin Island before heading west past Resolute, Cambridge Bay and Tuktoyaktuk. The more recent Arctic Fibre proposal shows a more southerly route to the west of Baffin Island and running past Cape Dorset, Igloolik and Gjoa Haven before taking the same route west from Cambridge Bay.

Each of those systems could pay for redundant capacity on the Nunavut Network, possibly in a quid-pro-quo arrangement to provide redundancy for Nunavut.

1.4 Connectivity

Appendix A, Proposed Route Plan, shows a possible routing of a fibre-optic cable to connect all 25 communities in Nunavut superimposed on a Google Earth map. The estimated distances involved are reflected in the following table.

NB: Nunavut communities are shown in red.

From	Pop.	To	Distance	LOAs	DC Syst
Primary Backbone					
Churchill MB	923	Arviat	275	0	0
Arviat	2339	Chesterfield Inlet	359	0	0
Chesterfield Inlet	383	Ivujivik PQ	668	6	2
Ivujivik PQ	350	Salluit PQ	158	0	0
Salluit PQ	1241	Kangiqsujuaq PQ	273	0	0
Kangiqsujuaq PQ	620	Qaktaq PQ	166	0	0
Qaktaq PQ	307	Iqaluit	532	5	2
Iqaluit	7010	Pond Inlet	1893	18	2
Pond Inlet	1465	Resolute	630	6	2
Resolute	255	Cambridge Bay	951	9	2
Cambridge Bay	1626	Tuktoyaktuk NT	1363	13	2
Total	16920	Total	7268	57	12

From	Pop.	To	Distance	LOAs	DC Syst
Spurs and Branching Units					
Whale Cove	400	BU	46	0	0
Rankin Inlet	2730	BU	71	0	0
Baker Lake	1964	Chesterfield Inlet	301	1	1
Repulse Bay	875	BU	411	3	1
Coral Harbour	870	BU	117	1	1
Cape Dorset	1407	Ivujivik PQ	233	0	0
Kimmirut	455	Kangiqsujuaq PQ	192	1	1
Pangnirtung	1476	BU	308	3	1
Qikiqtarjuaq	534	BU	93	1	1
Clyde River	922	BU	109	1	1
Grise Fiord	154	BU	356	2	1
Arctic Bay	746	BU	117	1	1
Taloyoak	891	BU	249	3	1
Gjoa Haven	1138	BU	107	1	1
Igloolik	1686	Taloyoak	489	5	1
Hall Beach	718	Igloolik	82	1	1
Kugaaruk	738	BU	155	2	1
Kugluktuk	1427	BU	78	1	1
Total	19941	Total	3514	27	15
		Total for backbone and laterals	Cable km 10,782	LOAs 84	DC Syst 27

From	Pop.	To	Distance	LOAs	DC Syst
Easterly Connection from Quebec					
Radisson PQ		Fort Georges PQ	99	0	
LG-1 Hydro Dam	0	BU	8	0	
Chisasibi PQ	4000	Drop		0	
Fort Georges PQ	620	Kuujjuarapik PQ	300	0	
Kuujjuarapik PQ	800	Umiujaq PQ	141	0	
Whapmagoostui PQ	500	Drop	0	0	
Umiujaq PQ	362	Sanikiluak	182	2	1
Umiujaq PQ		Inukjuak PQ	275	0	
Inukjuak PQ	1300	Povungnituk PQ	266	0	
Povungnituk PQ	1290	Akulivik PQ	122	0	
Akulivik PQ	510	Ivujivik PQ	202	0	
Kangiqsualujjuaq	620	BU	125	1	1
Kuujjuaq PQ	2132	Qaktaq	397	3	2
Kangirsuk PQ	466	BU	49	0	
Total	12600	Total	2166	6	4
		Total for all legs incl. Quebec	Cable km 12,948	LOAs 90	DC Syst 31

This easterly leg has been included for the purpose of serving Sanikiluak (Pop 744) and makes sense only as part of a larger scheme to service Nunavik. Until such time, it is likely that Sanikiluak would continue to be served by satellite communications since a microwave service connecting it to the rest of Nunavut does not appear to be a viable option.

2.0 Risks to Submarine Cables

2.1 Fishing

Fishing activity is traditionally one of the greatest threats to submarine cables on the continental shelf since commercial trawling can snag and damage buried cables that are not well protected. The corollary is that commercial fishing boats can lose a lot of expensive gear when fishing around heavily armoured cables. Although there is now a protection zone against commercial fishing off the coast of Alaska, there is not the same level of legislation in place off the Canadian coast. In fact commercial fishing has expanded significantly in Nunavut and is a significant contributor to the Territory's economy with a large processing plant in Pangnirtung and smaller operations in Iqaluit, Rankin Inlet and Cambridge Bay. Community facilities also exist in Gjoa Haven, Chesterfield Inlet, and Whale Cove according the GN website. Clearly, some thought has to be given to the interaction of cables with nets and this can be managed through education programs, marking cables on nautical charts, armouring of cables in fishing zones and policing of fishing practices.

2.2 Arctic Ice

Sea ice cover is an impediment to cable laying activity as well as maintenance and repair. Although ice breakers can extend the construction season somewhat, heavy ice broken by an ice breaker is a threat to the cable since roiling of ice floes in the wake of the laying ship can cause cable damage to the cable before it is safely below the zone of ice impact.

The shutdown of work after only two or three months at sea is a further complication since marine mobilization costs are enormous. Cables may have to be cut and marked for later pickup and splicing in the ocean, and the ship has to transit out of the area before being stranded by the ice. It has to get to a port where it can offload and reload for its next assignment and then be ready to remobilize when conditions permit but when there may be delays from the last project. Cable laying ships have been fully booked in recent years and costs have escalated in response to the demand.

2.3 Icebergs

Polar icebergs can be very large and will scour the ocean floor several kilometres out from land in shallower waters. A cable in the risk zone will very easily be broken by the passing iceberg. Under normal circumstances, the cable ship's on-board plough will be able to bury the cable on the sea bed to a depth of around 1.8m. However, this is not possible in rocky bottoms.

2.4 Chafing

Cables which are not properly laid can be destroyed over time by the constant movement of ocean currents. Harmonic oscillations in suspended cables and chafing over rock ledges are the primary concerns. The problem is best avoided by careful choice of the cable position and normally a good deal of time is spent before the cable is laid to understand the bathymetry of the sea floor and current velocities. Again, a complication arises in completing these surveys in arctic waters due to the short season and the potential for not knowing what currents are prevalent during the winter.

2.5 Marine biology and encrustation

Even in arctic waters, marine cables can be subject to encrustation by marine life. Cable sheath materials can be selected to minimize this risk but it is better to accept the potential for such growth and plan the cable location accordingly. Cables that grow in bulk, weight and rigidity are more susceptible to breakage so it is important to lay the cable where the length of catenary spans and exposure to currents are minimal.

2.6 Water depth

Because water pressure increases with depth, it may seem counter-intuitive to note that the deeper the water, the lighter the armouring that is required since pressure does not affect the optical fibres and the cable is generally safer at depth. Lightweight cable is typically employed at depths over 1,500m where the risks are least. On the other hand, when depths are less than about 400m the highest level of armouring is called for. Whenever threats increase from anchorages, fishing, high currents, tide exposure, etc., the cable can be further protected by burying it in the sea floor.

2.7 Maintenance & Repair

A fleet of repair ships is constantly at work around the globe attending to the repair of submarine cables. Cables can break, undersea repeaters can fail and branching units can take on water. In the arctic, the added complication is obviously the problem of access if the failure occurs when the sea is covered with ice. It may be weeks or months before the cable can be fixed. Cable is normally repaired by grappling the two broken ends in turn and bringing them to the surface to splice in a new length of cable. It may be possible to do this by working through holes in the ice but to the best of our knowledge it has never been done.

3.0 Marine Cable Construction Considerations

3.1 Marine Cable Laying

Oceanic cables are normally laid by purpose-built vessels designed to carry up to several thousand kilometres of submarine cable in a number of cable pans which are typically loaded directly from the cable factory. The vessels are equipped with facilities to splice in line amplifiers and branching units and carry a plough which is towed behind the ship and can bury the cable up to 2m deep in near shore areas, anchorages and fishing grounds. The ships are equipped with multi-beam sonar and GPS recorders to accurately place and record the location of the placed cable. The vessels are capable of remaining at sea for several months at a time.

3.2 Construction windows

With a trend to warmer average temperatures, sea lanes are open for longer periods than in recorded history. In the southern areas of the territory, the sea may be ice-free for some four to five months of the year. In the northwest, this reduces to about two months.

Some of the construction on land faces similar constraints to the marine work. Each cable landing to a coastal community will likely require at least one directional drill bore from the shore out to a location that is not subject to tidal action, ice scour, shipping anchorages or commercial fishing. If the community is directly on the network ring as opposed to being served by a branching unit, then two diverse landings will be required to preserve the ring's integrity. Drill shots for cable landings tend to be long – 1km is not unusual – and the equipment used is massive and very expensive. In order for it not to be stranded for the winter, the drills rigs can only be moved in and out of the ports during the shipping season.

Although it is beyond the scope of this study to assess the environmental factors, it is conceivable that the available construction period may conflict with migratory bird and fish spawning cycles that could add to the cost of the work.

Conventional marine cable laying is achieved by large ships which are capable of holding up to 5,000km of undersea cable and which spend weeks in loading and then many months at sea placing the cable and repeaters in a safe location. In the case where a cable ship may be limited in the time it can place the cable the efficiencies are lost since the standard routines do not work.

According to the North American Ice Service Season Outlook Report dated June 2, 2011, the median dates for ice breakup dates in the various water bodies (with some of the associated Nunavut communities in parenthesis) are:

Southern Arctic

- Frobisher Bay (Iqaluit) - 4 August
- Ungava Bay (Kuujjuak) - 31 July
- Hudson Strait (Cape Dorset) - 4 August
- Hudson Bay (Rankin Inlet) - 19 August

Eastern Arctic

- Baffin Bay (Clyde River) - 6 September
- Davis Strait (Qikiqtarjuaq) - 2 September
- Foxe Basin (Repulse Bay) - 20 September
- Pond Inlet - 8 August
- Foxe Basin (Repulse Bay) - 20 September
- Admiralty Inlet (Arctic Bay) - 6 August
- Jones Sound (Grise Fiord) - 29 July
- Foxe Basin (Hall Beach) - 29 August
- Barrow Strait (Resolute) - 24 July

Western Arctic

- Peel Sound - 29 July
- James Ross Strait (Taloyoak) - 12 August
- Queen Maud Gulf (Cambridge Bay) - 20 July
- Coronation Gulf (Kugluktuk) - 30 July

Generally, navigation in these areas of the arctic starts towards the end of July and ends around mid-October. The dates vary, sometimes considerably, from year to year although the season could potentially be extended with ice-breakers.

Canadian Coast Guard ice breakers have a primary responsibility for emergency assistance to vessels in difficulty and to assist in search and rescue efforts. Their services are extended at no charge in such work but in the event that it were possible to assign an icebreaker to a program of this sort, the cost would likely range from $50,000 to $90,000 per day depending on the class of vessel. However, we have been informed that missions to aid a construction program should first seek the assistance of a commercial vessel with a strengthened hull such as the Fednav Group’s MV Arctic. It must also be borne in mind that arctic vessels are laid up for extended periods in the winter to undergo repairs and refitting to prepare them for the rigours of the next season.

3.3 Materials Deliveries

As noted in the previous section, marine cables are typically fed into the ship's hold directly from the factory's cable production line. Repeaters are loaded onto the ship and installed on board as the cable is paid out. Thus the submarine cable operation is normally self-contained and the hand-off to the shore is made at the transition to the beach landing.

Where the construction season is restricted due to navigational constraints, it may not be practical to load an entire project on a cable-laying ship in contemplation of a continuous operation. It may be more efficient to transport individual cable spans in containers ready for installing by local operations during the open-water periods.

Materials for the shore landings would consist of drill pipe, manholes and terminal equipment that has to be transported by ship along with the drilling equipment and equipment shelters. A logistics plan will need to be developed to schedule the sequence of work in conjunction with the route operations of one of the three Arctic shipping firms serving Nunavut; namely:

- Nunavut Eastern Arctic Shipping Inc.
- Nunavut Sealink and Supply Inc.
- Northern Transportation Company Limited

3.4 Cable Shore Landings

A transition occurs in submarine cable links when the offshore cable enters the near-shore area where it can be exposed to a number of threats. These include: Tidal action, commercial fishing, sea bed movement, ice piling and anchorages. In the arctic, one of the more serious threats is the consequence of ice piling (or ice rafting) where sheets of pan ice can be turned on edge and knife down through sediments – sometimes to a depth of 2m. The extent and location of ice buildups needs to be investigated and adequate steps taken to protect the cable.

Two methods are commonly used to minimize the risk of cable damage in these areas and, normally both methods are used in tandem. The first is to install the cable in a conduit that is drilled out from the shore using directional drilling equipment. The second is to bury the cable using an undersea plough which is towed by the cable laying ship until the cable is in a sufficient depth of water that it no longer needs protection.

Cable landing points in areas of surface bedrock are best avoided because the cost to protect the cable goes up sharply. Directional drilling can be done through rock but it is slower and more expensive than in soft ground. However, beyond the end of the drill, ploughing is not possible and if it needs to be protected over a shelf, rock can sometimes be chiselled out by a hydraulic excavator, or cut with a rock saw if the water is shallow, or by placing the cable in a steel pipe anchored to the rock. Such methods are very costly.

Large tidal fluctuations can add to the difficulty of installing cable landings as will active sea lanes and ship anchorages. Each location will require a detailed study to determine the conditions and optimal construction solutions.

For horizontal directional drilling, the objective would be to drill out no more than is absolutely necessary to clear the high risk areas near the shore. Risks may stem from ice packing, iceberg stranding, anchorages and unstable cliff areas. The maximum drill distance should be taken to be around 1,000m although longer shots can be achieved with very large equipment. The photograph below shows a typical drilling unit. However, along with this comes a similarly sized rig containing the drilling fluid and recovery system.

Photo: LTS – Horizontal Directional Drill for beach landing

Burial of cable in the sea bed is achieved using an undersea plough of the type shown in the following illustration. Towed behind the cable laying ship, the cable is commonly buried in high risk areas to a depth of around 1.0m. Depending on the sea bed conditions, this can be extended to close to 2.0m but the progress of the vessel at such depths is extremely slow. It would therefore be reserved for very unusual circumstances such as in areas that may be traversed by large icebergs.

Photo: Global Marine Website

3.5 More Detailed Review of 4 Primary Communities

A preliminary evaluation of four strategic communities has been carried out at a desk-top level of detail using the available marine charts obtained from the Canadian Hydrographic Service. The four communities are described below:

3.5.1 Iqaluit

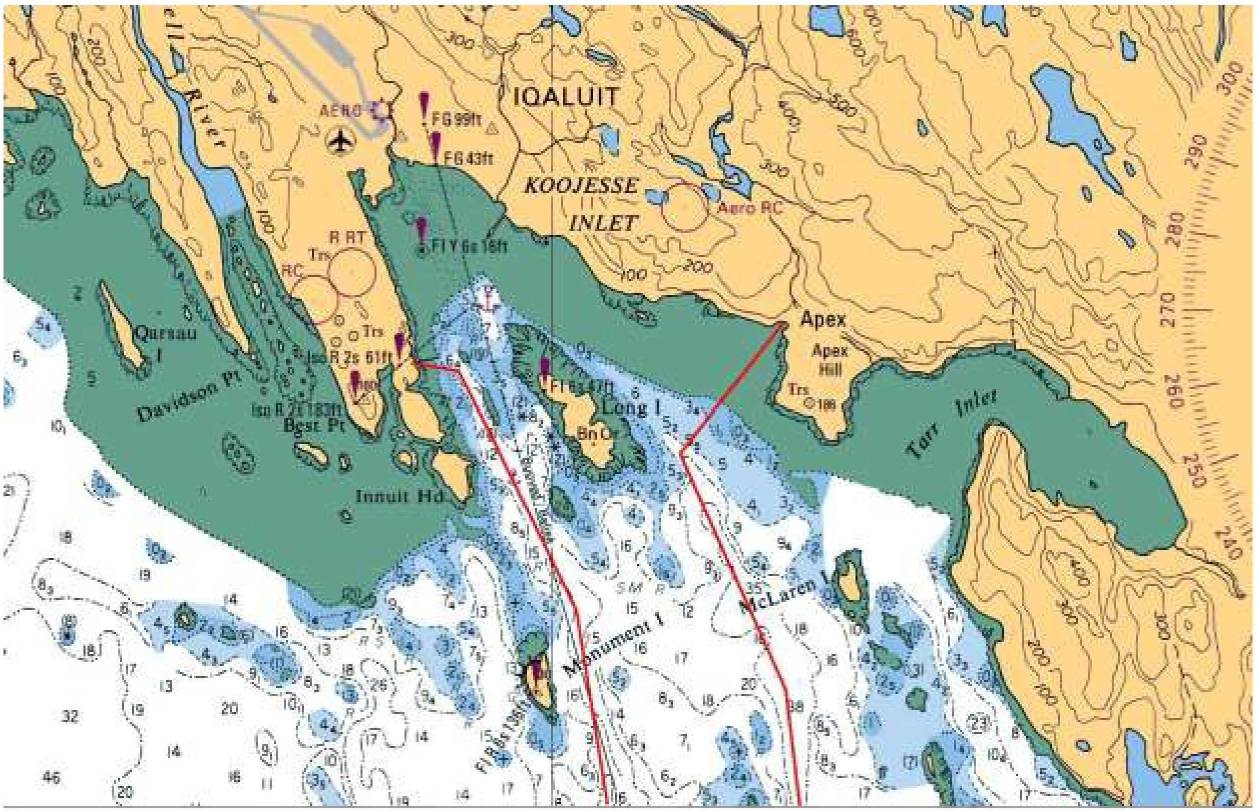
Iqaluit is located at the north end of Frobisher Bay, a 250km long navigable sea inlet.

Two diverse paths are proposed from the ocean into Iqaluit and the cable would need to be buried in the bed of the inlet for an estimated 7km from Iqaluit to minimize the risk of damage by ice, fishing and anchorages. In order for the cable to properly protected in the near shore areas we recommend that a pair of directional drill shots be completed from the shore into deeper water; one from near the jetty at the end of Aqiliq Road on the west side of the harbour and the other from Bill Mackenzie Street in Apex on the east side of the harbour, as indicated by the red lines on the chart below,. The drill on the west side would need to be about 400m long and the east side about 1,000m. The two beach manholes would be linked via terrestrial cables installed to a single point of presence (POP) near the centre of town.

One particular phenomenon of Iqaluit which is not shared by the other four primary communities is a tidal range for Frobisher Bay that is similar to the Bay of Fundy. The range is 11.1m according to the Canadian Hydrographic Service (CHS) with an extreme high water mark (HHWLT) in the island group 60km south of Iqaluit of over 12m above chart datum. The high tidal range means that currents in

Frobisher Bay will be high. CHS have run computer modelling of the flows and estimate that, in the narrowed channels between the island groups, the mean current velocities would reach between 4 and 11 knots depending on the channel. Local surface currents could be even higher. For cable laying operations this means limited times of access for an ocean-going vessel to the north end of Frobisher Bay and most likely a transfer of operations to a shallow-draft barge. Procedures would have to allow for full control of a barge in high-velocity current areas.

Iqaluit Harbour – Based on CHS Chart 712201



Note on Charts: This product has been produced by Ledcor Technical Services based on Canadian Hydrographic Service Charts and/or Data, pursuant to CHS Direct User Licence No. 2012-0120-1260-L. The incorporation of data sourced from CHS in this product shall not be construed as constituting an endorsement by CHS of this product. This product does not meet the requirements of the Charts and Nautical Publications Regulations under the Canada Shipping Act, 2001. Official charts and publications, corrected and up-to-date, must be used to meet the requirements of those regulations.

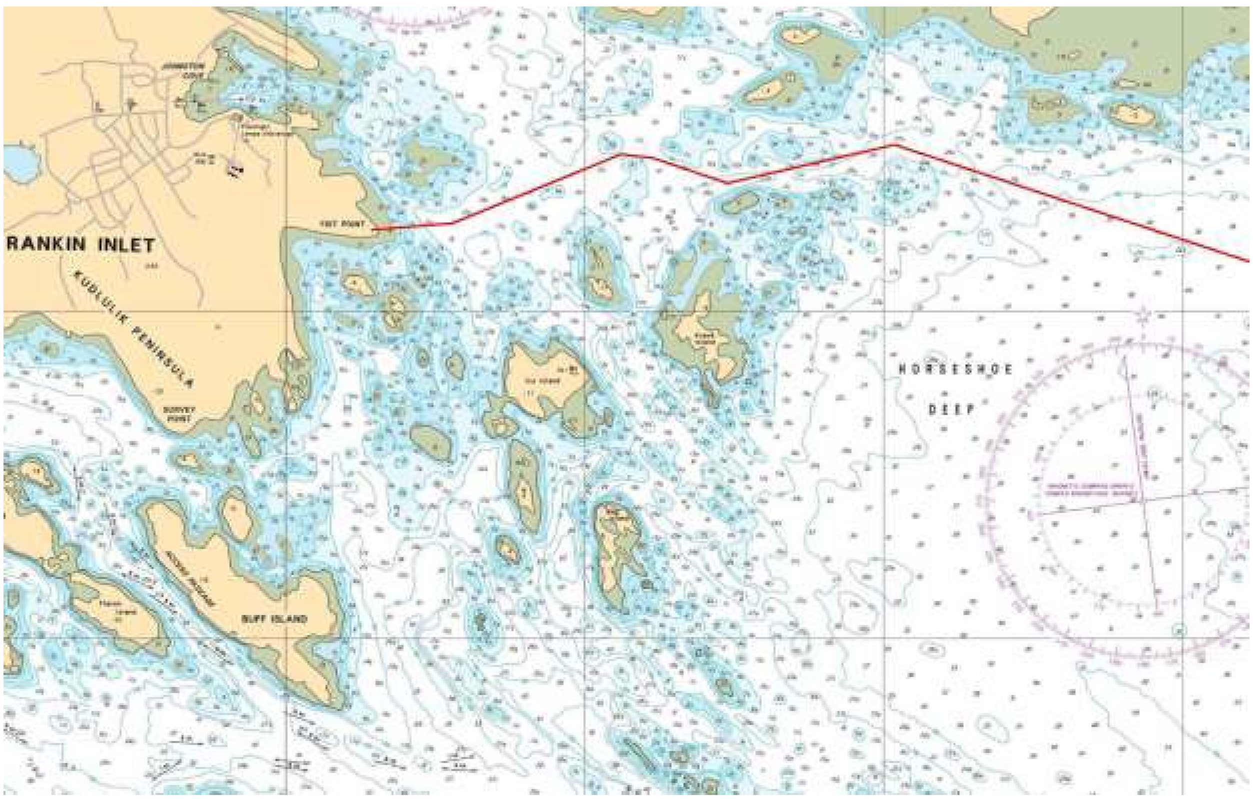
3.5.2 Rankin Inlet

The problem with laying subsea cables into Rankin Inlet is the relatively shallow depth of water that extents out some 40km to Marble Island in Hudson's Bay. We have some concerns about ice piling near the mainland shore as well as around the shores of the many islands that surround Rankin Inlet. There will need to be studies to determine the best route into deep water using bathymetric surveys and interviews with captains of craft using the port. The tidal range is 4m, not insignificant, but chart depths are based on low water (LLWLT) and therefore worst case.

Another issue, common to many of the Nunavut communities, is the changeable nature of the sea bed due to the movement of sediments by currents. There are therefore risks that a deeper channel identified in one year may have moved the next.

As a result of the above concerns we have proposed that Rankin Inlet be served by a single cable from a branching unit rather than risk the main ring being lost if the cables coming to shore at this point were to be damaged. We have proposed Chesterfield Inlet as the better location for a regeneration facility equipped with diverse shore landings.

The line shown in red on the chart is only one possible path from Rankin Inlet out into deep and we estimate that a 500m-long drill shot from Fist Point would terminate in approximately 12m of water.

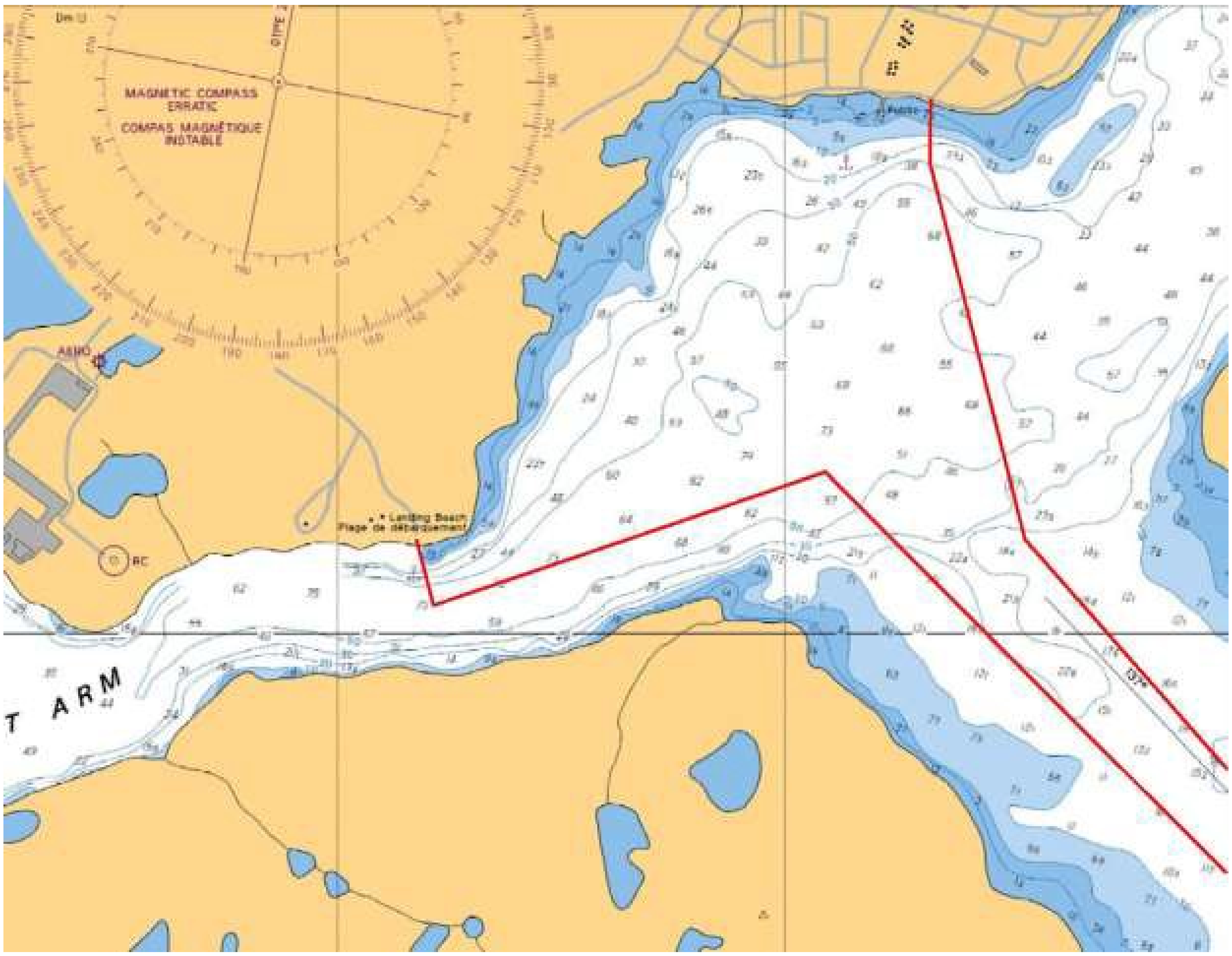


Produced by Ledcor Technical Services based on Canadian Hydrographic Service Charts – see full note below chart of Iqaluit

3.5.3 Cambridge Bay

The Cambridge Bay community is located at the north end of the bay of the same name which runs inland from the narrow Dease Strait/Queen Maud Gulf between Victoria Island and the Kent Peninsula. There is a deep water channel that runs into Cambridge Bay itself and it should be possible to accommodate separate east and west cable links from the main backbone ring into a regeneration facility in the community via a terrestrial cable linking the two shore ends.

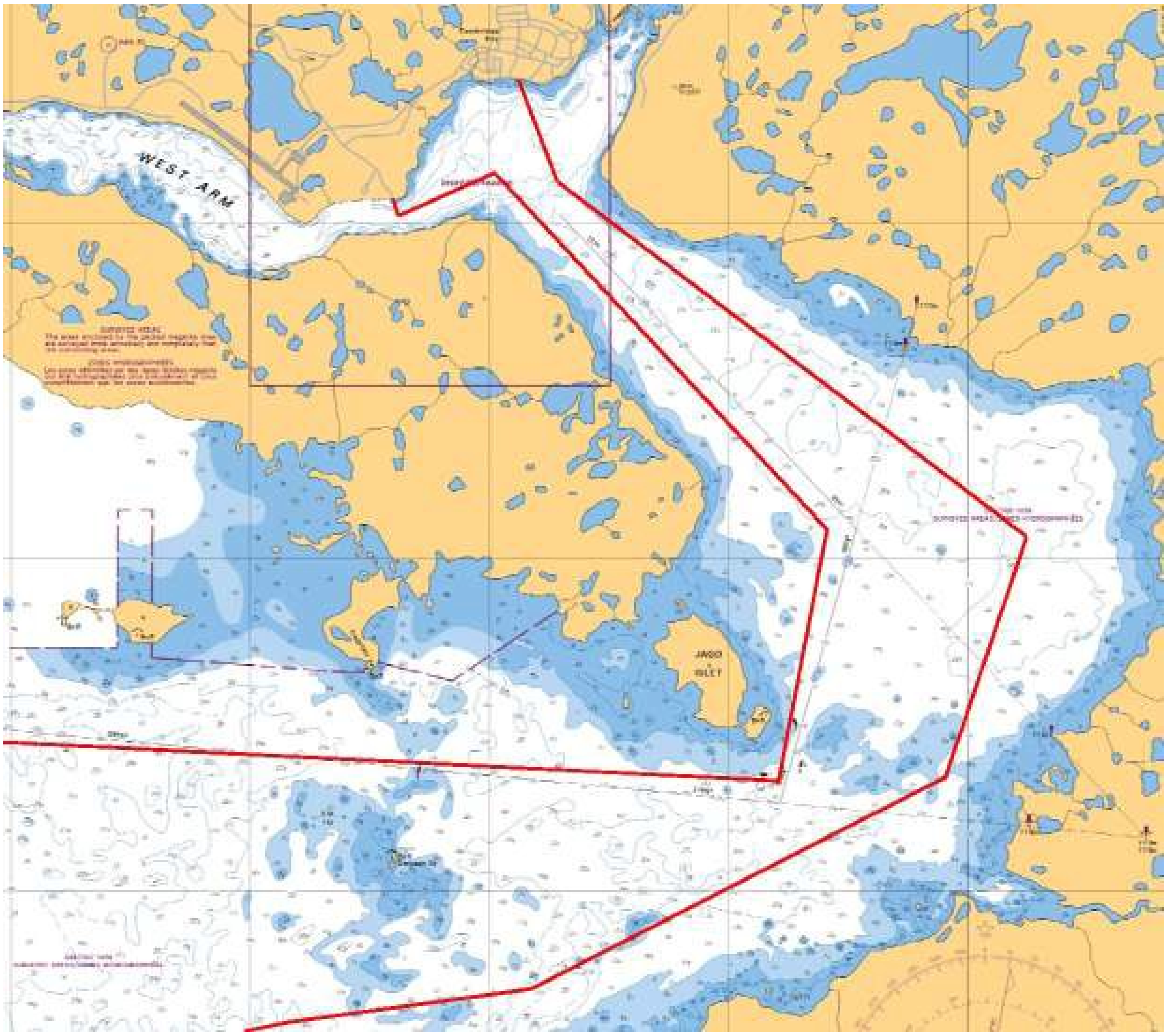
The chart below shows a detail of the suggested routes, the easterly feed coming ashore in the main part of the hamlet and the westerly feed coming ashore near the airstrip. Short drill shots from the shore of perhaps 150 to 250m in length should place the cable into deep water.



Produced by Ledcor Technical Services based on Canadian Hydrographic Service Charts – see full note below chart of Iqaluit

The second chart illustrates the possible routes through the bay itself into the Dease Strait for the westward traverse towards Kugluktuk, and into Queen Maud Gulf for the east side of the ring towards Resolute.

There appear to be two deep channels through the shallows at the south end of the bay next to Jago Islet that should be suitable for placing the cable safely, probably using a subsea plough to bury the cable below the shipping lanes and into deeper water. The extent of ploughing would be determined by the risk of ice scour. The tidal range in Cambridge Bay is only 0.6m according to the Canadian Hydrographic Service and therefore of little consequence.



Produced by Ledcor Technical Services based on Canadian Hydrographic Service Charts – see full note below chart of Iqaluit

The Dease Strait is quite narrow and probably one of the most risky areas to place cable due to relatively shallow waters and ice build-ups. It may require quite extensive distances of ploughing to properly protect the cable.

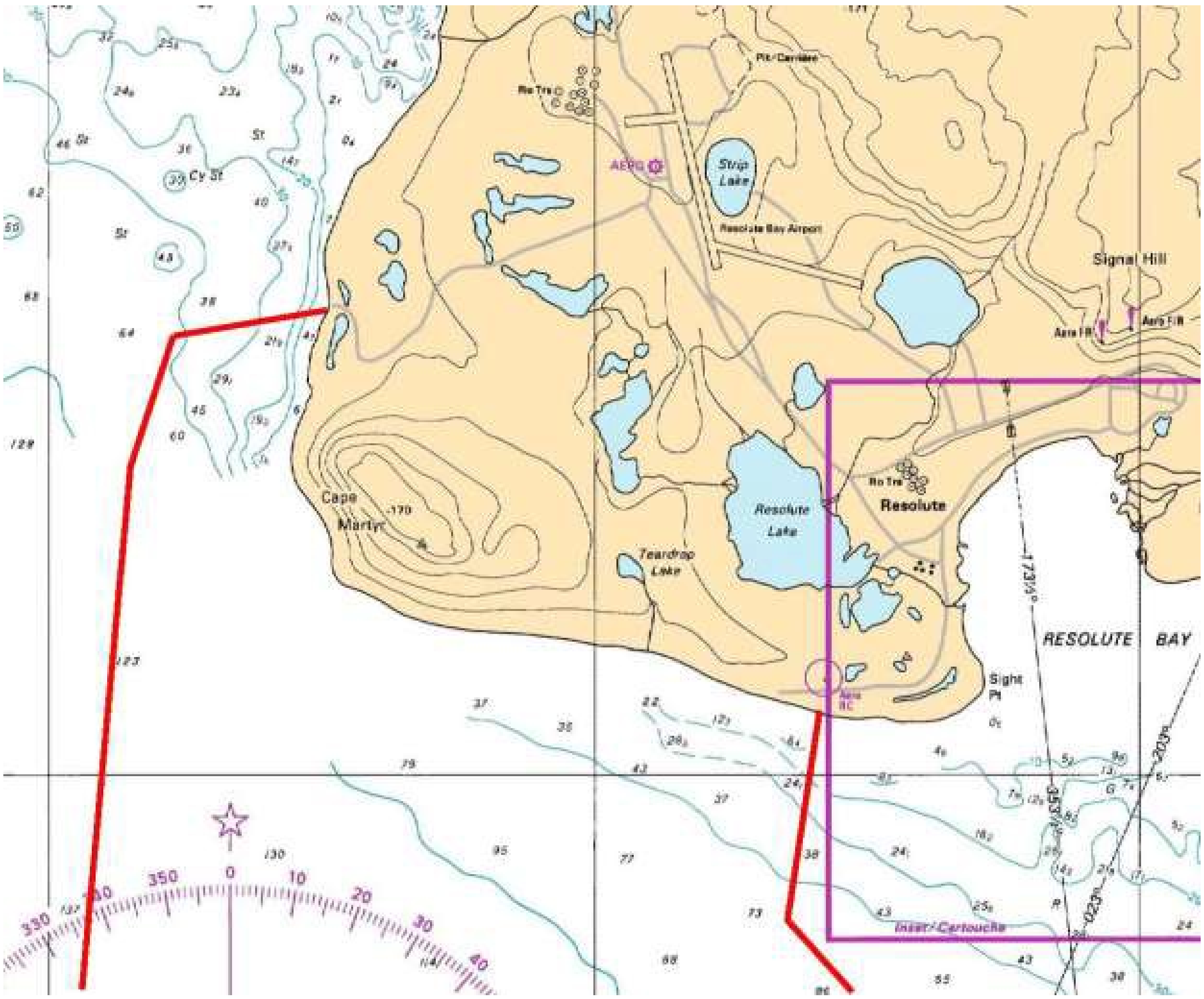
3.5.4 Resolute

Resolute, located on the south shore of Cornwallis Island, sits off the quite deep waters of Barrow Strait.

Two diverse cable paths are proposed to a regeneration site in the hamlet. A cable from Pond Inlet could come ashore due south of the airfield and Resolute Lake. A shore drill shot at this point would need to be about 700m long to reach 20m water depth. A westerly route towards Cambridge Bay could come ashore to the west of the airfield where a 900m directional drill would reach about 20m of water.

A further 2 or 3 km of subsea ploughing from the end of either drill shot should reach 100m of water depth. Maximum tides in the area are 2m, therefore inconsequential. On land, a terrestrial cable would connect the two landings to a regeneration facility at or near the airfield or closer to the residential area.

From Resolute both cables could be routed between Griffith Island and Cornwallis Island - or the western route could run down the west side of Griffith Island.



Produced by Ledcor Technical Services based on Canadian Hydrographic Service Charts – see note below chart of Iqaluit

3.6 Terrestrial Cable Construction

From where the submarine cable comes ashore it can either be transitioned to a terrestrial cable at a “beach manhole” or continued directly to a Cable Landing Station if it is located close to the beach. The terrestrial cables contain the same type of optical fibres but the armouring of the cable means that a lighter and cheaper cable can be employed.

The choice of terrestrial cables for an outside plant fibre optic system must bear in mind the stresses and strains associated with permafrost and, in particular, discontinuous permafrost conditions; and the cables must be capable of being installed and maintained in extreme low temperatures.

Cables can be installed below ground or on aerial pole lines. Buried installations are normally preferred because they are less vulnerable to damage from wind, fire, vehicle accidents, lightning strikes and vandalism and the temperature fluctuations are not as extreme.

Direct-burying the cable to a depth of between 300mm and 1.0m (depending on the terrain and obstructions), can be achieved using conventional hydraulic backhoes or, in frozen ground and across lakes, using the equipment of the type shown below:

Wheel Trencher

Chain Trencher

4.0 Optical Transport Equipment

4.1 Dense Wave Division Multiplexing (DWDM)

In the early days of fibre-optic transmission a single 1310nm wavelength was used and transmission speed was limited to a of 2.5 Gb/s. Then came improvements in the fibre and equipment and speeds were increased to 10 Gb/s at 1550nm. DWDM uses different wavelengths of light to carry signals. Current systems in widespread use employ up to 32 x 10 Gb/s channels but some suppliers have now tested up to 128 channels and speeds of between 40 and 100 Gb/s per channel.

4.2 Transmission Components

Submarine line terminal equipment (SLTE) is located at each end of a submarine cable span in a cable landing station. Send and receive units in each landing station work on a pair of optical fibres. Multiple fibre pairs may be lit by SLTE but there are limits on the number of fibre pairs that can be active when the distance between SLTE requires the use of optical line amplifiers (OLAs) since the OLAs have to be powered.

Power to each OLA is via a copper tube into which the fibres are placed. A DC voltage source typically allows a voltage drop of 10v per fibre pair from the copper tube to ground (in this case the ocean). Allowances for line voltage drops and electromagnetic interference from solar flares have to be included in the calculation of power requirements. Systems are usually designed such that the entire span can be powered from either landing station in the event of a power interruption at one end. The longer the span, the greater the voltage and hence the practical limit on the number of fibre pairs that can be lit.

The span limit for an unrepeated signal is currently in the order of 350 to 450km. This is significantly longer than the typical 80-100km fibre span between OLAs and it is achieved by a number of specialized optical components in the SLTE such as Distributed Raman Amplification. The equipment significantly increases the cost of the SLTE equipment but can produces an overall saving in the combined system cost when DC power supplies and OLAs are eliminated.

For spans greater than about 400km there needs to be amplification. In such cases, an OLA is capable of boosting the amplitude of every wavelength in the light transmission and thereby is extremely efficient in power consumption and is far less mechanically complex than a regenerator. For repeatered legs, the design rules for standard OLA spacing would apply – typically 80 to 100km apart. Since the capacity requirements of the Nunavut population are expected to be relatively modest, we have based our estimates on the assumption that OLAs would be spaced around 100km apart and with just one active fibre pair capable of operating with 10 or 40 Gb/s channels. Thus, for the maximum span in the network of around 1,900km, a total of 18 intermediate repeaters have been allowed for - each 100km apart.

There is a trade-off in distance between repeaters and fibre capacity. SLTE systems coming to market are expected to have a channel capacity 100Gb/s and dense channel counts, while our OLA spacing assumptions in this report are based on current technologies. However, these assumptions should be sufficient for 40Gb/s channels but as the transmission rates get higher, closer OLA spacing is required to preserve signal quality. A decision will have to be taken as to whether shorter spacing should be selected for Nunavut based on possibilities that the backbone ring could end up serving as a redundant path for other systems being contemplated in the arctic. However, if the assumed spacing and fibre count were to change in order for all or part of the network to become a trunk for traffic, say between Europe and Asia, the economic model would also benefit considerably.

If the length of a span were to be so great that the signal quality would be degraded to the point where it has to be regenerated, then the optical signal from each wavelength is converted to an electrical signal and re-transmitted. However, the spans involved on this project are far less than the several thousand kilometres at which regeneration becomes necessary.

4.3 Branching Units

Branching units (BU) are the physical means by which traffic is directed to and from the main backbone undersea cable to a destination on shore. They are installed in line with the main cable with a stub or lateral cable running off the main line. A stub can be left in place to be activated at some time in the future or it can be terminated with a cable to the shore location soon after the main cable is laid. The branching cable is often laid by a smaller ship or barge to reach closer in to shallow water.

BUs are usually configured such that one side of a fibre pair is diverted to the branch. For example, if the main cable connects A to B and there are mid-span branch to communities C and D, then one fibre runs direct from A to B and the other concatenates from A to C to D to B. In the case of a fibre break on one of the branches, the capacity from A to B is halved. The better option may be to provide wavelength filtering using a Wavelength Selectable Switch in the BU. Since a fibre can currently handle up to 128 discrete wavelengths each, it is possible to dedicate one or more wavelengths to a shore destination to serve the needs of the community or industry. A dedicated wavelength would be reserved for each community between the primary nodes on the backbone cable. In the event that a branching unit is cut, the main ring is unaffected.

The BUs can be installed as a single cable lateral or a pair of units can be installed with diverse paths from the main cable to the shore to preserve service redundancy to a critical destination.

Power for a BU can be from the main cable if it contains repeaters, or it can be fed back from the shore station.

4.4 Capacity of the Various Systems

The capacity of a pair of optical fibres is currently in the range of 320 Gb/s to 2 Tb/s depending on the electronics deployed and length of the longest span. If the cable contains 2 fibre-pairs (the usual minimum for undersea cable) then the transport capacity is increased accordingly. However, it must be remember that to activate two pair will require double the OLA capacity and this will virtually double their cost.

By comparison, a point-to-point digital microwave transmission employing multiple wavelengths currently reaches around 5 Gb/s and a digital communications satellite can communicate at over 1 Gb/s. Spot-beam technology used in recent and planned satellite deployments using the Ka band is expected to a achieve a total capacity of 70 Gb/s but it must be remembered that this is shared over a large part of a continent.

5.0 Cost of Submarine Cable Networks

5.1 Capital Cost

The following table is intended as an order-of-magnitude assessment of the system capital cost. A great deal more information about the design would need to be known to before an estimate could be provided with any greater degree of accuracy.

We have estimated the construction cost of a backbone ring (Churchill to Tuktoyaktuk) and connections to all the Nunavut communities with the exception of Sanikiluak which we feel would only make economic sense if it were to be included with the Nunavik communities on the Ungava Peninsula of Quebec.

No.	Description	Notes	Quantity	Unit	Rate	Total
1	Route marine survey/bathymetry & burial study	Omits easterly connection from Quebec	10,800	km	$ 3,750.00	$ 40,500,000.00
2	Permits and land acquisition	Allowance	1	LS	$ 10,000,000.00	$ 10,000,000.00
3	Backbone submarine cable lay – ocean going vessel	Placing 4f cable incl splice, test, spare joints	8,100	km	$ 2,000.00	$ 16,200,000.00
4	Laterals to shore - surface laid	Ditto using DP vessel	1,500	km	$ 20,000.00	$ 30,000,000.00
5	Laterals to shore - plowed below sea bed 1.5m deep	Ditto	1,200	km	$ 90,000.00	$ 108,000,000.00
6	Double Armour submarine cable	Assume 4f; one pair lit	8,750	km	$ 16,000.00	$ 140,000,000.00
7	Single Armour submarine cable	Ditto	1,500	km	$ 13,000.00	$ 19,500,000.00
8	Light submarine cable	Ditto	550	km	$ 8,500.00	$ 4,675,000.00
9	Shipping Cable		1	LS	$ 5,400,000.00	$ 5,400,000.00
10	Additional cost to add repeater (one fibre pair)	Includes submarine repeater	84	ea	$ 200,000.00	$ 16,800,000.00
11	Additional cost to add branching unit (BU)	Includes BU but not tail to shore	13	ea	$ 750,000.00	$ 9,750,000.00
12	Icebreaker support		200	days	$ 60,000.00	$ 12,000,000.00
13	Beach landing HDD shot in soft ground - 1 km long	Assume average 1000m shot incl materials	41	ea	$ 800,000.00	$ 32,800,000.00
14	Added allowance for beach landing HDD shot in rock	Assume average 1000m shot incl materials	10	ea	$ 1,800,000.00	$ 18,000,000.00
15	Supply and install (S&I) beach manhole (BM)		41	ea	$ 30,000.00	$ 1,230,000.00
16	S&I BU shore station – prefabricated building	Including genset but excluding SLTE & DC plant	30	ea	$ 1,600,000.00	$ 48,000,000.00
17	S&I Ocean Ground Bed (OGB)	Assuming 7 anodes in soils	41	ea	$ 200,000.00	$ 8,200,000.00
18	S&I OSP from BM to Landing Station and POP	Terrestrial build	50	km	$ 100,000.00	$ 5,000,000.00
19	S&I SLTE equipment (DWDM) - standard & repeatered		38	ea	$ 250,000.00	$ 9,500,000.00
20	S&I SLTE equipment (DWDM) - long span	Includes Raman pumps	5	ea	$ 500,000.00	$ 2,500,000.00
21	S&I DC Power Feed Equipment for repeatered systems		27	ea	$ 750,000.00	$ 20,250,000.00
22	Mobilization/Demob – Cable laying vessel		3	season	$ 2,400,000.00	$ 7,200,000.00
23	Cable Laying Vessel standby cost		100	days	$ 50,000.00	$ 5,000,000.00
24	Allowance for spare equipment		1	LS	$ 2,500,000.00	$ 2,500,000.00
25	Post Lay Inspection and Burial (PLIB)	For ROV	60	days	$ 85,000.00	$ 5,100,000.00
26	Mobilization/Demob – HDD equipment	One setup per community	30	ea	$ 750,000.00	$ 22,500,000.00
27	Shipping materials for Shore Station, OGB, OSP, BM, HDD	One setup per community	30	ea	$ 750,000.00	$ 22,500,000.00
28	Mobilization/Demob – Workforce	One setup per community	30	ea	$ 30,000.00	$ 900,000.00
	TOTAL ESTIMATE					**$ 624,005,000.00**
	Contingency Allowance				20%	$ 124,801,000.00
	BUDGET ALLOWANCE					**$ 748,806,000.00**

Not included in these costs are central office space for network monitoring and operations, back-office systems for customer service, provisioning and billing, or a maintenance centre for parts storage and equipment.

5.2 Maintenance Cost

The operating costs of a fibre-optic network have not been estimated at this stage since they would be similar in many respects to the facilities which already exist for the telecommunications services provided to the Nunavut communities. In terms of maintenance and repair, the risks of service outage from cable cuts are listed in A.2.0. In terms of expectations, most of the risks can be mitigated by proper design and the main ring should be relatively immune from service loss due to the depth. However, to illustrate the risk in similar conditions, TELE Greenland has had three cable breaks off Nuuk in the short time since the cable was commissioned in 2009. However, in each case it was the result of large icebergs in the Labrador channel scouring the sea bottom close to shore where the cable was inadequately protected. The solution is to directionally drill from the shore out into deeper water as described in Section 3.4 of this report. The second big risk to cables is not from natural causes but human activities – fishing, anchorages, offshore drilling and the like. However, these should be quite manageable compared to more populated areas and certainly less than terrestrial cables which are frequently cut by backhoes and other construction machinery.

Thus, for a properly installed system, the frequency of repair should be fairly small with the branches being the most vulnerable in shallow water close to the shoreline. Overall, for a network of this size, we would budget for at least one underwater cable repair per year.

6.0 Potential for Laying Cable by AUV

6.1 History

The Defence Research Department Canada (DRDC) undertook a program called "Theseus" using an Autonomous Underwater Vehicle (AUV) – a remote-control, battery-operated submarine – in 1995/6. A fibre-optic cable was laid out from Ellesmere Island to sensors designed to track submarine traffic under a now declassified Canada-US program. They placed two runs of 175 km each but the cable failed and was abandoned after only three years due to signal loss and the difficulty of repair.

The failures were attributed to way the cable was laid; namely, the AUV's thrust alone pulled the cable out of the rear of the sub and so there was no extra slack for the cable to sink to the profile of the sea bottom. Suspended in the water between rock shelves, the cable was at the mercy of ocean currents which are believed to have dragged the cable over the rock and caused abrasion damage. Another problem was a rapid build-up of marine life that added bulk to the cable, increasing the stresses from ocean currents.

The cable that was used was of small diameter (approximately 10mm) with the optical fibres contained in a longitudinally-welded stainless-steel tube and sheathed in plastic. For the sake of compactness, the cable was built without the helically-wound steel-wire armour of conventional submarine cables.

The AUV was designed and build by International Submarine of Coquitlam BC, a firm that continues to supply AUV for specialist military purposes. Both the AUV and US-sourced cable were designed for a maximum 1,000m water depth. The lay speed was 6 km/hr., so in theory, 144km could be deployed in a 24-hour period.

6.2 Lessons Learned

The AUV-as-cable-layer concept was certainly proven. The vessel operated remotely using on board OAS (Obstacle Avoidance Sonar) to navigate around ice or underwater obstacles with guidance input if needed from shore-based operators using the cable as an umbilical to transmit the sonar data and help steer the vessel when navigating under deep shelf ice that may have given the automated guidance system conflicting signals. The on-board navigation program worked faultlessly and the vessel can be guided solely by pre-programming its route but for more pinpoint accuracy its course can home-in on beacons placed along the route.

The problem of slack could be overcome with better bathymetric studies ahead of the lay to select a more secure route and having a system on board to pay out additional cable where it is needed to follows the undersea profile.

The problem of the rather fragile cable would be more difficult to deal with as a conventional underwater cable is not only much larger in diameter but more weighty. This would create difficulties in the size of AUV needed to carry the cable but also in the payload storage and pay-out mechanism that would be needed to safely deploy the cable.

6.3 Future Potential

An AUV that can traverse 1,000km underwater on a single charge has been built and there is no reason that a similar range for a larger vessel carrying cable would not be possible. In its current form, the vessel that has been used before could be adapted to carry out bathymetric surveys which are more difficult to do in arctic waters from a ship.

The structural design of a larger vessel is also quite possible and not significantly more expensive than the roughly $3M prototype because most of the cost is bound up in the electronics rather than the shell and batteries. The payload area is flooded, so pressures are balanced. Only the vessel's electronics and buoyancy tanks need to withstand the water pressure since the vessel is unmanned.

The manufacturer has suggested that the vessel could be programmed to oscillate at it pays out the cable so as to create slack. However, this would seem to be too imprecise a solution and a traction motor of the type used in cable jetting would appear to be a better solution.

The onboard "brains" of the AUV could be enhanced with side-scan sonar programmed to pay out more cable as the depth changes, or the umbilical could be used to transmit data to the shore so that the operator can take charge of the payout rate.

Because the AUV is unmanned, the cost of operating the vessel will be significantly lower than a comparable marine cable ship. Its ability to lay cable below the ice also means that it can operate year-round. Its payload being much smaller also means that the cable can be pre-packaged in a cassette reel that can be inserted at any pre-determined shore location. Its size means it can operate closer in to the shore and it can be programmed and sent off to any location in the artic where it be load and charged ready for the next deployment. This could even be done from the ice surface if generators and cassette installation gear are designed to operate from a load-spreading platform on the ice.

6.4 Problems to be Overcome

Before an AUV could be considered further, there are a number of key areas that would have to be developed:

a) Repeaters: A fibre-optic span that exceeds about 250km in length requires that undersea repeaters be added and these are powered from the shore by a DC generator. The addition of repeaters therefore adds a double complication; the repeater has to be pre-installed and must be capable of being passed through the cable guide-way at the rear of the vessel. Because it is not a pressure vessel per se, this should be possible with some sensors and doors. However the bigger problem is the larger cable that is needed to contain the copper conductors for the DC power supply.
b) Research and Sea Trials: While this proposed system has merit in its potential to save cost and be less affected by ice conditions and weather, it is an unproven technology that requires research into the vessel, the cable and the laying techniques. There is no point proceeding to a full scale roll-out over thousands of kilometres of Arctic Ocean without knowing that the technique works, and that the network maintenance and lifespan are not compromised.
c) Inability of an AUV to plough cable. This may call for a two pronged approach – using the AUV for the deeper work and a cable ship near shore.

Our conclusion from this brief review is that the AUV option should be eliminated from the deployment options unless there is funding for a research program and there is a time frame of two to three years to develop a robust system.

B. TECHNICAL ASSESSMENT – WIRELESS ALTERNATIVES

1.0 High Capacity Digital Microwave

1.1 Design Parameters

At a feasibility level, we have looked at one particular leg from Chesterfield Inlet to Baker Lake since it may be difficult to install a fibre-optic cable in the waterway leading up to Baker Lake. However, this can be considered representative of other links if it is determined that a microwave solution would be more practical.

Our quality of service (QoS) premise for microwave systems is 99.9% in-service time – or an out-of-service time of 9 hours per year. Although less than the QoS expected of fibre networks, this level of reliability is typical of microwave systems which are sensitive to loss of service due to atmospheric conditions, reflections over water, and temperature inversions.

A detailed field survey will be required followed by transmission link modelling to better evaluate the system requirements and design capacity based on the available frequency licenses. For the purposes of this exercise, we have assumed a transmission rate of 500 Mb/s.

For long distance MW, the optimal frequency for high capacity transmission would be the 7 GHz band.

1.2 Components

For the approximately 300km span from Chesterfield Inlet to Baker Lake link, we estimate that approximately 9 tower sites will be required; one at each end and seven intermediate repeaters. Except for the first leg out of Baker Lake, the hops should be able to avoid water, but we point out that spans over water will likely require spatial or frequency diversity to provide an acceptable QoS. The former would add a second pair of antennae dishes spaced vertically away from the first, the latter would add a second frequency to ensure the integrity of the microwave links.

Aside from the over-water leg, a pair of dishes would provide a dual redundant path at each site. We estimate that the minimum antenna dish size would be 1.8m (6') but it is conceivable that a dish as large as 3m (10') may be required depending on the terrain and frequencies being used.

A tower height of 40m is expected since the area is north of the tree line. However, a more thorough survey of the terrain will be required to determine the specifics of each tower.

1.3 Reliability

Between Chesterfield Inlet and Baker Lake, the first 30km or so would be across Baker Lake itself so there will be a risk of microwave reflection under certain conditions. This can be mitigated, but not completely eliminated, by the addition of antennae or frequency channels as noted above. Furthermore, since no ocean water is involved, the problem of tidal changes to water levels will be avoided.

All radio links should be installed with a 1+1 protected system (main radio with backup radio configuration), as there is no route diversity from Baker Lake.

MW component reliability should be robust providing the environmental controls in the equipment shelters are maintained. This will depend to a large degree on the power source as discussed below.

1.4 Terrain Constraints

Mountainous or hilly terrain will obviously be an issue: for potential loss of service; for civil construction at the tower sites; and for subsequent maintenance and fuel supply. It would appear that the terrain between Chesterfield Inlet and Baker Lake is relatively flat and treeless, however, access for construction equipment and the MW components across land will not be easy due to the absence of roads or tracks and the multitude of water crossings. However, this particular span could be accessed by the waterway that connects the two communities – although the same cannot be said of many of the links between the other communities in Nunavut in the event that a decision is made to use MW rather than a submarine fibre-optic cable.

Similarly, routes to the Nunavut communities which containing a lot of lakes or the need to cross arms of the sea, will be problematic for MW.

1.5 Typical spans, Antennae Heights and Power Requirements

Typical link lengths will average between 30 and 40 km for optimum transmission capacity and reliability - hence the eight-link path between Chesterfield Inlet and Baker Lake. Antenna heights will need to be determined when actual line of sight engineering is being performed but across relatively flat terrain, a height of 40 m would be an appropriate assumption. Final path lengths will be determined by frequency, transmit power, bandwidth, modulation, dish size/gain, climate and other external variables.

Power requirements for the MW repeaters will be minimal, since no traffic is being dropped in between the two communities. The repeater sites will include the MW radio, power bay and batteries and (the biggest power drain) the climate control system in the shelter or walk-in closet. We expect the repeater site power requirement would be in the area of 10 kWh. The terminal sites will draw more depending on the optical interface equipment but commercial power is available in both communities.

1.6 Power Supply Options

Considering the remote location of these sites, propane-powered generators will be virtually the only option. Solar power is not possible in the arctic winter and wind turbines are susceptible to icing problems. Propane gensets do require regular fuel and maintenance, however, as well as remote monitoring via a SCADA panel connected to the MW transmission. Ideally the fuel capacity should be sufficient to last a year and this may require several large propane tanks. The need for helicopter access for maintenance and refueling should be built into the operational plan.

1.7 Construction Access & Site Preparation

Access will once again depend on the terrain. Without vehicle access, most sites which are not on the coast or near a winter road will need to rely on helicopter access. Each site will be assessed for its suitability for helicopter access and if a suitable platform has to be created in rocky terrain, it will be done by blasting.

Even the cost of shipping towers, antennae and support systems to the community harbours will be time consuming and expensive. A good deal of pre-planning will be necessary to match the shipping companies' schedules.

Soil conditions may vary from muskeg to tundra to rock and a geotechnical assessment will be required to engineer the appropriate foundations for the tower and shelter. Where concrete is either unavailable or too costly to transport, steel plate footings or rock anchors may be options.

1.8 Maintenance and Repair

Maintenance and repair of these sites, if engineered and installed correctly, should be limited to periodic inspection and refuelling. Without the need for waveguide, no tuning of radios need be done, and all equipment can be remotely monitored. The system should be designed to be resistant to weather extremes, icing and high winds. While no remote site is vandal proof, it should be protected against animal damage.

2.0 Cost

2.1 Capital Cost

Our firm has had a good deal of experience in the installation of towers in remote locations such as this and we believe that from design through procurement, installation and testing, a likely cost would be between $1.0 and 1.2 million per site. This would include the supply and installation of the tower, antennae, microwave radio, shelter, foundations, access works, genset, fuel, climate controls, security system and include the transportation. Thus for the roughly 300km span from Chesterfield Inlet to Baker Lake requiring 9 towers, the cost estimate would range from $9.0M to $10.8M or $30,000 to $36,000 per kilometre.

Not included in these costs are central office space for network monitoring and operations, back-office systems for customer service, provisioning and billing, and maintenance centre for parts storage and equipment.

2.1 Maintenance Cost

The operating costs of a microwave network have not been estimated at this stage since, as already noted in the fibre-optic section, they would be similar in many respects to the facilities which already exist for the telecommunications services provided to the Nunavut communities. However, compared to a submarine cable system where the maintenance cost is largely expected to be the response to unforeseen cable cuts, a microwave system must, in addition to emergency response, be subject to a maintenance management system to inspect each and every remote site and supply fuel at least annually. Since the sites are remote, a helicopter will be needed for access.

C. REGULATORY MATTERS

1.0 Environmental Assessment

1.1 Permit Authorities

This project falls under the jurisdiction of many Territorial and Federal departments – which in the context of the Nunavut Settlement Area fall under the umbrella of the Nunavut Impact Review Board (NIRB). NIRB's responsibility is to receive the project documentation and distribute the relevant elements to the affected local parties and government departments.

1.2 Potential Environmental Impacts

The proposed cable routes appear not to cross any National or Territorial park or any of the five National Wildlife Areas in Nunavut. There will, however, be the potential for impacts on both the human and natural environment with regard to the installation of submarine cables; fisheries and shipping in the case of the human environment, and fish spawning areas and bird migrations with regard to the natural environment.

If terrestrial options involving microwave towers or buried cables are considered, there may be concerns related to the potential impacts on bird nesting, animal migrations and disturbance to permafrost.

1.3 Nunavut Impact Review Board

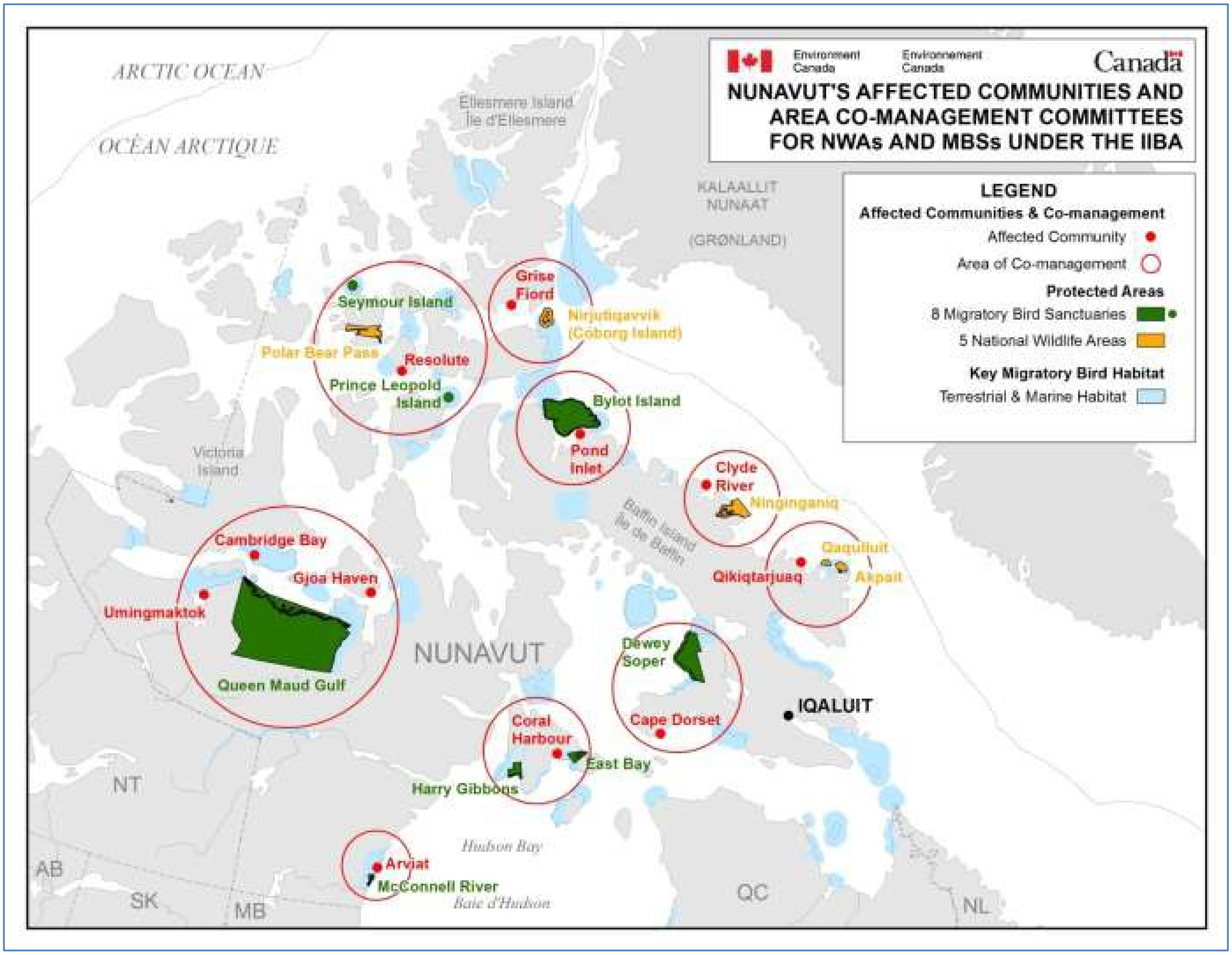
This project would have to be submitted to the Nunavut Impact Review Board (NIRB) for screening and their process would determine if it was screened at a Part 4, 5, or 6 level under the NIRB regulations. NIRB receives its mandate from Article 12 of the Nunavut Land Claims Agreement (NLCA) and the geographic extent is the Nunavut Settlement Area which includes the land areas, sea passages and coastal zones. NIRB distributes the project information to all agencies and affected groups for comments and then makes a recommendation to the Minister as to how to proceed. A "Part 4" process can be done in a few months, a "Part 5" process would take significantly more time. A "Part 6" project refers the documents to a Federal Environmental Assessment Panel but to date this appears never to have been done so timing is unknown but it would be significant. This program is likely to fall under Part 5 due to its far-ranging scope but low overall impact.

The data collection phase may encompass reviews of fishing activity; sea lanes and anchorages; and commerce and residences in the area of the shore landings. With regard to the natural environment, the potential impacts may be to fish spawning areas, bird migrations, wildlife, etc. If impacts are expected then the assessment would include the mitigation options. Part of the process may involve a public participation element to seek the advice and input of the local communities and interest groups.

1.4 Environment Canada

Environment Canada has provided the following map of protected areas (i.e. migratory bird sanctuaries and national wildlife areas) in Nunavut. These protected areas are co-managed by local community committees so projects that occur within protected areas would also involve these local committees. Areas that are called Key Migratory Bird Habitat Sites are shaded in blue, and these areas tend either to have high concentrations of migratory birds (depending on the season) and thus are protected under the Migratory Birds Convention Act, or they have species-at-risk that may be listed under the Species At Risk Act (SARA).

Environment Canada Map of Designated Habitat Areas



The proposed routes appear to cross a number of designated Migratory Bird Habitat areas where the cable would come into shore – Arviat, Coral Harbour, the entrances to Frobisher Bay and Pond Inlet, the crossing to Grise Fiord, Cambridge Bay area and some of the communities on the Ungava Peninsula. While the passage of an ocean-going cable laying vessel through the normal sea lanes should not be a problem, the proposed work plan will need to be reviewed by Environment Canada.

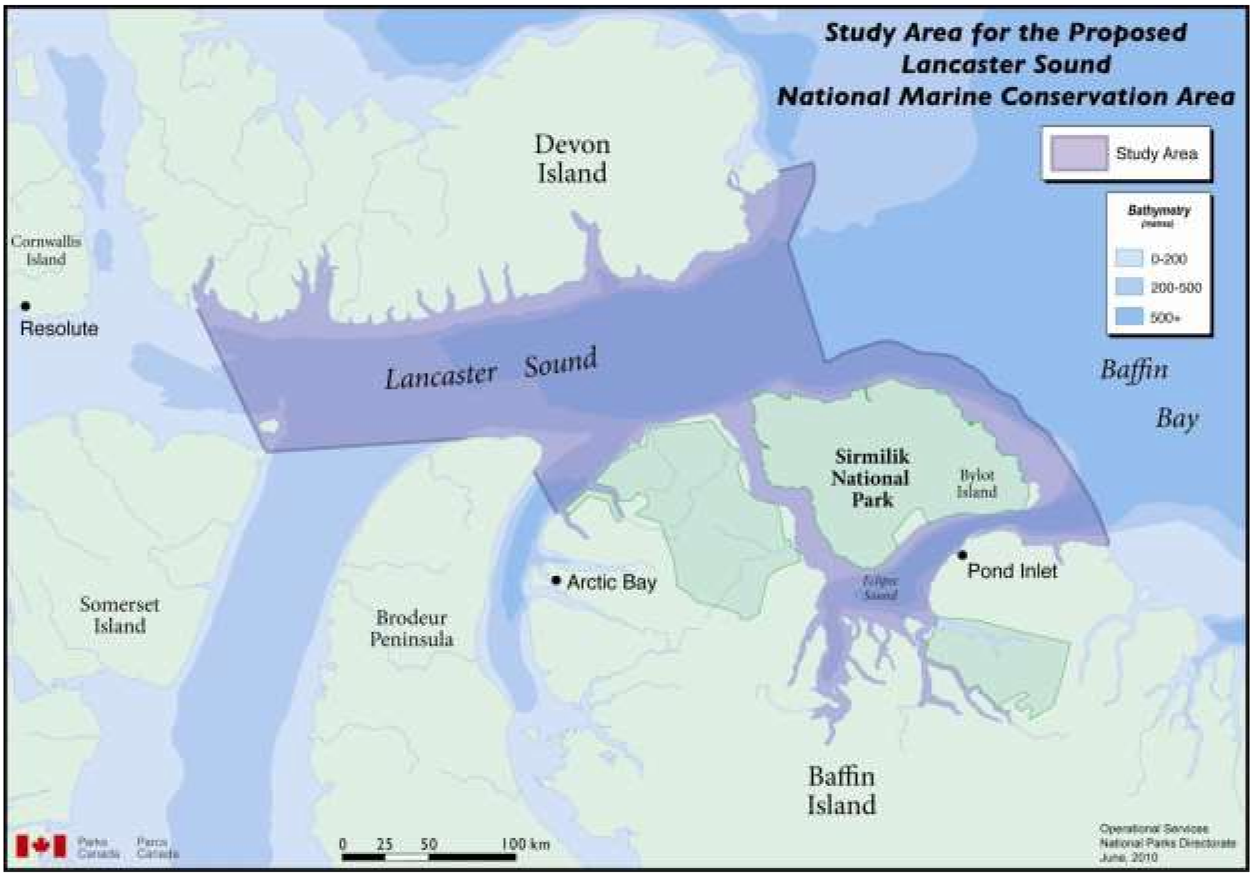
In areas where there will be a directional drilling operation from the community out past the foreshore, there may be restrictions as to when this work could be done so as to avoid migratory bird activity at certain times of year. Environment Canada will be able to check their records to establish any likely blackout periods if the nature of the work is such that it is deemed a hazard to the birds.

One proposed route through Pond Inlet will pass to the south and west shores of Bylot Island which is a designated Bird Sanctuary. Environment Canada advises that as long as there is no cable landing on Bylot Island, they do not foresee any problems in laying a cable in the channel.

1.5 Parks Canada

Parks Canada is in the currently in the process of setting up a National Marine Conservation Area in Lancaster Sound. The attached map is a draft of the affected area and may be legislated by the time the cable in installed.

Parks Canada Proposal for a National Maritime Conservation Area



2.0 Permits & Process

2.1 Federal Department of Fisheries and Oceans

Undersea cable routes within Canada's Economic Zone will require review of any potential fisheries impact. A route map will also need to be provided to Canadian Hydrographic Service in order to add the alignments to the official nautical charts. This will serve to protect the corridor against encroachments by future activities such as drilling platforms, other cables, pipelines, etc.

2.2 Municipal Government

Route drawings will need to be submitted to the administration officer of each community for approval for the cable routes and any associated infrastructure such as towers, equipment shelters, power feeds, office space, etc.

2.3 Transport Canada

Transport Canada would be involved if there is any impact on port facilities, anchorages or sea lanes.

2.4 Contact Information & Reference Material

Fisheries and Oceans Canada

Eric Kan and Derrick Moggy, Iqaluit
Phone: (867) 979-8000

Lyndon Kivi, Kenora
Phone: (807) 468 6441 x29

For DFO Operational Statements see - Link
For the Operational Statement for underwater cables see - Link

Aboriginal Affairs and Northern Development Canada,

Rosanne D'Orazio, Environmental Assessment Coordinator, Iqaluit
Phone: (867) 975-4554

Jeff Mercer, Manager of Lands, Iqaluit
Phone: (867) 975-4280

Environment Canada

Mark Dahl, Ocean Disposal Specialist, Winnipeg
Phone: (204) 983-4815

Allison Dunn, Senior Environmental Assessment Coordinator, Iqaluit

Canadian Wildlife Service, Environment Canada

Jason Akearok, Habitat Biologist, Environmental Stewardship Branch, Iqaluit
Phone (867) 975-4641

Canadian Coast Guard

Mike Hines, Superintendent, Operational Business & Arctic Programs, Sarnia, ON
Phone : (519) 383-1856

Canadian Ice Services (Environment Canada)

- Web Link

Parks Canada

Nick Irving (Nick.Irving@pc.gc.ca) and Doug Yuick (Doug.Yurick@pc.gc.ca)

Canadian Hydrographic Service

Sandy Bishop, Engineering Project Supervisor: Central and Arctic Region Burlington, ON
Phone: (905) 336-6440

Terese Herron, Engineering Project Supervisor: Tides, Currents and Water Levels
Phone: (905)336-4832

Shipping Company Web Links

- NEAS - Link
- Arctic Link - Link
- NTCL - Link

D. IMPLEMENTATION

1.0 Potential Staging of the Program

1.1 Assumptions

This staging plan assumes the provision of fibre to each of the 25 communities and is based on the time taken for a single cable laying ship to deploy cable within the normal arctic construction season extended by 4 to 6 weeks with the aid of icebreakers. No account has been taken of the Arctic Fibre or Arctic Link proposals to install from Europe to Asia through Nunavut in this scenario.

The planning and design of the network is assumed to take eighteen months to two years during which time the EA process would be run in parallel. The planning would be carried out with bathymetric data collected during this period and perhaps even into the start of construction.

Any links which are to be completed with a microwave transmission line could be planned and designed in parallel with the subsea cable routes.

1.2 Caveats

Although the arctic climate appears to have moderated considerably in recent years and global warming is cited as the cause, there is another school of thought which posits that the arctic climate is undergoing a warming cycle and that this could any at any time reverse itself, thereby returning the Northwest Passage to it former status as a formidable barrier to shipping. In short, the extended shipping seasons of recent years is no guarantee of a similar experience next year.

Dangers to arctic shipping already exist in the form of inadequate marine chart detail, underwater channels which are subject to movement, iceberg transits and ice pushed by wind. At an operational level, the Arctic is a forbidding place requiring vessels with strengthened hulls, equipment designed to operate in severe icing conditions, experienced crews with specialized training to work in extreme weather and contingency plans for the likes of medical emergencies. More information is required to assure that suitable vessels and crews could be deployed successfully. This would mean discussions with marine cable laying operations such as Tyco, Global Marine, KDD and Alcatel.

1.2 Phase 1 – Manitoba to Iqaluit

MTS Allstream appears to be prepared to upgrade their network to Churchill to provide capacity for an arctic network. From Churchill the plan would be to lay a submarine cable to Arviat, then Chesterfield Inlet, then to Ivujivik on the Ungava Peninsula and then to Iqaluit. The time to lay this 2500km route with a branching unit into Rankin Inlet would be in the order of 2 months depending on the amount of burial by marine plough. Branching units would be installed for future connections into a number of communities close to the route but not installed until later. It would take some additional time beyond the two months to install the shelters and equipment to light the system.

1.3 Phase 2- Iqaluit to Resolute Bay

Another 2500km link from Iqaluit to Resolute Bay would stop only in Pond Inlet but have a potential 5 branching units left for future connections. It may be decided that Pangnirtung and Grise Fiord would be best served by MW links to other communities. Again, two months would be needed to lay the main cable with additional time to activate the link. It is quite conceivable that Phase 2 could be completed in the same season as Phase 1.

1.4 Phase 3- Resolute Bay to Cambridge Bay

The route distance here is 950km with one branching unit to serve the five communities close to the Gulf of Boothia. Although shorter than the previous phases, we believe it would take a similar length of time due to the greater amount of ploughing. This leg might start a second season of cable laying in concert with Phase 4.

1.5 Phase 4 – Cambridge Bay to Tuktoyaktuk

The route distance is around 1375km and would have one branching unit for Kugluktuk. About 6 weeks would be required to lay this backbone. The biggest difficulty would be laying the cable into the Mackenzie Delta area to reach Tuktoyaktuk where we anticipate the fibre optic cable from the Alberta border would complete the ring back to Manitoba.

1.6 Phase 5 – Branching Units

This would include completion of the spurs to all the remaining communities. Some or all of these could be completed during the main cable laying activities depending on cash flow and length of season available but a total of 3500km of cable would be needed if every one of the communities (except Sanikiluak) were to be connected by submarine cable.

2.0 Deployment Models

2.1 Submarine Cable vs. Microwave

With a complete submarine cable installation being estimated at around $69,000/km versus around $35,000/km for microwave, it may seem as though MW would be the preferred solution. However, considering the much lower capacity of the MW system and the far higher operating costs for 250 to 300 towers accessible only by helicopter, there remains a compelling case for submarine cable.

Notwithstanding the above, only a detailed comparison of capital and operating costs for some of the legs will determine whether MW would be the more economical choice to service certain communities. Candidates include Baker Lake served by MW from Chesterfield Inlet; Repulse Bay from Kugaaruk; Pangnirtung from Qikiqtarjuak; Hall Beach from Igloolik; and Kugaaruk from Taloyoak.

2.2 Providing Fibre Optic cable to Four Strategic Hubs at Least Cost

The alternative to a complete build out to all 25 communities could be an initial deployment of fibre to Iqaluit, as the capital of Nunavut; to Rankin Inlet, as the major community on Hudson’s Bay; to Cambridge Bay, as the future home of the Arctic Research Centre; and to Resolute Bay, the premier military base in Nunavut.

We estimate the total order-of-magnitude cost of this option to be in the vicinity of $177 to $213M as outlined in the table below.

Service to Chesterfield & Rankin Inlets; Iqaluit; Resolute and Cambridge Bay						
No.	Description	Notes	Quantity	Unit	Rate	Total
1	Route marine survey/bathymetry & burial study	Omits easterly connection from Quebec	3,990	km	$ 3,750.00	$ 14,962,500.00
2	Permits and land acquisition	Allowance	1	LS	$ 10,000,000.00	$ 10,000,000.00
3	Backbone submarine cable lay – ocean going vessel	Placing 4f cable incl splice, test, spare joints	3,590	km	$ 2,000.00	$ 7,180,000.00
4	Laterals to shore - surface laid	Ditto using DP vessel	200	km	$ 20,000.00	$ 4,000,000.00
5	Laterals to shore - plowed below sea bed 1.5m deep	Ditto	200	km	$ 90,000.00	$ 18,000,000.00
6	Double Armour submarine cable	Assume 4f; one pair lit	3,235	km	$ 16,000.00	$ 51,760,000.00
7	Single Armour submarine cable	Ditto	120	km	$ 13,000.00	$ 1,560,000.00
8	Light submarine cable	Ditto	235	km	$ 8,500.00	$ 1,997,500.00
9	Shipping Cable	0	1	LS	$ 2,160,000.00	$ 2,160,000.00
10	Additional cost to add repeater (one fibre pair)	Includes submarine repeater	31	ea	$ 200,000.00	$ 6,200,000.00
11	Additional cost to add branching unit (BU)	Includes BU but not tail to shore	1	ea	$ 750,000.00	$ 750,000.00
12	Icebreaker support	0	-	days	$ 60,000.00	$ -
13	Beach landing HDD shot in soft ground - 1 km long	Assume average 1000m shot incl materials	10	ea	$ 800,000.00	$ 8,000,000.00
14	Added allowance for beach landing HDD shot in rock	Assume average 1000m shot incl materials	2	ea	$ 1,800,000.00	$ 3,600,000.00
15	Supply and install (S&I) beach manhole (BM)	0	11	ea	$ 30,000.00	$ 330,000.00
16	S&I BU shore station – prefabricated building	Including genset but excluding SLTE & DC plant	8	ea	$ 1,600,000.00	$ 12,800,000.00
17	S&I Ocean Ground Bed (OGB)	Assuming 7 anodes in soils	8	ea	$ 200,000.00	$ 1,600,000.00
18	S&I OSP from BM to Landing Station and POP	Terrestrial build	10	km	$ 100,000.00	$ 1,000,000.00
19	S&I SLTE equipment (DWDM) - standard & repeatered	0	6	ea	$ 250,000.00	$ 1,500,000.00
20	S&I SLTE equipment (DWDM) - long span	Includes Raman pumps	4	ea	$ 500,000.00	$ 2,000,000.00
21	S&I DC Power Feed Equipment for repeatered systems	0	6	ea	$ 750,000.00	$ 4,500,000.00
22	Mobilization/Demob – Cable laying vessel	0	1	season	$ 2,400,000.00	$ 2,400,000.00
23	Cable Laying Vessel standby cost	0	15	days	$ 50,000.00	$ 750,000.00
24	Allowance for spare equipment	0	1	LS	$ 2,500,000.00	$ 2,500,000.00
25	Post Lay Inspection and Burial (PLIB)	For ROV	25	days	$ 85,000.00	$ 2,125,000.00
26	Mobilization/Demob – HDD equipment	One setup per community	10	ea	$ 750,000.00	$ 7,500,000.00
27	Shipping materials for Shore Station, OGB, OSP, BM, HDD	One setup per community	10	ea	$ 750,000.00	$ 7,500,000.00
28	Mobilization/Demob – Workforce	One setup per community	10	ea	$ 30,000.00	$ 300,000.00
	TOTAL ESTIMATE					**$ 176,975,000.00**
	Contingency Allowance				20%	$ 35,395,000.00
	BUDGET ALLOWANCE					**$ 212,370,000.00**

The above model assumes the provision of the following long-haul undersea fibre links:

- From the fibre-optic network in Churchill and thence via submarine cable to Aviat and Chesterfield Inlet with a branching unit to Rankin Inlet.
- A submarine fibre cable from Tuktoyaktuk to Cambridge Bay.
- A submarine fibre cable from Cambridge Bay to Resolute.
- A submarine fibre cable from Iqaluit to Nuuk, Greenland, to connect with the existing TELE Greenland network.

In this scenario, the four communities would not be equipped with a redundant fibre links but rather would have to rely on Satellite communications for backup. In addition, the remaining 21 communities in Nunavut would continue to be serviced by satellite until such time as the links could be extended with undersea cable or via microwave backhaul.

2.3 Addition of a Link to TELE Greenland in Nuuk

The backbone ring formed between MTS-Allstream's network in Churchill and NorthwesTel's in Tuktoyaktuk provides system redundancy in the event of a fibre cut at some point in the ring. However, with such a large ring and the problem of winter inaccessibility, there is a risk of a second break happening before the first could be fixed. This would leave those communities between the two breaks isolated. One option to add security to the network would be to install an additional branching unit from the proposed backbone in Davis Strait east of Frobisher Bay, connecting across the strait to Nuuk in Greenland.

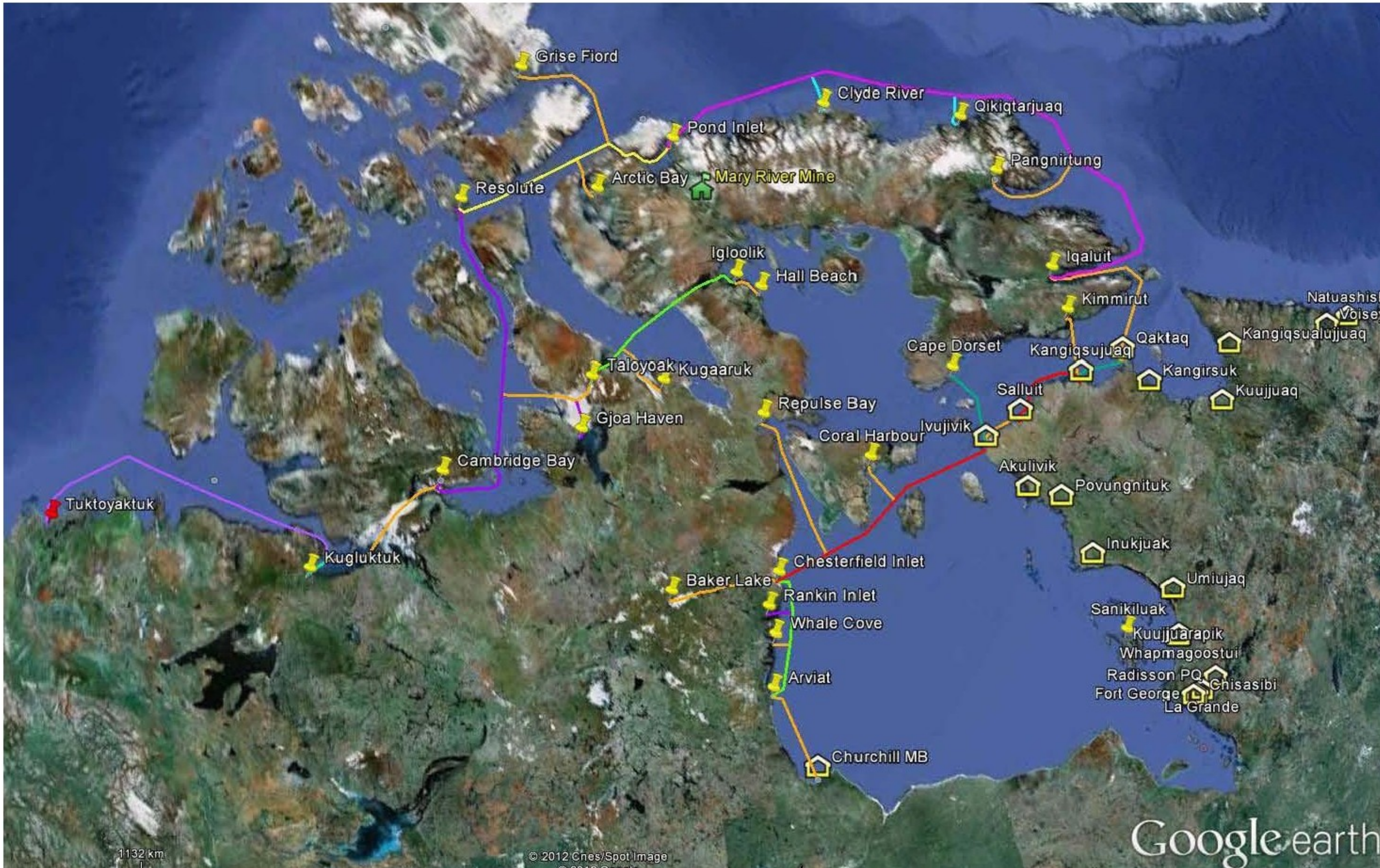
If there is already a deep water, surface-laid branching unit in place and available on the TELE Greenland submarine cable, the incremental construction cost to add this link could be as little as $10M. This includes bathymetric studies, the addition of one branching unit, around 410km of single armour cable and 4 repeaters. However, subject to detailed design, the link may require additional or upgraded power feed equipment on one or both sides of the Davis Strait which could add another $2M.

If there is no existing BU on the TELE Greenland system and a shore landing is required the cost would escalate significantly, probably to the $20-24M range.

APPENDICES

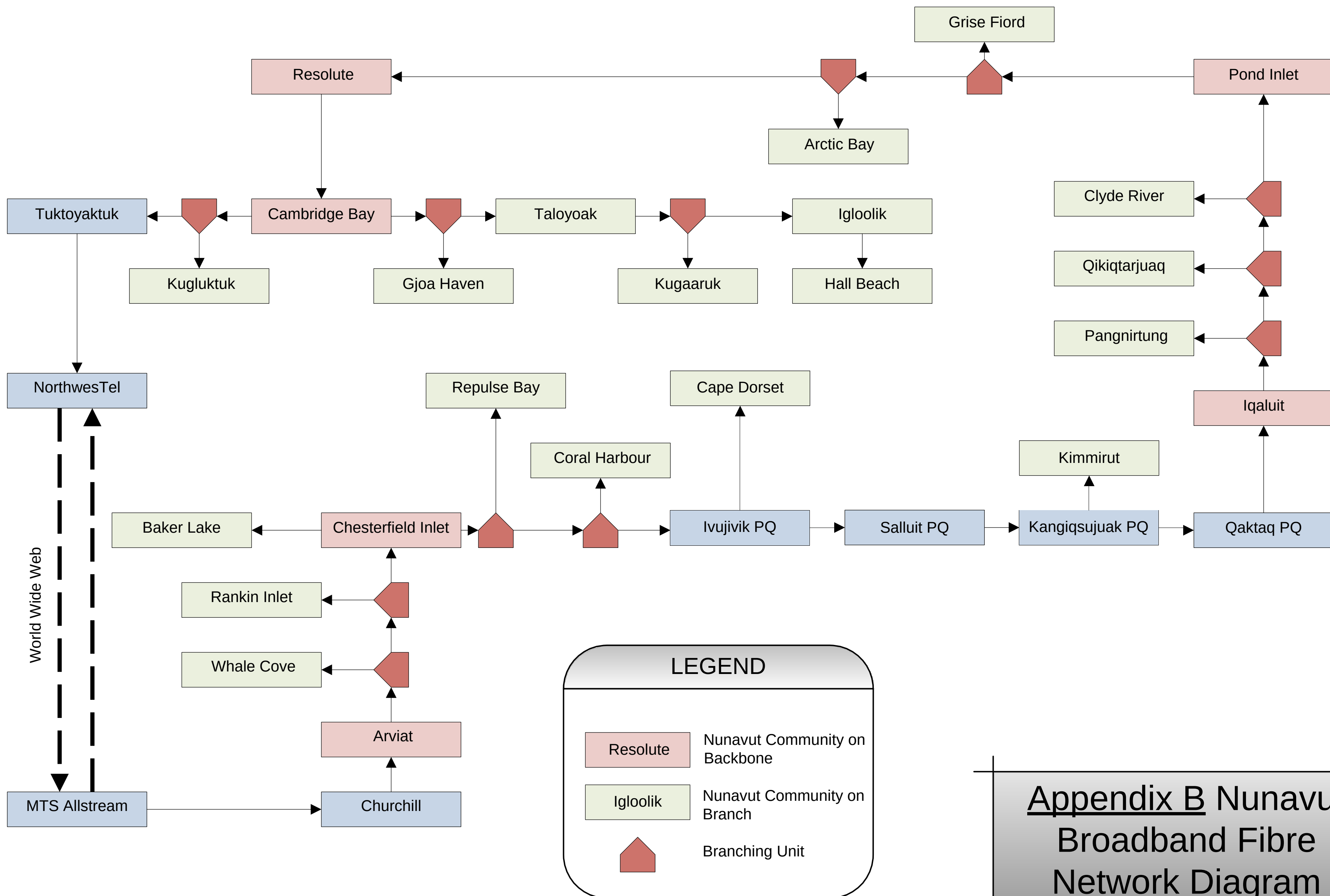
Appendix A - NUNAVUT BROADBAND FIBRE NETWORK - GOOGLE EARTH OVERLAY

Appendix B - NUNAVUT BROADBAND FIBRE NETWORK DIAGRAM

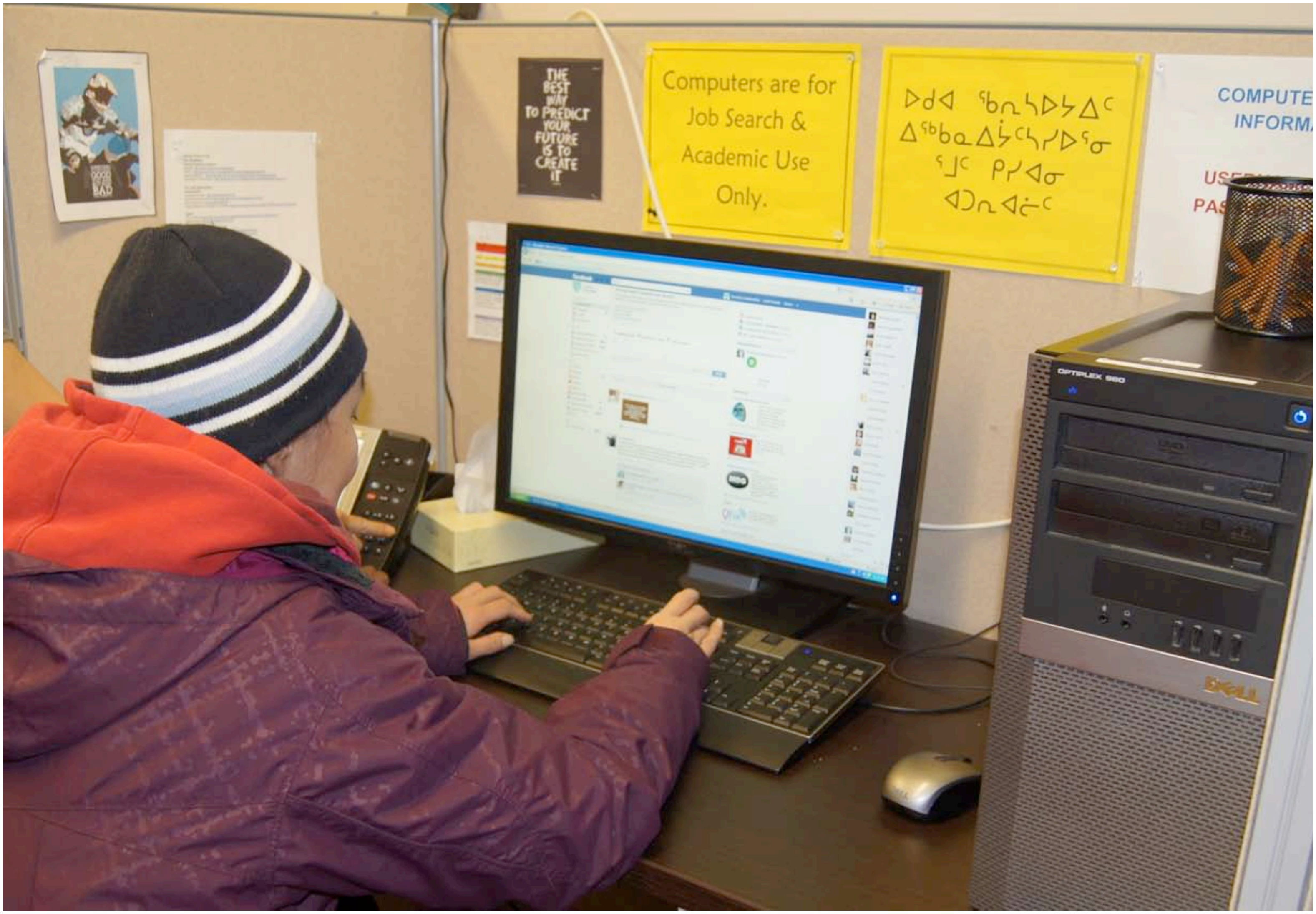


Appendix A

Nunavut Broadband Fibre Network
Google Earth Overlay



Appendix B Nunavut Broadband Fibre Network Diagram



Inuit Studies student Veronica Emikotailak of Sanikiluaq at Nunavut Arctic College, Iqaluit. p. L Thomas

Nunavut Fibre-Optic Socio-Economic Overview

Prepared for Nunavut Broadband Development Corporation by Lorraine Thomas, Imaituk Inc.

Imaituk Inc.
366 Kingston Crescent
Winnipeg, MB R2M 0T8
lorraine.thomas@imaituk.ca
204 231-0278
www.imaituk.ca

March 31, 2012

Table of Contents

1.0 Executive Summary

1.1 Potential for socioeconomic benefit from communication backbone investment

Gross Domestic Product is rising faster in Nunavut than in any other Canadian jurisdiction. Yet a bleak socioeconomic outlook for Nunavut persists.

As Canadians, we look to governments to make strategic investments in things like schools, health care and business incentive programs, highways and ports to ensure people benefit locally and regionally from increased economic opportunities.

One such investment for Nunavut that is both important and affordable is communication infrastructure, to benefit the people of Nunavut directly, and at the same time, support the exploding growth of the resource sector -- a benefit to both Nunavummiut and all Canadians.

It is ironic the Government of Nunavut (GN) - the government in the territory with the highest GDP growth in Canada - does not have the funds to significantly increase its investment in people through programs and infrastructure. Instead, now and in the future the Government of Canada (GoC), which collects the lion's share of the resource revenues, will be the key player in supporting communication investment.

1.2 Economic drivers for communication backbone investment

This report focuses on the impact of connecting some communities to a fibre-optic backbone, while leaving other Nunavut communities to rely on existing satellite connections.

The report argues that while the GoC will be the primary investor in improved communications infrastructure, the key economic driver for investing public money will be the resource sector. Furthermore, as resource sector expansion is happening in most corners of Nunavut and affects everyone, any roll-out and routing plans for communication infrastructure, notably for connections with fibre-optic cable, must take a territory-wide approach.

At the same time any investment in communication infrastructure must consider the socioeconomic impact of such investment on all Nunavut communities. If some communities have significantly better connectivity than others, the disparity in opportunities that results will create a significant political and cultural challenge and may lead to a significant gap between the have-communities and have-not communities within Nunavut.

This document does not deal at length with resource sector issues. Its primary emphasis is on what the impact of an investment in fibre-optic connections might be on socioeconomic opportunities at a community level. The report also looks at some of the concerns of Nunavummiut in an investment of this nature, and poses a number of questions regarding how government investment will benefit Nunavummiut and Nunavut communities.

1.3 Overview of report

This document on the socioeconomic impact of partial fibre connectivity and implications on service parity is a small part of a much larger engineering report conducted by Salter Consulting Group and Ledcor, contracted by the Nunavut Broadband Development Corporation.

Sections 3 and 4 provide a brief overview of the current socioeconomic state of Nunavut, followed by a summary of needs for better connectivity for all sectors in Nunavut, and the reasoning behind why people are looking into fibre as an investment.

The report then examines the various economic investment drivers for a large communication backbone investment in Section 5.

Sections 6 and 7 review the two models of fibre investment - one which sees a shorter term plan of hooking up a handful of communities and another which envisions connecting 24 of 25 communities one day to fibre. It also raises the question of investments required in increasing satellite delivered capacity to non-fibre connected communities, as well as to act as a back up to fibre links that have a single point of failure.

The key question for public investment in determining the mix of fibre and satellite investment is to determine which backbone technologies and routing can best connect communities for equal opportunities to benefit, while also being able to support mining and exploration industries, and serve the military-sovereignty, environmental monitoring and management activities in Nunavut.

1.4 Conclusions on ensuring service parity in design of backbone investment

The report concludes in Section 8 with a series of recommendation to ensure any investment in communications backbone infrastructure benefits everyone, as we seek to develop the prospects of the entire territory for the future of all Nunavummiut and Canadians.

- Recommendation 1: Investment in infrastructure must benefit Nunavummiut as it also seeks to benefit Canada
- Recommendation 2: Reliability and redundancy paramount
- Recommendation 3: Strategic concurrent backbone investment required in satellite
- Recommendation 4: Future revenue streams required to maintain and innovate

It is hoped this socioeconomic look at a partial fibre roll-out will help policy makers to ensure that broadband in Nunavut acts as an enabler, not a constraining factor in the lives of Nunavummiut, as they seek to take their rightful place in the success of Canada.

2.0 Terms of Reference - Socio-Economic Impact of Fibre-optic Connections on the Parity of Telecommunications Service to Nunavut Communities

2.1 *Background*

This socio-economic report, prepared by Imaituk Inc, focuses on the impact of fibre-optic connections on the parity of telecommunications service to Nunavut communities (“service parity”). More specifically, it deals with the socio-economic impact of connecting a relatively small number of Nunavut communities to fibre, with most other communities relying on satellite.

This report is part of a broader study commissioned by the Nunavut Broadband Development Corporation (NBDC) to examine the feasibility of establishing a fibre-optic connection to the Internet backbone to Nunavut communities. NBDC contracted Salter Consulting Group (SCG) to examine a range of fibre-optic issues, including fibre-optic technologies suitable to an Arctic environment, the status of arctic fibre networks in the adjacent regions to Nunavut, a study of possible landing points, engineering, tasks, costs, financing options and potential timeline for a fibre-optic network build in Nunavut.

The opinions presented in this report are those of Imaituk Inc., based on previous experience in researching impact of connectivity in communities, and user needs, research data, and economic documents, articles and reports referenced throughout this paper.

2.2 *Methodology*

Because the bulk of the fibre study was to determine the engineering, costs and options, the socio-economic impact on service parity forms a very small portion of the project, and no original socio-economic data was collected.

Key data used for this report was taken from two main sources: a) the “Nunavut Fibre-Optic Feasibility Study” produced by Ledcor, dated February 29, 2012 and the overview report by SCG of the same name, dated in March of 2012; and b) the research conducted for the Arctic Communications Infrastructure Assessment (www.aciareport.ca, by Imaituk, 2011).

The fibre study (and its companion socio-economic piece) is meant to complement but not overlap an NBDC Broadband Socioeconomic Impact Assessment project being completed by another firm. This other study is being conducted concurrently to this study, focusing on the economic and social benefits of Broadband in an overall sense, independent of any specific technology. Unfortunately, due to timing, data from the main Broadband Socioeconomic Impact Assessment was not available to inform this document.

3.0 The Economy, Society, and Need for Connectivity

3.1 Socioeconomic overview

Economic overview

According to a report issued by the Conference Board of Canada in March of 2012, Nunavut's economy grew by 6.8 per cent in 2011 and the territorial economy is forecast to grow by 16 per cent in 2012. [1] (This compared to a projection of 2.1% for the rest of the Canadian economy.)

While Nunavut's economy is active in a number of other sectors, including construction, fisheries, tourism, and arts and crafts production, most of Nunavut's recent economic growth can be attributed to the explosion of mining exploration, with the sustained global demand for metals. This is very good economic news for the mining sector, and for all Canadians in general.

The Government of Nunavut (GN) projected spending for the 2011-2012 year was $1.2 billion.[2] Of this amount, $1.13 billion was from federal transfers to run the affairs of Nunavut.[3]

As a young territory, the GN has very little in the way of taxation power, and relies on the Federal government for the vast majority of its annual budget. In essence, Canadian taxpayers currently pay for the majority of the costs of maintaining the infrastructure and social programs for Nunavut as a Canadian territory.

On the other hand, the federal government (on behalf of all Canadians) collects the vast majority of mining royalties and taxation from any mining activity in Nunavut. Unlike the provinces the GN receives virtually no royalties from mining activity within its jurisdictional borders. So in fact Canadians will receive the benefit of the wealth created in the mining sector in Nunavut, potentially offsetting a significant amount of the expense of operating the GN. In addition, a large portion of the overall capital spending in Nunavut (whether government or mining investment) goes toward the purchase of imported building materials, fuel, machinery and equipment, ultimately benefiting the producers of these goods, located south of 60.[4]

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[1] Ottawa Citizen, March 14, 2012: *"Canada's North Poised to Cash in on Mining Boom: Report"*, Chantal Mack http://www.ottawacitizen.com/story_print.html?id=6301415&sponsor=

[2] Nunavut Economic Forum: *"2010 Nunavut Economic Outlook: Nunavut's Second Chance",* Impact Economics, p 43, figure 5.7

[3] Ibid, p 44

[4] Ibid, p 45

Importance of communities to Canadian economic and sovereign interests

Mining exploration relies on the existence of communities scattered across Nunavut, such as Repulse Bay, Baker Lake, Kugluktuk and Pond Inlet that serve as exploration hubs, providing airports, electricity, hotels and local communication networks when companies begin their exploration, and eventually look to hire local people.

The existence of Nunavut communities in strategic locations are important to mining companies in their exploratory stages, but these communities are also critical in serving other national level interests.

Many federal government departments depend on the existence of Nunavut communities dotted across the Arctic to be able to carry out duties important to the whole country, and to establish Canadian Arctic sovereignty. Different communities act as staging points for research, military operations, or north warning system sites, such as Hall Beach, Cambridge Bay, Resolute Bay, and Arctic Bay. The Canadian Coast Guard, Parks Canada, and Environment Canada rely on communities all over Nunavut to more easily conduct their operations.

The gradual opening of the Northwest Passage and increasing trans-Arctic air traffic from North America to Europe further cements the need for a network of communities dotted all over the Arctic landscape to provide for additional monitoring and emergency response services over the long term.

However, even though the existence of Nunavut communities makes access to many parts of the Arctic much easier for mining and sovereignty claims, there is a chronic shortage of funds for any new infrastructure in Nunavut's 25 communities. The scale of infrastructure deficiencies in housing, medical facilities, youth facilities, power generation, water treatment, transportation and communication networks, has been characterized as "past critical in some settlements and merely a national embarrassment in others".[5]

According to Dr. Ken Coates, author of the Federation of Canadian Municipalities document On the Front Lines of Canada's Northern Strategy, "The North will, over time, generate a huge amount of revenue for Canada as a whole from its natural resources and from the other economic development that will occur there…It's important to start tying those resources to the actual development of the region itself."[6]

Socioeconomic picture - how Nunavummiut are faring

The coming economic boom in Nunavut will not necessarily translate into opportunity for the

[5] Federation of Canadian Municipalities: *"On the Front Lines of Canada's Northern Strategy",* July 27, 2010, Dr. Ken Coates and Dr. Greg Poelzer University of Saskatchewan, page 8

[6] Nunatsiaq News, August 31, 2010 "Canada lags on Arctic infrastructure, report says" http://www.nunatsiaqonline.ca/stories/article/310810_canada_lags_on_arctic_infrastructure_report_says/

local population living in the Arctic, without investment in the people who live there.

The March 2012 Conference Board of Canada report noted that while the mineral exploration-driven GDP in Nunavut is skyrocketing, opportunities for local people are not. The real challenge for the mining industry is not finding the markets for the resources they extract, but rather finding the skilled workers necessary to work in the expanding Arctic mining industry.[7]

In an ideal world, the local population of the Arctic would supply trained workers who already live in the Arctic to support, as well as benefit from, mining ventures. There is a national shortage of mine workers, and the industry is 'leaving no stone unturned' looking for new talent to fill future jobs.[8]

Repulse Bay Mayor Hugh Haqpi summed up the gap between the economic outlook and the reality in his community:

> "We're looking at Baffinland, Peregrine Diamonds, North Country Gold, Agnico-Eagle, Vale, all these exploration companies going to Nunavut and they will need skilled workers," Haqpi said.
>
> The latest numbers from Statistics Canada show Nunavut has almost 18 percent unemployment. Planning and training are needed now to ensure out-of-work Nunavummiut get the jobs, Haqpi said.[9]

Just as the GN struggles to find funds to invest in infrastructure, it also struggles to cover the ever-increasing costs of health care, education and social programs to serve the population of the territory, as everyone works to improve the standard of living for the average citizen, and try to prepare for potential job opportunities that lay ahead.

Further, while the unemployment rate is high at 18%, many Government of Nunavut jobs are not staffed,[10] often due to lack of housing for imported workers who have the necessary qualifications, or because the local population lack the qualifications to fill the jobs.

While there are many bright spots in Nunavut's future, the overwhelming message from the

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[7] Ottawa Citizen, March 14, 2012: *"Canada's North Poised to Cash in on Mining Boom: Report"*, Chantal Mack http://www.ottawacitizen.com/story_print.html?id=6301415&sponsor=

[8] Globe and Mail, March 22, 2012 : *"In search of talent, mining sector leaves no stone unturned",* pB10, Paul Brent.

[9] CBC News North, March 15, 2012: *"Mining expected to driver economic growth across North",* http://www.cbc.ca/news/canada/north/story/2012/03/15/conference-board-of-canada-economic-forecast-growth-mining-north.html

[10] As of March 2009, it was reported that 23% (800 of the 3000) GN jobs were vacant, 2010 March Report of the Auditor General of Canada, http://www.oag-bvg.gc.ca/internet/English/nun_201003_e_33568.html#hd5b

2010 Nunavut Economic Report[11] is that Nunavut's population will not benefit unless investment is made into the people and the infrastructure by government today, in preparation for tomorrow.

3.2 Socioeconomic imperative to connect Nunavut communities to reliable backbone

> It is clear northern economies are very strong and are getting stronger. It is also very clear the challenges the North face are not economic, but social. Broadband-enabled services have a very significant role to play in ensuring a higher quality of life while helping to build and maintain sustainable communities and lessening the digital divide.[12]

There is a great deal of international data to back up the idea that improved broadband services lead to improved socioeconomic opportunities for any population.[13] Nunavut is no different.

The Arctic Communications Infrastructure Assessment report detailed the need for vastly improved connectivity and redundancy for both the territorial and federal governments to operate effectively. All governments provided detailed challenges to their provision of services for residents of Nunavut.[14]

The high cost and relatively low through-put of telecommunications networks dependant on satellite in Nunavut was cited as key challenges to governments in their operations.

Some of the future needs the GN identified in the ACIA report include[15]:

- improving management of Government of Nunavut operating in a decentralized model with more reliable networks that can properly support various applications to run a modern government in a vast geographic territory[16];
- increase learning opportunities for all residents through distance education initiatives[17] leading to local residents being able to fill more available jobs;

[11] 2010 Nunavut Economic Outlook: Nunavut's Second Chance, 2010, pp. 10-25 http://www.nunavuteconomicforum.ca/public/files/library/NEO%202010%20Outlook%20%20Report.pdf

[12] Northern Communications and Information Systems Working Group, April 30, 2011: "A Matter of Survival: Arctic Communications Infrastructure in the 21st Century", Imaituk Inc., Graeme Clinton p 164 http://www.aciareport.ca/resources/acia-ch8-v1.pdf

[13] Ibid, Chapter 8

[14] Ibid, Chapter 5, http://www.aciareport.ca/resources/acia-ch5-v1.pdf

[15] Ibid, pp 134-137

[16] Ibid, Appendix C, http://www.aciareport.ca/resources/acia-appc-v1.pdf

[17] Nunavut Arctic College recently announced funds in February 2012 to boost Adult Education in all Nunavut communities, and is working with Imaituk Inc. to investigate how to better integrate

- more access to health care support and expertise outside of Nunavut, leading to better health care services;[18]
- more support for commerce in communities to build local economic capacity, leading to local business development.[19]

The Government of Canada highlights included:

- Ensuring Nunavummiut can properly access new federal online services like all other Canadians, particularly as the GoC moves more critical services into an online environment;
- Need better ability to connect from the field (in locations outside of communities) for environment, sovereignty, research, shipping, safety, emergency response etc;
- Mobile communications capacity required for federal agents working in the North to carry out duties that increasingly rely on mobile connections.[20]

Having reliable, affordable networks are fundamental in ensuring successful government operations -- and in Nunavut successful government operations correlate very highly with successful socioeconomic development. "In Nunavut, government has a far greater influence in shaping the growth of society than one might find elsewhere. For Nunavummiut to achieve their ultimate goal of a high and sustainable quality of life, a well-functioning and responsive government is imperative.[21]

Information and Learning Technologies into Community Learning Centres to provide more learning opportunities for adult learners.

[18] Ibid, ACIA report, p 133

[19] Baffin Regional Chamber of Commerce is developing a set of procedures with Consilium to support small businesses to create a Virtual Office, whereby all financial transactions can be effectively controlled from any Nunavut community, using broadband to link to accountants, bookkeepers, and banking services outside of their communities.

[20] Ibid, ACIA report pp 122-128

[21] Ibid, 2010 Nunavut Economic Outlook, p9

4.0 Why is Fibre Desirable?

4.1 Capacity: Fibre vs. current satellite services

According to the ACIA report[22] conservative estimates for the bandwidth needs in Iqaluit is about 239 Megabits per second (Mb/s) inbound, and 207 outbound, for a total of 446 Mb/s (Adjusted Total). These estimates are based on total government needs, and 256 kb/s inbound for consumers. In other words, today's basic need for bandwidth in Iqaluit is about half a Gigabit per second (Gb/s).[23]

According to the fibre-optic study by Ledcor [24] a pair of optical fibres carries a minimum of 320 Gb/s. The amount of bandwidth a fibre pair can deliver therefore far exceeds what the average Nunavut community uses to operate today, about 640 times more than what the ACIA report listed as the 'need'.

One can quickly see how attractive fibre is to a consumer frustrated with current bandwidth constrictions, who is trying to connect to southern applications that are built to operate on much higher bandwidth than is available to most users.

Every time Nunatsiaq News or CBC North covers a story about a fibre project, the public respond with great enthusiasm, thinking that their bandwidth problems will soon be solved -- if only they could have fibre.

4.2 Shortcomings of satellite delivery

The ACIA report documents government agency representatives' complaints about the Arctic satellite-served communications infrastructure. These include:

No service parity within Arctic, or between North and South: In satellite-served communities people cannot use the same software programs as are available in the south (or in some cases, in other parts of the north), so are not able to access certain health-care programs, education programs, or federal programs, leading to a lack of parity in terms of benefiting from services.

Affordable bandwidth shortage and latency on satellite: People were under the impression that there simply is not enough affordable satellite bandwidth available. Telesat provided documentation showing it has additional C-band capacity that footprints the Arctic, but

[22] Ibid, ACIA Report, p 151, http://www.aciareport.ca/resources/acia-ch7-v1.pdf

[23] The conservative ACIA numbers are based on known and desired applications listed by various government departments, and assume consumers only have access to 256 kb/s in and 128 kb/s out - a speed that is no longer considered adequate.

[24] Ledcor, February 29, 2012, "Technical Report: Nunavut Fibre Optic Feasibility Study for Nunavut Broadband Development Corporation", p. 19

admitted there is additional ground station investment required by resellers to take advantage of this bandwidth, leading users to believe there is a shortage of affordable bandwidth for purchase.

High cost to end user: Many ACIA participants complained of the high cost of purchasing bandwidth on satellite-served networks, and government budgets were simply not high enough (particularly when they compared what other governments pay on fibre networks for access).

Reliability, network outage problems: It should be noted that ACIA participants also complained about fibre connections as well, citing frequent outages, lack of back up and redundancy, and a new dependence on a service that when down for a lengthy period of time, becomes the 'cause of the emergency'. (Note: the participants in the ACIA report were interviewed before the satellite failure in October 2011.)

The report delves into the reasons why satellite is more expensive, and documents all of the known public investments into satellite and terrestrial networks. Nunavut public investment into satellite capacity (at the time of the ACIA report) totaled in the tens of millions.

5.0 Economic Review: Investment in Fibre Backbone

There is no question that the cost of recurring satellite bandwidth far exceeds the cost of recurring fibre bandwidth - *once the initial fibre build has been paid for.* The challenge is obtaining the funds to put in fibre in remote communities in Nunavut.

In the initial cost estimates of the Ledcor desk study, the cost of laying fibre to a point of presence in 24 of 25 Nunavut communities is estimated at $750 million ($1,050 million with the appropriate risk contingency included).[25]

The investment required to link Nunavut communities to a fibre backbone is of such large magnitude that it must demonstrate significant benefit, either financially in the case of private investors, or strategically, in the case of the Government of Canada. Possible rationales for government or private sector investment include:

- Government investment for socioeconomic purposes;
- Government investment for sovereignty purposes;
- Telecommunications sector investment backstopped by government;
- Government telecommunications investment to attract northern mining investment

These scenarios are investigated in more detail as follows:

5.1 Government investment for socioeconomic purposes

It is difficult to make the case for a $1 billion fibre backbone infrastructure investment in Nunavut, if the reason to connect communities in Nunavut is defined only by the socioeconomic needs of its 31,000 residents. It is equally difficult to make a case for $300 million to connect 4 communities (Iqaluit, Rankin Inlet, Cambridge Bay and Resolute Bay), with a total population of around 12,000.

It might be argued over time, costs for providing government services such as health care, education, and social services would start to drop as a percentage of the economic spending, as Nunavummiut move into their rightful place as economic drivers, healthy people, independent workers, business owners, suppliers, and home owners in their own land. This a compelling reason from a Nunavut perspective, and one that has been successfully used in the past to better connect communities to the satellite infrastructure that is now in place.[26]

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[25] Salter Consulting Group: "Nunavut Fibre Optic Feasibility Study, presented to Nunavut Broadband Development Corporation", March 2012, p. 63

[26] Nunavut Broadband Development Corporation, March 2003: "Nunavut Broadband: Business Plan Submission for Implementation Funding, Executive Summary" http://www.nunavut-broadband.ca/PDF/WebNBDC_BusinessPlan_ExecSum_030612.pdf

However, the financial argument is hard to make on the basis of community well-being alone. Certainly the territorial government, with a total annual budget of $1.2 billion (of which 1.13 comes from federal transfer payments) and Nunavut municipal governments have negligible capacity to finance or pay off a billion dollar investment for backbone infrastructure. As the only major investor in Nunavut's communities, any serious financial investment must come from the federal government as a key player in the investment and final decision, and it is extremely unlikely the federal government will commit to this investment on socioeconomic grounds alone.

5.2 Government investment for sovereignty purposes

Sovereignty from a military perspective has also struggled to be the 'market maker' for more telecommunications investment to date. The Federation of Canadian Municipalities (FCM) report argued that any military telecommunications investment should also benefit communities.[27]

But while sovereignty is often held up as the reason for federal investment, investment is not predictable, nor necessarily linked to community development. The March 22nd, 2012 announcement that the military investment in the Nanisivik site is being scaled back dramatically (for now) is just a current example of how sovereignty investment changes as government priorities change. News reports indicate that planned telecommunications for this site will now rely on satellite phones, and water services will be trucked in from the Hamlet of Arctic Bay.[28]

The FCM report recognized that interest in the north (from a military-sovereignty investment perspective) comes and goes depending on the political issues of the day.[29]

5.3 Telecommunications sector investment backstopped by government

Canada's telecom sector is built on a private sector investment model, requiring companies to compete for customer business to stimulate innovation and keep prices low, assuming there is a large enough customer to recoup investment over time. Without the prospect of financially robust customers, no one can expect the private sector to invest in a high risk infrastructure project of this nature without potential for profit in the long term.

Of course, in this model, small communities located far from a fibre link to the Internet backbone are the losers, as these small geographically disperse communities with small

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[27] Ibid, Federation of Canadian Municipalities Report, p iv

[28] Nunatsiaq News, March 22, 2012 : *"Nanisivik: Nunavut's incredible shrinking naval facility",* Jim Bell. http://www.nunatsiaqonline.ca/stories/article/65674nanisivik_nunavuts_incredible_shrinking_naval_facility/

[29] Ibid, Federation of Canadian Municipalities Report, p i

populations are unlikely to attract sufficient communications industry investment. While Canada has made progress in urban settings, our current telecom model for broadband distribution has not worked well for rural and remote communities. The further from the backbone, the smaller the population, the less likely you will be connected to fibre.[30]

With a significant Canadian government investment into an Arctic backbone, a private sector company may be able to leverage additional opportunities for a return on investment. The Ledcor report suggests a ringed architecture could be used to sell redundant connections to other fibre networks such as the proposed Northwest Passage lines.

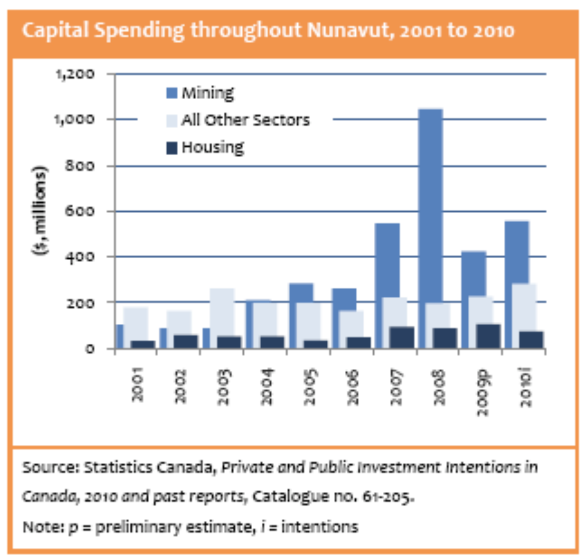
All proponents of a Northwest Passage fibre line are willing to connect Nunavut communities located along the path of their proposed backbones, if they can obtain significant future revenue commitments from the Canadian Government and in many cases, direct capital investment. This proposition defaults immediately to the two previous models of government infrastructure investment: the GoC will invest deeply for either socioeconomic or sovereignty reasons to pay for the cost of the branch from the main backbone to local communities.

5.4 Government telecommunications investment to attract resource sector investment

The chart below shows the comparison of infrastructure investment between mining, housing and all other sectors. In good mining years, (such as the 2008-2009 year) mining companies spent almost as much money on infrastructure in one year, than the entire annual GN budget.

Mining investment in Canada's north is highly dependant on the price of base metals, and all economic indicators point to an increase in the value of base metals for the foreseeable future, and interest in mining in Nunavut is skyrocketing.

Canada is competing with other countries for mining investment. For example, Arcelor-Mittal (iron ore) operates in countries such as Kazakhstan, China, Brazil, India and



Nunavut Economic Outlook, 2010 Figure 5.9, p 44

[30] Tech Crunch, Oct 23, 2011: "The Last Thousand Miles", by Kevin Coldewy, http://techcrunch.com/2011/10/22/the-last-thousand-miles/

Liberia. Whether it is gold, diamonds, nickel, iron ore, or uranium, mining companies look for stable economies, educated populations from which to hire, clear rules for engagement, speedy environmental reviews, low tax regimes, and existing infrastructure.

The oil and gas sector is also likely to expand in Nunavut. In the 1980s, 21 significant discoveries represent a known reserve of 118 million cubic feet of Oil and 303 billion cubic feet of Natural Gas. Climate change, improvements in technology, and rising values of oil and gas will see increased exploration of this potential resource in Nunavut as well.[31]

Mining companies are interested in investing in infrastructure to support their mines. They look to governments wherever possible to build roads, sea ports, and communication networks that they can hook into - investments that done well, also serve the local population. They do not traditionally invest in large infrastructure projects on speculation, nor do they build projects that only meet community needs.

Nunavut's low population base, combined with the sheer costs of physical infrastructure (such as roads and deep sea ports) in Canada's Arctic prohibits the Government of Canada and Nunavut from building infrastructure mines need, such as roads, railways and deep sea ports. A 1,300 kilometre road linking northern Manitoba to the Kivalliq region is estimated at 1.3 billion.[32] A 149 kilometre railway and a port for moving iron ore is estimated at $6 billion dollars on Baffin Island. [33]

So when comparing costs between deep sea ports and roads and the cost of installing communication networks that mines can take advantage of, suddenly $750 million does not seem as prohibitive a number for government to consider investing into a solid infrastructure project that could be used by both mines and the community. Especially if there is a way to generate revenue for the government from future mines.

Mines will choose the cheapest, most reliable option for communications. But they will not build the backbone for community benefit alone - whether that backbone is fibre, or a network of satellites footprinting the Arctic. They will have stringent requirements for quality of service, redundancy and back up systems.

An excellent example of how mining companies will work to meet their own needs, while partnering with other investors who have community needs in mind, one need only look to the

[31] *"Nunavut, the Untapped Petroleum Frontier",* 2006. http://www.cspg.org/documents/Conventions/Archives/Annual/2006/199S0131.pdf

[32] Globe and Mail, May 14, 2011: *"Have road, will travel: Rural Nunavut hopes for a way out"* http://m.theglobeandmail.com/news/national/nunavut/have-road-will-travel-rural-nunavut-hopes-for-a-way-out/article1970759/?service=mobile

[33] News North, November 14, 2011: *"Rail line considered best option"* http://www.nnsl.com/business/pdfs/mining/baffinland_focused.pdf

example of the Hope Bay Mine site in the Kitikmeot region. Newmont recognized it would eventually need more bandwidth than is currently available by satellite to run its highly computerized operations - which must be fed by the most reliable system possible, with enough bandwidth to operate. They determined the best option was microwave. In working out how to build the string of microwave towers that best met the mine's needs, the Nunavut Resource Corporation (a Kitikmeot company owned by the Inuit of the region) planned to invest in the string of microwave towers (along with Newmont) which would link the future Hope Bay mine — and ultimately the rest of the Kitikmeot — to the South's fibre-optic telecommunications network.[34] Both the mine's needs, and the communities' needs would be met, as investment is pooled to achieve a mutually beneficial outcome. Unfortunately, the Hope Bay mine has recently been put on long-term care and maintenance and, without the revenue from the mine site usage, there is currently no business case for the microwave build.

The challenge is to determine how much taxpayer and regional investment money can be used to build a communications infrastructure that will actually contribute to attracting mining investment in Nunavut, rather than in Liberia.

If carefully planned, an investment in backbone infrastructure in which both communities and mines can connect, is potentially a key driver for investment into backbone infrastructure. The question is - what is the right backbone to meet the community needs and the mining needs?

5.5 If government invests, who owns the backbone?

The ACIA report's Chapter 8 goes into great detail on ownership of backbone networks in other jurisdictions.

For example, in Sweden, where the government sees that there are no willing investors to build a backbone to remote areas, the government builds and owns the backbone, and encourages the private sector to connect to the point of presence, and compete delivering the last mile. This system works in Sweden, as they still have a government-owned, national telecommunications provider.[35] There is no national telecom in Canada.

In other jurisdictions, the backbone is seen as a critical piece of infrastructure that is required to attract investment to a region - without which the country cannot compete for international

[34] Nunatsiaq News, Feb 13, 2012: *"Hope Bay's Kitikmeot Ring Continues to Elude Kitikmeot Inuit Association"*, Jane George http://www.nunatsiaqonline.ca/stories/article/65674hope_bays_golden_ring_.eludes_kitikmeot_inuit_assoc/

[35] Ibid, ACIA report, p 166 http://www.aciareport.ca/resources/acia-ch8-v1.pdf

investment. In Australia, huge amounts of government investment is being made to build backbone infrastructure to compete with other nations.[36]

In Nunavut, the building of a fibre backbone will have to be paid for primarily as a federal investment into the future of Nunavut, for all of Canada's benefit.

How the financing of the build is done, is up for debate. Financing the build is only one part of the equation, and could be done in a P3 model, or a contract to build parts of the network according to a plan to which federal, territorial and community governments agree.

Ownership afterwards, and maintenance of the network are complicated. If a private sector firm owns the backbone, who will control the point of presence charge to consumers and last mile resellers, particularly if the vast majority of the backbone was paid for by the government?

ACIA participants in Yukon and NWT complained of very high prices to the POP charged by the owner of the fibre backbone - prices that far exceeded what users perceived as the cost of building and maintaining the network. Unraveling this POP pricing is an ongoing challenge for the CRTC, the company in question, and the users of services. [37]

5.6 Maintaining a backbone and recurring service costs

If a branch line to a community of 700 people breaks, and it costs $2,000,000 to fix it, who will be responsible for fixing the line?

If government does choose to invest in fibre, the following questions will become critically important in negotiating for a long term stable network that is maintained and upgraded as needed:

1. Once a fibre primary backbone has been built, who maintains it, who pays to fix a break on the main line, or on a branching unit?

2. Who is responsible for redundancy in the event of an outage, which may last weeks or even months depending on where a fibre break occurs, and the time of year.[38]

3. How much will access to an existing branching unit cost (in the case of a mine or community who wishes to connect after the main cable is laid?)

[36] Australian Government, National Broadband Network, 2012, *"Online Engagement for Australian businesses and not-for-profit sectors"* http://www.nbn.gov.au/for-business/

[37] CRTC: SSi Micro Ltd.: 8661-S93-201109885 Application regarding Northwestel Backbone Connectivity Services - 2011-06-23 http://www.crtc.gc.ca/Part1/eng/2011/8661/s93_201109885.htm

[38] Ibid, Ledcor report, p 2

4. Who controls the pricing to the POP - how much will a reseller have to pay to get access to bandwidth? If the POP pricing is not controlled to ensure affordability to the buyer (community, mine, military buyers) it is completely feasible that the end users cannot afford to hook in.[39]

5.7 Summary – Investment options

Canada now ranks 9th in the G20 in terms of Internet contribution to the GDP and by 2016, is expected to slide to 12th place, overtaken by Mexico and Saudi Arabia. According to a report issued by Boston Consulting Group, Canada needs a 'shot in the arm' to catch up to other countries such as South Korea and Australia, or else "Canada runs the risk of falling further behind." [40]

While there are important socioeconomic and sovereignty reasons to better connect all Nunavut communities, these reasons alone are not strong enough arguments to see a significant investment in a better communication backbone in Nunavut. Certainly they have not been reason enough to connect all manner of small communities in other parts of Canada, so it is difficult to imagine in this time of economic restraint, that this argument will see the Federal government invest the kind of money required.

The private sector too, will not connect communities on their own, as the initial outlay is simply too large for the private sector to see a return on their investment in the foreseeable future.

Mining companies will also not build a backbone for Nunavut, because their interest is in their own mining needs, and how best to support their immediate local requirements.

Recognizing the reality of federal investment to kick start any serious investment, the best argument for combining the various drivers of investment, (community, military, international competition for resource sector investment, and private sector) all contribute to the argument to make a significant public investment into the communications backbone in Nunavut.

[39] Globe and Mail March 23, 2012, *"Telecoms may face greater disclosure",* Rita, Trichur, p B5.

[40] Globe and Mail, March 19, 2012, *"Canada lags peers in 'Internet economy",* Tavia Grant, p B3.

6.0 Option 1: Fibre to Three Regional Centres and Resolute:

6.1 Overview

Recognizing the cost and sheer logistical challenge of connecting all 25 Nunavut communities to fibre at the same time, the SGC report recommends starting with connecting the 3 regional centres of Iqaluit, Rankin Inlet, Cambridge Bay, and Resolute (as a key military site).

This is well thought-out, logical response, that follows the Canadian model of connecting the largest centres first.

The initial plan would hook up the 4 communities at an estimated cost of $250 million (or $300 million with the appropriate risk contingency). The assumption is that these initial fibre connections would be extended as time and investment permitted, with an articulated plan of the routing to connect 24 of 25 Nunavut communities.

6.2 Does phased-in approach risk creating political inertia?

We have seen in Canada that once major centres are hooked up to better communications services, there is not necessarily a 'trickledown' effect that automatically connects the harder-to-reach communities. If the regional centres are hooked up, who will continue to agitate on behalf of the remaining 21 communities for connectivity?

Nunavut politicians are keenly aware of the need to ensure people in communities outside the three regional centres have opportunities - that is the reasoning behind the government's continued decentralized model. Will the political will to connect all communities fade once the key centres have access, leaving communities with even less opportunity than before? Or will better connectivity in major centres spur people on to ensure all communities are better connected?

6.3 Phased-in approach impact on program development for Nunavut's unique demographic profile

Nunavut's demographics are very different the rest of Canada, and from NWT and Yukon. In Nunavut, the majority of people do not live in the capital and regional centres. Populations in almost all of the communities outside of Iqaluit, Rankin and Cambridge continue to grow.[41]

Unlike NWT and Yukon, the population of Nunavut's three regional centres *combined* is only 10,573 - not even 1/3 of the total population in Nunavut. This means that 2/3rds of Nunavut residents live in the other 22 communities.

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[41] Government of Nunavut, Executive and Intergovernmental Affairs, Stats Update, Feb 12, 2012: "*Nunavut Population Counts*" http://www.eia.gov.nu.ca/stats/census/2011/StatsUpdate_ Nunavut%20Community%20Population%20Counts_2011%20Census.pdf

In NWT, the regional centres of Yellowknife, Inuvik and Hay River (all road linked) comprise 62% of the population. In Yukon, over ¾ of the people live in Whitehorse alone. By connecting the road linked capitals and regional centres, the majority of people in these regions are served. While everyone in NWT and Yukon want remaining communities to be served equally, there is less of a demographic imperative than in Nunavut for communications service parity in order to deliver services to the majority of the population.

The NWT has some programs in health and education that rely on terrestrial connection speeds in order to operate. While great effort is made to achieve service parity, these same programs are not properly supported by existing communication networks serving smaller, more remote communities where speeds are too slow. But this situation (while not perfect) reflects the Canadian standard -- whereby a small percentage of the overall population are not connected because of their location and small population in relation to the regional centres.

Because Nunavut's demographics are different, any healthcare, education or business support system must be able to work outside the regional centres, simply because a large proportion of the population live outside of the regional centres, unlike other jurisdictions. Due to Nunavut's demographics, the incentive for developing innovative programs through communication systems disappears if half the population can't access the program.

For example, a distance education initiative aimed at improving Adult Basic Education opportunities that relies on fibre speeds that is only available in the regional centres will do little for improving the opportunities for the majority of Nunavut residents.

In an ironic twist, regional centres already have college campuses and better health care facilities. What the regional centres don't have is adequate housing for people from other communities to come for further education.

It is the communities outside the regional centres that truly need the better connections to take advantage of the socioeconomic opportunities that communication networks can provide.

If a program depends on high through-put connectivity for its implementation, and only regional centres are connected, there will be little incentive to implement any new program that can improve socioeconomic opportunities in Nunavut if more than half the population can't connect.

6.4 Technical challenges with the 4 community approach

There are some additional risk factors to the 4 community approach that may increase the need for a satellite back up system in the event of a fibre break.

The initial build will not be done using a ringed architecture to start. (See more details on the advantages of the ring architecture in section 6.) This increases the risk for a break to these communities. For example, if any point of failure occurs between Tuktoyuktuk and Cambridge Bay, Resolute will also be cut off. If there is a failure between Newfoundland and Iqaluit, Iqaluit will be cut off. In essence, in the first phase, these communities have the same (or greater in the case of the festooned model used for Cambridge Bay to Resolute) risk profile as a branch link.

In the event of a break in the first phase, the only options will be the same as a branch line option, a) fix it and/or b) move to satellite in the interim.

7.0 Option 2: Fibre to 24 Nunavut Communities

7.1 Overview

The Ledcor report projects a cost of $750 million to lay fibre to a point of presence in 24 of Nunavut's 25 communities. SCG adds a risk contingency, bringing the total projected cost to $1,050 million. (The proposal did not include Sanikiluaq, a community on the Belcher Islands in Hudson's Bay, which is geographically closest to Nunavik, so should one day hook into a fibre ring initiated by Nunavik.)

7.2 24 community plan: reliability built into the design

The Ledcor report designed a full system that concentrated on protecting the primary backbone system, to increase the reliability of a fibre system in the Arctic. The proposal for connecting 24 communities has the following features to reduce risk, and to keep costs as low as possible with a phased-in approach:

1. Ringed Architecture promotes reliability of backbone: The primary fibre backbone is built using a ringed architecture -- linking the Arctic backbone to multiple other fibre networks adjacent to Nunavut. In the event of a break along the main fibre route, the signal can come from the opposite direction, buying time to fix the broken line before any services are cut off on the primary backbone.

2. Phased approach using branch units to connect communities later, as more investment becomes available: Branch units can be installed on the primary cable that can later be pulled up from the sea bed floor to connect a branch line to a community in the future. If these single branch lines from the primary backbone is broken, the integrity of the main backbone remains (although the branch line feed will be broken until the cable is repaired.) While mining needs are not part of the scope of this project, branch units could be installed in advance in likely locations in the event a mining operation goes into production during the 30-year life of the fibre primary backbone.

3. Full plan before initial build: The report requires a full plan for connecting 24 communities over time (before the initial cable is laid), so that once the initial backbone is built, communities can be added, connecting to pre-laid branching units off the backbone.

4. Likeliest points of failure reduce risk to backbone: The likeliest locations for a break are where cables come to shore. By using a ringed architecture (that links to two separate fibre systems) that then links communities using branching units, the primary backbone is more protected than in a festooned system that sees the backbone landing in every community, increasing the likelihood of a break on the primary backbone. In a 'festooned' system that does not follow a ringed architecture, if one community fails, all subsequent communities along the line fail -- like the old fashioned Christmas tree lights.

5. Interconnection with multiple adjacent fibre networks required for increased reliability: Assumes interconnection to four other fibre systems, all run by different operators (MTS, NWTel, TeleGREENLAND and Bell)

7.3 Branch design risks to individual communities

The risks are clearly identified in the Ledcor report, which assumes that Nunavut can expect one break a year in a fully deployed fibre system serving 24 communities, based on other fibre networks in the world. They have proposed to greatly reduce the risks associated with a break on the primary backbone with a ringed architecture, as it will require two simultaneous breaks to disable the fibre network - a less likely event.

However, there remains a risk to Nunavut communities in the 'branch design'. Communities connected to a branch line have a single point of failure. And since the landing point is the highest risk component, there is a higher risk of losing fibre connectivity to a community connected to a branch line. In the event of a failure of a branch line, the options for the community are:

a) repair the fibre line (which may be delayed for significant time periods if the break is under the ice) or

b) switch to satellite to provide emergency connectivity, until the branch can be repaired.

Note: In all Europe to Asia fibre plans, any Nunavut communities would be connected via branch links into the primary backbone, in order to protect the primary Europe-Asia link. If a branch line breaks, investors assume communities will rely on satellite backup to serve the affected Nunavut location.[42]

7.4 Satellite as a back up in the event of fibre failure

If satellite will be the "go-to" back up system in the event of a fibre failure to Nunavut communities, investment will also be required in higher through-put satellite - both to connect communities that do not yet have fibre, but also to be a viable back up system in the very real chance that a branch line fails for an extended period of time.

One proponent of a fibre line across the Northwest Passage, Arctic Fibre, is publicly urging Industry Canada to abandon its traditional investment in satellite connectivity and instead, direct that investment to Arctic Fibres's project, that would see 4 Nunavut communities connected. [43]

[42] At the Northern Lights Conference, CEO of Arctic Fibre stated that in the event of branch line failure connecting a community to the Europe-Asia backbone, the community would move to satellite as backup.

[43] Nunatsiaq News, January 24, 2012: *"Fibre optic cable headed for Canadian Arctic?"*, Sarah Rogers. http://www.nunatsiaqonline.ca/stories/article/65674is_fibre_optic_cable_on_its_way_to_the_canadian_arctic/

The ACIA emergency preparedness participants clearly stated that if a back up system is not consistently used, in the event of an emergency, that back up system will likely fail.[44] For satellite to be used as back up for a fibre line, serious and concurrent investment will be required to connect 21 of the communities (and other Arctic users such as military, environment, Coast Guard, mines etc) that are not part of the first phase, as well as provide back up to the branch lines.

7.5 Creating dependency on higher speeds

Once a jurisdiction develops a reliance on applications that must have fibre-like speeds to operate, you can't go back.

In the ACIA report, multiple fibre breaks to the single fibre line service to Whitehorse caused all cell phones to stop working, as well as debit and credit point of purchase capacity in the city. NWTel back up systems could not properly support these services. Once the fibre land lines were repaired (within 24 hours) people once again had access.

This experience has Yukoners calling for redundant fibre lines into their key centres. People have become reliant on their fibre link to run their businesses, deliver their health care and conduct their education. With increased reliance on a fibre backbone, a communications failure itself causes an emergency, as so many services become dependant on the system in order to operate.

If mine engineers located in Dallas Texas, are doing remote monitoring of critical equipment operating Nunavut, that assumes fibre speeds to operate, a failure in a connection can mean disaster. A mine must have reliable backups in place -- whether it is trained people at the mine site that can continue to monitor the equipment locally, or if it is a seamless switch to a satellite back up that can manage the data transfer. Any organization must have a back up plan in a high-risk environment like the Arctic.

As Yukon participants in the ACIA study pointed out, most people in Whitehorse no longer have options like wood stoves to heat their homes if the central heating system fails. The same holds true for communication dependencies.

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[44] As predicted in the ACIA report on emergency preparedness (p. 108, chapter 5), back up systems must be in daily use to be effective during an emergency. During the October 6th satellite failure, communities in Nunavut were not always able to effectively use satellite phones, Nunatsiaq News, Oct 17, 2011: *"Oct. 6 Nunavut telecommunications failure an eye-opener: GN"*
http://www.nunatsiaqonline.ca/stories/article/65674oct._6_nunavut_telecommunications_failure_an_eye-opener_gn/

The more reliant a populations becomes on connectivity, the more difficult and damaging it is to lose that connectivity. In the north, a truly communication dependant jurisdiction that loses connectivity could lose the ability to do financial transactions, to manage a remotely controlled heating system, to run mission-critical equipment, complete a lab test, consult a doctor, take a course, file their income taxes, or respond properly to an emergency.

If the majority of communities and people in Nunavut are not connected to similar services, we can be assured that one of two things will happen;

1. nobody will become reliant on communication networks, because they cannot launch programs that take advantage of the networks' capacity for positive socioeconomic opportunities across the territory OR

2. smaller communities will rely on a duplicate, narrow system of connectivity that leaves them significantly further behind communities that are properly connected.

7.6 Fibre impact on existing and future satellite services

Assume, for a moment, that significant public investment is secured to link regional centres to fibre (as in the Ledcor report first Phase, or via branch feeds from the proposed Northwest Passage routes), through a combination of capital investment and/or guaranteed revenue from government over the long term.

Even as fibre is rolled out, it will continue to be necessary to maintain satellite connectivity for the fibre connected communities, as there is an assumption that satellite will fill the role of 'back up' to a branch line configuration. In addition, satellite will be required to provide services to the remaining majority of Nunavut communities (and majority of the population) that are not connected to a fibre line.

While one could argue there is really no business case to connect any Nunavut community to any kind of backbone[45], if one were to remove the three regional centres and Resolute from the satellite delivery business model, per capita costs for satellite delivery to remaining communities would likely go up in the long run, not down.

Currently, satellite bandwidth is purchased in bulk and shared across all 25 communities, in 3 time zones in the most efficient model possible to save money, attempting to operate in a private sector model with targeted public support. If three regional centres and Resolute were moved to fibre, the amount of money available to purchase shared satellite bandwidth for the remaining 21 communities would (in theory) drop by 1/3. But it is not as simple as taking satellite support away in favour of connecting a handful of Nunavut communities to fibre.

Removing some larger communities from the satellite bandwidth pool reduces the efficiency of satellite delivery, which relies on sharing a big pipe into all communities concurrently. The most

[45] Ibid, ACIA report, p.154

likely outcome of removing publicly supported satellite feeds to 4 communities is that even more public money per capita will be required to serve the remaining 21 communities to the existing service, because the satellite shared-pipe business model would no longer benefit from the buying power of the three regional centres. Public investors must look at the larger impact of any fibre investment decision on the existing satellite-delivery models serving Nunavut.

We know that satellite (as it is configured today) is inadequate to act as a proper back up to a fibre system failure (as evidenced in Yukon). We also know it cannot provide the speeds expected to support applications that expect a fibre-like environment, at least not for a price end users are able to pay.

In an effort to obtain information about potential upgrades to satellite services for Nunavut, Stuart Salter of SCG Consulting received this information from Telesat via email:

> *"The comparison between northern fibre and northern satellite networks should be made between optimized network designs. The current C-band satellite payloads were designed to cover all of North America. A satellite network optimally designed to focus on the communities of Nunavut and other Northern communities would exploit the technologies of the current generation of High Throughput Satellites such as ViaSat and Jupiter (in Canada and US) and KA-SAT (in Europe). End to end costs of such an optimized satellite network would be between 10 and 20% of the current C-band based networks. This optimized satellite network could have a dedicated Northern capacity in the order of 10's of Gb/s, far exceeding any estimate of requirements. Such a satellite network would serve all communities, of any size, as well as surrounding areas, and the expanding resource sector. The higher Ka and V-band frequencies allow for smaller community antennas, which are less expensive to install and operate. All of Canadian Satellites in orbit have capability to serve the north. There is extensive capacity available today without the need to construct anything."*[46]

Telesat has unused capacity today, and given an opportunity to have a significant, Arctic-specific investment, a satellite provider may be able to deliver much better throughput, building a higher fibre-like service that can act as a back up in the event of a fibre failure. In addition, this system would be required to provide connectivity to remaining communities, new mining ventures, federal military installations, environment and search and rescue outposts that are not connected to fibre.

If the federal government chooses to invest $300,000,000 into fibre, careful consideration will have to be made on how to concurrently upgrade satellite with similar levels of investment for the remaining communities and other users of communication services in the Arctic.

[46] Email correspondence from Telesat representative, Jack Rigley, to SGC Consultant, Stuart Salter, March 2012.

7.7 Last mile connectivity, and its maintenance and support issues

As the Ledcor report notes, the fibre study does not include the last mile required to hook up the local population to the fibre point of presence via local fibre loop, wireless, ADSL or mobile communication networks. Nor do the costs cover the necessary communications shelter, maintenance or power needs.

Whether the backbone connectivity to a community is delivered via satellite or fibre, there still needs to be equipment on the ground to connect the local population.

It is likely that the purchasing power of citizens, businesses and government within most communities will be adequate for private companies to build, maintain, and upgrade the last mile from the point of presence (POP), as long as pricing to the POP is low (or at least similar to POP pricing that resellers pay in urban centres.)

A greater challenge is in developing the local capacity for successful operation of any system. Knowledge of maintaining communication systems in communities was highlighted as a major challenge in the ACIA report.

For example, an instructor flies into a community to teach a 5 day course on Geographic Information Systems, and plans to rely on connectivity to the Internet backbone to teach. In a real-life example, a local person was not trained to fix a broken, local connection to the KA band dish located on top of the College learning centre. The cost to bring in the instructor and their wages exceeded $7000. There are stories of these small, local capacity challenges that no amount of backbone investment can fix, unless investment in last mile and capacity is also considered.

As seen in Nunavut in the past, you can send a giant tractor into a community to help with local road work, but if nobody knows how to change the oil and the tractor breaks, then it is a useless investment.

7.8 Implications on connecting drivers of investment

The economic section of this paper looked into possible drivers of investment to help pay for backbone investments.

Some questions to be considered when choosing to invest in one of the fibre backbone proposals, the design, and the routing:

- What backbone technologies and routing can best connect mining and exploration industries (as the key economic driver in the region);
- What backbone technologies and routing will best serve the socioeconomic needs of Nunavut;
- What backbone technologies and routing can best serve military, search and rescue, and environmental-monitoring and management?

While this paper examines the implications of fibre, investment will have to also examine what throughput could be achieved through satellite infrastructure with similar levels of investment to meet the socioeconomic and sovereignty needs of communities, as well as the needs of the economic drivers of mining and exploration.

8.0 Conclusion

If one takes the argument that the Government of Canada is responsible for creating an investment climate to attract resource sector companies, while also protecting the environment, ensuring the local population have control and input on how these projects proceed over their land, and have opportunities to benefit from that investment, then how would the Government of Canada evaluate a $1,000,000,000 investment into a communications backbone?

Given the unique demographics, the desire for fibre, the importance of the existence of communities in all regions to Canada, and the unlikely possibility of hooking up fibre concurrently to all communities, we know that it is likely we will end up with a mix of fibre and satellite connections to Nunavut communities and regions.

We also know that the GDP is expanding at a rapid rate in Nunavut, but that socioeconomic benefit to communities does not necessarily follow a rise in GDP. In fact, the social impact of a rise in GDP without concurrent investment in people can leave the local population in a worse socioeconomic situation that before the GDP rose.

Finally, we know that the economic driver for investing in a communication backbone is not socioeconomic - the more likely economic driver (in an era of government restraint) is the backbone's ability to attract investment into Nunavut in the mining and exploration sectors.

Given these realities, the socioeconomic review of the fibre proposal has the following recommendations:

8.1 Recommendation 1: Investment in infrastructure must benefit Nunavummiut as it also seeks to benefit Canada

As the Government of Canada invests in communications infrastructure to both meet the needs of sovereignty and attract mining investment, there will need to be rules to ensure this investment also directly benefit community members in all Nunavut communities with opportunities to benefit from increased connectivity to every community.

All federal investment, mining investment and other commercial sites in Nunavut outside of existing communities must use their buying power to help better connect and share broadband access with local communities. It makes little sense to connect a mine or a military site to fibre, but not the community 100 km away. The mine sites need an educated population locally, and their investments in communications can be critical to helping communities achieve more, and ensure Nunavummiut benefit from the expansion of the GDP.

8.2 Recommendation 2: Reliability and redundancy paramount

Recognize that fibre lines, by the very nature of the Arctic environment, are at relatively high risk of damage and difficult to repair. Any investment decisions should focus on redundancy either through a robust ringed architecture system, and/or through high throughput satellite for back up. If there is not a robust back up system, then in the event of a failure, the communications failure becomes the emergency.

With better connectivity, comes more reliance on communication networks, which in turn, means that connectivity must be more reliable.

8.3 Recommendation 3: Strategic concurrent backbone investment required in satellite

Recognize that even with fibre investment, satellite will continue to play a significant role -- both in terms of providing back up to fibre connected communities, as well as providing primary connectivity for others. There must be a strategic balance of investment in both fibre and satellite backbones. With balanced investment, all communities can benefit from a reliable infrastructure that provides socioeconomic benefits for all.

8.4 Recommendation 4: Future revenue streams required to maintain and innovate

After an initial investment into a backbone infrastructure, there must be a system developed for continued investment for maintenance on branch lines, innovation, quality of service requirements and regulations to ensure the costs to the end user do not creep into the 'cost-prohibitive' category. The federal government must continue to play a role in the management, regulation and continued investment into fibre and satellite backbones serving Nunavut into the future to avoid some of the challenges that have occurred in the past, as documented in the ACIA report.

8.5 Final remarks

Broadband access should be an enabler, not a constraining factor in the lives of Nunavummiut.

The real questions of access, equity, opportunity to benefit from broadband have always been closely linked with the thorny challenge of paying for a backbone that far exceeds the territorial and community financial capacity to solve.

The work of NBDC, Ledcor and SCG to put a dollar figure to a fibre outlay has helped to clarify the socioeconomic issues facing residents of Nunavut, the Government of Nunavut, and the Government of Canada in its deliberations on which fibre proposal to support and the conditions under which each proposal can be considered.

Public Works and Government Services Canada

Project Complexity and Risk Assessment Manual

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Table of Contents

1. INTRODUCTION

1.1 PURPOSE

The purpose of this manual is to assist Public Works and Government Services Canada (PWGSC) staff in performing Project Complexity and Risk Assessments. The PWGSC Project Complexity and Risk Assessment (PCRA) Manual has been designed to ensure PCRAs are performed consistently across the Department. This PWGSC PCRA Manual is a supplemental aid to the PCRA Tool developed by the Treasury Board Secretariat (TBS).

1.2 SCOPE

The scope of the PWGSC PCRA Manual includes the following:

- Background - description of new TB Policy on the Management of Projects
- PCRA Scoring methodology and quality assurance process for PCRA scores; and
- PCRA question interpretation specific to PWGSC projects.

This manual is to be used for all PWGSC projects, which are required to complete a PCRA, as follows:

- All Real Property capital asset and space projects, including lease projects > $1 million total value, including GST or HST, and excluding client costs, if applicable; Note - For real property lease-projects, the $1 million threshold is based upon Lease Project Approval values.

- All PWGSC Business Projects – Information Technology (IT) Enabled with a planned value of $1 million or more;

- At the discretion of the Department, non-routine initiatives that have characteristics analogous to a project may also be requested to conduct a PCRA.

1.3 DEFINITION OF PROJECTS – PWGSC CONTEXT

Within the context of PWGSC, the following are the definitions of the two main types of projects carried out within the Department:

> **Real Property Projects:** All real property asset acquisitions or improvements, including entering into a lease, fit-up of accommodation space, construction, renovation and remediation of a built-work (building, bridge, dam, road, etc.) or crown-owned land.
>
> **Business Projects – IT-Enabled:** Business Projects – IT Enabled are projects which develop solutions to achieve and maintain efficient and effective business processes and service delivery that are facilitated by Information Technology; some of these projects may transform business practices.

Other activities can also be deemed to be managed as a project at the discretion of the Department where the activity will be undertaken within a limited time span with fairly

well defined start and end dates; a clear outcome, output and budget; identified high risk and cost; a requirement for dedicated resources. It is possible that a modified tool will be developed for that purpose in the future. TBS officials may however require PWGSC to conduct PCRAs on high-risk activities.

Real property projects have been further defined into 2 main categories as follows:

- “Asset-Based” – Primary driver is a problem or an issue associated with the base building assets (e.g. Building foundation and structure, plumbing, HVAC, fire protection, electrical and telecommunication systems). In PWGSC facilities, are generally PWGSC funded, though can also be client funded tenant service work.

- “Space-Based” - Primary driver is a client’s need for accommodation. Projects can be PWGSC, joint-funded, or tenant service work.

2. BACKGROUND

2.1 POLICY ON THE MANAGEMENT OF PROJECTS

The Treasury Board *Policy on the Management of Projects* (PoMP) came into effect on June 7, 2007 and is being phased in across all government Departments over a 4-year period. This policy replaces the following TB policies:

- Project Management Policy;
- Policy on the Management of Major Crown Projects; and the
- Project Approval Policy.

The *Policy on the Management of Projects* focuses on project governance, oversight and departmental capacity to manage projects. The policy re-defines project approval authority and oversight levels based on an organization’s capacity and a project’s complexity and risk profile.

Two additional standards were approved in conjunction with the PoMP, namely:

- *The Standard for Organizational Project Management Capacity;* and
- *The Standard for Project Complexity and Risk*.

The Policy and two supporting standards, establishes clear responsibilities for deputy heads to manage their projects in an integrated manner across the Department, rather than on a project-by-project basis. The expected results of this Policy, associated standards are that:

- Projects achieve value for money;
- Sound stewardship of project funds is demonstrated;
- Accountability for project outcomes is transparent; and
- Outcomes are achieved within time and cost constraints.

Deputy heads are responsible for conducting:

- An organization-wide capacity assessment in accordance with *The Standard for Organizational Project Management Capacity*, and
- An assessment of each planned or proposed project in accordance with *The Standard for Project Complexity and Risk*.

The two scores from the PCRA and OPMCA are compared to determine the level of Treasury Board oversight required. Deputy heads must seek Treasury Board approval for any project who's assessed risk and complexity exceeds the assessed level of project management capacity that the sponsoring minister can approve as is summarized in the following table.

Assessed Project Management Capacity	Assessed Project Complexity and Risk
Class 4	Level 4 – Transformational Level 3 – Evolutionary Level 2 – Tactical Level 1 – Sustaining
Class 3	Level 3 – Evolutionary Level 2 – Tactical Level 1 – Sustaining
Class 2	Level 2 – Tactical Level 1 – Sustaining
Class 1	Level 1 – Sustaining
Class 0 (Limited or no assessed capacity)	$1 million

2.2 STANDARD FOR ORGANIZATIONAL PROJECT MANAGEMENT CAPACITY

The Standard for Organizational Project Management Capacity outlines the basis for determining the capacity of an organization to manage projects. The organizational project management capacity must be assessed every three years by performing an Organizational Project Management Capacity Assessment (OPMCA). The OPMCA is comprised of a total of 92 questions, and generates a weighted average indicating the classification of organizational project management capacity on a scale of 0-4 ("0" indicating a limited capacity for the organization and "4" indicating a transformational organizational capacity).

PWGSC has obtained a Assessed Project Management Capacity rating of Class 3 from Treasury Board and therefore will be able to internally approve projects whose complexity and risk are assessed at levels 3, 2 or 1, based upon the TB approved PWGSC Integrated Investment Plan which will be completed for the first time this fiscal year. It is important to note however, that, as per the *Policy* Treasury Board Ministers have the prerogative to consider any project for approval, regardless of the PCRA rating. Please refer to the Protocol for the Review of Project Complexity and Risk Assessments (PCRAs) between PWGSC and TBS.

2.3 STANDARD FOR PROJECT COMPLEXITY AND RISK

The Standard for Project Complexity and Risk outlines the basis for determining the level of complexity and risk of a project. Every project identified in the Department's investment plan must be assessed by performing a Project Complexity and Risk Assessment. The PCRA is comprised of a total of 64 questions, and generates a weighted average to indicate the classification of complexity from 1-4.

The PCRA tool is a questionnaire that seeks to determine the nature of a proposed project by asking 64 risk-related questions in 7 categories as follows:

Section	Description
Project Characteristics (18 Questions)	This category is designed to build a profile of a given project with respect to key attributes, including funding, budget, size and number of resources, duration, scope, technology scope, stakeholders, dependencies, and external considerations.
Strategic Management Risks (6 Questions)	This category assesses a project's alignment with its organization's investment plan: Is the project well positioned to achieve the goals and objectives of the plan? Is the project a potential risk to the plan?
Procurement Risks (9 Questions)	This category assesses the extent to which procurement activities present potential risks to the project.
Human Resource Risks (5 Questions)	This category assesses whether the project team has the right skill sets in place, with the appropriate roles and responsibilities.
Business Risks (5 Questions)	This category assesses the extent to which the project affects the organization operationally and legislatively.
Project Management Integration Risks (6 Questions)	This category assesses whether the project demonstrates implementation of key project management control measures and deliverables. This assessment includes addressing the state of the project management plan, project management and control disciplines, and information management processes.
Project Requirements Risks (15 Questions)	This category assesses, by considering the number, type, and degree of certainty of the requirements, the extent to which the specific requirements of the project add risk and complexity.

Once the questions have been answered they are scored and weighted according to the following table:

Section	No. of Questions	Maximum Score	Weighting
Project Characteristics	18	90	28%
Strategic Management Risks	6	30	9%

Procurement Risks	9	45	14%
Human Resource Risks	5	25	8%
Business Risks	5	25	8%
Project Management Integration Risks	6	30	9%
Project Requirements Risks	15	75	24%
TOTAL	**64**	**320**	**100%**

Note that the PCRA calculates a score out of 320 points and that the questions are each given an equal percentage in the overall score. Because the PCRA score evaluates a wide range of inherent risks, it is unlikely that a single project would be susceptible to all of the potential risks. The worst-case scenario would be that 70% of the inherent risks would be present in any one project. Therefore the actual raw score of the assessment is divided over 70 to show how the project compares to the worst case. Project Managers do not have to do this weighting calculation themselves, it is done automatically by the Treasury Board's tool.

Expressed as a percentage, this score corresponds to the complexity and risk rating of a project as shown in the following table:

Complexity and Risk Level	Definition	Score
1. Sustaining	Project has low risk and complexity. The project outcome affects only a specific service or at most a specific program, and risk mitigations for general project risks are in place. The project does not consume a significant percentage of departmental or agency resources.	25–44 / 100
2. Tactical	A project rated in this class affects multiple services within a program and may involve more significant procurement activities. It may involve some information management or information technology (IM/IT) or engineering activities. The project risk profile may indicate that some risks will have serious effects, requiring carefully planned responses, on the department or agency. The scope of a tactical project is operational in nature and delivers new capabilities within limits.	45–63 / 100
3. Evolutionary	As indicated by the name of the class, projects with this level of complexity and risk introduce change and new capabilities and may have a fairly extensive scope. Disciplined skills are required to successfully conduct evolutionary projects. Scope frequently spans programs and may affect one or two other departments or agencies. There may be substantial change to business process, internal staff, external clients, and technology infrastructure. IM/IT components may represent a significant proportion of total project activity.	64–82 / 100
4. Transformational	This class of projects requires extensive capabilities and may have a dramatic effect on the organization and, potentially, on other organizations. Horizontal (i.e. multi-departmental, multi-agency, or multi-jurisdictional) projects are transformational in nature. Risks associated with these projects often have serious consequences, such as restructuring of the organization, change in senior management, and loss of public reputation.	83–100 / 100

3. CONDUCTING A PCRA ASSESSMENT

The procedures for conducting PCRAs have been integrated into the departmental investment and project governance and approval process of PWGSC. In this regard the Department has established a PWGSC National Project Management System. The methodology outlined in this guide provides further guidance supporting the NPMS policy and procedures.

A PCRA must initially be prepared at the time of listing the project in the PWGSC Investment Plan. As a project matures, the information used in the PCRA will evolve and improve. As a result the PCRA is to be reviewed and updated at regular intervals (i.e. at the NPMS approval of the Statement of Requirements, Preliminary Project Approval/Lease Project Approval, and Effective Project Approval).

A working version in EXCEL of the PCRA tool is to be used by project teams to complete the PCRA assessments. An online web version of the PCRA tool is used by

the Office of Investment Planning to notify TBS of PCRA scores for planned projects. Project team leaders can obtain the tool from the NPMS Website. When preparing the PCRA assessments, project teams should also use Annex A of this Guide. This guidance has been developed within the PWGSC context to enable consistency in interpretation of the questions.

3.1 RESPONSIBILITIES FOR CONDUCTING PCRA ASSESSMENTS

Project Leads - The responsibility for carrying out the initial PCRA rests with the originator of the project. Normally this will be the originating Branch and Region and would generally be conducted by the Project Leader/Originator in consultation with the Project Manager and project team where necessary.

Branch Investment Plan Designated Contact - The respective Branch Investment Plan Designated Contacts (i.e. generally the Branch PWGSC Investment Plan Working Group Member and to be confirmed by each Branch) are responsible to validate the identification of planned projects and, validate PCRA scores developed by their respective Project Leads. Final approvals of Branch planned projects and PCRA scores will follow the approval process for the PWGSC Investment Plan.

Office of Investment Planning - Finance Branch established an Investment Plan group to:

- Provide a secretariat function to maintain and store all of the PCRA scores and any related documentation;
- Undertake a final quality review of the individual PCRA scores, providing feedback to the respective designated Branch Investment Plan Contacts, to enable consistency of application of the PCRA tool;
- Once PWGSC approval for the investment plan and/or updated project listing is obtained, to upload the PCRA scores onto the TBS PCRA website once

Strategic Planning and Enterprise Architecture (SP&EA), Information and Technology Services Branch (ITSB)

- Will provide technical support to Branches, and the Office of Investment Planning, to review PCRA scores for PWGSC's planned Business Projects – IT Enabled of to be listed in the IIP and when seeking initial listing, and updates (i.e. at least at PPA/LPA and EPA approvals).

Project Management (Advisory & Practices) - Real Property Branch, Professional & Technical Services sector

- Will provide technical support to the Real Property Branch, and in Consultation with the Office of Investment Planning, to provide training to RPB staff, and act as a technical resource support center
- Provide additional support to review higher value, more complex projects PCRAs as per the NPMS project Quality Knowledge Area procedures.

3.2 DOCUMENT FILING

The Office of Investment Planning will maintain a file structure system to maintain record of the up-to-date PCRA scores presented in the Investment Plan.

3.3 PROCESS FOR SUBMISSION OF THE PCRA SCORES TO TBS

Project PCRAs are provided to Treasury Board Secretariat, through the TBS PCRA web portal for review with TBS. The Finance Branch manages this web portal for PWGSC. The following describes the process to be followed for preparation of the PCRAs for submission to Treasury Board Secretariat.

Action		**Action By**		
		Region (Real Property)/ Branch project Originator/ Project Lead	**Branch Investment Plan Designated Contact**	**Finance Branch Office of Investment Planning**
1. Identification of New Projects for Inclusion in the PWGSC Investment Plan				
1.1	The project originator/Project Lead drafts the PCRA, using the EXCEL version and sends it to their respective Branch Investment Plan Designated Contact.	√		
1.2	The Branch Investment Plan Designated Contact reviews the draft PCRA assessment in the EXCEL format and interacts with the originator as required until both are agreed that the proposed PCRA score is acceptable;		√	
1.3	The Branch Investment Plan Designated Contact will recommend their planned investments and associated PCRA scores to the Office of Investment Planning.		√	
1.4	Office of Investment Planning files the PCRA score and provides feedback with regard to consistency of the PCRA score back to the Branch Investment Plan Designated Contact. Notes: 1) For IT projects, Strategic Planning and Enterprise Architecture (SP&EA) provides support to the Office of Investment Planning, to conduct technical QA reviews			√

Action		Action By		
		Region (Real Property)/ Branch project Originator/ Project Lead	**Branch Investment Plan Designated Contact**	**Finance Branch Office of Investment Planning**
	of the planned project PCRA scores. 2) For RP projects, RPB, Advisory & Practices (Project Delivery) provides support to the Office of Investment Planning to conduct technical QA reviews unpon request of RP projects.			
1.5	Once PWGSC approval for the investment plan and/or updated project is obtained as per the IIP governance, the <u>Office of Investment Planning</u> loads the project PCRA score onto the TBS web portal for review with TBS.			√
2. Updates of PCRA Scores – Project Initiation Stage – Identification Stage – Delivery Stage				
2.1	When submitting project for approval of the Statement of Requirements, Preliminary and Effective Project Approvals, the project originator/Project Lead confirms the PCRA score in light of the current status of the project, and identifies any changes and submits the updated PCRA score in the EXCEL format, to the <u>Branch Investment Plan Designated Contact</u>	√		
2.2	The <u>Branch Investment Plan Designated Contact</u> reviews the updated PCRA scores and interacts with the originator as required until both are agreed that the proposed PCRA update is acceptable;		√	
2.3	The Branch <u>Investment Plan Designated Contact</u> will recommend the updated PCRA score for the planned investments to the Office of		√	

Action		Action By		
		Region (Real Property)/ Branch project Originator/ Project Lead	**Branch Investment Plan Designated Contact**	**Finance Branch Office of Investment Planning**
	Investment Planning.			
2.4	Office of Investment Planning files the updated PCRA score and provides feedback with regard to consistency on the PCRA score back to the Branch Investment Plan Designated Contact. Notes: 1) For IT projects, Strategic Planning and Enterprise Architecture (SP&EA) provides support to the Office of Investment Planning, to conduct technical QA reviews of the planned project PCRA scores. 2) For RP projects, RPB, Advisory & Practices (Project Delivery) provides support to the Office of Investment Planning to conduct technical QA reviews unpon request of RP projects.			√
2.5	Once PWGSC approval for updates to the investment plan and/or updated project is obtained as per the IIP governance, the Office of Investment Planning loads the project PCRA score onto the TBS web portal for review with TBS.			√

Annex A Project Complexity and Risk Assessment Tool - PWGSC Interpretation and Guidance to Questions

General

- All 64 questions must be must be answered. If you are sure a question *does not* apply to your project, answer with the lowest score (“1”) for that question;
- Provide brief comments in the PCRA excel spreadsheet to substantiate responses
- If the answer to a question is unknown, answer with the highest score (“5”) for that question; and
- If you answer “1” to Question 2 in the “Project characteristics” section 1, questions in the “Procurement risks” section 3 should be answered with a “1” only.
- In situations where the PCRA questions whether certain documentation (e.g. project charter, etc.) is available, for projects that:
  - Are fairly mature,
  - are “routine” in nature,
  - where the document is required by PWGSC Policy, and
  - where the document is in fact, routinely developed.

Future State Scenario:

Planned projects meeting the above noted criteria which are not yet initiated or in a development phase prior to seeking preliminary project approval can be scored as though the routine documents and NPMS deliverables are completed, even if they are not yet finalized at the time that the PCRA is completed.

The following are the questions that are impacted by the future state scenario, whereby at the time of definition (SoRA), it is standard for the following documents to not yet be prepared, though would be expected to be prepared at the preliminary project approval (PPA) / effective project approval (EPA) / lease project approval (LPA) control points:

- Q21 completion of a business case,
- Q23 preparation of a communications plan,
- Q25 documented project procurement strategy,
- Q40 change management plan,
- Q44 preparation of a project management plan,
- Q48 preparation of a risk management plan,

- o Q53 regarding validation of the business requirements,
- o Q54 preparation of feasibility studies.

When completing a PCRA, if **one** of the above eight questions is scored based on the future state scenario, all of the eight questions must be scored accordingly.

The PCRAs completed on a future state basis must be clearly identified as such in the project title.

Bundling of projects:

Based on a review of real property projects, 7 types of projects were identified has having generic characteristics resulting in a bundling approach on PCRA scoring.

The bundling approach mainly consist in using a generic PCRA scoring template for each of the following 7 types of projects: *(**Note:** The bundling of projects is only to be used for asset projects with a total planned investment of $1 million to $5 million or for lease projects less than 7,500 m2r).*

<u>**Asset Projects (total planned investment of $1 million to $5 million):**</u>

- Type 1 (PCRA score: 2): Structural / Envelop upgrades / Repairs (e.g. roof replacement, envelop upgrade, windows, seismic upgrades);
- Type 2 (PCRA score: 2): Renovations – directly affecting client space (e.g. accessibility, office area renovation, elevators, washroom upgrades);
- Type 3 (PCRA score: 1): O&M Projects (e.g. plumbing upgrades, HVAC, electrical systems);
- Type 4 (PCRA score: 2): Fire, Health & Safety and Security Upgrades (e.g. fire alarm replacement).

<u>**Lease Projects (under 7,500 m2r):**</u>

- <u>Type 5 (PCRA score: 2): Lease Tender Projects with Fit-up Projects</u>
- <u>Type 6 (PCRA score: 1): Lease Renewal Projects with no Fit-up</u>
- <u>Type 7 (PCRA score: 2): Portfolio Lease Acquisitions (acquiring lease space based upon potential need).</u>

The PCRAs completed on the bundling approach must be clearly identified as such in the project title with the bundling type number.

IMPORTANT NOTE - It is important to note that the assessments MUST reflect the actual situation, when the projects are being put forward for project approval (i.e. PPA, EPA or LPA).

For large or complex projects, especially where non-conventional approaches are being developed whereby the current standard practices may not be fully in place, the questions should not be answered as positive until the particular document/ requirement has in fact been completed.

- TBS has established a "Triple Constraint" criteria, which will automatically elevate the score. In the PCRA tool, the following parameters related to budget, scope and time as defined in questions 1, 3, and 11 of the PCRA tool have been defined as the "Triple Constraint" whereby scores on each of these 3 questions at the highest level (i.e. 5 points) will result in the highest score being applied to all other questions in the section. I.e.
  - Q1 - Total budget request for this project >$100 million
  - Q3 - Relative to the average project in your organization – project is considered to be "Large"
  - Q11 – Project is susceptible to time delays

Ensure that the project tombstone data is acurately and completely completed as follows:

Date Prepared	Indicate date that the PCRA score was prepared/updated
Prepared By/ Contact	List the lead and project team members who participated in the preparation of the PCRA score
Project Name	Provide project name as listed in PWGSC Investment Plan. When applicable, indicate at the end of the project name: ▪ Future state; ▪ Bundling type #.
Project Description	Provide a brief description of the project to provide context and scope for reviewers of the PCRA
Project Type	Select from drop down menu project type as being either: - Materiel - IT Enabled - Real Property - Other

Project Status	Select Project Status from Drop down list i.e. - Concept (Prior to NPMS Analysis Phase and Preliminary Project Approval/ Lease Project Approval) - Planning (NPMS Planning and Design Phase up to Effective Project Approval) - Execution (NPMS Implementation Phase) - Completion (NPMS Project Close Out Phase) -
Investment Plan	Indicate year of the Investment Plan that the project was identified in. I.e. currently working on the 2010/1011 Investment Plan
Investment Plan Year	Within the Investment plan, indicate the year of planned investment (i.e. scope of the plan is 5 years - so indicate investment plan year from 1 to 5).
Location: Country	Indicate country (i.e. can select Canada from drop down list)
Location Canada: National Capital Region (NCR), Province or Territory	For projects to be undertaken within Canada, select from the drop down list, the province or territory.

PCRA Questions and Guidance

Question	Rating	Guidance / Interpretation
1. PROJECT CHARACTERISTICS (18 Questions)		
1. What is the total budget request[1] for this project? **NOTE - TRIPLE CONSTRAINT QUESTION** *See page 11 of this Guide for details*	1 = $1–5 million 2 = $5–10 million 3 = $10–25 million 4 = $25–100 million 5 = >$100 million	"Total budget request" includes the formal securing of funds for all phases of the project. This includes all acquisitions, capital costs and re-fit/ improvement costs, and PWGSC delivery staff fees. **<u>In the case of space – lease projects, the Lease Project Value (LPA) is to be used for this question.</u>** In the case of jointly funded projects, it is the lead department (i.e. the department of the responsible Minister) that completes the PCRA for the whole project. That PCRA would include all funding for the project, no matter which source it is coming from. It is possible that the department contributing the least would be the lead. *For Projects that have not yet started:* - Total budget request refers to "total estimated budget" of the project. *For Projects currently in progress:* – Total budget request refers to "total actual expenditures plus remaining forecasts".
2. What percentage of the overall project budget is for procurement?	1 = No procurement is required—answer "1" to all questions in the "Procurement risks" section 3 2 = <25 per cent 3 = 26–50 per cent 4 = 51–75 per cent	For RP projects, typically the largest percentage of the project budget is used for procurement (e.g. building purchase and/or re-fit using contractors) as opposed to services being supplied internally, thus the score will most often equal "5".

3. Budget request could include any formal securing of funds.

Question	Rating	Guidance / Interpretation
	5 = >75 per cent	For IT-enabled projects using a COTS solution, the score will typically range between 3 and 5.
3. Relative to the average project in your organization, which of the following adjectives describes the total budget of this project? Note: Total project budget includes capital and operating costs **NOTE - TRIPLE CONSTRAINT QUESTION** *See page 11 of this Guide for details*	1 = Small 3 = Medium 5 = Large	Within the context of PWGSC's profile of projects, use the following guidelines for definition of average project size: • Small Projects: <$5 million for IT-enabled & RP asset projects <u>OR</u> <15,000m^2 rentable for space/lease projects • Medium Projects: $5-10 million for IT-enabled & RP asset projects <u>OR</u> 15,000-30,000 m^2 rentable for space/lease projects • Large Projects: >$10 million for IT-enabled & RP asset projects <u>OR</u> >30,000m^2 rentable for space/lease projects
4. How many people are required to complete this project at its peak activity? Note: People can be part-time or full-time on the project, including GC employees and individual contractors, but excluding vendor-supplied work teams	1 = <10 2 = 10–25 3 = 26–100 4 = 101-250 5 = >250	Include government employees and contractors who work on the project and are managed directly by PWGSC staff. E.g. For construction projects: - <u>Exclude</u> construction staff, & - <u>Include</u> design consultants and contracted Project Managers
5. From project initiation to project implementation, what is the expected duration of the project? Note: Use definitions from *A Guide to the Project Management Body of Knowledge* for initiation and implementation	1 = <12 months 2 = 12–24 months 3 = 24-36 months 4 = 36–48 months 5 = >48 months	"Expected duration" spans from the Project Initiation point (receipt of Preliminary Project Approval) to the end of Project Implementation and the in-service date or transfer of administration/registration of the asset/ property. Time lines for post product activities such as warranty following and claims resolution are not to be included in these time lines due to their inherently non-predictable nature. In the case of Real Property projects, the typical score will be 3 or 4 (greater than 24 months but usually less than 48 months).

Question	Rating	Guidance / Interpretation
6. Horizontal (i.e. cross-departmental or cross-agency) scope: How many sponsoring or funding departments or agencies are involved? Note: Service providers such as Public Works and Government Services Canada (PWGSC) or central agencies should not be included. Include only the departments or agencies that will co-sponsor or jointly fund the project.	1 = The project involves only one department or agency 2 = The project involves another department or agency 3 = The project involves two other departments or agencies 4 = The project involves three other departments or agencies 5 = The project involves four or more other departments or agencies	Include only the departments or agencies that will co-sponsor or jointly fund the project. Do not include TBS and other PWGSC branches in the count. -For typical PWGSC fully funded internal real property asset projects, the score would be 1. - For real property space-based projects for other Departments, single occupant, the score would be 2 or more. - For IT-enabled projects where PWGSC is providing a service, which will impact another department, the score will range between 2 and 5.
7. Project reach The outcome of this project changes or directly affects the following:	1 = One business process[2] within a sector[3] 2 = Multiple business processes within a sector 3 = Multiple sectors 4 = Multiple branches 5 = Multiple departments or agencies	Interpret "Sector" as meaning "Division or Directorate" in the PWGSC context. Interpret "business process" as procurement, accommodation and portfolio management, and IT support.
8. The proposed or established governance structure demonstrates adequate support for how many of the following project factors?	1 = Support for all factors is demonstrated. 2 = Support for three of the factors is demonstrated.	Typical scores should be 1-2 for routine projects being developed under a project management regime. For real property projects the

2. A business process is a collection of related activities that produce something of value to the organization, its stakeholders, or its clients. Management processes refer to the processes needed to run the operation and comply with all relevant requirements. Typical management processes include corporate governance and strategic management. Operational processes deliver value to the client; they are part of the core business (e.g. service delivery). Supporting processes support the core processes. Examples include accounting, recruitment, and IT support.

5. A sector here is defined as a division or directorate within a department or agency.

Question	Rating	Guidance / Interpretation
a) appropriate representation of stakeholders and executive management; b) documented decision-making processes; c) documented roles, responsibilities, and authorities within the governance structure; and d) documented information requirements.	3 = Support for two of the factors is demonstrated. 4 = Support for one of the factors is demonstrated. 5 = Support is not demonstrated for any of the factors.	typical score should be 1 when they are fully complying with the NPMS, completing the necessary NPMS approvals, and pre-requisite documentation.
9. In supporting the achievement of the expected outcomes, how many of the following criteria apply to the funding model? a) Cost estimates are generated at the work-package level; b) Cost estimates are based on historical data, industry benchmarks, or both:	1 = Both criteria are met. 3 = One of the two criteria is met. 5 = None of the criteria are met.	*Note – "Funding" should be interpreted as costing.* For typical projects, score the project based upon the expectations of the current phase of the project. - Preliminary cost estimates are normally based on historical comparisons with similar projects and more detailed cost estimates are later provided after the Planning Phase is completed based upon the actual design and current industry costs. - Cost estimates should be moved from planning to indicative estimates at the Preliminary Project Approval and to substantive at the Effective Project Approval Note - A work package is defined as the lowest level element identified in the project Work Breakdown Structure (WBS). Together the work packages under the WBS define the total scope of the work to be undertaken to complete the project.
10. In supporting the achievement of the expected outcomes, how many of the following criteria apply to the costing model? a) The source of funds has been identified b) The funds are committed (i.e. authority to spend)	1 = Both criteria are met. 3 = One of the two criteria is met. 5 = None of the two criteria are met.	*Note – "Costing" should be interpreted as funding* In the government context, the word "committed" has a legal meaning per the FAA, Section 32. Under FAA Sec 32, funds can only be committed in the current fiscal year. For purposes of this question,

Question	Rating	Guidance / Interpretation
		interpret the word “committed” as meaning that funds have been identified in the Investment Plan. Projects can only be placed in the Investment Plan if funds have been identified for the project. Typical score should be 1.
11. Is the project susceptible to time delays? Time delays can have a number of causes, such as the following: a) Changes in technology; b) Requirements of participating organizations; c) Seasonal considerations; d) The need for policy approvals; and e) External influences. **NOTE - TRIPLE CONSTRAINT QUESTION** *See page 11 of this Guide for details*	1 = No, the project is not susceptible. 3 = Yes, the project is moderately susceptible; time delays will have minor effects on the schedule. 5 = Yes, the project is highly susceptible; time delays will have major effects on the schedule.	Score 1 if potential time delays would result in no significant impacts to overall project schedules. Score 3 if potential time delays would result in moderate impacts on schedule, and which could also result in impacts on meeting key project objectives, but have been planned for as part of the overall project contingency, and therefore would have minor impact on meeting the overall project schedule objectives. Score 5 if potential time delays have a significant level of possibility, and which would severely impact the project schedule outside planned contingencies, and cause adverse impacts on meeting project objectives, likely requiring revised project approvals. E.g. Projects in remote areas with potential problems of supply of materiel or of trained staff would likely be scored as a 5.
12. Do geographical considerations influence the manner in which the project is conducted? Consider the following statements: a) Project activities or team members are distributed across a wide geographical area. b) The project will be conducted in a remote or difficult	1 = Neither statement applies. 3 = One statement is true. 5 = Both statements are true.	Typical response will be 1 for non-remote projects unless the team is distributed, in which case a 3 might be appropriate If remote, response will be 3 or 5 depending on dispersion of team members. Note: If 5 is scored here, question #11 may also be 5.

Question	Rating	Guidance / Interpretation
location.		
13. Do environmental considerations influence the manner in which a project is conducted	1 = No 5 = Yes	IT Enabled projects typically would score 1. For Real Property projects, as per the Canadian Environmental Assessment Act, projects requiring an Environmental Assessment (EA) will determine if there are environmental considerations that may impact the project. If other non-legislated environmental requirements have been identified, such as meeting high levels of environmental and sustainable performance, whereby markets, methods and/or techniques are not yet well established, and will significantly impact the manner in which the project will be delivered, score the project as 5. E.g. Achievement of LEED Gold for a project involving a non-typical office or special purpose space, located in a northern climate would likely be scored as a 5. For projects where practices are well established and markets are readily available to meet LEED Gold environmental requirements, the project would likely be scored as a 1.
14. Are there any socio-economic considerations that must be taken into account? e.g. Considerations relating to industrial regional benefits, Aboriginal peoples, and green procurement.	1 = No 5 = Yes	Other socio-economic considerations could also include managing designated heritage assets. Projects with these considerations would typically be scored as 5. Other projects would typically score 1.
15. Consider how the availability of facilities will influence the manner in which the project is conducted:	1 = appropriate facilities are available to conduct the project. 3 = Facilities available to	This question relates to the Implementation Phase of the project only and refers to such things as the availability of office

Question	Rating	Guidance / Interpretation
	the project are inadequate 5 = Facilities are unavailable for the project	facilities for the project team and availability of equipment. Typical score is 1.
16. Does public perception influence the manner in which the project is conducted?	1 = No 5 = Yes	Decisions are mainly based on operational need and are not usually susceptible to public influence. Typical score is 1. Example Exception: - Real property projects involving contaminated sites or other projects with significant environmental considerations whereby the Environmental Assessment has determined that public consultation will be required, the project should be scored as 5.
17. Do considerations relating to Aboriginal people (including land claims) influence the manner in which the project is conducted?	1 = No 5 = Yes	Subject to findings of normal due diligence in identifying Aboriginal consideration. Note: If the answer here is “yes”, question #14 may also be “yes”. Typical score is 1.
18. Do health and safety requirements add significant complexity to the requirements for this project	1 = No 5 = Yes	Typical score is 1 for most projects For real property projects, health and safety is a consideration for most projects, and needs to be effectively managed. Question should be scored as a 5 if the project presents special health and safety considerations to make the project significantly more complex. I.e. such as the presence of extensive amounts of asbestos or other hazardous materials including site contamination requiring remediation measures.
2. STRATEGIC MANAGEMENT RISKS (6 Questions)		
19. How well and how clearly does the project align with the department or agency’s mandate and outcomes?	1 = The project is critical to the outcomes of the department, agency, or program.	Typical score is 1 for projects that have been approved through the branch/departmental governance (i.e. NPMS) and is in-line with the departmental and branch

Question	Rating	Guidance / Interpretation
	3 = There is good alignment with an indirect contribution to the outcomes of the department, agency, or program. 5 = There is a weak alignment with the outcomes, or the outcomes have not been established.	investment plans.
20. To what degree is this project considered to be of critical importance to the Department or Agency	1 = The project is a critical priority: all resources necessary will be allocated to it. 5 = The project is a normal priority: resources may be shared with a project of equal or higher priority.	Typical score is 5 as resources are shared for most projects. For larger projects whereby resources are fully dedicated to the project, the score can be 1.
21. How thoroughly does the project business case demonstrate the value of the project to the organization? Note: A business case (when it is required) is defined by the operational requirements of the department or agency.	1 = The business case is compelling, and value is extensively documented OR a business case is not required 3 = The business case provides a good demonstration of value; some details require further clarification. 5 = The business case does not demonstrate value or is not complete.	Typically, the project Investment Analysis Report/Business Case will provide the necessary demonstration of value to the organization and is a key parameter for approval of the project. Typically, routine projects will be scored as 1.
22. To what degree are the department's management and relevant stakeholders aware of the project	1 = There is consistent, clear, and comprehensive understanding of the project at all relevant levels. 3 = There is good general awareness of the project, its implications, and its budget. 5 = There is minimal awareness of the project in relevant levels of the	For typical routine projects that have in place a signed Project Charter between all key stakeholders (i.e. PWGSC and client) the score is 1. In the case of very large projects, senior management oversight committees may also be required in order to score the project as 1. In addition, for real property asset projects, where an approved Project Plan is available, developed in consultation with all

Question	Rating	Guidance / Interpretation
	organization.	key stakeholders, the score is 1.
23. Does the project have a communications plan?	1 = Yes, there is a project communications plan. 3 = The project communications plan has not yet been completed 5 = No, a project communications plan does not exist	The requirement to ensure effective communications is a requirement of effective project management practices. This requirement will become standardized under the departmental application of the NPMS. Typical score for a project following standard project management practices is 1 however, if the project has obtained PPA and appropriate communication plans have not been developed and are pending then the score would be 3. If a communications plan will not be prepared then the score is 5. Not all projects require the same level of detail in the communications plan. In answering this question, consideration is to be given to the scope of the project and requirement for effective communications. For example in the case of a proposed lease renewal, no formal communications plan would be required, as there would be no “physical work” to be undertaken and result only in a contractual transition to renew the lease. In this case, the communications plan would require only confirmation with the tenant has been consulted that the renewal option is being pursed. Typical response for lease renewals would therefore be “1”.
24. How extensive is the commitment of the organization, senior management, stakeholders, partners, and project sponsors to the timely and successful completion of this project? Consider the following criteria:	1 = All four criteria are met. 2 = Three of the four criteria are met. 3 = Two of the four criteria are met. 4 = One of the four criteria is met. 5 = None of the four criteria	a) Most small and medium PWGSC real property projects do not normally have a “project champion” b) Resources must be allocated to the project when it is inserted into the Investment Plan c) Senior staff oversight is

Question	Rating	Guidance / Interpretation
a) A senior management champion is engaged. b) Stakeholders are willing to reallocate resources if necessary. c) Senior executive oversight is in place. d) Commitment from all stakeholders is confirmed	are met.	applied depending upon the complexity, risk and size of the project. For example, highly complex and risky Real Property projects are either assigned to the branches Major Crown Project sector with a designated DG to provide oversight. d) Projects are not implemented without commitment of stakeholders Typical score is 2
3. PROCUREMENT RISKS (9 Questions)		
25. The documented project procurement strategy:	1 = addresses all project requirements. 3 = is high-level and adequately describes required procurement activities. 5 = is incomplete or inappropriate for the project.	A documented project procurement strategy is a requirement within the Project Plan. This requirement will become standardized under the departmental application of the NPMS. Typical score for a routine project is 1 or 3 depending how far advanced the Project Plan documentation is.
26. What is the supplier availability and willingness?	1 = There are qualified bidders in the market willing to work with the Government of Canada. 3 = There is a limited number of qualified bidders in the market, or some bidders are reluctant to work with the Government of Canada. 5 = There is only one bidder, or there are no qualified bidders that can meet the requirements.	In the case of construction projects where it is known that the project is to be constructed in areas of intense labour shortages (e.g. Northern Alberta at this time); a judgment must be made as to whether the available and qualified contractors will be willing to bid on comparatively small projects. Typical score is 3. In the case of work in most metropolitan areas where qualified bidders are anticipated, the typical score is 1. If however there are known shortages, the score should be

Question	Rating	Guidance / Interpretation
		increased to 3 or 5 accordingly.
27. Will the project required products, goods, or services be supplied in a timely manner by an appropriate vendor?	1 = Yes: products, goods, or services can be readily supplied. 3 = Potential slippage of project schedule may be due to procurement complexity or vendor challenges. 5 = The project deliverables, schedule, or budget may be seriously affected by limited qualified bidders, significant request-for-proposal (RFP) process delays, or extended challenges.	In the case of projects being undertaken in most metropolitan areas where required products, goods, or services can be procured in a timely manner, the typical response is 1. If however there are known shortages that could impact the schedule the score should be increased to 3 or 5 accordingly.
28. Contracting capabilities How many of the following statements are true? a. Personnel supporting this project have expertise in writing specifications or RFPs/SOWs. b. The personnel supporting this project have subject-matter expertise with the goods or services being procured. c. There is a robust departmental process for reviewing all awarded contracts.	1 = All statements are true. 2 = Two statements are true. 4 = One statement is true. 5 = None of the statements are true.	Typical score is 1. Exceptions may occur due to a lack of subject-matter expertise for the goods or services to be procured.
29. Number of contracts How many separate contracts associated with key deliverables are planned for this project?	1 = One contract 2 = Two contracts 3 = Three contracts 4 = Four contracts 5 = Five or more contracts	Typical projects have more than 1 contract, and so the score will be greater than 1. In the case of a contract, which has multiple tasks authorizations, the number of contracts is to be interpreted as 1 contract.
30. Contract characteristics How many of the following statements are true?	1 = None of the statements are true. 3 = One statement is true. 4 = Two statements are	The cut-off for construction projects under NAFTA is $10.9 million

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a) The firm or individual obtaining the contract will subcontract to other companies. b) Contracts are subject to trade agreements. c) The results of the contract are dependent on the results of another contract. Note: Only count the statement as true if it is true for all contracts related to the project as per Question 29.	true. 5 = All statements are true.	In virtually all cases, construction contracts involve the use of subcontractors Typical score is 3 or 4.
31. Degree of control over supplier selection and anticipated contract style The contract is as follows: Note: If more than one method of supply is involved, use the method with the highest score.	1 = directed (sole-source, Advance Contract Award Notice) 2 = a standing offer call-up 4 = a supply arrangement procurement 5 = a public tender (request for quotation, invitation to tender, RFP)	Typical score is 5 as contracts are publically tendered. In the case of a lease renewal, the score could be as low as 1.
32. Contract management How many of the following statements are true? a. The personnel who wrote the contract are involved in the management of the contract. b. There is a standardized acceptance process for the review of the completion of contracts (e.g. peer reviewing or review of the completion of deliverables). c. The lines of communication between the contract authority and the contractor are well defined and regularized. d. There is a standardized process for reporting progress (e.g. punctual evaluation or regular meetings). e. There is a mechanism in place to address any contractual disagreements between parties regarding the completion of a contract.	1 = All statements are true. 2 = Four statements are true. 3 = Three statements are true. 4 = Two statements are true. 5 = One or none of the statements are true.	All statements are true based on requirements defined by standard departmental contracting procedures. Typical score is 1.

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33. Has PWGSC or a delegated contracting authority been formally engaged through a service agreement to provide adequate support for the procurement process?	1 = Yes or not required 3 = This is planned but not yet in place 5 = No	Typical score is 1.
4. HUMAN RESOURCES RISK (5 Questions)		
34. Does your organization anticipate a shortage of available personnel with appropriate skills during a significant period of the project? Note: Resources can be internal or external to the Government of Canada.	1 = No 5 = Yes	Typically, the project will have time to plan and acquire resources. Unless the project is in an isolated post or in an area where there are many major projects ongoing, the score should be 1. If resource shortages are present however, the score is 5
35. What is the predicted stability of the project team? Consider the following criteria: a. The project team has previously worked together. b. A low rate of turnover is expected. c. It is expected that suitable replacements will be readily available.	1 = All three criteria are met. 2 = Two of the three criteria are met. 4 = One of the three criteria is met. 5 = None of the three criteria are met.	Typical score will be 1 or 2. In light of recent resource shortages in some sectors, the score could be as high as 5
36. Commitment of project team members What percentage of the project team is assigned full-time to the project?	1 = >80 per cent 2 = 61–80 per cent 3 = 41–60 per cent 4 = 20–40 per cent 5 = <20 per cent or all part-time	In the case of IT-enabled projects such as software development, this question should include contractors who are an integral part of the project delivery mechanism. In the case of construction contracts, do not include contractor's staff as team members for purposes of this question. Note that in almost all real property projects, staff is not assigned to a project on a full time

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		basis but rather work on many projects simultaneously. For RP projects, typical score will be 5; Larger projects may have dedicated resources and can score 1. For IT-enabled projects, a typical score would be 2-4.
37. Knowledge and experience Consider the following criteria: a) The project will use a proven approach. b) This type of project has been done before in the Government of Canada. c) The project will use resources that have been applied to this type of project before.	1 = All three criteria are met. 2 = Two of the three criteria are met. 4 = One of the three criteria is met. 5 = None of the three criteria are met.	Most projects will have a typical score of 1.
38. Has the assigned Project Director or Project Manager worked on a project of this size and complexity before?	1 = Yes 5 = No	Typical score will be 1.
5. BUSINESS RISKS (5 Questions)		
39. Describe the overall effect of this project on the organization:	1 = Project will fit with current departmental or agency processes, use existing workforce and skills, and not require substantial changes to technology and other infrastructure. 3 = Some changes to processes, staffing models, or technology will be required. 5 = Significant restructuring of business processes, staffing requirements, partner relationships, and infrastructure will be required.	Typical score will be 1 for real property projects IT-enabled projects are inherently designed to impact organizational processes and would normally score higher.
40. Does the project have a change management plan?	1 = Change management (CM) will be required	For real property projects, in the case of most small to medium sized construction projects,

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	and a CM plan has been prepared. Alternatively, there are no significant change management requirements. 3 = Change management will be required and preparation of a CM plan is incorporated or included in the project management plan. 5 = Change management will be required but there are no plans to establish a CM plan.	change management is not an issue. Projects that involve the significant relocation of a facility will normally encompass some change management issues as staff tries to adjust to such problems as getting to and from work and as logistics are modified to suit the new location. Typical score will be 1 for real property projects. IT-enabled projects are inherently designed to impact processes and require organizational change, and would normally score higher.
41. Public engagement What is the level of public involvement required to achieve expected outcomes? (The level of involvement is expressed in the number of people, length of time, or number of groups involved.)	1 = No public participation is required for project success. 2 = Limited public participation is required for project success. 4 = Moderate public participation is required for project success. 5 = Extensive public participation is required for project success.	In some cases it is necessary to meet with local residents to outline the nature of the proposed project and with problems related to its implementation. Typical response will be 1 or 2
42. What level of legal risk will be introduced by this project through the addition of new liabilities, regulatory requirements, and legislative changes?	1 = No legal review is required; no legislative changes are required; liability is assessed as low. 2 = One or more risk events will likely occur resulting in legal costs and effort; a legal review has been completed. 3 = One or more risk events will likely occur resulting in legal costs and effort; a legal review has *not* been completed. 4 = There is a high probability of liability and other legal risks; extensive legal	For standard project delivery processes, contract development should take any of these potential liabilities or risks into consideration. Typical score will be 1 for most projects. Projects intending to follow new or rarely used approaches would score higher.

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	resources will be required during the project; legislative change is required to implement the project; a legal review has been completed. 5 = There is a high probability of liability and other legal risks; extensive legal resources will be required during the project.	
43. What level of complexity is introduced to ensure that this project complies with relevant Treasury Board policy requirements, such as those regarding security, accessibility, and common look and feel standards for the Internet, and management of government information?	1 = The project fully complies with all applicable policies. Alternatively, the project is not subject to any of these policies. 3 = There are some challenges associated with policy requirements, but the project team is adequately equipped to address these. 5 = There is a lack of confidence that policy requirements can be met on schedule and within the budget.	This question is typically related to IM/IT projects. I.e. - IT-enabled projects that receive a waiver to meeting TB policy requirements (such as meeting accessibility requirements) should score a 3. - For projects whereby non-compliance is known and has not been addressed (no waiver from TBS has been obtained), score is 5. Typical score of Real Property projects is 1.
6. PROJECT MANAGEMENT INTEGRATION RISK (6 Questions)		
44. How many of the following elements are defined in the project management plan? a) scope b) costs c) schedule d) project controls e) risks f) deliverables g) team or skills	1 = All elements are defined. 2 = Five or six elements are defined. 3 = Three or four elements are defined. 4 = One or two elements are defined. 5 = No plan has been completed.	The elements noted are standard requirements of a Project Plan. These requirements will become standardized under the departmental application of the NPMS. Routine projects following a project management process should typically score 1 or 2.
45. To indicate the extent of the project team's is appropriately organized to undertake a project of this scope, how many of these criteria are	1 = All three criteria are met. 2 = Two of the three criteria are met. 4 = One of the three criteria	A Project Charter/Project Plan should layout these requirements. Resources should be available before approval is given to execute a project.

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met? a) Project team composition, resource levels, and roles and responsibilities are defined and documented. b) Resources are dedicated (i.e. available when required). c) Responsibilities and required authorities for managers and leads within the project team are defined and documented.	is met. 5 = None of the three criteria are met.	Typical score is 1; however scores can be up to 5 in the case of resource shortages present in some sectors.
46. Has a project reporting and control process for the project been documented?	1 = Yes 3 = The development of a project reporting and control process is in the Project Plan, but not yet completed 5 = No	Where Branches have established standard project reporting and control processes, score will be 1.
47. How many of the following disciplines will or does the project employ? a) quality assurance b) risk management c) outcome management d) issue management	1 = All four disciplines 2 = Three of the disciplines 3 = Two of the disciplines 4 = One of the disciplines 5 = None of the disciplines	Based on standard project management practices, the typical response is 1 for real property projects. Smaller projects may score 2.
48. Has a risk management plan been completed, and to what degree have appropriate contingency plans been included which respond to the risks as identified in the plan? Consider the following criteria: a) Identified risks have been assessed and prioritized. b) Appropriate controls and mitigations are in place for all significant residual risks. c) A risk management plan has been integrated into the project management plan. Note: An organizational risk management group should be involved.	1 = All three criteria are met, OR a risk management plan is not required. 2 = Two of the three criteria are met. 4 = One of the three criteria is met. 5 = None of the three criteria are met.	The requirement for a risk management plan and contingency planning are standard requirements of a Project Plan. These requirements have been standardized under the departmental application of the NPMS. The Office of the Chief Risk Officer is involved in all larger projects to review risk plans. The risk plan is required to evolve as the project is developed. Routine projects, which have identified appropriate risk management measures for the current phase of the project, would have a typical score of 1.

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49. Is an appropriate information management process planned or in place to collect, distribute, and protect relevant and important project information, such as designs, project plans, baseline, and registers?	1 = Highly effective IM practices are in place or planned to support the project throughout its life cycle. 3 = Standard IM practices are planned or in place and resourced. 5 = Minimal IM practices are in place or planned within project.	Typical response is 3.
7. PROJECT REQUIREMENTS RISK (15 Questions)		
50. How many of the following statements are true? a) The project solution requires a high degree of availability. b) The project solution requires customization beyond normal configuration. c) The project solution requires a high degree of performance quality d) The project solution requires a high degree of reliability. Note: "Project solution" is the major output that the project will deliver.	1 = None of the statements are true. 2 = One of the statements is true. 3 = Two of the statements are true. 4 = Three of the statements are true. 5 = All of the statements are true.	For a typical real property project, the sore would be 1-2. Complex projects scoring 4-5 would be in the event of the following typical scenarios: - a) Degree of availability of space to operate beyond normal operating hours (i.e. operations 24/7) - b) Degree of customization refers to requirements for fit-up customization above current standards requiring special base-building modifications - c) Performance requirements above current office standards (e.g. Requirements for high loads, high security requirements) - d) Degree of reliability refers to requirements to ensure operations above current office standards (e.g. Critical security installations) IT-enabled projects would also likely require at least some level of customization as well as requiring high levels of availability, performance quality and reliability. Typical score is 4-5
51. In defining project requirements, how many of the following statements are true? a. The requirements can be	1 = Four of the statements are true 2 = Three of the statements are true 3 = Two of the statements are true.	For a typical real property lease project, the project scope is driven by the Office Accommodation Framework, and fit-up standards as well as typical terms and conditions of PWGSC leases. For these types of projects, typical

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defined with very few people. b. The requirements can be defined in a short period of time. c. There are a small number of individual requirements to define. d. The requirements do not require a high degree of detail.	4 = One of the statements is true. 5 = None of the statements are true.	score is 1-2 depending upon the number of tenant departments involved in confirming the actual requirement for the size of the accommodation. For real property construction and asset based projects, and Business Projects - IT Enabled, typical score is 4-5. None of the statements are generally true.
52. Information availability for planning, integration, and development To what extent have available sources/methods been employed and verified to provide information for this project as applicable (e.g. research, consultations, workshops, surveys, and existing documentation)?	1 = Feasibility studies are not required. 2 = All sources/methods have been employed but have not been verified. 3 = Some sources/methods have been employed. 4 = Few sources/methods have been employed. 5 = No information has been gathered or is available.	Typical score for a project following standard project management practices is 2 i.e. In the case of most PWGSC projects, information exists in order to effectively establish and conduct a full options analysis to complete a Business Case/ Investment Analysis Report. .
53. Have the business requirements been validated with users with an appropriate technique, such as “walk-throughs”, workshops, and independent verification and validation?	1 = Yes 3 = Validation is a planned activity but has not yet been completed. 5 = No	For projects following the NPMS, the typical score is 1. Projects initiated without validation of business requirements would score 3-5 as noted.
54. Have feasibility studies been conducted and is there confidence in the assumptions made in the feasibility studies? Note: Prototypes or proof of concept exercises are included as feasibility activities.	1 = Feasibility studies are not required, because none of the requirements are technically difficult to implement. 2 = Feasibility studies were conducted, and there is confidence in the assumptions made. 4 = Feasibility studies were conducted, but there is not complete confidence in the assumptions made. 5 = Feasibility studies were necessary but not	Typical score is 2 See question 52.

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	conducted.	
55. Indefinable requirements (Known unknowns) What percentage of tasks cannot be fully defined until the completion of previous tasks? Note: These are tasks that may be understood but cannot be documented in detail due to dependency on results from a previous task.	1 = 10 per cent or less 2 = 20 per cent 3 = 30 per cent 4 = 40 per cent 5 = >40 per cent	For small to medium projects, detailed technical specifications can be developed in the normal course of the project development and there are no significant unknown project scope elements, which could significantly impact the project requirements. Score is 1-2. For projects whereby there are identified unknowns, such as the extent of contamination present in a contaminated sites remediation project, the typical score would be 4-5
56. To what extent are the project's requirements clear, completed, and communicated?	1 = All requirements are clear, complete, and communicated. 3 = Up to 10 per cent of total requirements are not complete or are undocumented. 5 = More than 10 per cent of total requirements are not complete or are unclear.	Projects should establish clear project requirements. Typical score is 1. If uncertainties are present, scores may increase up to 5.
57. How many of the following project characteristics are expected to remain stable? a) quality b) functionality c) schedule d) integration e) design f) testing Note: Project characteristics should be expected to remain stable if the project requirements are stable	1 = All of the project characteristics are expected to remain stable. 2 = Five of the six project characteristics are expected to remain stable. 3 = Four of the six project characteristics are expected to remain stable. 4 = Three of the six project characteristics are expected to remain stable. 5 = Two or less of the project characteristics are expected to remain stable.	Typical score is 1 to 3. E.g. Multiple stakeholders may mean the schedule is not expected to remain stable.
58. Are any other projects	1 = No	Typical score is 5.

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dependent on outputs or outcomes of this project?	5 = Yes	I.e. When the project forms part of an integrated program. E.g. - Multi-tenant accommodation project. - Development of an IT application to support the renewal of a number of related business processes. If the project is a single event with limited operational or strategic requirements the response is 1. E.g., - upgrade of a building system, with no dependencies or impact for any other planned projects in the facility - development of a IT application for a single user
59. Are outcomes of this project dependent on the outputs and/ or outcomes of any other projects?	1 = No 5 = Yes	Similar to question 58, if the assessed project is dependant on other projects, the typical score is 5.
60. What degree of integration with other projects, systems, infrastructure, or organizations is required?	1 = There are few complex integration requirements; activities to specify integration are included in the project management plan. 3 = There is adequate understanding and planning for integration. 5 = There are highly complex or numerous integration requirements and insufficient planning of required activities.	The response for this question should focus on the integration points with <u>other</u> projects. Typical response is 1 if there are no dependencies with other projects, systems, infrastructure or organizations. Typical response is 3 if there is integration with organizations outside of the project.
61. What degree of integration is required within the project?	1 = There are few complex integration requirements; activities to specify integration are included in the project management plan. 3 = There is adequate	The response for this question should focus on the integration <u>within</u> the project. Typical score is 1 for smaller projects with few requirements for integration and when the Project Plan as been completed.

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	understanding and planning for integration. 5 = There are highly complex or numerous integration requirements and insufficient planning of required activities.	Typical score is 3 for medium to large complex projects when the integration requirements are addressed in the plan.
62. Relative to the average (typical) project in your organization, which of the following adjectives describes the number of tasks, elements, or deliverables in the work breakdown structure?	1 = Small 3 = Medium 5 = Large	Typical answer is 3 however some minor capital and O&M projects will be 1. Examples • Small - IT projects involving clear user requirements to be met using standard proven vendor supplied applications with few modifications - Most RP asset projects with no dependencies on other systems - Single client space projects with no dependencies on other projects • Medium - IT projects involving vendor supplied applications with significant modifications - medium sized space/lease projects with multiple tenants • Large - IT Projects requiring highly customized applications for complex systems - Large space/lease projects with multiple tenants
63. Dependency of tasks (critical path) Does the project schedule accommodate the critical path of the project, including appropriate contingencies?	1 = Yes 5 = No, OR no critical path analysis has been performed.	For a project to score 1, the following must be true: - The project critical path is documented - Contingencies are in place to accommodate the critical path variances.
64. Resources What is the effect on the project of the requirement for scarce resources or resources that are in very high demand?	1 = No scarce resources are required or not applicable. 2 = The project will incur minor delays or minor cost overruns due to scarcity of resources.	For the purposes of this question, resources include material and human resources (i.e. people with required skills to carry out the work). E.g. - Availability of roofing contractors who are often in high demand

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Note: Resources can be internal or external to the government and can be people, goods, or services. If a resource is scarce internally but available externally, then the resource is not considered scarce.	3 = The project will incur moderate delays or moderate cost overruns due to scarcity of resources. 4 = The project will incur significant delays or significant cost overruns due to scarcity of resources and must return to Treasury Board for revised approval. 5 = The success of the project is critically dependent on scarce resources.	may impact and delay project schedules and cause cost increases as a result. Typical response is 1- 3.