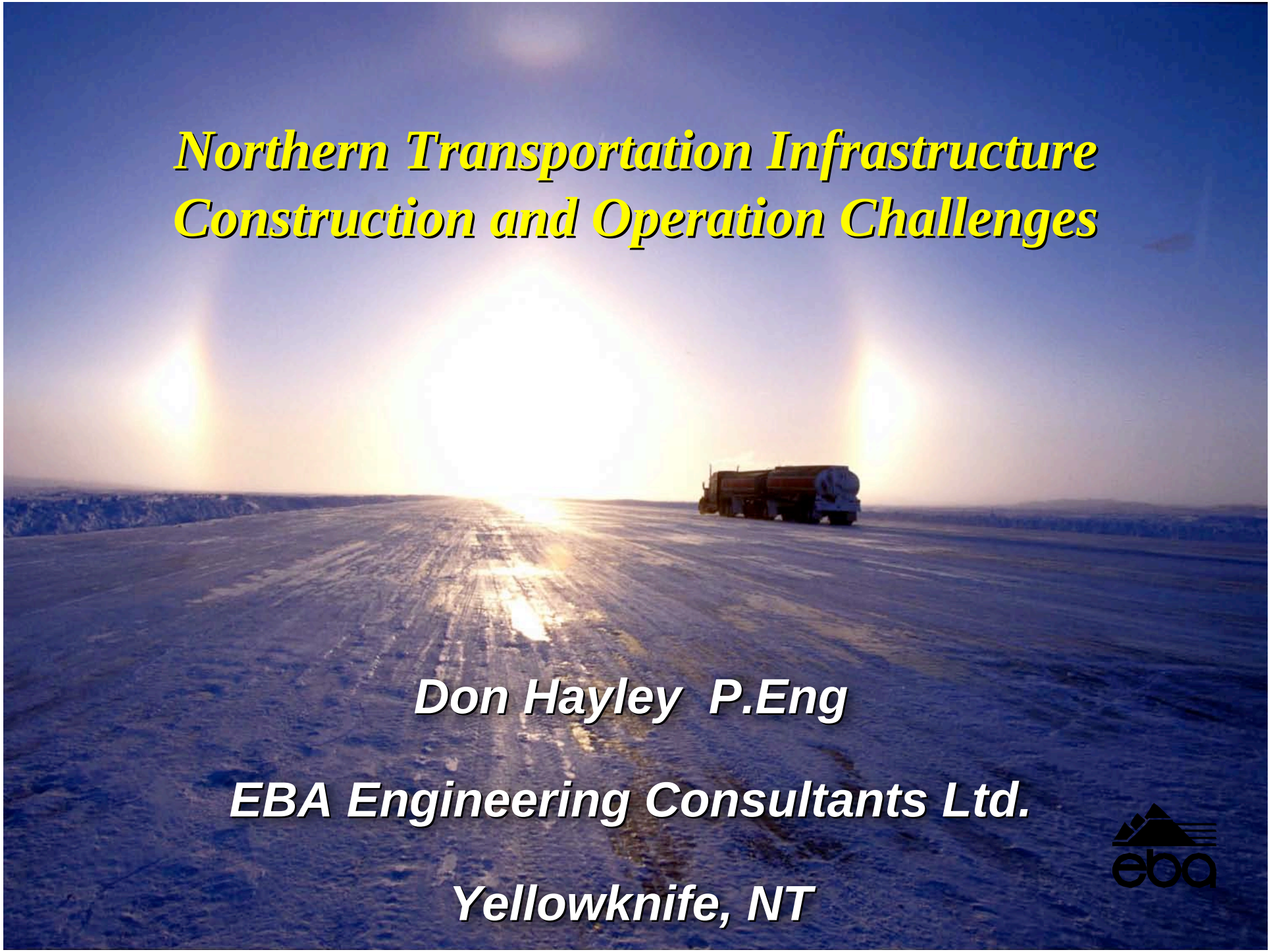


Northern Transportation Infrastructure Construction and Operation Challenges

Don Hayley P.Eng

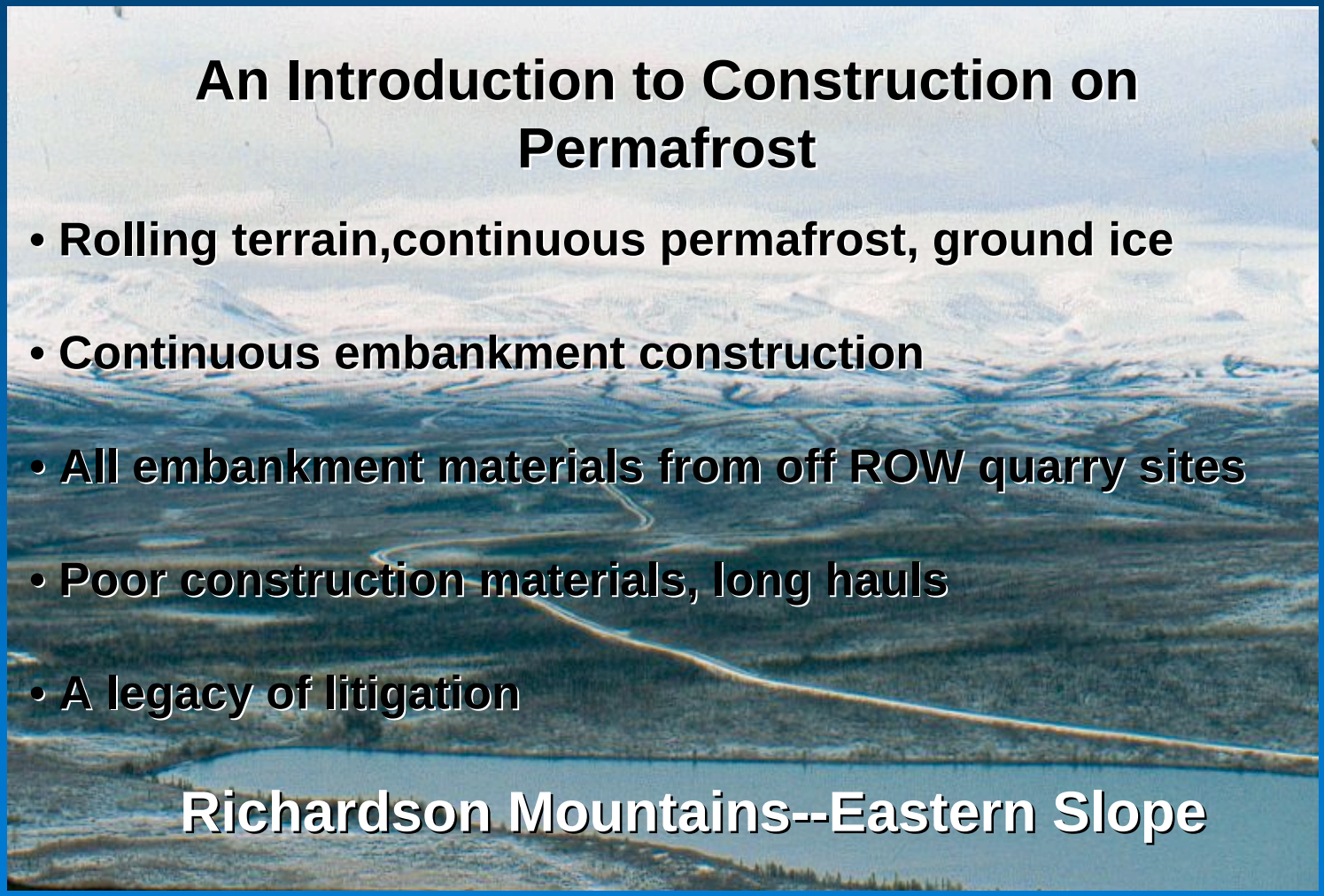
EBA Engineering Consultants Ltd.

Yellowknife, NT

Dealing With Permafrost and Ice -Three Case Histories-

- Dempster Highway
  - 1970's
- Yellowknife Highway Upgrade
  - 1999 to present
- Tibbitt to Contwoyto Winter Road
  - 1995 -ongoing

Dempster Highway



An Introduction to Construction on Permafrost

- Rolling terrain,continuous permafrost, ground ice
- Continuous embankment construction
- All embankment materials from off ROW quarry sites
- Poor construction materials, long hauls
- A legacy of litigation

Richardson Mountains--Eastern Slope

Dempster Highway

Dempster Highway Subgrade Collapse

Dempster Highway Subgrade Collapse

GPR survey for high risk locations

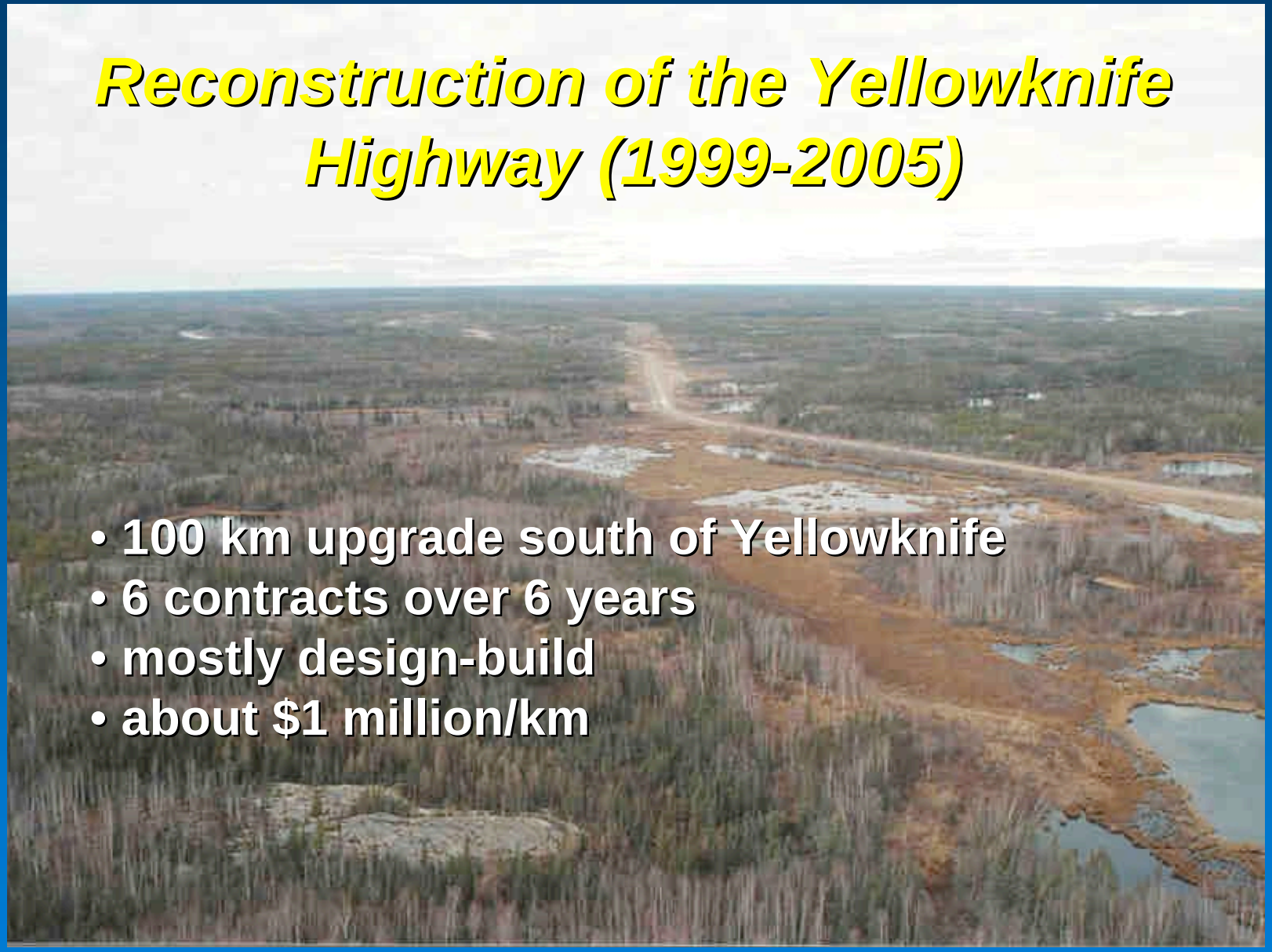
Design-Construction Lessons from 1970's

- Understand the terrain impacts
- Integrate the design with a feasible and flexible construction plan
- Adopt a realistic schedule
- Provide contractors with complete data
- Provide for uncertainties in cost estimates

Embankment Thaw-settlement

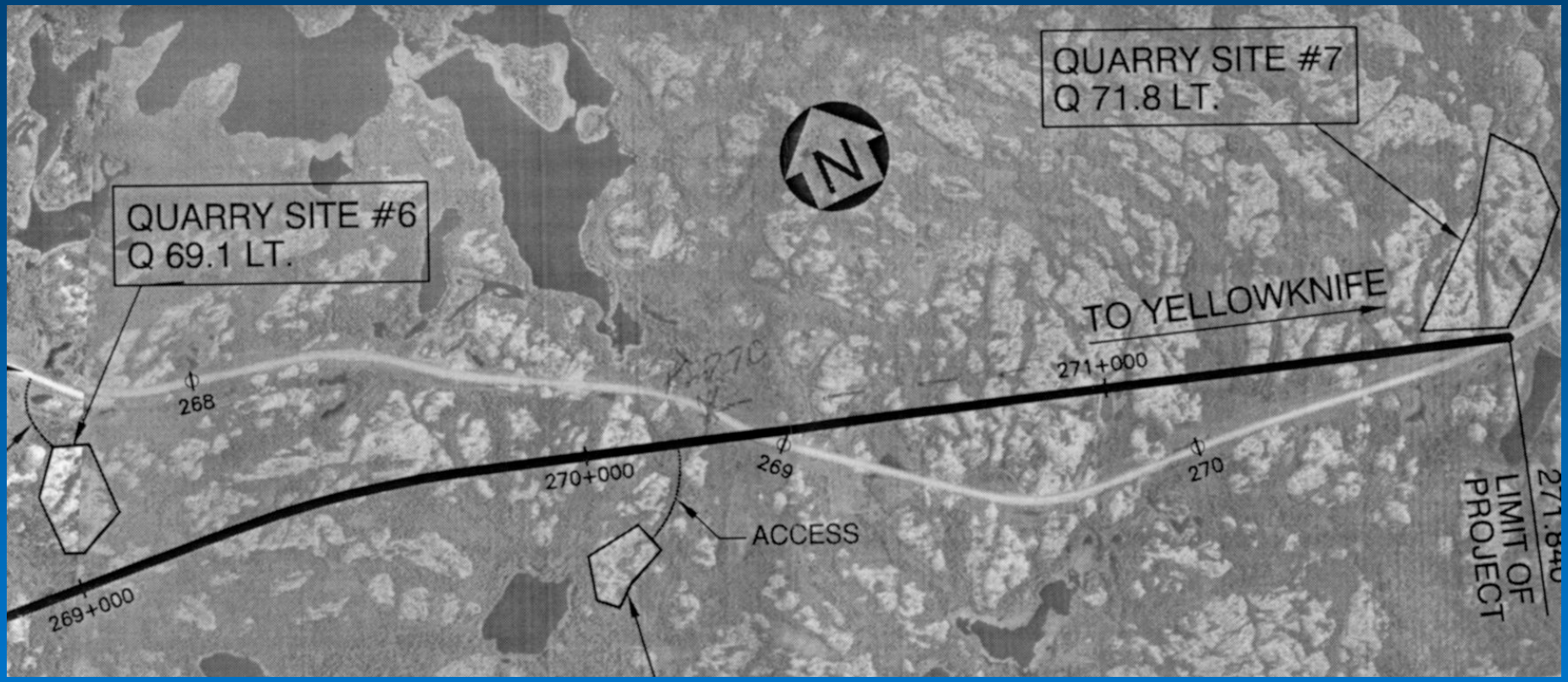
Experimental Road Construction, Yamal Peninsula , Siberia

Reconstruction of the Yellowknife Highway (1999-2005)



- **100 km upgrade south of Yellowknife**
- **6 contracts over 6 years**
- **mostly design-build**
- **about $1 million/km**

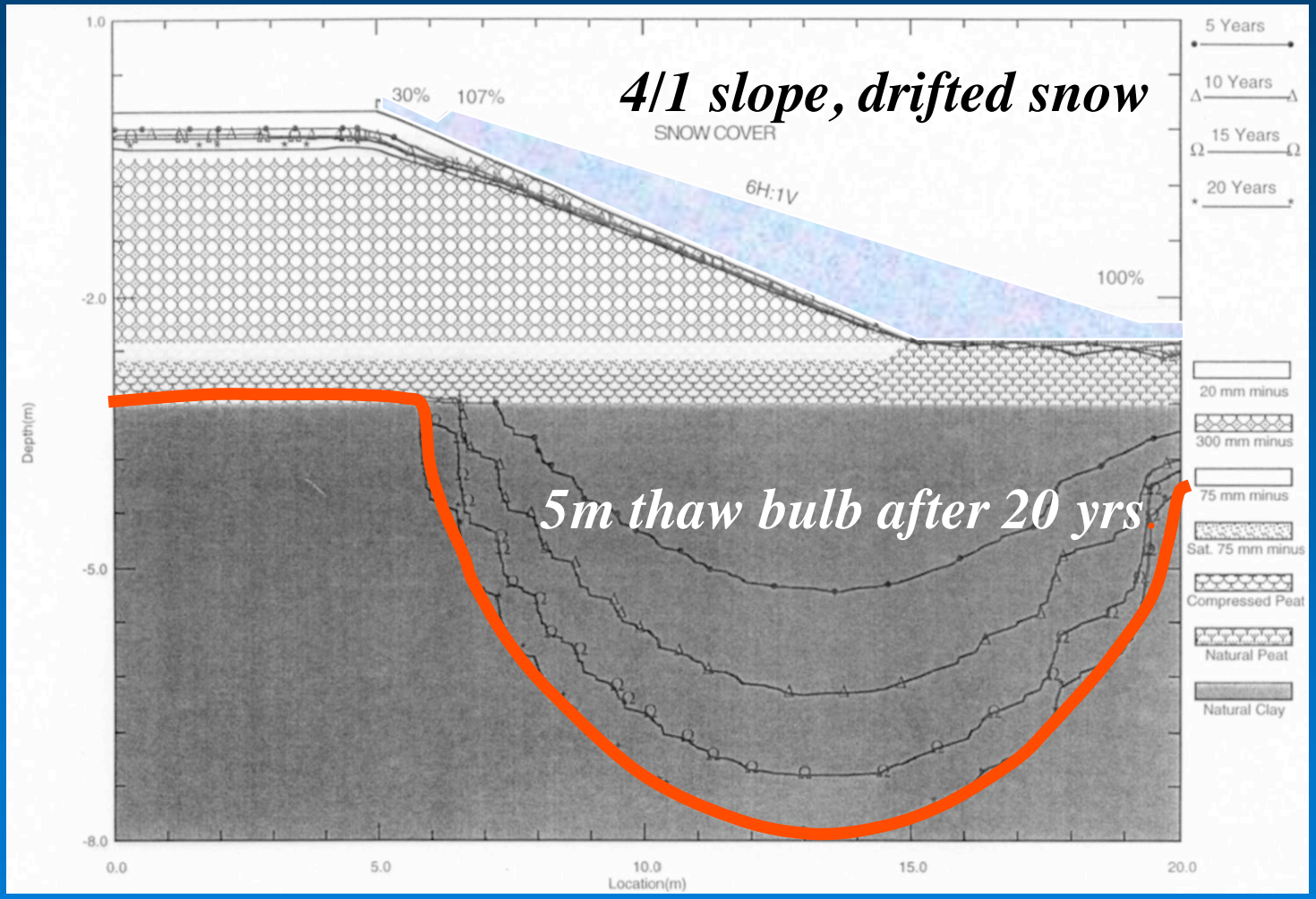
Terrain Challenges



- **Half the terrain is granite outcrop,half lacustrine soils**
- **Half the lacustrine soils are warm, ice-rich permafrost**
- **Quarry rock (granite) the only available material source**

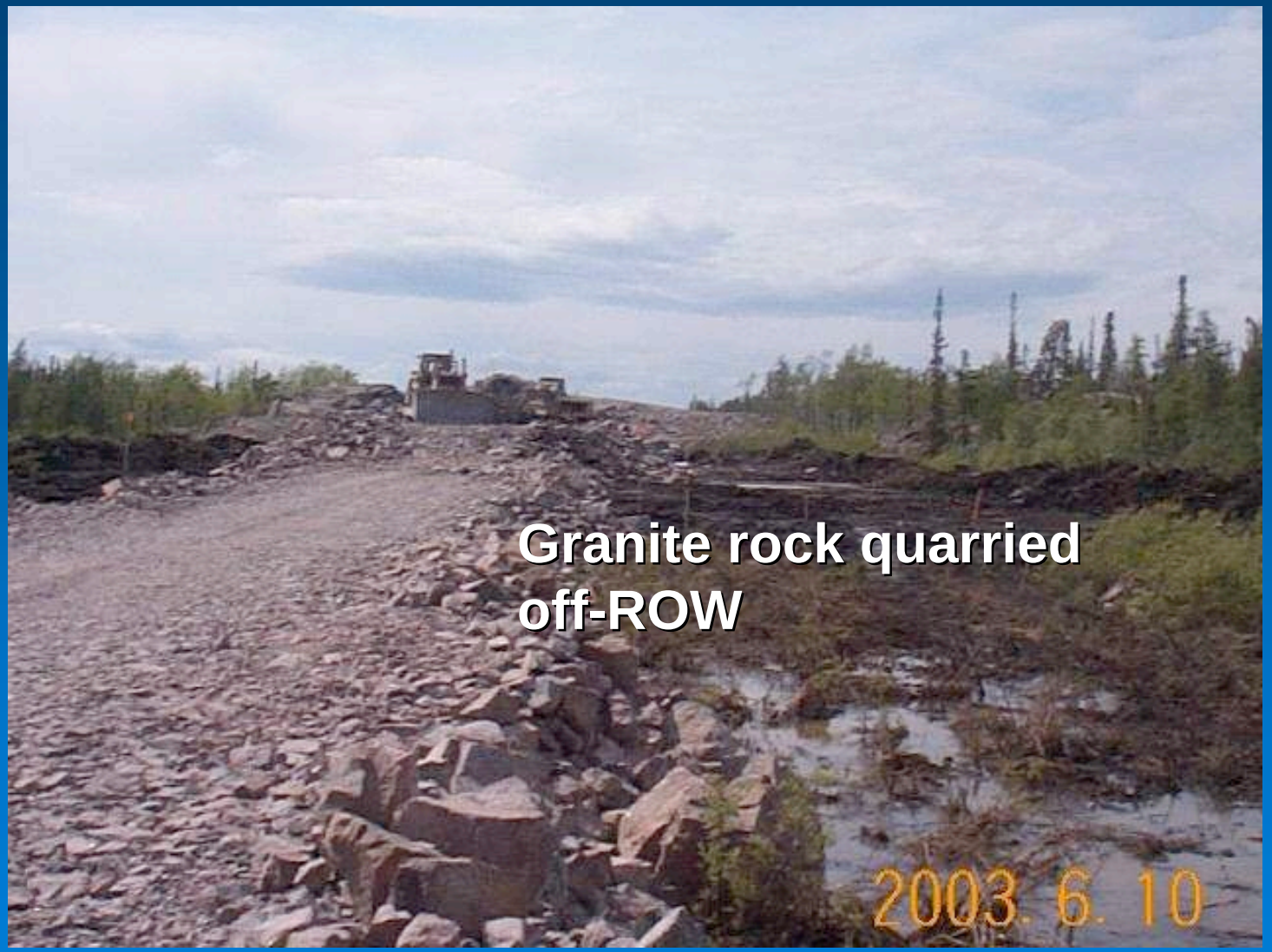
Exposing Ice-rich Permafrost

Predicted Permafrost Response (1998)



Progression of 0°C isotherm below toe of 2 m thick embankment (EBA Design Guidelines Report, 1998)

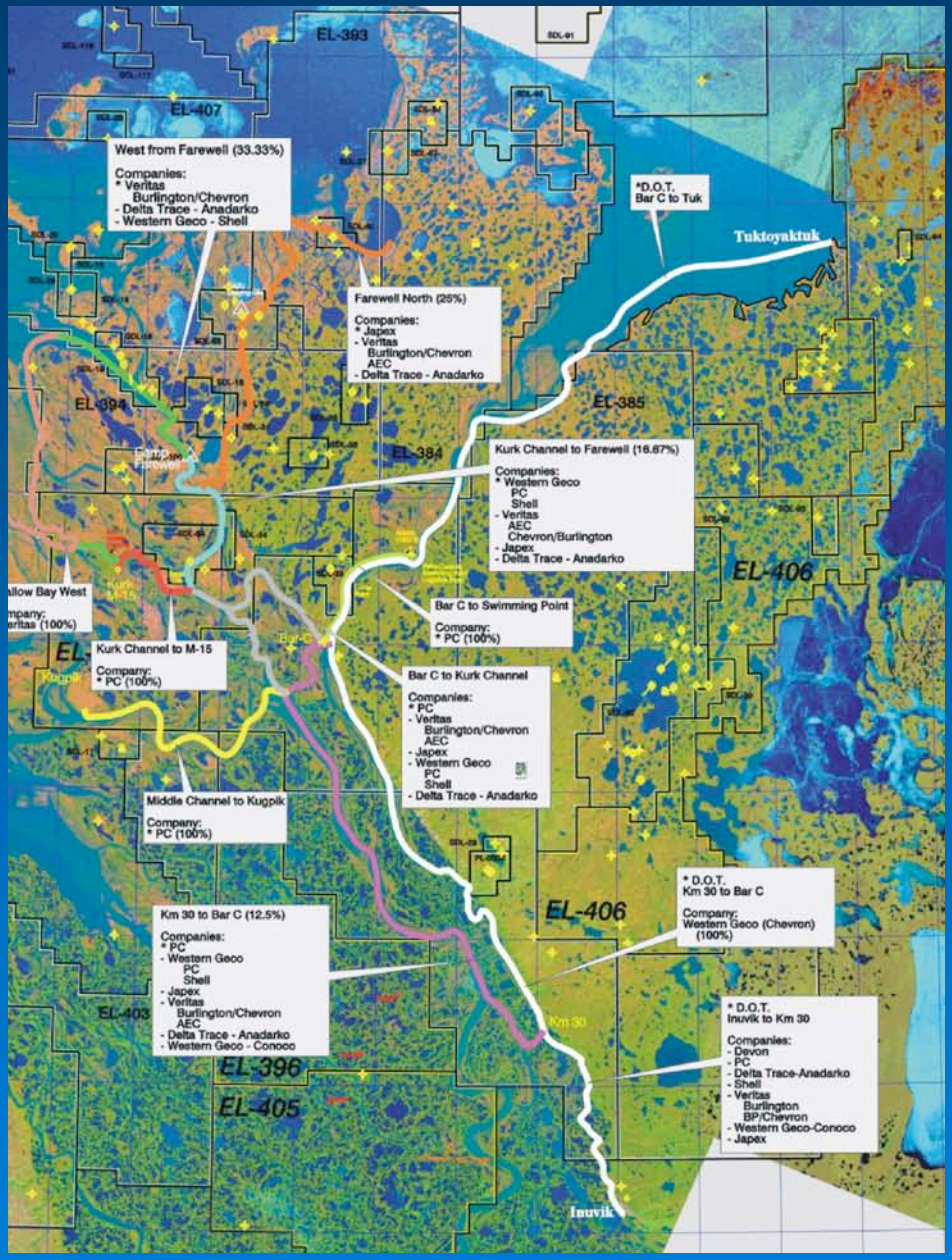
Embankment Materials



NT Highway 3 Today

Winter Roads for Resource Development

- **Seasonal--typically 70 to 90 days (southern NT)**
- **No significant grade construction**
- **Low capital cost**
- **Follow lakes and rivers**
- **High annual maintenance**
- **Risks operating over floating ice**
- **Low environmental impact**

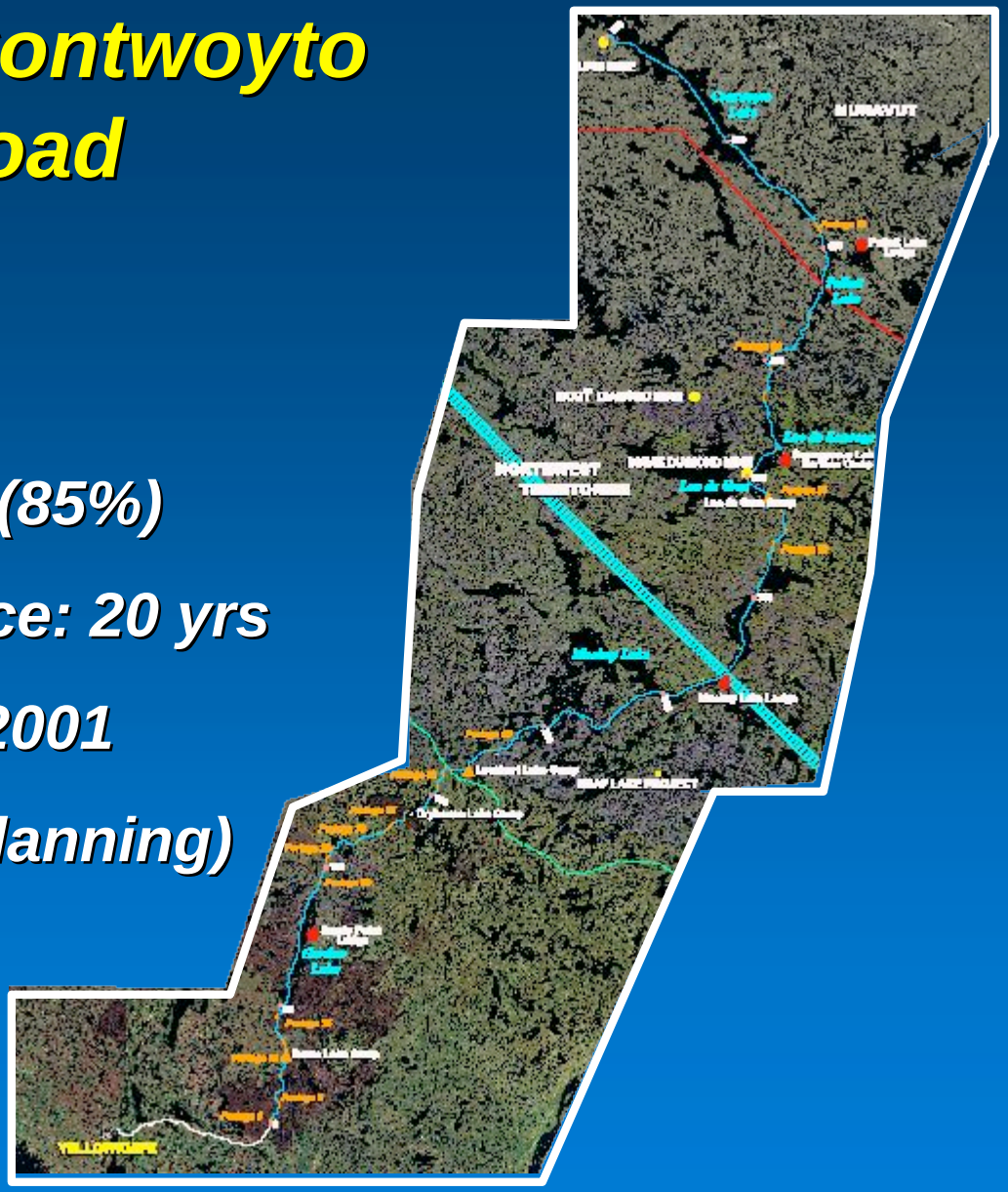


Winter Roads in the Mackenzie Delta, 2002

- Public roads
- Industrial roads

The Tibbitt to Contwoyto Winter Road

- Length: 600 km
- Ice Crossings: 65
- Ice Length: 495 Km (85%)
- Operating Experience: 20 yrs
- Max loads: 8050 in 2001
- Window: 78 days (planning)



TIBBITT TO CONTWOYTO
WINTER ROAD JOINT VENTURE

Economic Importance

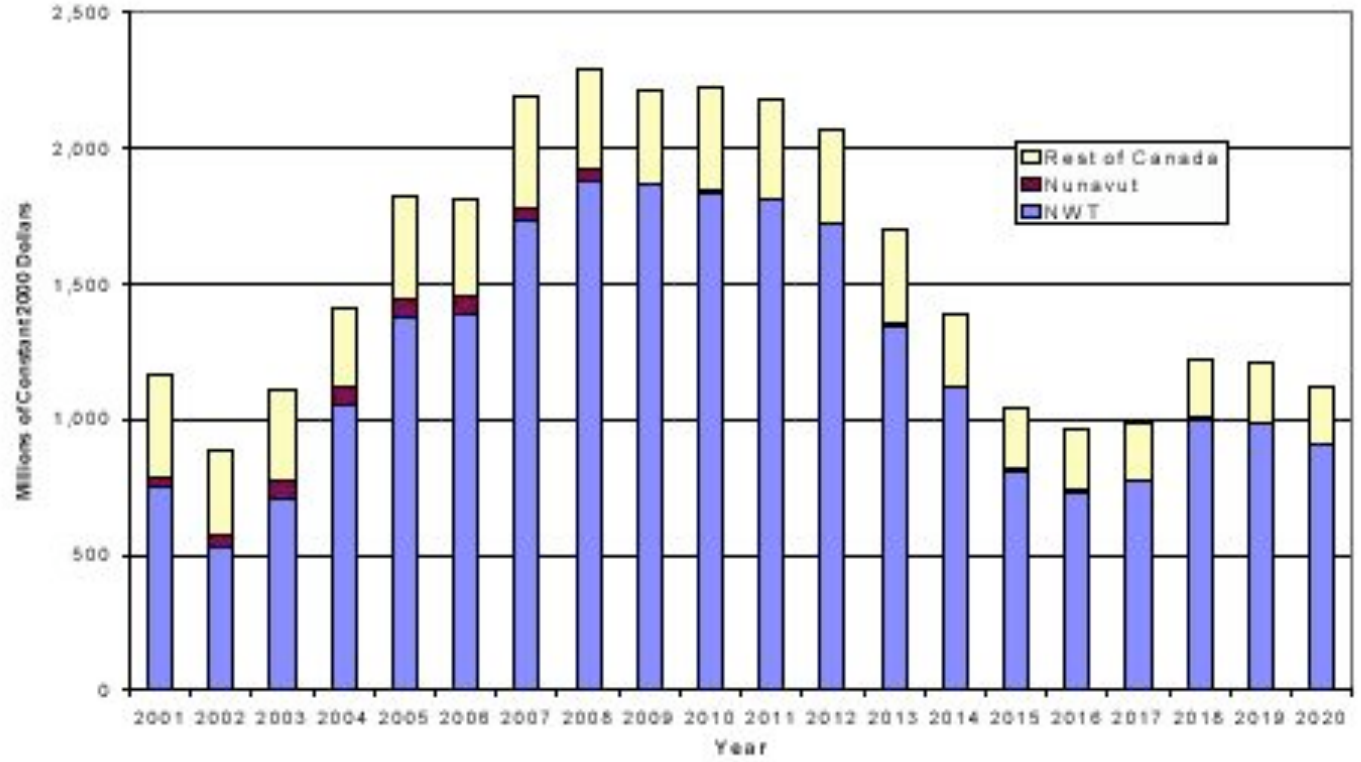


Figure 3.9-1 Annual Contribution of the Winter Road and Associated Projects on Gross Domestic Product (GDP) in NWT, Nunavut and Rest of Canada, 2001-2020

Source: TCWR Project Description Report (EBA, 2001)

Components of the Road System

- Ice Crossings
- Portages
- Construction
- Infrastructure
- Traffic Management

Safety of Ice Crossings
Standard Operating Procedures

- Serviceability ice capacity (load restrictions)
  - Ice thickness profiling
- Dynamic effects and fatigue (speed restrictions)
  - Water depth
- Secondary effects (experienced judgment)
  - Snow banks
  - Wet cracks and slush
  - Surface deterioration
- Contingency planning (emergency preparation)
  - Survival in the event of ice failure

Technology Improvements
(TCWR 2000 to 2005)

- Ice profiling with ground penetrating radar

Profile by GPR

Ice Augering

Technology Improvements
(TCWR 2000 to 2005)

Technology Improvements
(TCWR 2000 to 2005)

Ice capacity by stress analyses

- More efficient use of B-trains for fuel haul
- Safe movement of heavy loads

Technology Improvements
(TCWR 2000 to 2005)

Ice Failure
Personal and Environmental Risk

Failure resulting from speed-related blowout, March 2001

A Closing Message

- Highways in the north are costly, environmentally disruptive and require long lead times
- The resource industry has learned to live with the seasonality of winter roads
- A properly managed winter road over ice is not a high risk operation
- Application of good engineering planning and monitoring principles can result in further optimization and improvement in use of ice covers for transportation.

Many Thanks

- **GNWT, Transportation**
- **TCWR Joint Venture**
- **Nuna Logistics**