

B Transportation

CANADIAN CONSULTING
engineer



ASSOCIATION OF CONSULTING
ENGINEERING COMPANIES | CANADA
ASSOCIATION DES FIRMES
D'INGÉNIEURS-CONSEILS | CANADA

2018 CANADIAN CONSULTING
ENGINEERING AWARDS



Northwest
Territories

Inuvik Tuktoyaktuk Highway



TETRA TECH



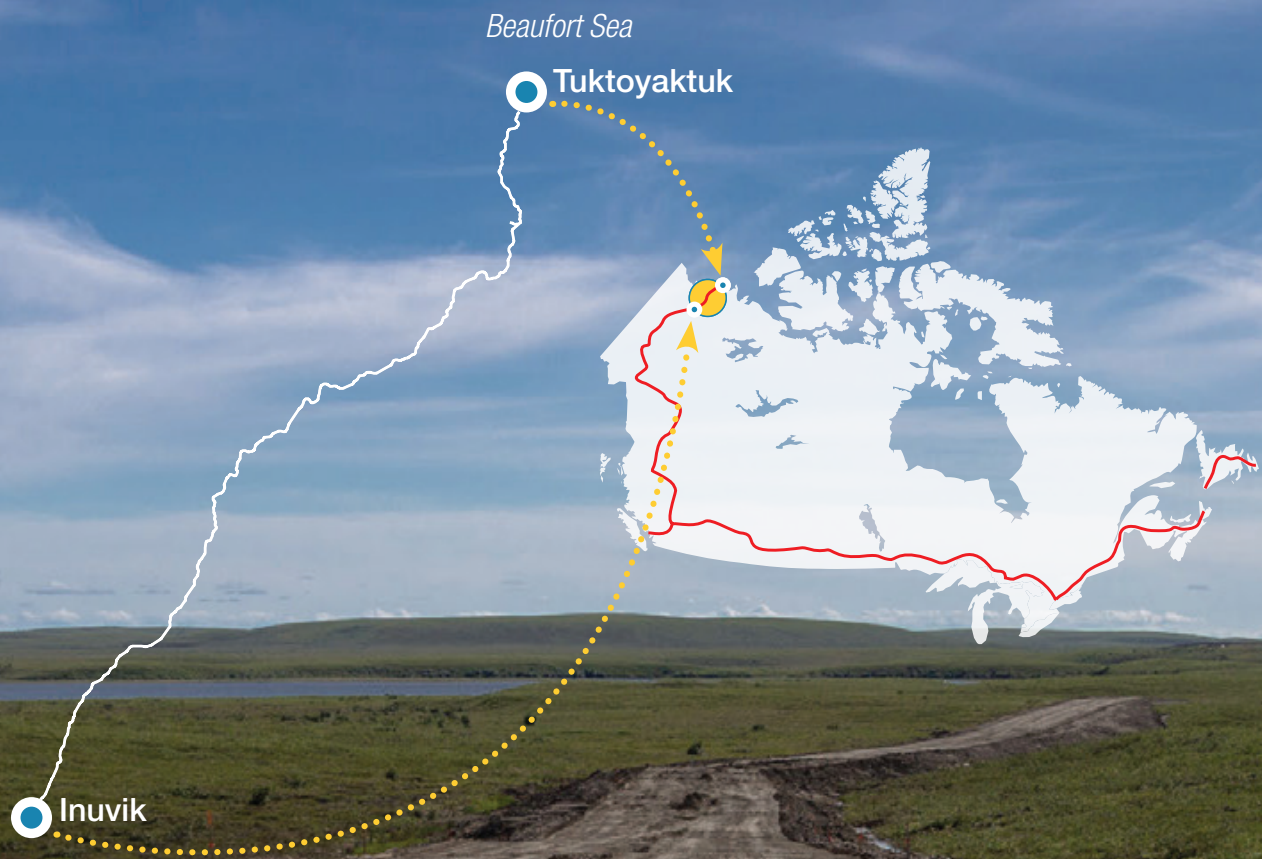
Stantec



KIGGIAK - EBA



KAVIK-STANTEC



1ST ROAD CONNECTING CANADA'S ARCTIC COAST

The Inuvik Tukttoyaktuk Highway opened on November 15, 2017, and is the first all-weather road to the Canadian Arctic Coast, connecting Canada's highway network from coast to coast to coast.

\$300M Road Project **4** Years to Construct **8** Bridges **300+** Culverts

2018 CANADIAN CONSULTING ENGINEERING AWARDS

Inuvik Tuktoyaktuk Highway

Introduction

The Inuvik Tuktoyaktuk Highway (ITH) was opened to the public in the fall of 2017. It connects the communities of Inuvik and Tuktoyaktuk, and with this final link complete, Canada's highway system connects the Arctic Ocean to the rest of the Canada. This unique project fulfills a strategic mandate that the Government of the Northwest Territories and the Government of Canada have held since the 1960s.

This historic project involved placing over 3 million cubic metres of embankment material, constructing 8 bridges, and installing over 300 culverts. This is the first public highway in Canada constructed in a thaw-sensitive continuous permafrost environment.

Those most affected by this project are the peoples of the Inuvialuit Settlement Region. The ITH strengthens the communities by allowing people and goods to move more easily within the region. It also encourages and supports increased tourism and other industries.

Tetra Tech and Stantec were instrumental in all phases of the project from initial planning through to construction completion. The highway is truly a unique project in Canada as it connects the country from coast to coast to coast!





Thaw-sensitive, continuous permafrost environment

Innovation

The project goal was to plan, design, and construct a cost-effective, resilient, two-lane gravel highway on thaw-sensitive continuous permafrost terrain, which presented challenges not encountered in southern environments.

Permafrost is any permanently frozen soil or rock. The permafrost soils along the ITH are characteristically ice rich, containing discrete bodies of massive ground ice. Construction approaches in a permafrost environment differ from southern projects. If the permafrost was allowed to melt, any structure or road constructed on it can fail through both material volume change (thaw settlement) and loss of soil strength. Maintaining the permafrost regime was key to designing and constructing this infrastructure. Between the permafrost and the ground surface is a transition layer referred to as the active layer because it undergoes a seasonal freeze-thaw cycle—it thaws during the warmer summer months and refreezes during the colder winter months. Various processes are associated with this freeze-thaw cycle. In the summer months, the active layer soils thaw

from the ground surface down; they are typically covered by organic material, saturated, and have a low bearing capacity. Constructing a road in the summer is extremely difficult because the active layer cannot support construction equipment. As a result, the ITH was planned to be constructed in the winter when the ground was frozen.

Our approach was to remove weakness associated with an unfrozen subgrade by building an embankment that would insulate the underlying permafrost and raise it to the bottom of the road embankment. We used in-house thermal modelling to calculate the embankment thickness needed to protect the permafrost, so the infrastructure would meet its design life and beyond.

Drainage and erosion control are critical design considerations for roads, especially in northern permafrost environments. Poor drainage along a road over permafrost may cause surface water ponding, thermal erosion, thermokarst (localized depressions produced by the selective melting of permafrost), and icings. The effects



Installation of culverts along the road embankment for drainage and erosion control

of these processes can be detrimental to both the environment and traffic, and result in high maintenance costs. Water ponding changes the geothermal conditions and accelerates thawing of the perennially frozen soils around and below a road embankment. If ice-rich permafrost and ice bodies are present, then the ponded water gradually melts the ground ice. The resulting settlements have many adverse effects. Ditching was not an option in the permafrost, so culverts were installed at all low points along the road embankment to minimize potential ponding. Additional culverts were installed during construction when ponding started due to minor ground subsidence caused by placing the embankment.

Granular materials needed to construct the embankment were scarce along the project corridor. Terrain mapping was undertaken to identify potential borrow sites, and then geotechnical drilling programs were completed with nearly 700 boreholes to classify and delineate granular borrow sources. Ideally, granular fill used for embankment construction

in the north would consist of well-graded gravel and sand, and the material would be relatively free-draining. However, for the ITH the available embankment materials were silty, up to 35% fines (silt and clay sized particles), contained little gravel, and were frozen with visible ground ice. In the chosen borrow sites, there was considerable variation in ice content and material composition. Tetra Tech developed an innovative approach to assist the Contractor in minimizing the work effort and environmental impact. 3D models using Mining Visualization Software identified the various strata and ice rich areas, thus allowing for intelligent development of the pit.

Due to the remoteness of the site and difficult construction conditions, all bridge elements were designed to be prefabricated and assembled on site. We also needed to carefully consider the constructability of all elements in winter conditions; all above-ground structural elements needed to be welded steel or precast concrete.



Three-Span Bridge supported on steel pipe adfreeze piles under construction

Bridges are commonly founded on deep foundations (piles) unless competent bearing materials are present at shallow depth. Along the ITH, near-surface permafrost soils could not support the fixed structures, and bedrock was more than 30 m below the ground surface. Therefore, we selected adfreeze steel pipe piles as the foundation support for the bridge structures.

Adfreeze piles are used in permafrost environments and rely on the frozen bond between the permafrost soils and the steel pipe pile for bearing capacity. Typically, adfreeze steel pipe piles are used for relatively light loads, and there is little precedent for using adfreeze steel pipe piles as bridge foundations. However, since the traffic loadings on these bridges were expected to be very short term, they were well-suited to an adfreeze pile, and the loading conditions were accommodated with this foundation type.

Allowable adfreeze bonds depend on the pile configuration, the nature of the load being supported, subsurface conditions, and allowable deformation of the structure. The strength of frozen soil is time and temperature dependent—

ice-rich soil is strong when resisting short-term loads but will deform under sustained loads, and creep deformations increase as temperatures warm. Therefore, the design premise accepted an allowable creep settlement over the life of the structure.

All bridges were designed with simple spans to compensate for the anticipated differential creep settlements of the adfreeze pier and abutment piles over the life of the bridges. Ground temperature monitoring cables were installed to monitor the thermal regime over the life of the structure. Thermal modelling indicated that intervention measures may be required to ensure adequate performance over the life of the structures, under the condition of warming permafrost.

Thermosyphons (passive heat transfer devices that operate on the principle of convection through vaporization and condensation) were installed next to the bridge piles.

The subsurface temperatures will be monitored throughout the life of the project to determine when to implement intervention.



Winter construction

Complexity

The remote location of building a road on permafrost from Inuvik to Tuktoyaktuk posed unique challenges. In summer, the top active layer of the permafrost thaws, restricting construction equipment. Thus, construction was undertaken in winter, in darkness, with temperatures often below -30°C .

The embankment was designed to be constructed in winter by placing frozen materials. Frozen soils cannot be compacted to the same densities as unfrozen soils. We developed site-specific specifications for material selection, establishing maximum moisture contents and grain size distributions for the embankment materials. We estimated the amount of settlement associated with the embankment thawing in the summer, and designed the embankment template with an overbuild.

Schedule and cost were carefully monitored. Due to budgetary constraints, it was necessary to reduce project costs. The most significant cost-reduction was to reduce embankment quantities. However, reducing the minimum embankment

thicknesses changed the original design concept of maintaining a continuously frozen subgrade under the embankment.

To address this challenge, we used field reconnaissance, terrain mapping, and engineering judgment to identify sections of the alignment where the effect of a thinner embankment on the road and terrain was reduced. Thermal modelling was completed to simulate the effects on different terrain types. The modified design required sections of the road to be redesigned in a tight timeframe before winter construction resumed.

Protected a permafrost environment by designing an insulating embankment that would protect the permafrost in the road structure.



Joining the southern and northern spreads of the road during construction

Social and Economic Benefits

This long-anticipated road will provide essential services, reduce the cost of living, and provide a year-round, physical connection to the rest of Canada. It will provide employment opportunities through tourism and resource development along this scenic highway and create economic resource opportunities.

Following are some quotes that speak to the benefits from this road.

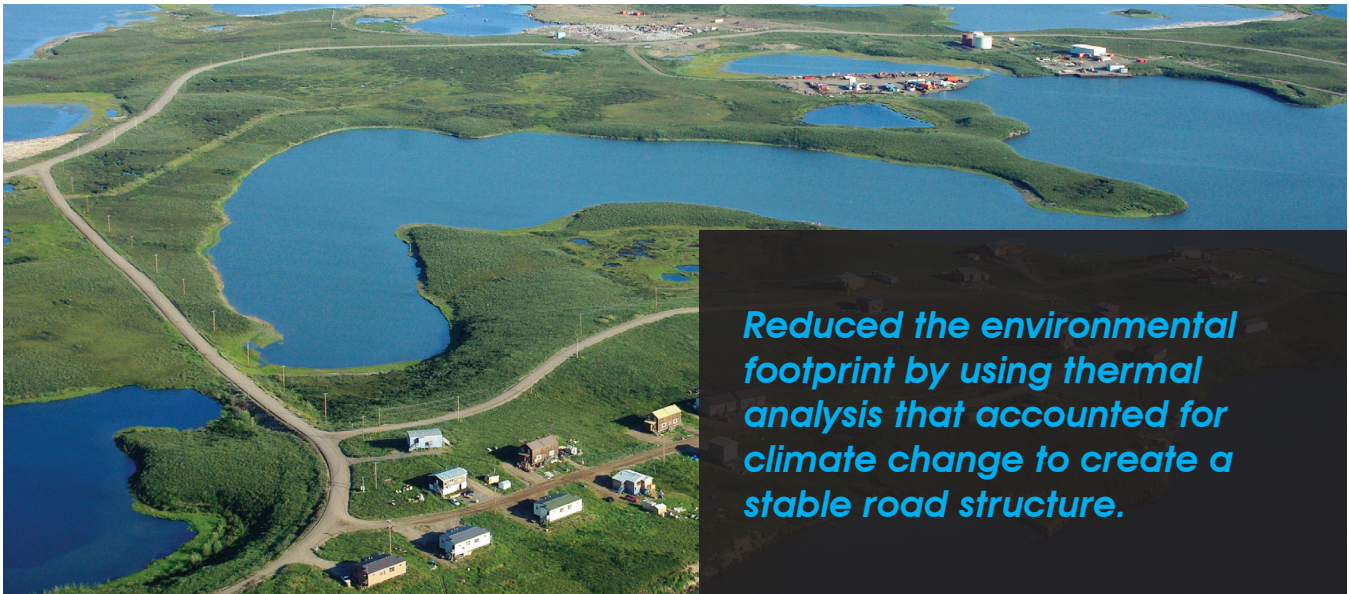
"Our shared goal with Northerners is to build strong families, communities and economies in the North. This new all-season road will create new economic development opportunities, provide better connection to essential services for individuals, and help lower the cost of food and supplies for families in Tuktoyaktuk. It will also allow for more Canadians to experience the beauty and majesty of the Arctic and meet the inspiring Northerners who live there."

The Honorable Carolyn Bennett, M.D., P.C., M.P.
- Minister of Crown-Indigenous Relations and Northern Affairs

"Transportation has always been at the forefront of enabling Northerners to grow and develop our economy, and never has it been more important in guaranteeing our future growth and prosperity than today. Expanding our transportation system with the opening of the Inuvik Tuktoyaktuk Highway will help us connect residents to new social and employment opportunities, stabilize the cost of living in the territory, increase our resiliency and adapt to the impacts of climate change, and provide better access to natural resources."

The Honorable Wally Schumann, Minister of Infrastructure, Government of the Northwest Territories.





Access to northern communities without the yearly impact of winter road construction

Environmental Benefits

The all-season road immediately benefits the region by eliminating the need for a seasonal winter road to be constructed each year. This reduces the environmental impact/risk on the water boundaries and sensitive tundra crossings caused by annual construction and traffic by mitigating silt and hydrocarbon contamination within the waterbodies. Access to the communities is also assured; the long-term sustainability of the winter ice road was not guaranteed given the projected trends associated with climate change and long-term warming predictions.

At the project level, environmental effects were mitigated by protecting the permafrost, and minimizing the project footprint.

- **Borrow Sources:** Excavating and developing the borrow sources changed the permafrost regime, and it will take many years to establish a new thermal equilibrium. Ice melt results in settlement and slumping slopes. To mitigate this, a pit management plan was developed to provide a framework for

Reduced the environmental footprint by using thermal analysis that accounted for climate change to create a stable road structure.

ensuring no immediate effect on downstream waterways and a monitoring plan for GNWT to enact until a new thermal regime is reached.

- **Peat/Organic cover:** Removing the protective insulating organic cover would disturb and degrade the permafrost, so all organic materials were left in place and embankments were constructed ovetop. Also all ditches were eliminated from the design.
- **Surface Water:** Flowing and ponding water heat the soil, which degrades ice-rich permafrost and leads to failures. To maintain a stable permafrost regime, approximately 300 equalization culverts were installed to manage the movement of surface water.



Opening Ceremonies Ribbon Cutting at Km 0 (with Honourable Wally Schumann, Minister of Infrastructure; Honourable Robert R. McLeod, Premier of the Northwest Territories; Her Excellency the Right Honourable Julie Payette, Governor General; Honourable Amarjeet Sohi, Minister of Infrastructure; and Honourable Carolyn Bennett, Minister of Crown-Indigenous Relations and Northern Affairs)

Meeting Client's Needs

Tetra Tech and Stantec, working through their indigenous partners Kiggiak-EBA and Kavik-Stantec, provided comprehensive engineering services to EGT Northwind Ltd., a joint venture construction consortium of E. Grubens Transport Ltd. and Northwind Industries Ltd.

Of our client's many expectations, one of their key objectives was to construct a road using local labor, resources, and equipment. The engineering design team worked closely with EGT Northwind to develop a constructible design that respected the available resources and workforce, the constraint of winter construction, and the challenging northern environment.

Collectively, Kiggiak-EBA, Kavik Stantec, and EGT Northwind were working for the Owner, the Government of the Northwest Territories. The GNWT's primary concern was receiving a cost-effective highway that was safe and resilient, with reasonably predictable operation and costs. Our team worked closely with the GNWT through design and construction finding solutions to allow Canada's first highway constructed on sensitive,

continuous permafrost terrain to be safe, economical, and resilient.

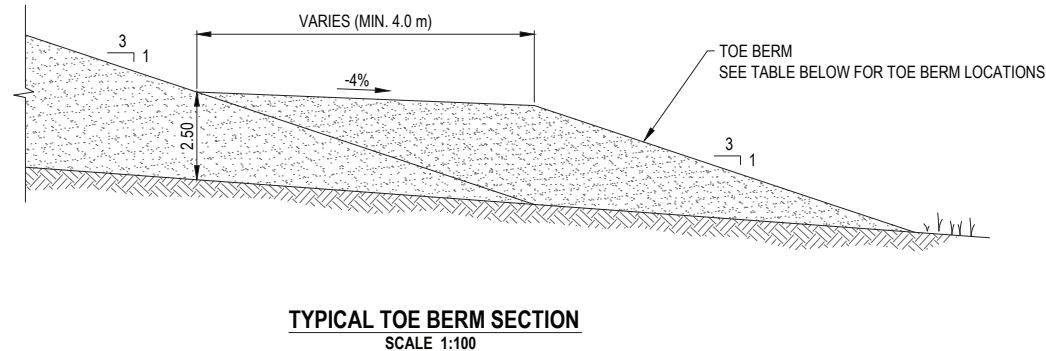
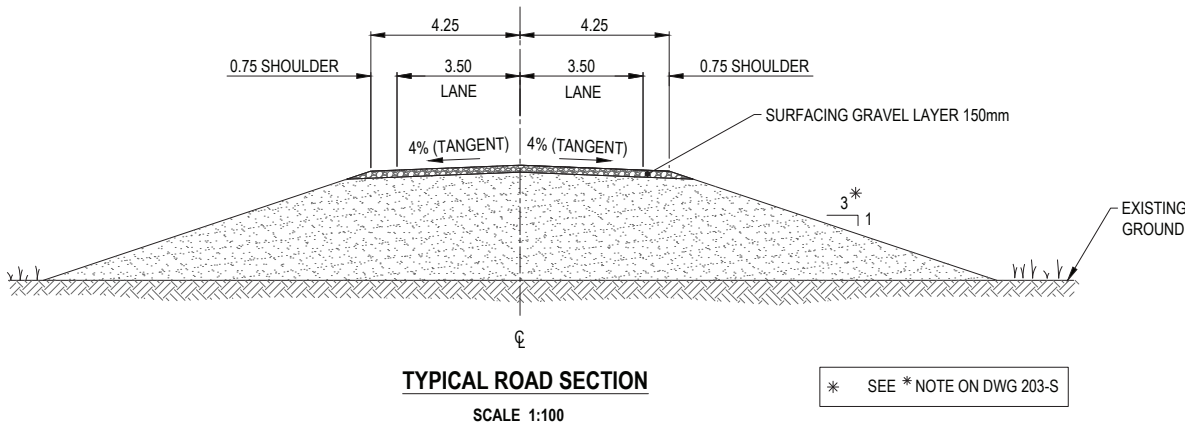
The ultimate client is every user of the road. The ITH is a transformational piece of infrastructure that benefits communities and local individuals today by giving more mobility for residents and goods than ever before. The road will create economic opportunities beyond what we can imagine.

Engineering geothermal modelling analysis was part of the design to make sure the highway and bridges last well into the future even as the climate warms.

Typical Road Section Designs

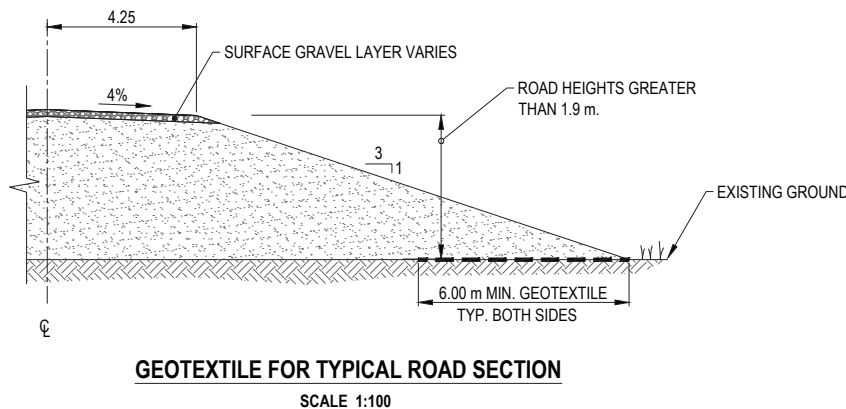
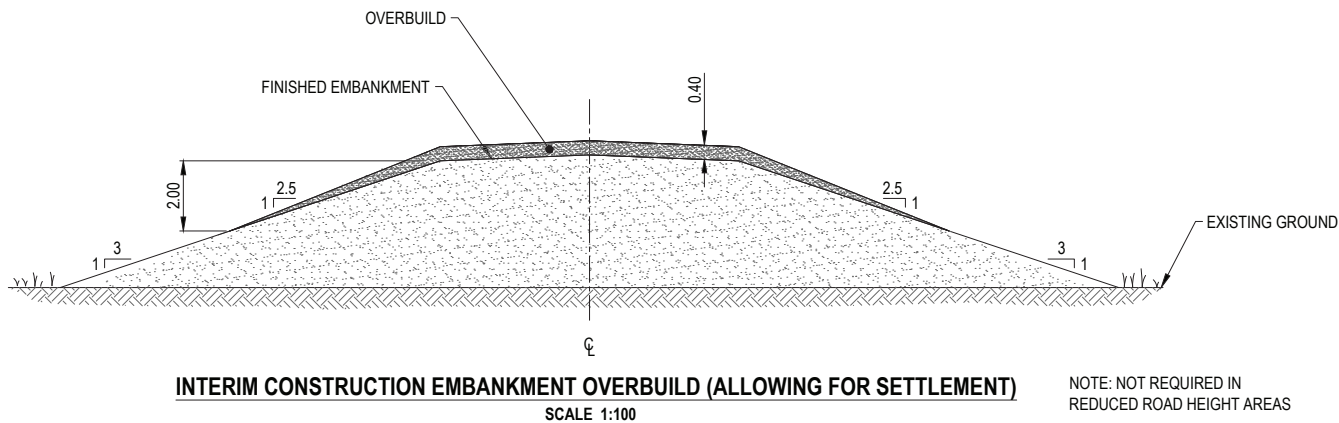
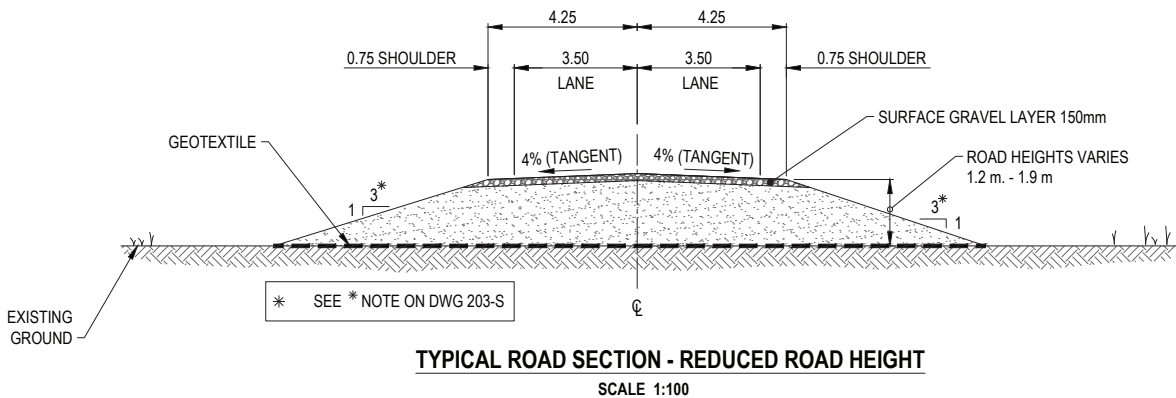
REDUCED ROAD HEIGHT AND FULL WIDTH GEOTEXTILE LOCATIONS:

START STA	END STA	START STA	END STA
20+870	21+050	46+470	46+710
21+230	21+390	46+850	48+130
21+410	21+470	48+290	48+490
21+750	21+870	48+530	48+910
21+950	22+030	48+930	48+990
22+050	22+110	49+030	49+130
22+390	22+570	49+770	49+810
22+830	22+850	49+910	49+930
22+870	23+050	50+330	50+710
23+070	23+210	50+870	50+990
23+310	23+470	51+030	51+250
23+650	23+770	51+270	51+470
23+850	23+910	51+490	51+610
24+030	24+270	51+710	51+810
24+350	24+450	51+890	52+090
24+530	24+630	52+130	52+330
24+750	24+890	52+390	52+470
24+990	25+090	52+530	53+830
25+390	25+730	53+950	54+030
25+950	25+990	54+250	54+290
26+230	26+250	54+310	54+430
26+630	26+730	54+510	54+590
26+790	26+890	54+710	55+090
26+910	27+450	55+150	55+216
27+490	27+690		
27+750	27+990		
28+030	28+850		
28+910	29+030		
29+090	29+350		
29+450	29+690		
29+890	30+130		
30+170	30+270		
30+310	30+350		
30+370	30+390		
30+470	30+650		
30+710	30+910		
30+930	31+090		
31+110	31+390		
31+410	31+470		
31+490	31+690		
31+710	31+870		
31+990	32+430		
32+510	32+570		
32+610	32+670		
32+830	32+990		
33+030	33+110		
33+250	34+410		
34+430	34+750		
34+810	34+890		
34+950	35+110		
35+150	35+210		
35+290	35+350		
35+390	35+950		
36+050	36+250		
36+330	36+390		
36+590	36+690		
36+730	36+750		
36+790	36+850		
36+870	38+730		
38+770	38+790		
40+010	40+030		
40+290	40+310		
40+670	40+870		
40+930	41+150		
41+210	42+090		
42+150	42+310		
42+370	42+510		
42+650	42+730		
43+010	43+250		
43+270	43+510		
43+650	44+410		
44+470	44+570		
45+090	45+610		
45+670	45+750		
45+790	45+850		
45+930	45+110		
46+190	46+310		



TOE BERM LOCATIONS:

LEFT TOE BERM		RIGHT TOE BERM	
START STA	END STA	START STA	END STA
4+990.000	5+030.000	5+840.000	5+880.000
6+510.000	6+550.000	6+170.000	6+210.000
48+190.000	48+230.000		
49+210.000	49+250.000		





No other constructed project
in North America has the same
permafrost challenges as the
Inuvik Tuktoyaktuk Highway



TETRA TECH



Stantec

