Hamlet of Grise Fiord
Master Drainage Plan

PRESENTED TO
Department of Community and Government Services (CGS)
Government of Nunavut

DECEMBER 22, 2021
ISSUED FOR REVIEW
FILE: 704-ENG.WTRI03028-01

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ACRONYMS & ABBREVIATIONS

Acronyms/Abbreviations	Definition
DEM	Digital Elevation Model
GIS	Geographic Information System
GPS	Global Positioning System
SWMM	Stormwater Management Model
AES	Atmospheric Environmental Service

LIMITATIONS OF REPORT

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1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) was retained by the Government of Nunavut (GoN) to develop a Master Drainage Plan (MDP) for the Hamlet of Grise Fiord (Grise Fiord). The scope of the MDP entailed the development of a drainage study covering both the existing town site and planned subdivisions identified in the Community Plan.

The Hamlet of Grise Fiord, hereafter referred to as the study area, is located beyond the Arctic Circle, at latitude 76°25’ N on the south coast of Ellesmere Island in Nunavut.

The Terms of Reference (ToR) developed by GoN confirmed that the Hamlet had developed a Community Plan (By-law No. 65, 2016) and the Zoning By-law (By-law No. 66, 2016). To ensure the community plans are developed in harmony with the local site drainage limitations, it was recommended that a complete review of the local drainage system be carried out. In addition to a detailed review of the community plans and its impacts on the existing stormwater system, GoN identified the need to review and evaluate the conditions of the existing drainage system and undertake an investigation to assist in the siting of future community expansions.

The 2016 Community Plan estimated the population of Grise Fiord to be 130 people. The Grise Fiord Community Plan aims to prepare for a population of 170 people by 2035. It estimated an additional 6 housing units will be required over this period to meet the estimated population growth – an average of 1 new dwelling every three years. In order to ensure that Grise Fiord has sufficient and suitable developable land to accommodate population growth forecast in the Community Plan, it was necessary for a qualified team of professionals to conduct a drainage study for these subdivisions.

The study conducted by Tetra Tech encompassed the following tasks:

- A review of all available background material;
- A site visit to Grise Fiord by a hydrotechnical engineer to identify, assess, and document all drainage infrastructure and known drainage issues;
- A site visit to Grise Fiord by a geologist to document and assess the nature of the local geology;
- Development of an inventory covering existing drainage and geological issues;
- Development of inputs to a hydrologic model;
- Assess the drainage system for existing and proposed development conditions; and
- Completion of the Grise Fiord Master Drainage Plan.

2.0 REVIEW OF BACKGROUND INFORMATION

Tetra Tech collected, compiled and processed all information related to the drainage system of Grise Fiord made available by officials from the Government of Nunavut, the Hamlet, and from publicly available reports and data.

The initial background review process provided Tetra Tech with an understanding of the terrain, climate, long-term land-use plans, and known drainage issues in Grise Fiord.

Reviewed background data has included the following:

- 2020 Satellite Imagery (.tif);
- 2020 Digital Elevation Models (Bare earth and surface models available in .tif and .asc formats);
- 2020 Building footprint, infrastructure, and transportation vector datasets (AutoCAD .dwg and ESRI File Geodatabase or Shapefile formats);
- 2020 Hydrology (water bodies and watercourses) vector datasets (AutoCAD .dwg and ESRI File Geodatabase and Shapefile formats);
- 2020 Contours vector datasets (AutoCAD .dwg and ESRI File Geodatabase and Shapefile formats);
- 2016 Community Plan and Community Plan By-law;
- National Topographic Survey (NTS) 1:50,000 Topography Map of Grise Fiord;
- Google Earth 2020 Satellite Imagery; and
- Historical climate data for Grise Fiord, monitored and made available by Environment Canada.

Additional anecdotal background information was collected through informal discussions with Hamlet staff and local residents during the 2021 field visits.

2.1 Community Plan, Population and Expansion Plans (Land Use)

The Government of Nunavut CGS division maintain and regularly update community plan maps for each community within the Territory. The purpose of these community plans is to outline Council's policies for managing the physical development of each Hamlet for the next 20 years.

The community plan includes existing land parcels as well as proposed parcels of land allocated for future community growth. This combination of existing and proposed development forms the scope of our Master Drainage Plan, which aims to improve the existing drainage system and provide design of drainage features in future areas of development. It is recommended that the results of this community drainage study be incorporated within future community plan updates.

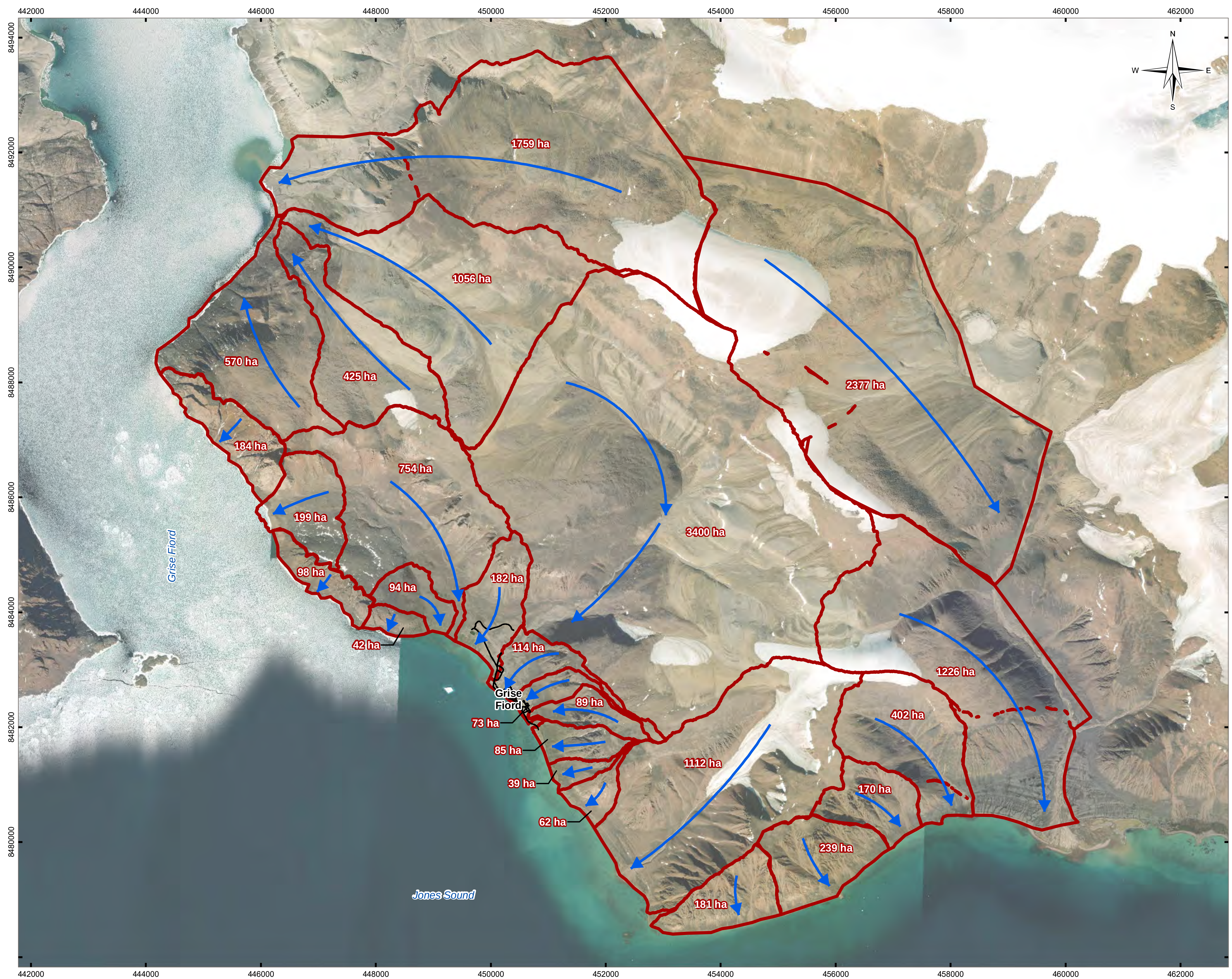
2.2 Terrain

The terrain surrounding Grise Fiord is characterized by its location within the Arctic Cordillera mountain range of Ellesmere Island. The landscape of the south coast of Ellesmere Island is dominated by staircase-like topography formed by a series of the Quaternary marine terraces and accumulations of scree (rock rubble) forming colluvial cones (**Cc**), fans (**Cf**) and aprons (**Ca**) on slopes and at the foot of the high rock cliff located in the northeast part of the study area. The community itself is set on the 1st and 2nd marine terraces (**Mt_1** and **Mt_2**) and in a river valley cutting through bedrock ridges which rise over 500 metres in elevation to the North. This large river runs through Grise Fiord, with its headwaters located in the glaciated, mountainous terrain North of the community.

2.2.1 Topography and Watershed Delineation

A Digital Elevation Model (DEM) of the Grise Fiord region was developed to represent the topography of the project area. The DEM was derived from aerial photographs used to extract elevation information through a technique called photogrammetry. The use of measurements from photographs is of sufficient accuracy for use within a drainage planning exercise. ArcticDEM data was used to supplement the provided DEM data for areas outside of the community, including the mountainous terrain North of the hamlet which forms the majority of the watershed area which flows through the community. ArcticDEM provides 2.0 m resolution surficial data for much of the arctic including Nunavut.

Tetra Tech has reviewed this DEM in conjunction with NTS 1:50,000 topography maps of the area and has performed a watershed delineation analysis to identify drainage patterns in the Grise Fiord area. The existing drainage patterns are presented in Figure 2-1 and were confirmed during the July 2021 field visit. Note that several paths are impacted by the presence of other surficial obstructions such as buildings and conveyance systems such as culverts and ditches.



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LEGEND

- Flow Direction
- Watershed
- Gravel Road

NOTES
Base data source:
1. Grise Fiord road data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN
GRISE FIORD, NU

Watershed Delineation

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:65,000
1 0.5 0 1
Kilometres

TETRA TECH

FILE NO.
WTRI03028-01_WatershedDelineation.mxd

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December 8, 2021	ENG.WTRI03028-01

Figure 2-1

2.2.2 Surficial Geology and Permafrost

Surficial geology and permafrost feature mapping of the study area was completed by Vladislav E. Roujanski, Ph.D., P.Geol., with GIS support provided by Stephanie Leusink, GISP and Megan Verburg, GIS Analyst. The mapping is based on stereoscopic interpretation of the 1:8,000-scale color air photos (August 13, 1995) and analysis of the GoogleEarth™ high resolution color satellite imagery (July 21, 2020) with reference to field observations made during a site reconnaissance visit on August 16 to August 19, 2021, as well as review of the available reports and maps listed in References of this report.

The resultant surficial geology and permafrost feature map (Figures 2-2, 2-3, 2-4 and 2-5) shows spatial distribution of surficial materials, mass movement processes and permafrost-related geomorphic features and processes. Surficial geology polygons were delineated in areas where terrain and subsurface data was available or observed during the August 2021 site reconnaissance. This information was then extrapolated to unknown areas using appearance (texture, colour, hue etc.) on the air photos. Mass movement and permafrost-related terrain features, such as debris flows, thaw flows (slumps), ice-wedge polygons, thermokarst, thermal erosion features etc.), which may pose a challenge for the proposed community expansion, are shown on the map as point and line symbols.

All surficial geology polygons were assigned a drainage class, except for “the Anthropogenic Material (A)” map unit, drainage of which was modified during the land development. The following three drainage classes are used to characterize drainage conditions across the study area:

- Well drained (**w**);
- Imperfectly drained (**i**); and
- Poorly drained (**p**).

These drainage classes are relative and qualitative.

The terrain and permafrost feature map is presented at a scale of 1:5,000 (Figures 2-2, 2-3, 2-4 and 2-5) and should be considered accurate to that scale.

2.2.2.1 Surficial Geology

Five marine terraces (**Mt_1 to Mt_5**) have been distinguished in the study area between elevations of 0 and 80 m (Figure 2-6). They were formed by sea erosion and deposition during periods of postglacial isostatic rebound of the land following retreat of continental ice-sheets in Pleistocene and Holocene. These staircase-like landforms are gently sloping from the colluvium-covered foot of the steep rock cliff in the northeast of the study area down to the sea level.

1st Marine Terrace (Mt_1) of the Holocene epoch is situated at elevations between approximately 2 m and 20 m. It is a bench-like part of the coastal zone above the beach composed of marine deposits (stratified clay, silt, sand and gravel, 5 to 20 m thick) forming coarsening upward sequences. The well-defined **Mt_1** scarp, which is the slope connecting the flat service of the **Mt_1** tread to the gently sloping surface of the beach (**Mb**) is illustrated in Figure 2-6 and Photo 1.

Photo 1: Mt_1 slope connecting the flat service of the Mt_1 tread to the gently sloping surface of the beach (Mb). Photo taken on August 17, 2021.

2nd Marine Terrace (Mt_2) of the Holocene-Late Pleistocene epoch is situated at elevations between approximately 20 m and 30 m. Geotechnical borehole drilling completed by Stantec (2014) to a depth of 10 m below the existing ground surface of **Mt_2** to assist with foundation design for a new power plant encountered mainly sandy and gravelly soils near surface becoming finer grained silts and clays with depth. The upper portions of the boreholes generally comprised gravel with sand and were underlain with variable finer grained soils. The finer grained soils generally varied from silty gravel with sand, clayey gravel with sand, silty sand, sandy silt, clayey sand, sandy clay, and clay. Cobbles and boulders were encountered throughout all boreholes.

The **Mt_2** surface soils at the power plant site comprised light greyish brown gravel with sand containing cobbles and boulders. Boulders were present on the ground surface and measured up to approximately 2.0 m in diameter. Little to no vegetation was observed at the site. Bedrock was not encountered within the depths of the boreholes (10 m) drilled at this site.

Photo 2 shows slightly undulating, gently sloping surface of the **Mt_2** tread near Field Observation Site (FOS #16). The surface soils consist of gravel and cobbles with scattered boulders and patches of moss, lichen and sedge in the low-lying areas. Photo 3 shows a drainage path approx. 50m upslope from FOS #16.

Delineation of the boundary between **Mt_1** and **Mt_2** within the Hamlet boundaries was a challenge because of the human-modified terrain of the developed area shown as anthropogenic material (**A**) in Figures 2-7 to 2-8. Therefore, these two lower terraces were mapped within the Hamlet limits as undifferentiated marine terrace (**Mt**), as shown in Figures 2-2, 2-3, 2-4 and 2-5.

Photo 2: Slightly undulating gently sloping surface of Mt_2 near FOS #16, looking North. Photo taken on August 17, 2021.

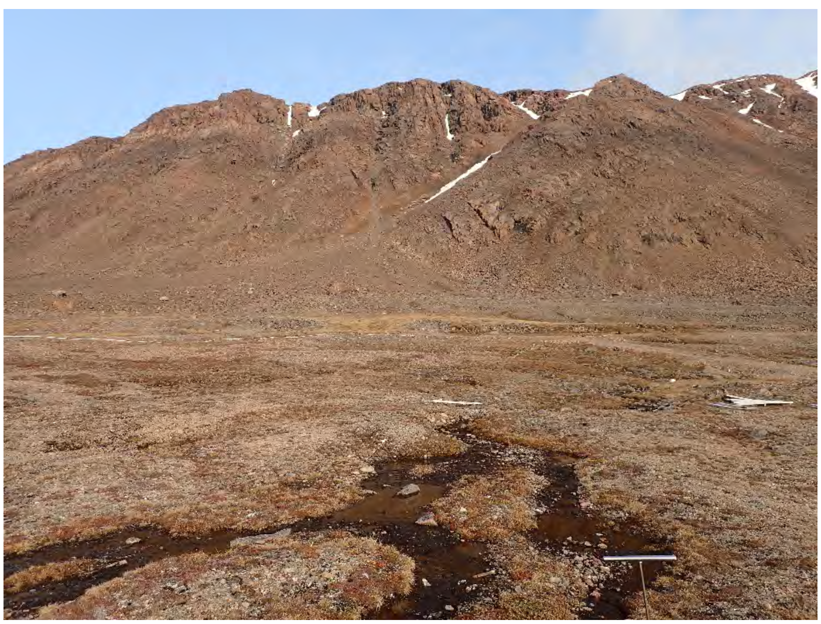


Photo 3: Drainage path on gently sloping surface of Mt_2., looking NE, upslope. Photo taken on August 17, 2021.

3rd Marine Terrace (Mt_3) of the Late Pleistocene epoch is situated at elevations between approximately 30 m and 50 m.

The **Mt_3** scarp which connects the **Mt_3** tread to the **Mt_2** surface is well defined, as illustrated in Figure 2-6 (Profile 1-1) and Photos 4 and 5.

Photo 4: Mt_3 scarp near FOS #47 looking SE. Photo taken on August 19, 2021.

Photo 5: Mt_3 scarp at FOS #47 looking SE. Photo taken on August 19, 2021.

The surface of the **Mt_3** tread is flat to gently undulating with predominantly gravelly and cobbly surface soils, and boulders scattered across the terrace surface. Patches of moss and lichen were observed on the well- to imperfectly drained surface. In some locations, patches of poorly drained saturated silty soils were mapped with mud boils, grass, sedge, and small pools of standing water between boulders on the surface of the **Mt_3** tread (Photo 6). Evidence of surface water flow was observed in some locations.

Photo 6: Gently sloping, poorly drained surface of the Mt3 tread at FOS #53, looking NE towards well-defined scarp of Mt4 (in background). Photo taken on August 19, 2021.

4th Marine Terrace (Mt_4) of the Late Pleistocene epoch is situated at elevations between approximately 50 m and 60 m.

Well-defined **Mt_4** scarp connects the **Mt_4** tread to the **Mt_3** surface, as illustrated in Photos 6 and 7.

The surface of the **Mt_4** tread is perfectly flat with predominantly gravelly (fine to medium) surface soils (Photo 8) and widely spaced large frost-crack polygonal patterned ground (composite-wedge polygons (?) or sand-wedge polygons (?) shown in Photos 9 and 10. No evidence of surface water flow was observed on the terrace surface, except along the bottom of an erosion feature incised into the **Mt_4** tread at FOS #55 (Photo 11).

Photo 7: Well-defined scarp of Mt_4, looking South Photo taken on August 19, 2021.

Photo 8: Perfectly flat, well-drained surface of Mt_4. The surface soils are gravelly and devoid of vegetation, looking East. Photo taken on August 19, 2021.

Photo 9 : Frost-crack polygonal patterned ground (composite-wedge polygons (?) or sand-wedge polygons (?) on the flat surface of the Mt_4 tread near FOS #43, looking NW. Photo taken on August 18, 2021.

Photo 10: Frost-crack polygonal patterned ground (composite-wedge polygons (?) or sand-wedge polygons (?)) on the flat surface of the Mt_4 tread near FOS #43, looking W. Photo taken on August 18, 2021.

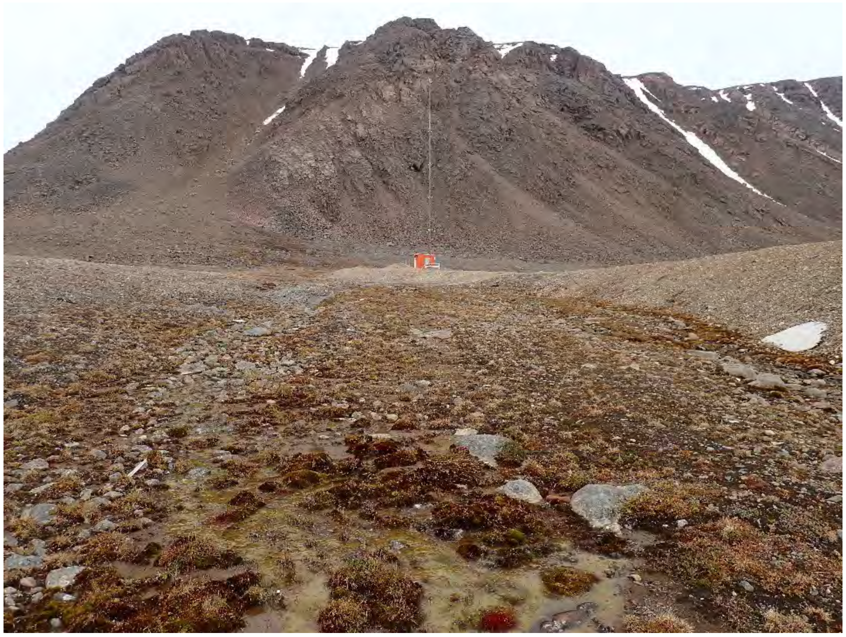


Photo 11: Drainage path along the bottom of an erosion feature incised into the tread of Mt_4 at FOS #55, looking North. Photo taken on August 19, 2021.

5th Marine Terrace (Mt_5) of the Middle Pleistocene epoch is situated at elevations between approximately 60 m and 80 m. It is the highest and oldest terrace level in the study area.

Well- to imperfectly-drained surface of the **Mt_5** tread is gently sloping from the talus (scree) apron at the foot of the steep rock cliff in the northeast of the study area down to the **Mt_4** tread (Figure 5).The upper part of the terrace tread, adjacent to the cliff toe is partially covered by colluvium, rock fall blocky debris, and debris flow accumulations with some large rock blocks found in the middle of the **Mt_5** tread. The boulder-strewn surface of the **Mt_5** tread is devoid of vegetation and is underlain by cobble- and gravel-sized material with boulders disseminated throughout (Photos 12 and 13).

Photo 12: Gently sloping, undulating surface of the Mt_5 tread (at FOS #46) underlain by gravelly and cobbly surface soils. Boulder-strewn surface devoid of vegetation, looking West. Photo taken on August 18, 2021.

Photo 13: Gently sloping, undulating surface of the Mt_5 tread (at FOS #46) underlain by gravelly and cobbly surface soils. Boulder-strewn surface devoid of vegetation, looking SE. Photo taken on August 18, 2021.

At FOS #44 (Figures 2-2, 2-3, 2-4 and 2-5), steep (approx. 50°) bouldery scarp connects the **Mt_5** tread to the lower surfaces, as illustrated in Photo 14. The scarp is well-defined and up to 3 m high in some locations.

Photo 14: Steep bouldery scarp of the Mt_5 tread up to 3 m high near FOS #44, looking North. Photo taken on August 18, 2021.

Debris flows and slides moving down the steep rocky cliff form debris cones and fans at the foot of the cliff (Photo 15). They were interpreted from the air photos and satellite imagery and delineated on the maps during the desktop study. The August 2021 site reconnaissance allowed to refine their boundaries and confirm the landslide runout zones. Some of the runout zones were found to be approximately 60 m away from the proposed future community expansion / development areas (Figures 2-2, 2-3, 2-4 and 2-5). With the climate change, this distance may become shorter threatening proposed developments.

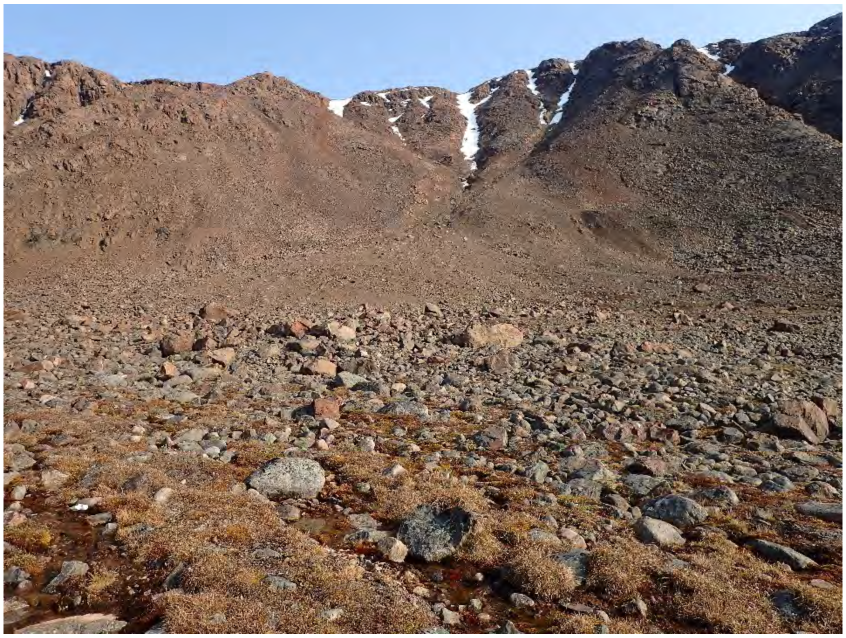


Photo 15: Debris flow landslide (in background), as viewed from FOS #36 (a future development area). The downslope boundary of the landslide runout zone is located approximately 60 m from the upslope boundary of the proposed development, looking NE along Profile 2–2. (Figure 2-6). Notice suprapermafrost water resurfacing (the foreground) from underneath the colluvial fan (Cf) and cone (Cc) (Figures 2-2, 2-3, 2-4 and 2-5). Photo taken on August 18, 2021.

2.2.2.2 Permafrost

According to the Permafrost Map of Canada, the study area is located within the zone of continuous permafrost, in which 90 to 100% of land area is underlain by permafrost (Heginbottom et al, 1995).

The only ground temperature data for the study area was available from NunamiStantec's report (2014). Ground temperatures measured by NunamiStantec on September 23, 2014 with thermistor strings installed in boreholes to depths of up to 6.0 m below the ground surface was -5.6°C. However, this temperature was measured within the interval of seasonal ground temperature fluctuations, i.e. above the depth of zero annual amplitude and, therefore, cannot be considered representative of permafrost temperatures in the study area.

Based on field observations of frozen soil recoveries during advancement of the boreholes at proposed power plant development site on September 23, 2014, NunamiStantec determined that the permafrost table was encountered at a depth of approximately 1.0 m below the ground surface (NunamiStantec 2014). At this time of the year, this depth can be considered the actual active layer thickness (ALT). However, the ALT has likely increased since due to the ongoing climate warming. The increasing ALT influences the drainage patterns in the Hamlet area. It leaves some of the culverts dry (Photo 16) because suprapermafrost water occurring in the active layer changes its depth and direction and resurfaces downslope triggering water ponding (Photo 17) and thermal erosion (Photo 18). The former, in turn, causes thermokarst development.

Photo 16: Dry culvert due to the increased Active Layer Thickness (ALT) at FOS #38, looking South. Photo taken on August 19, 2021.

Photo 17: Ponding of suprapermafrost water near Co-op Store, looking North. Photo taken on August 19, 2021.

Photo 18: Developing thermal erosion rill on the road surface near the Co-op Store, looking West. Photo taken on August 19, 2021.

In August 2021, the seasonal thaw depths measured by Tetra Tech with permafrost probe in several locations of the study area within isolated patches of silty, clayey, sandy, and organic soils ranged between 0.6 m and more than 1 m (the length of the permafrost probe). The probing locations and measured thaw depths are shown in Figures 2-2, 2-3, 2-4 and 2-5.

Permafrost-related geomorphic processes and landforms identified during the August 2021 site reconnaissance include patterned ground features (ice-wedge, composite-wedge and sand-wedge polygons), thermal erosion, thaw flows (slumps) of ice-rich material on the slopes and thermokarst (Figures 2-2, 2-3, 2-4 and 2-5).

Many permafrost-related landforms result from either the formation or melt of ground ice. Ground ice is the general term used to refer to all types of ice formed in frozen ground. Ground ice occurs in the pores, cavities, voids, or other openings in soil and rock (French 2007).

Little is known about ground ice occurrence and distribution in both unconsolidated deposits and in bedrock of the study area because all intrusive geotechnical investigations in the Grise Fiord area were conducted using a Gardner Denver air-track drill (model ATD3700) supplied and operated by Canadrill Ltd. The percussion rotary air blast drilling method doesn't allow accurate identification and characterization of ground ice because soil samples obtained from the boreholes are recovered in highly disturbed condition.

The only useful information on excess ice in the near-surface soils of the study area was found in NunamiStantec report (2014). Examination of disturbed frozen soil samples recovered by NunamiStantec during advancement of the boreholes at the proposed power plant development site allowed to identify an ice-rich zone at a depth of approximately 1.0 m below the ground surface based on observed ice crystals.

No ground ice exposures were observed within the study area during the August 2021 site reconnaissance visit.

2.2.3 Development Suitability Ranking

Development suitability analysis completed for the study area is based on the identification and mapping of terrain constraints.

Terrain constraints in the study area include surficial material types, permafrost conditions (thermal state and ice content, especially occurrence of ground ice), permafrost-related geomorphic processes and landforms, drainage conditions, flooding of areas of low-lying ground adjacent to major stream channels, terrain stability and its ruggedness, particularly slope steepness and mass movement processes, including landslides. These naturally occurring features affect the design, construction techniques and maintenance of the community infrastructure, housing and facilities.

The most serious constraint in the study area is mass movement on the steep rock cliff in the northeast of the study area, i.e. the movement of rock debris material downslope associated with landslide events. The interpreted runout zones of some of the debris flows, which are delineated in Figures 2-2, 2-3, 2-4 and 2-5 as colluvial cones (Cc) and colluvial fans (Cf) are located precariously close to the proposed future development areas (Figures 2-7 and 2-8). For example, a debris flow landslide located upslope from FOS #35 (the downslope boundary of the landslide runout zone) is located approximately 60 m from the upslope boundary of the proposed development area (FOS #36 – see Photo 15 and Profile 2–2; Figure 2-6).

Geohazards in Grise Fiord include landslides (debris flows, debris slides and rockfalls) dashing down the steep rock cliff in the northeast of the study area, thermal erosion, permafrost degradation in the form of thermokarst resulting in ground differential settlement and subsidence, and other hazardous geomorphic processes and phenomena. These processes may damage or adversely affect existing or potential infrastructure, housing and facilities. To illustrate, a combination of lateral and thermal erosion of the west bank of a major glacier-fed stream near the Grise Fiord airport causes slope instability resulting in slope failures and retrogression of the bank slope. Open tension cracks were observed by Tetra Tech on the surface just above the slope brake near the runway on August 16 indicating that another potential slope failure at this location is imminent (Photos 19 and 20; Figures 2-2, 2-3, 2-4 and 2-5).

Photo 19: Developing tension crack (foreground) near the existing runway (background), looking NW. Photo taken on August 19, 2021.

Photo 20: Developing tension crack (foreground) near the existing runway (background), looking SW. Photo taken on August 19, 2021.

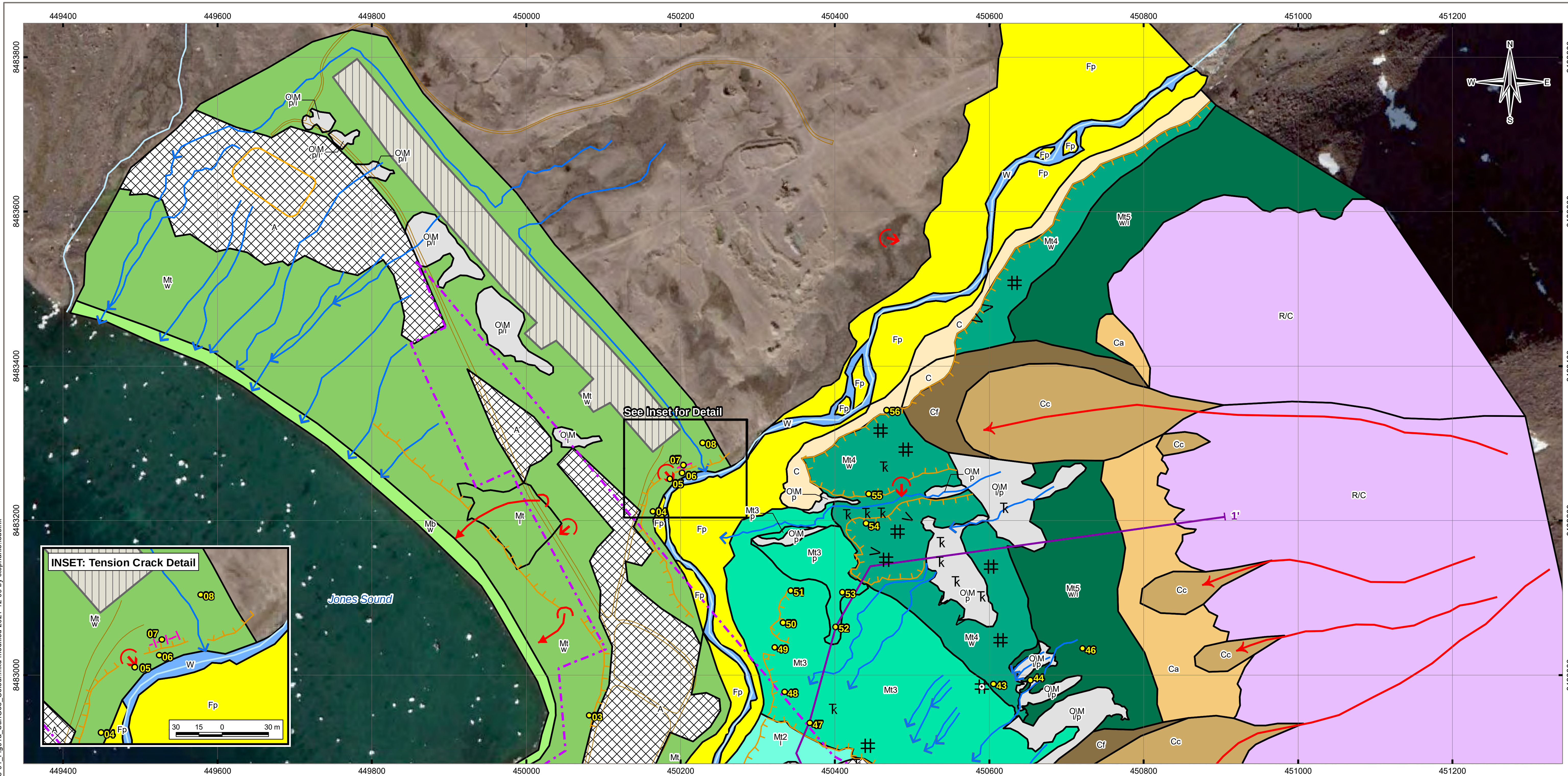
These terrain constraints were identified through background data review, desktop terrain analysis, surficial geology mapping, and field verification of the desktop study results during a recent site reconnaissance visit. The constraint analysis and mapping results are depicted in Figures 2-9 and 2-10: Development Suitability Map of the study area compiled at a scale of 1:5,000.

The development suitability classes for the project area were established as follows:

- **Suitable for Development:** Mass movement processes do not pose a hazard for proposed development, permafrost appears to be predominantly ice-poor with ground ice content generally less than 10% by volume of visible ice; permafrost terrain is generally stable; the ground surface is well- to imperfectly-drained; relatively flat to gently sloping and permafrost processes are limited.
- **Conditionally Suitable for Development (provided Tetra Tech's Drainage Improvement Plan is implemented, landslide debris barrier control structures are constructed and clean-up of the contaminated soils is complete):** Mass movement processes present a moderate geohazard for proposed development meaning that the potential landslide impact can be mitigated by erecting debris barrier control structures. Permafrost appears to be of medium to high ice content, i.e. 10 to more than 20% by volume of visible ice and may locally contain significant accumulations of ground ice; permafrost is relatively stable to locally unstable and sensitive to human-induced disturbance; ground surface is imperfectly to poorly drained with pools of standing water; and there is evidence of active hazardous permafrost processes, such as

thermokarst. Clean up of the presently contaminated areas, such as the area located northeast of the existing runway, is complete.

- **Unsuitable for Development:** Mass movement processes present a severe geohazard for proposed development meaning that the potential landslide impact cannot be mitigated. Unsuitable for development terrain category consists of rugged bedrock outcrops with steep slopes, and patches of unstable colluvial veneer, frost-shattered and frost-jacked blocks of rock. The slopes are covered with unstable colluvial blanket. There is evidence of permafrost-related mass movement processes, such as thaw flows, solifluction, and other hazardous permafrost-related geomorphic processes, such as thermal erosion and thermokarst.



LEGEND

- Field Observation Site
- Active Layer Thickness (m, measured)

Patterned Ground
- Frost-crack polygons
- Ice wedge polygons
- Circles and polygons, undifferentiated

Landslides
- Thaw flow
- Debris flow

Erosion Features
- V Thermal erosion feature, isolated
- Thermokarst feature, isolated
- Drainage path
- Escarpment
- Tension crack

Surficial Material
- A Anthropogenic Material
- O Organic Deposit
- C Colluvium
- Ca Talus (Scree)
- Cc Colluvial Cone
- Cf Colluvial Fan
- Fp Fluvial Floodplain
- M Marine Deposit
- Mb Marine Beach
- Mt Marine Terrace (Undifferentiated)
- Mt1 1st Marine Terrace
- Mt2 2nd Marine Terrace
- Mt3 3rd Marine Terrace
- Mt4 4th Marine Terrace
- Mt5 5th Marine Terrace
- W Water
- R Bedrock

- Study Area
- Profile
- Runway
- Sewage Lagoon
- Water Supply Reservoir
- Gravel Road
- Watercourse

NOTES
Base data source: Government of Nunavut.
Imagery provided by Google Earth; Maxar (July 21, 2020).

STATUS
ISSUED FOR REVIEW

GEOTECHNICAL INVESTIGATION AND DRAINAGE PLANNING GRISE FIORD, NUNAVUT

Surficial Geology and Permafrost Features

PROJECTION: UTM Zone 17
DATUM: NAD83
CLIENT: Nunavut

Scale: 1:5,000
100 50 0 100
Metres

TETRA TECH

FILE NO.
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Figure 2-2

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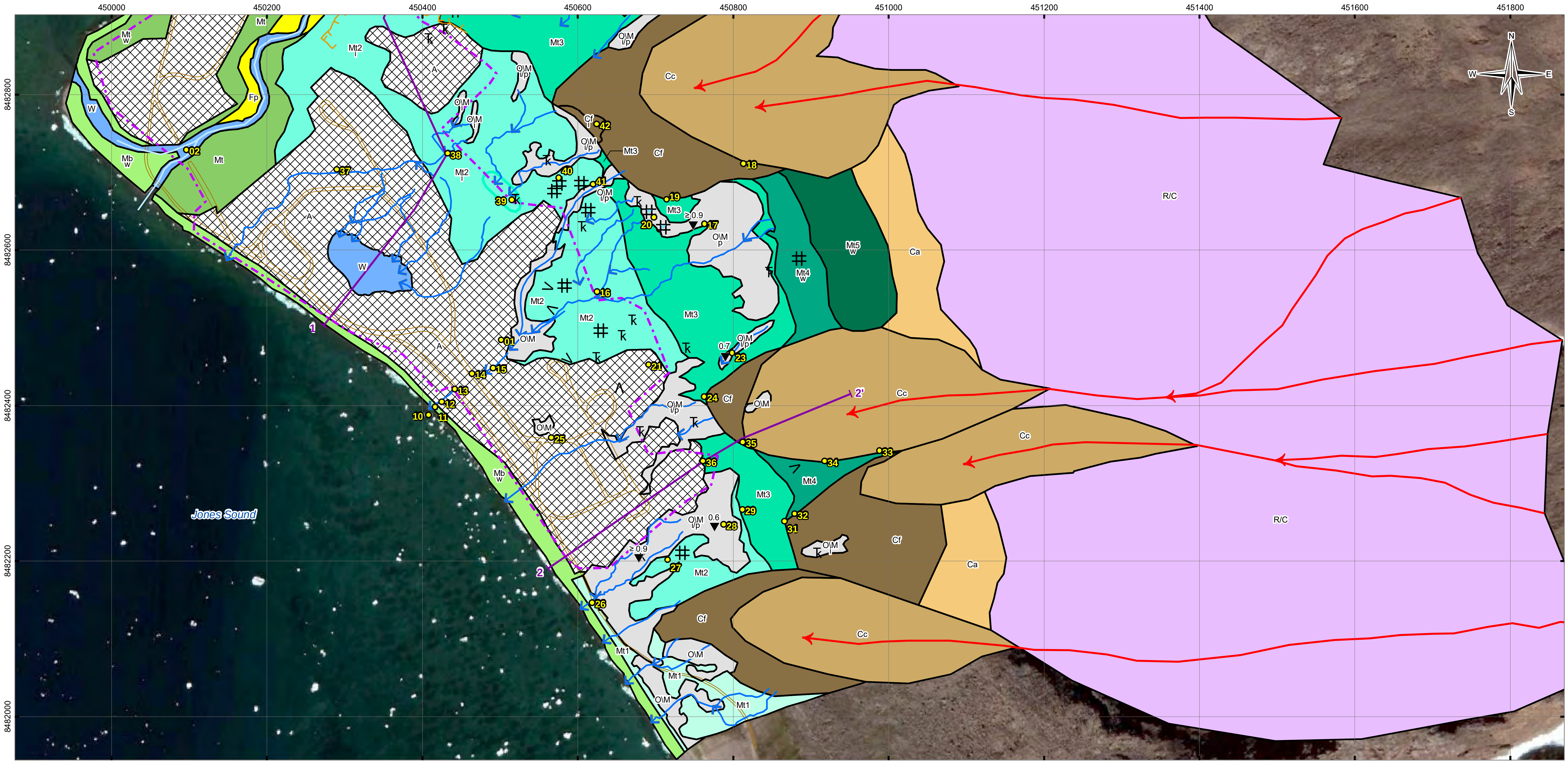

LEGEND

Field Observation Site

Active Layer Thickness (m, measured)

Patterned Ground

Frost-crack polygons

Ice wedge polygons

Circles and polygons, undifferentiated

Landslides

Thaw flow

Debris flow

Erosion Features

V Thermal erosion feature, isolated

Thermokarst feature, isolated

Drainage path

Escarpment

Tension crack

Surficial Material

A Anthropogenic Material

O Organic Deposit

C Colluvium

Ca Talus (Scree)

Cc Colluvial Cone

Cf Colluvial Fan

Fp Fluvial Floodplain

M Marine Deposit

Mb Marine Beach

Mt Marine Terrace (Undifferentiated)

Mt1 1st Marine Terrace

Mt2 2nd Marine Terrace

Mt3 3rd Marine Terrace

Mt4 4th Marine Terrace

Mt5 5th Marine Terrace

W Water

R Bedrock

Study Area

Profile

Runway

Sewage Lagoon

Water Supply Reservoir

Gravel Road

Watercourse

NOTES

Base data source: Government of Nunavut.

Imagery provided by Google Earth; Maxar (July 21, 2020).

STATUS
ISSUED FOR REVIEW

GEOTECHNICAL INVESTIGATION AND DRAINAGE PLANNING GRISE FIORD, NUNAVUT

Surficial Geology and Permafrost Features

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:5,000

100 50 0 100

Metres

FILE NO.
WTRI03028-01_Fig01b_SurfGeo_Colour.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	SL	MRV	VER	0

DATE	PROJECT NO.
December 9, 2021	ENG.WTRI03028-01

Figure 2-3

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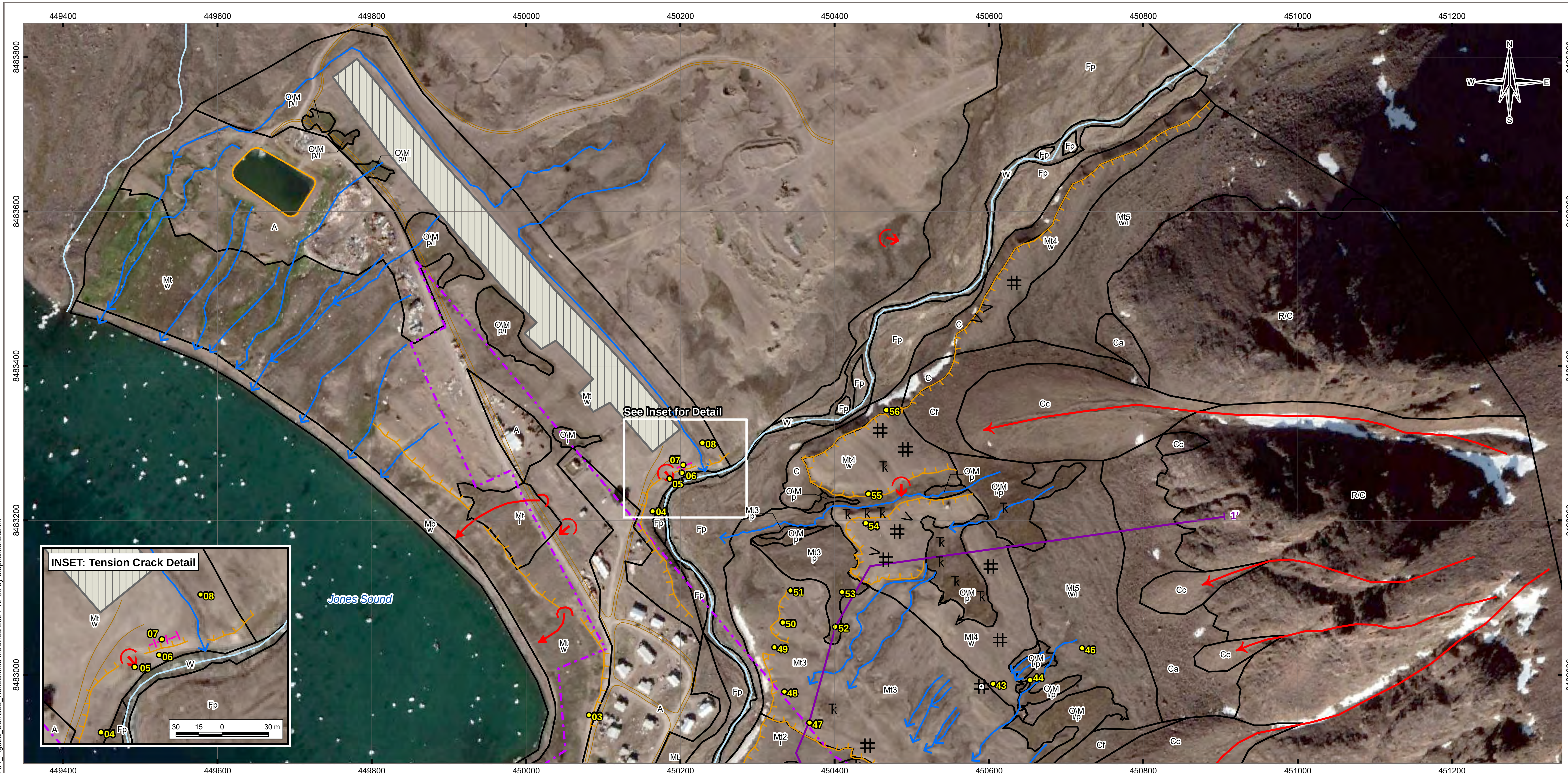

LEGEND

- Field Observation Site
- Active Layer Thickness (m, measured)

Patterned Ground

- Frost-crack polygons
- Ice wedge polygons
- Circles and polygons, undifferentiated

Landslides

- Thaw flow
- Debris flow

Erosion Features

- V Thermal erosion feature, isolated
- Thermokarst feature, isolated
- Drainage path
- Escarpment
- Tension crack

Surficial Material

A	Anthropogenic Material
O	Organic Deposit
C	Colluvium
Ca	Talus (Scree)
Cc	Colluvial Cone
Cf	Colluvial Fan
Fp	Fluvial Floodplain
M	Marine Deposit
Mb	Marine Beach
Mt	Marine Terrace (Undifferentiated)
Mt1	1st Marine Terrace
Mt2	2nd Marine Terrace
Mt3	3rd Marine Terrace
Mt4	4th Marine Terrace
Mt5	5th Marine Terrace
W	Water
R	Bedrock

- Study Area
- Profile
- Runway
- Sewage Lagoon
- Water Supply Reservoir
- Gravel Road
- Watercourse

NOTES

Base data source: Government of Nunavut.
Imagery provided by Google Earth; Maxar (July 21, 2020).

STATUS
ISSUED FOR REVIEW

GEOTECHNICAL INVESTIGATION AND DRAINAGE PLANNING GRISE FIORD, NUNAVUT

Surficial Geology and Permafrost Features

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:5,000
100 50 0 100
Metres

FILE NO.
WTRI03028-01_Fig02a_SurfGeo_Hollow.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	SL	MRV	VER	0

DATE	PROJECT NO.
December 9, 2021	ENG.WTRI03028-01

Figure 2-4

LEGEND

- Field Observation Site
- ▼ Active Layer Thickness (m, measured)

Patterned Ground

- Frost-crack polygons
- Ice wedge polygons
- Circles and polygons, undifferentiated

Landslides

- Thaw flow
- Debris flow

Erosion Features

- V Thermal erosion feature, isolated
- Thermokarst feature, isolated
- Drainage path
- Escarpment
- Tension crack

Surficial Material

A	Anthropogenic Material
O	Organic Deposit
C	Colluvium
Ca	Talus (Scree)
Cc	Colluvial Cone
Cf	Colluvial Fan
Fp	Fluvial Floodplain
M	Marine Deposit
Mb	Marine Beach
Mt	Marine Terrace (Undifferentiated)
Mt1	1st Marine Terrace
Mt2	2nd Marine Terrace
Mt3	3rd Marine Terrace
Mt4	4th Marine Terrace
Mt5	5th Marine Terrace
W	Water
R	Bedrock

- Study Area
- Profile
- Runway
- Sewage Lagoon
- Water Supply Reservoir
- Gravel Road
- Watercourse

NOTES

Base data source: Government of Nunavut.
Imagery provided by Google Earth; Maxar (July 21, 2020).

STATUS
ISSUED FOR REVIEW

GEOTECHNICAL INVESTIGATION AND DRAINAGE PLANNING GRISE FIORD, NUNAVUT

Surficial Geology and Permafrost Features

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:5,000
100 50 0 100
Metres

FILE NO.
WTRI03028-01_Fig02b_SurfGeo_Hollow.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	SL	MRV	VER	0

DATE	PROJECT NO.
December 9, 2021	ENG.WTRI03028-01

Figure 2-5

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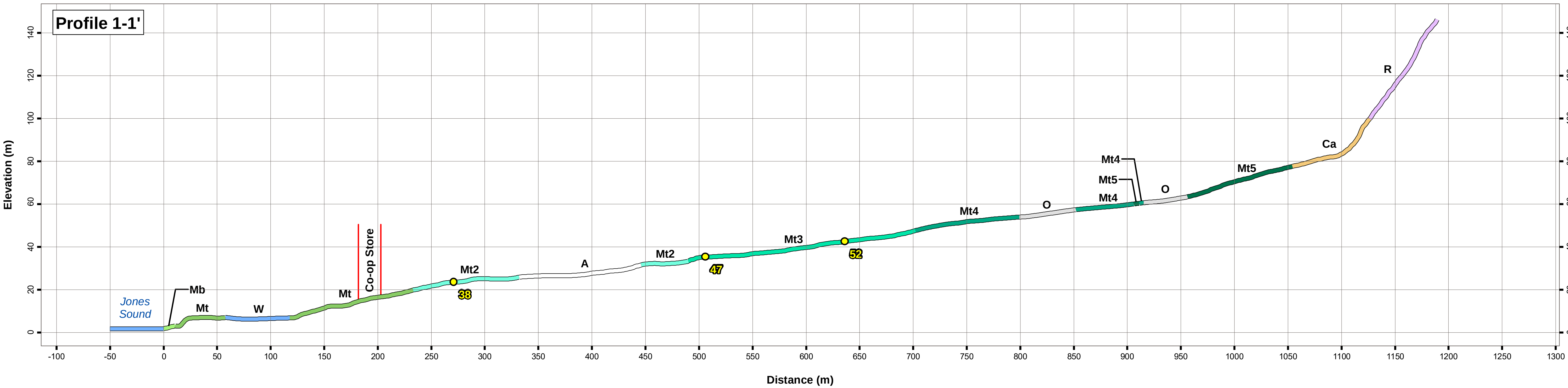

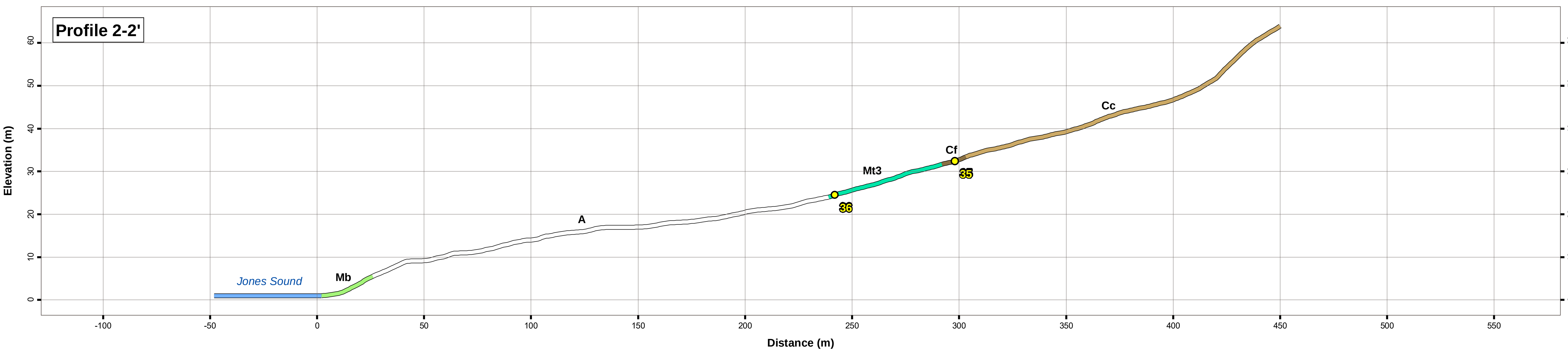

LEGEND

- Field Observation Site

Surficial Material

- Anthropogenic Material (A)
- Organic Deposit (O)
- Talus (Scree) (Ca)
- Colluvial Cone (Cc)
- Colluvial Fan (Cf)
- Marine Beach (Mb)
- Marine Terrace (Undifferentiated) (Mt)
- 2nd Marine Terrace (Mt2)
- 3rd Marine Terrace (Mt3)
- 4th Marine Terrace (Mt4)
- 5th Marine Terrace (Mt5)
- Water (W)
- Bedrock (R)

NOTES
Vertical Exaggeration = 2x

STATUS
ISSUED FOR REVIEW

GEOTECHNICAL INVESTIGATION AND DRAINAGE PLANNING GRISE FIORD, NUNAVUT

Profiles

PROJECTION	DATUM	CLIENT
N/A	N/A	Nunavut

FILE NO.
WTRI03028-01_Fig05_Profiles.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	VER	0

DATE	PROJECT NO.
November 30, 2021	ENG.WTRI03028-01

Figure 2-6

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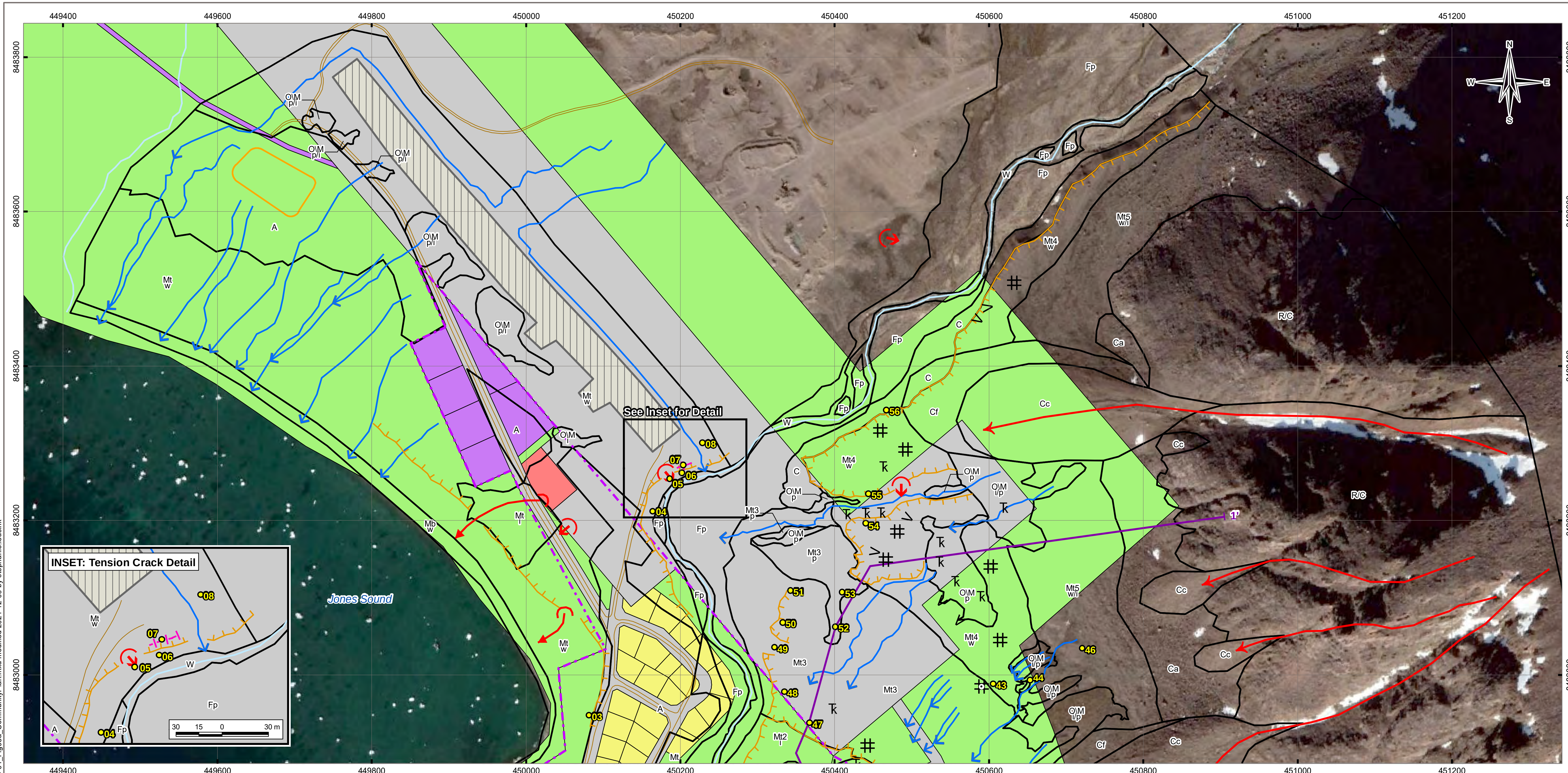

LEGEND

- Field Observation Site
- Active Layer Thickness (m, measured)

Patterned Ground

- Frost-crack polygons
- Ice wedge polygons
- Circles and polygons, undifferentiated

Landslides

- Thaw flow
- Debris flow

Erosion Features

- V Thermal erosion feature, isolated
- Thermokarst feature, isolated
- Drainage path
- Escarpment
- Tension crack

Surficial Material

A	Anthropogenic Material
O	Organic Deposit
C	Colluvium
Ca	Talus (Scree)
Cc	Colluvial Cone
Cf	Colluvial Fan
Fp	Fluvial Floodplain
M	Marine Deposit
Mb	Marine Beach
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Mt2	2nd Marine Terrace
Mt3	3rd Marine Terrace
Mt4	4th Marine Terrace
Mt5	5th Marine Terrace
W	Water
R	Bedrock

- Study Area
- Profile
- Runway
- Sewage Lagoon
- Water Supply Reservoir
- Gravel Road
- Watercourse

Zoning Category

- Community Use
- Industrial
- Open Space
- Residential
- Transportation

NOTES
Base data source: Government of Nunavut.
Imagery provided by Google Earth; Maxar (July 21, 2020).

STATUS
ISSUED FOR REVIEW

GEOTECHNICAL INVESTIGATION AND DRAINAGE PLANNING GRISE FIORD, NUNAVUT

Grise Fiord Community Plan with Surficial Geology

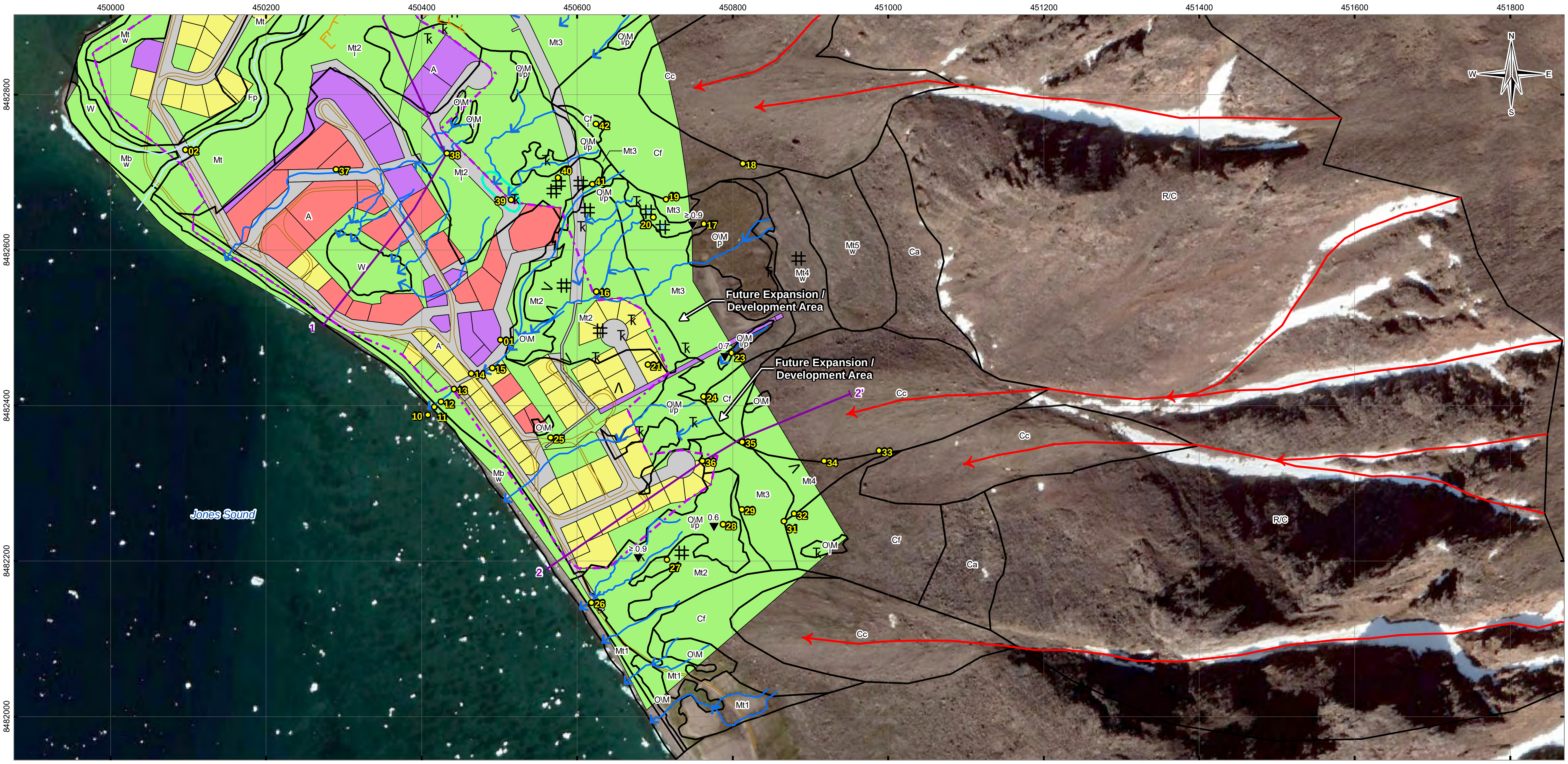
PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:5,000
100 50 0 100
Metres

TETRA TECH

FILE NO.				
WTRI03028-01_Fig03a_CommunityPlan.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-EDM	SL	MRV	VER	0
DATE	PROJECT NO.			
December 9, 2021	ENG.WTRI03028-01			

Figure 2-7



LEGEND

- Field Observation Site
- Active Layer Thickness (m, measured)

Patterned Ground

- Frost-crack polygons
- Ice wedge polygons
- Circles and polygons, undifferentiated

Landslides

- Thaw flow
- Debris flow

Erosion Features

- Thermal erosion feature, isolated
- Thermokarst feature, isolated
- Drainage path
- Escarpment
- Tension crack

Surficial Material

- A Anthropogenic Material
- O Organic Deposit
- C Colluvium
- Ca Talus (Scree)
- Cc Colluvial Cone
- Cf Colluvial Fan
- Fp Fluvial Floodplain
- M Marine Deposit
- Mb Marine Beach
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- Mt2 2nd Marine Terrace
- Mt3 3rd Marine Terrace
- Mt4 4th Marine Terrace
- Mt5 5th Marine Terrace
- W Water
- R Bedrock

- Study Area
- Profile
- Runway
- Sewage Lagoon
- Water Supply Reservoir
- Gravel Road
- Watercourse

Zoning Category

- Community Use
- Industrial
- Open Space
- Residential
- Transportation

NOTES

Base data source: Government of Nunavut.
Imagery provided by Google Earth; Maxar (July 21, 2020).

STATUS
ISSUED FOR REVIEW

GEOTECHNICAL INVESTIGATION AND DRAINAGE PLANNING GRISE FIORD, NUNAVUT

Grise Fiord Community Plan with Surficial Geology

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:5,000
100 50 0 100
Metres

FILE NO.
WTRI03028-01_Fig03b_CommunityPlan.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	SL	MRV	VER	0

DATE	PROJECT NO.
December 9, 2021	ENG.WTRI03028-01

Figure 2-8

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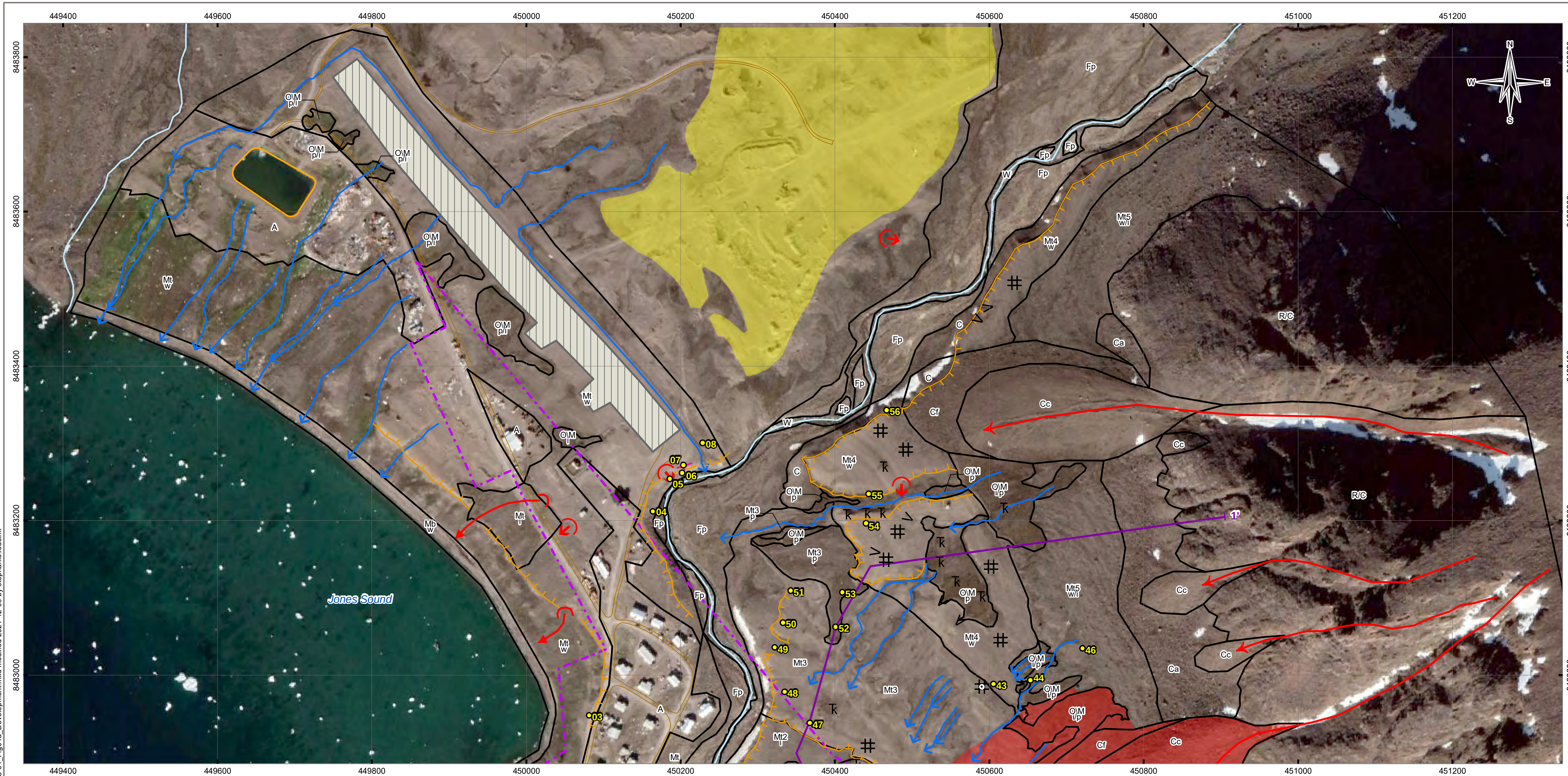

LEGEND

- Field Observation Site
- ▼ Active Layer Thickness (m, measured)

Patterned Ground

- Frost-crack polygons
- Ice wedge polygons
- Circles and polygons, undifferentiated

Landslides

- Thaw flow
- Debris flow

Erosion Features

- V Thermal erosion feature, isolated
- Thermokarst feature, isolated
- Drainage path
- Escarpment
- Tension crack

Surficial Material

A	Anthropogenic Material
O	Organic Deposit
C	Colluvium
Ca	Talus (Scree)
Cc	Colluvial Cone
Cf	Colluvial Fan
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Mt2	2nd Marine Terrace
Mt3	3rd Marine Terrace
Mt4	4th Marine Terrace
Mt5	5th Marine Terrace
W	Water
R	Bedrock

- Study Area
- Profile
- Runway
- Sewage Lagoon
- Water Supply Reservoir
- Gravel Road
- Watercourse

Development Suitability

- Suitable for Development
- Conditionally Suitable for Development
- Unsuitable for Development

NOTES
Base data source: Government of Nunavut.
Imagery provided by Google Earth; Maxar (July 21, 2020).

STATUS
ISSUED FOR REVIEW

GEOTECHNICAL INVESTIGATION AND DRAINAGE PLANNING GRISE FIORD, NUNAVUT

Development Suitability

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:5,000
100 50 0 100
Metres

TETRA TECH

FILE NO.
WTRI03028-01_Fig04a_Development.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	SL	MRV	VER	0

DATE	PROJECT NO.
December 9, 2021	ENG.WTRI03028-01

Figure 2-9

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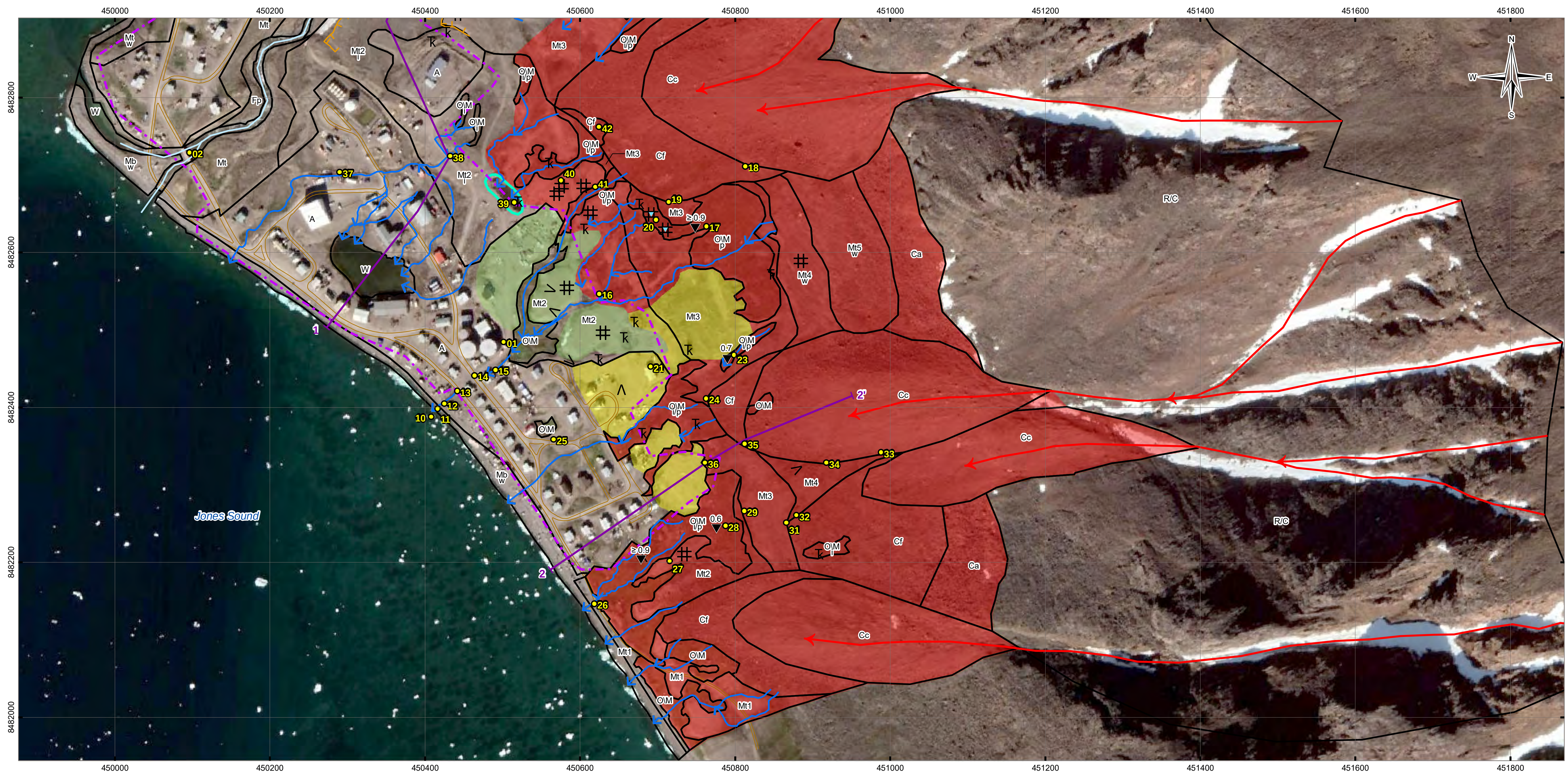

LEGEND

- Field Observation Site
- Active Layer Thickness (m, measured)

Patterned Ground

- Frost-crack polygons
- Ice wedge polygons
- Circles and polygons, undifferentiated

Landslides

- Thaw flow
- Debris flow

Erosion Features

- V Thermal erosion feature, isolated
- Thermokarst feature, isolated
- Drainage path
- Escarpment
- Tension crack

Surficial Material

- A Anthropogenic Material
- O Organic Deposit
- C Colluvium
- Ca Talus (Scree)
- Cc Colluvial Cone
- Cf Colluvial Fan
- Fp Fluvial Floodplain
- M Marine Deposit
- Mb Marine Beach
- Mt Marine Terrace (Undifferentiated)
- Mt1 1st Marine Terrace
- Mt2 2nd Marine Terrace
- Mt3 3rd Marine Terrace
- Mt4 4th Marine Terrace
- Mt5 5th Marine Terrace
- W Water
- R Bedrock

- Study Area
- Profile
- Runway
- Sewage Lagoon
- Water Supply Reservoir
- Gravel Road
- Watercourse

Development Suitability

- Suitable for Development
- Conditionally Suitable for Development
- Unsuitable for Development

NOTES

Base data source: Government of Nunavut.
Imagery provided by Google Earth; Maxar (July 21, 2020).

GEOTECHNICAL INVESTIGATION AND DRAINAGE PLANNING GRISE FIORD, NUNAVUT

Development Suitability

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:5,000

100 50 0 100

Metres

TETRA TECH

FILE NO.
WTRI03028-01_Fig04b_Development.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	SL	MRV	VER	0

DATE	PROJECT NO.
December 9, 2021	ENG.WTRI03028-01

STATUS
ISSUED FOR REVIEW

Figure 2-10

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2.3 Climate

2.3.1 Recorded Data

Climate data for Grise Fiord is based on daily records collected from 1984 to 2021. Data is collected and published by Environment and Climate Change Canada (ECCC). Station ID 1754 (Grise Fiord) was used for climate data between the dates of 1984 to 2008. Station ID 46568 was used for climate data between the years of 2009 to 2021. Table 2-1 presents the climate normals calculated by Tetra Tech using ECCC data for the period of 1984 to 2021.

The daily maximum, mean, and minimum temperatures in February, the coldest month of the year, are -27.5°C, -31.5°C, and -35.4°C respectively. The same temperatures in July, the warmest month of the year, are 6.7°C, 3.9°C, and 1.1°C respectively. The annual mean daily temperature is -14.1°C. Extreme maximum and minimum recorded temperatures are 15.6°C and -47.0°C respectively. The average annual precipitation for the climate normal period is 172.9 mm. Precipitation amounts are elevated throughout the summer but highest in the months of July and August, with a maximum recorded daily rainfall of 83.8 mm which occurred on August 11, 1991.

Table 2-1: Grise Fiord Climate Normals 2005-2015

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high (°C)	-27.1	-27.5	-24.9	-15.4	-3.9	3.8	6.7	5.4	0.2	-7.4	-16.4	-22.2	−10.4
Daily mean (°C)	-30.7	-31.5	-29.3	-20.5	-8.2	1.0	3.9	3.1	-1.9	-10.2	-19.9	-25.9	−14.1
Average low (°C)	-34.2	-35.4	-33.6	-25.5	-12.4	-1.7	1.1	0.9	-4.0	-12.8	-23.4	-29.5	−17.5
Record high (°C)	-0.6	-0.5	2.7	10.5	10.0	15.0	15.6	14.8	8.5	7.5	3.0	2.0	15.6
Record low (°C)	-47.0	-47.0	-46.0	-40.5	-30.5	-13.0	-5.0	-7.4	-16.0	-29.0	-41.1	-42.0	−47.0
Average precipitation (mm)	6.1	5.7	9.9	11.3	8.8	15.5	28.8	35.3	19.0	14.0	10.4	8.1	172.9
Record Daily Precipitation (mm)	12.6	5.6	18.6	22.8	19.0	32.1	41.0	83.8	61.2	37.4	16.6	34.4	83.8

2.3.2 Hydrologic Analysis

A frequency analysis was completed using the series of maximum annual daily precipitation amounts for Grise Fiord. The data was obtained from the ECCC stations 1754 and 46568. The statistical frequency analysis software, HYFRAN, was used to fit the maximum 24-hour precipitation data to selected best fit statistical distributions. Several probability distributions were tested and used to select the distribution with the best fit. The chart of the Lognormal fitting used for the daily precipitation data is shown in Figure 2-11. Results of the frequency analysis is shown in Table 2-2 below.

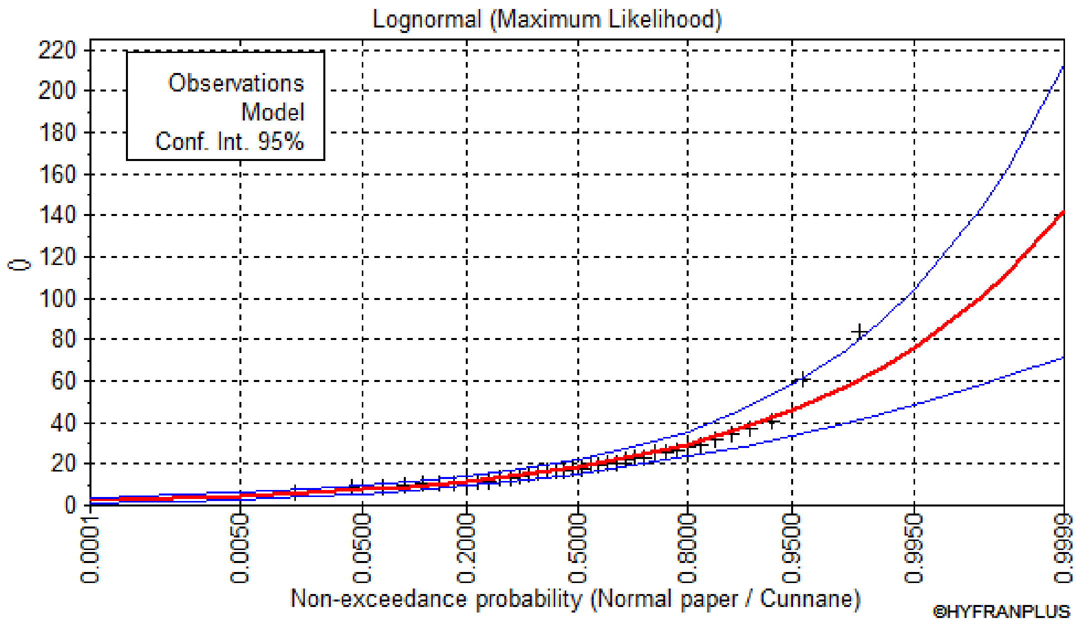


Figure 2-11: Frequency Distribution for Grise Fiord (Station ID: 1754 and 46568) Daily Precipitation Data

Table 2-2: Return Period Rainfall Amounts for Grise Fiord (1984 to 2021) (mm)

Return Period (years)	24-Hour Rainfall Depth (mm)
200	76.1
100	66.4
50	57.2
20	45.7
10	37.5
5	29.5
2	18.6

2.3.2.1 Regional Analysis

The rainfall depths shown in Table 2-2 above were used as input into a rainfall-runoff model for Grise Fiord community, where catchment areas are relatively small (less than 1 km^2). However, a rainfall-runoff approach is not suitable for the largest river which flows through Grise Fiord and has a catchment area of 33.9 km^2.

The hydrology for the large river was evaluated using a regional analysis approach. Regional analyses are used to estimate flow in ungauged watersheds by using relationships based on measured flows in gauged watersheds with similar physiographic characteristics. The hydrologic assessment in this report presents estimates of 2-year through 200-year peak flows at the bridge location.

Water Survey of Canada (WSC) hydrometric stations in the vicinity of the project site were reviewed to find gauged watercourses with similar watershed characteristics and sufficient data for meaningful statistical analysis. Two stations were selected for the analysis prior to further screening for physiographic characteristics similar to the watershed draining to the Grise Fiord river. Station information is included in Table 2-3 below.

Table 2-3: WSC Regional Stations

Station ID	Station Name	Latitude (DMS)	Longitude (DMS)	Watershed Area (km^2)	Period of Record	Data Available (years)	Status
10VC001	Allen River Near the Mouth	74° 50' 48" N	95° 03' 31" W	448	1970-1984	14	Discontinued
10VC002	Mecham River Near Resolute	74° 41' 28" N	94° 48' 13" W	86.8	1971-2016	12	Discontinued

A frequency analysis was completed using peak flows for each station. Due to the short period of record, years in which both stations had a peak flow were analyzed with a best-fit linear regression line. This allowed synthetic data to be estimated for years in which only one station had a peak flow value, increasing the number of years with a data point to 16 years.

The statistical frequency analysis software, HYFRAN, was used to fit the flow data to selected best fit statistical distributions. Several probability distributions were tested, and the Gumbel distribution was selected as the best fit. For example, a chart of the Gumbel fitting used for station Mecham River Near Resolute (10VC002) is shown in Figure 2-2. Results of the frequency analysis are shown in Table 2-2 below. The accuracy of the analysis is dependent on the years of record for each station, with longer records yielding greater confidence in the results. Figure 2-4 includes 95% confidence lines for the Mecham River Near Resolute frequency curve, from which it is apparent that the confidence in a particular estimate decreases with increasing return period (larger non-exceedance probability). In other words, the confidence in a 2-year estimate (0.5 probability) is higher than for a 200-year (0.995 probability). The confidence in the larger return periods increases for data sets with longer periods of record.

Table 2-4: Frequency Analysis Results

Station	Allen River Near the Mouth	Mecham River Near Resolute
Watershed Area (km^2)	448	86.8
Years of Data	16	16
200-Year (m^3/s)	142.0	48.6
100-Year (m^3/s)	129.0	44.2
50-Year (m^3/s)	117.0	39.8
20-Year (m^3/s)	99.3	34.0
10-Year (m^3/s)	86.0	29.5
5-Year (m^3/s)	72.2	24.8
2-Year (m^3/s)	51.2	17.7

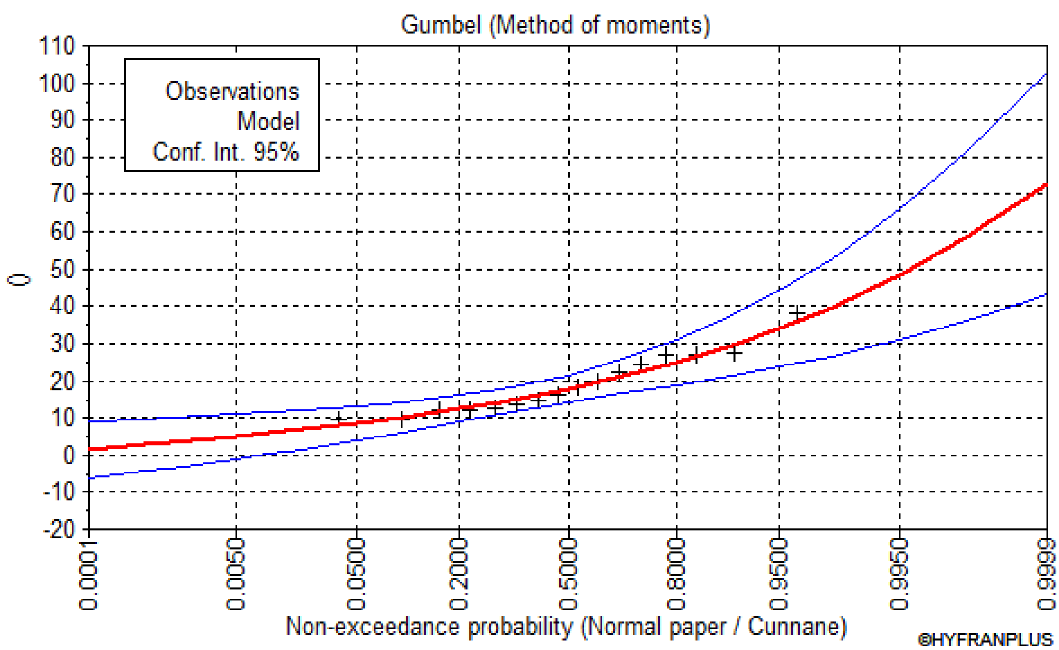


Figure 2-12: Frequency Distribution for Mecham River Near Resolute (10VC002) Peak Flow Data

As both stations have a larger watershed area than the Grise Fiord river (33.9 km^2), peak flows were adjusted using the equation:

$$Q_2 = Q_1 \times \frac{A_2}{A_1}^k$$

Where:

- Q_1 and Q_2 denotes flows of two watersheds;
- A_1 and A_2 denote watershed areas of differing size (km^2); and
- k is a peaking factor, recognizing heightened unitized runoff within smaller catchments. The Government of Saskatchewan's Hydraulic Manual specifies a factor in the range of 0.6 to 0.75 (Government of Saskatchewan Ministry of Highways & Infrastructure, 2014). To be conservative, a peaking factor of 0.6 was used.

Both WSC stations were adjusted for watershed area using the above equation. The Allen River Near the Mouth station results were the larger of the two sets of return-period data and were selected to be conservative. The results are shown in Table 2-3 below.

Note that due to the short period of record (16 years) and the large distance between Grise Fiord and the WSC stations which are both near Resolute, our confidence level in the flowrate estimates in Table 2-5 is low, particularly for the events larger than the 10-year in return period. Installation of a flow monitoring gauge on the Grise Fiord river is recommended to calibrate the estimated flowrates for improved accuracy.

Table 2-5: Frequency Analysis Results for Grise Fiord River at the Bridge

Return Period	Flowrate Estimate (m3/s)
200-Year	30.15
100-Year	27.39
50-Year	24.84
20-Year	21.08
10-Year	18.26
5-Year	15.33
2-Year	10.87

2.3.3 Climate Change Predictions

2.3.3.1 Grise Fiord Regional Climate Projections

Due to extreme rainfall flows being the dominant high flow events for the project region, it was assumed that peak flows are related to summer and fall precipitation depths. Climate change effects on peak flows were assessed with a simplifying assumption that the magnitude of these effects will be similar to modelled climate change effects on summer and fall precipitation.

Climate model data was obtained from the Pacific Climate Impacts Consortium (PCIC) Climate Explorer[1] for the summer and fall (June to November) Precipitation RCP 8.5 (high carbon) scenario. An ensemble[2] mean was calculated from six Global Climate Models recommended by PCIC for western North America and selected for having seasonal precipitation outputs. Results are shown in Table 2-6.

Table 2-6: Ensemble Global Climate Model June to November Mean Daily Precipitation for Region Including Project Site

Model Period	Min	Max	Mean	Median	Std. Dev	Units
1961 – 1990	0.48	0.73	0.61	0.61	0.04	mm/day
1971 – 2000	0.46	0.76	0.63	0.64	0.04	mm/day
1981 – 2010	0.50	0.81	0.65	0.63	0.04	mm/day
2010 – 2039	0.54	0.92	0.72	0.72	0.05	mm/day
2040 – 2069	0.65	1.17	0.82	0.78	0.05	mm/day
2070 – 2099	0.70	1.38	0.91	0.88	0.06	mm/day

Using the above projections in Table 2-4, an average increase in summer and fall precipitation of 27.6 percent is estimated for the project area for the time period of 2070-2099 versus the current time period of 2010-2039. Linear interpolation was used to adjust the median year of the 2010-2039 time period to the year 2021.

As a comparison, climate change effects on short duration rainfall events were reviewed using the IDF_CC Online Tool v5.0 developed by Western University (Simonovic, Schardong, Gaur, & Sandink, 2018). The tool provides rainfall intensity-duration-frequency (IDF) data from historic observations and climate change adjusted scenarios from the PICI bias corrected 24 GCMs. Projected IDF data for the RCP 8.5 scenario and the time period of 2021 to 2085 resulted in an expected precipitation intensity increase of 28.9 percent.

The 2085 time period used in the IDF_CC tool was selected to coincide with the median year of the PCIC model period which was used (2070 - 2099). This 2085 time period allows for a 50-year design life from the expected community expansion plan completion in 2035.

The PCIC Climate Explorer and IDF_CC projections are reasonably consistent. Climate change effects on project area peak flows were estimated using an average of the two methods, which resulted in an estimated 28.3 percent increase.

2.3.3.2 Short Duration Rainfall Events

Projected IDF data for the RCP 8.5 scenario and the time period of 2021 to 2085 is listed in Table 2-7. Hydrologic modelling of Grise Fiord was conducted based on these climate change adjusted rainfall depths. For the Grise Fiord river, the estimated peak flowrates were also adjusted by the climate change factor described above. The culverts downstream of the bridge were analyzed and sized using the climate change adjusted flowrates shown in Table 2-8.

- [1] https://services.pacificclimate.org/pcex/app
- [2] The models selected for ensemble analysis were: GFDL-ESM2M; GFDL-ESM2G; GFDL-CM3; CNRM-CM5; CanESM2; and MIROC5

Table 2-7: Projected IDF at Grise Fiord (mm) Including Climate Change Adjustment

Return Period (years)	24-Hour Rainfall Depth (mm)	24-Hour Rainfall Depth Including Climate Change Adjustment (28.3%, mm)
200	76.1	97.64
100	66.4	85.19
50	57.2	73.39
20	45.7	58.63
10	37.5	48.11
5	29.5	37.85
2	18.6	23.86

Table 2-8: Peak Flowrates for Grise Fiord River at the Bridge Including Climate Change Adjustment

Return Period	Flowrate Estimate (m^3/s)	Flowrate Estimate Including Climate Change Adjustment (28.3%, m^3/s)
200-Year	30.15	38.68
100-Year	27.39	35.14
50-Year	24.84	31.87
20-Year	21.08	27.05
10-Year	18.26	23.43
5-Year	15.33	19.67
2-Year	10.87	13.95

2.3.4 Climate Change Implications

Due to limited climate change research available for the Hamlet of Grise Fiord, relevant findings from Lewis and Miller's "*Climate Change Adaptation Action Plan for Iqaluit*" (2010) was utilized for this section of the report. Lewis and Miller (2010) presented a summary of perceived sensitivities to climate change in Iqaluit, including the following:

Infrastructure

1. *Damage to infrastructure is expected to increase due to increases in climate variability and extreme events.*
2. *A decrease in the permafrost layer was identified as the most significant climate-related concern for infrastructure.*
3. *The following may be particularly at risk: buildings with shallow foundations; buildings, roads and buried pipes along steep south facing slopes and/or in areas of high snow accumulation; any building or road in areas of poor drainage where water may pool.*
4. *The following infrastructure may be vulnerable to other climate change impacts: buildings or piping in poor condition due to age, absence of regular maintenance, outdated design or over-extended use; infrastructure*

located along the coast which may be susceptible to damage from flooding or storm surges; the drainage system which may be impacted by changes in precipitation; and the City's water supply.

5. *All new municipal infrastructure shall be designed and constructed to specifications that withstand projected changes in climate over their expected design life and meet sustainable development standards.*

6. *City outfalls should be designed to fall outside the range in tidal variability.*

Buildings

7. *With an increase of the active layer of permafrost, many existing building foundations could experience structural damage.*

8. *With a change in weather patterns such as extreme storm events, more extreme temperature variations, increased humidity in snow and more rain, buildings will be more susceptible to weathering and moisture damage.*

9. *Some waterfront buildings are vulnerable to flooding at extreme high tides or under storm surge conditions and minimum foundation levels may need to be established.*

Water Supply System

10. *Changes in permafrost will have implications for both existing and new underground piping.*

11. *Warmer air temperatures could cause surface evaporation of the City's water supply and could eventually reach temperatures that allow algae and other micro-organisms to grow, thereby compromising water quality.*

12. *Increased rainfall could potentially put the municipal water supply at risk by washing contaminants and soil into the reservoir.*

Wastewater Treatment System

13. *Increased precipitation, in the form of heavy rainfall, could overwhelm the system and cause failure or overflow, which could contaminate adjacent water bodies.*

Waste Disposal System

14. *Increase in the active layer of permafrost could lead to changes the freeze-thaw cycle, drainage and water flow around the landfill. Design and operation of the landfill needs to take this into consideration.*

3.0 EXISTING DRAINAGE SYSTEM AND ISSUES

A critical task in the development of a Drainage Master Plan is to identify, assess, and log all critical drainage infrastructure and known deficiencies. For Tetra Tech, the process included documenting the geometric locations, descriptions, and conditions of the physical assets that form the Grise Fiord drainage system. Using field and desktop data, this information was used to build a georeferenced map of the drainage infrastructure. The inventory also includes the location and description of existing issues such as ponding and damaged culverts. The following sections describe the activities conducted during the site visit, and the development of the georeferenced map detailing the drainage system.

3.1 Site Visit

A site visit was conducted from July 20th – 22nd, 2021 by Tetra Tech hydrotechnical engineering staff Eric Rothfels. The purpose of the site visit was to:

- Conduct a walkthrough inspection of the drainage system of the Hamlet;
- Conduct informal interviews with local residents regarding known drainage issues; and
- Document and develop a photo inventory of all drainage infrastructure and discernible issues.

3.1.1 Walkthrough Inspection

A walkthrough of Grise Fiord was conducted from July 20th – 22nd, 2021 with the following objectives:

- Develop an understanding of the drainage patterns through the Hamlet;
- Identify main drainage routes and infrastructure assets;
- Document GPS points of key infrastructure locations, including upstream and downstream culvert ends;
- Measure culvert dimensions and document culvert conditions;
- Identify ponding areas and uncontrolled overland flow;
- Record a photo inventory of key elements of the drainage infrastructure;
- Identify drainage outlet/outfall locations; and
- Conduct informal interviews with Hamlet residents.

A complete inventory of all existing culverts documented and photographed within the Hamlet during this field visit is included in Appendix E.

3.2 Development of Georeferenced Mapping

Using the GPS points, field notes and photographs obtained during the site visit, the topology of the drainage network was put together in a GIS shapefile. The shapefile includes locations of open channels (ditches and swales) or culverts. A naming convention was developed, and every asset was named in the shapefile. Connectivity of the drainage system was developed using data from the site visit and supplemented by mapping data provided by CGS. A separate shapefile was created to mark areas with drainage issues identified during the site visit. The drainage issues identified included ponding areas, damaged culverts, uncontrolled overland flow and erosion issues. The Drainage Issues Map included in Appendix I highlights the documented issues.

3.3 Drainage

Grise Fiord's drainage patterns follow the natural relief, however the construction of fill pads for buildings and road embankments have modified the natural streams and lead to an increase in surface runoff and peak flows. A large portion of the runoff in Grise Fiord originates from the steep slopes behind the community, with the headwaters of the watercourses located within the mountainous region east of the community. The largest watercourse running through the community originates approximately 8 km northeast of the hamlet. We estimate the largest watercourse to have a watershed area of approximately 33.8 km^2.

Tetra Tech has completed a delineation of the existing subcatchments within the Grise Fiord region using the 2020 Digital Surface Model (DSM) as well as from observations and photographs collected during the site visit. Drainage areas and flow paths are presented on Figure 2-1 in Section 2.2.1.

Based on the 2016 Community Plan, land allocated for future expansion is located primarily in two locations southeast of the community. The development of proposed drainage channels and drainage infrastructure for these future expansion areas is included within the scope of Tetra Tech's Master Drainage Plan.

3.4 Drainage Infrastructure

During the 2021 site visit, existing culverts, ditches, swales, and natural streams were inspected. A total of 76 culverts were assessed as part of this site visit. The diameter of the culverts ranged from 100 mm to 1200 mm, with the majority having a diameter of 450 mm, 600 mm, or 750 mm. A significant number of these culverts were damaged and/or partially/fully buried. As such the existing functionality of each culvert varies significantly. An Inventory of Existing Culverts and their conditions is included in Appendix E.

3.5 Drainage Issues

Developing and maintaining a well-functioning drainage system is an ongoing concern for northern communities which experience harsh climates and rely on semi-permanent infrastructure. During Tetra Tech's 2021 site visit, several categories of drainage issues in Grise Fiord were identified. Of the existing culverts, many were damaged, buried, and/or blocked with sediment, rocks, and debris. Through interviews with local residents, Tetra Tech documented both areas susceptible to flooding and culverts susceptible to damage or blockages. The lack of formalized swales is a separate issue which promotes the ponding of water and surface overflow across roadways leading to washouts and erosion during larger rain or snowmelt events.

Location specific drainage issues noted during the field investigation through observations and discussions with the local residents are as follows:

- Ponding was observed near the Hamlet's water storage silos. Poor grading and lack of a swale to drain surface water in this area was noted. The nearby Culvert C19 was found to be damaged and lacking cover. Holes along the top of the culvert were noted which allows water to flood the surface during a large storm event.
- Several culverts were crushed by heavy-vehicle traffic due to lack of cover depth, including culverts C26, C19, C34, C35, C11, and C6. These culverts should be installed deeper when replaced.

- A local resident pointed out the groundwater surfacing issue around the Co-op store. This issue is caused by stormwater and freshet flows infiltrating into the soil at higher elevations east of the community and then surfacing in the community where grades flatten. The Tetra Tech representative was informed by the local resident that the foundation of the store is possibly being impacted.
- Ponding was observed in the parking lot of the new hamlet government building by the storage containers. The ponding occurs due to improper grading.
- Overland flow along roadways was noted in the following locations:
  - along the road from the new community learning centre down to the church;
  - along the road from the airport down to the curve; and
  - on the road on the south side of the bridge.

These overland flows can be mitigated by adding a crown to the road geometry. The crowned road surface works to direct surface water off of the road surface where it can be collected and transported using roadside swales.

A summary of the most common drainage issues observed throughout the community of Grise Fiord are detailed in Table 3-1 below.

Table 3-1: Most Common Grise Fiord Drainage Issues

Issue	Cause
Spring Flooding	Yearly extreme runoff volumes. Culverts blocked by ice/snow.
Damaged Culvert Inlet/Outlet	Damage caused by snow removal and/or spring de-icing activities
Undesirable Flows which Cross Roadways and Traverse Residential Properties	Lack of formalized Ditches/Swales and blocked Culverts
Buried or Blocked Culvert Inlet/Outlet	Culvert inlet and/or outlet blocked due to sediment, rock, and debris deposition, and/or ice blockage.
Ponding	Blocked culverts, poor grading, vegetation overgrowth, lack of outlet.
Erosion	Velocity threshold for erosion is exceeded.

The Drainage Issues Map in Appendix I identifies Grise Fiord's existing drainage infrastructure, locates the typical issues described above and specifies an existing condition for all culverts within the community. Tables 3-1 and 3-2 provide guidance as to each of the condition categories, how the conditions assigned are defined and the potential remediation actions available to the Hamlet. Appendix E includes a summary of the existing culverts identified within the community and their condition. Tetra Tech's recommended action for each culvert is provided in Section 5.0 - Drainage Master Plan.

Table 3-2: Existing Culvert Condition Categories, Descriptions and Potential Actions

Culvert Condition	Description	Potential Actions
Functioning as Intended	Full Conveyance Capacity (80-100%) No Damage	No Action Required, Relocate, Upsize
Damaged	Non-superficial Damage Observed. Damage is the primary concern.	Repair, Replace, Abandon
Blocked	Inlet or outlet is completely blocked or buried. Blockage is the primary concern.	Remove Debris, Replace, Abandon
Partially Damaged	Non-superficial Damage Observed. Damage is the primary concern, but is minor in nature such as repairable damage to the ends	Repair, Replace, Abandon
Partially Blocked	Capacity Restricted (30-70%) due to Sediment Build Up	Remove Debris, Replace, Abandon
Undersized	Capacity is inadequate for conveying observed flows.	Upsize, Abandon

3.5.1 Example Photos

Figures 3-1 to 3-9 depict examples of the typical drainage system deficiencies identified during Tetra Tech's site visit.

Figures 3-1 to 3-9: Example Photos of Grise Fiord Drainage Issues from July 20 – 22, 2021 Site Visit

Figure No.	Description	Image
3-1	Buried culvert inlet (Culvert C12)	

Figure No.	Description	Image
3-2	Damaged culvert. Insufficient cover. (Culvert C34)	
3-3	Undesirable flow crossing the roadway on the south side of the bridge	

Figure No.	Description	Image
3-4	Ponding (Beside the Church)	
3-5	Ponding due to poor grading (Near the new Government building)	

Figure No.	Description	Image
3-6	Undesirable Flow across roadway due to lack of formalized swales	
3-7	Repairable Damage on Inlet of Culvert C8	

Figure No.	Description	Image
3-8	Damaged Culvert inlet due to lack of cover and/or snow clearing activities. (Culvert C11)	
3-9	Erosion through ditch behind Co-op store	

4.0 ANALYSIS OF DRAINAGE SYSTEM

The Drainage Principles, Design Criteria, Design Scenarios and Modelling Results used to develop the proposed conveyance system for the Hamlet of Grise Fiord are described in this section of the report. Overarching recommendations for improvements are also provided at the end of this section.

4.1 Drainage Principles

According to the guidelines for Community Drainage System Planning, Design, and Maintenance in Northern Communities (CSA Group, 2015), the drainage system should be designed in accordance with the level of risk that is established during the planning process. The CSA Group also noted that:

- “It is recognized that the capacity of any drainage system might be exceeded at some point”;
- “The design will be impacted by physical constraints present within communities”;
- “The desired acceptable level of risk might not be achievable in any given community due to physical (spatial) limitations, resources, subsurface conditions, and topography, among other factors”;
- The acceptable level of risk established might be impacted by the changing the climate, for example, due to the changing climate, what was previously considered to be a 1-in-10 year event might occur on average every five years in the future”.

In addition to the CSA Group’s design principles, the development of the proposed upgrades was based on Tetra Tech’s own best practice principles as follows:

1. Effectively capture and route water around populated areas to protect buildings and communities.
    a. Where possible, minimize the imposition of waterways through populated areas and by forcing water towards the edges of the more populated areas.
2. Utilize shallow swales for driveway crossings and roadside drainage.
3. Minimize complexity for drainage system construction, maintenance, and management by:
    a. Minimizing the number of different culvert diameters specified.
    b. Minimizing the number of new culverts, which would not only need to be barged to Grise Fiord for installation, but also need to be maintained once installed.
    c. Minimizing the number of different ditch and swale dimensions specified.
    d. Keeping the design simple such that the Hamlet foreman and crew can not only construct but also maintain the new drainage systems with ease.
4. Capture and immediately convey water towards the nearest major watercourse/waterbody (i.e. ocean, lake, river, or stream).
5. Use multiple outlets to add redundancy at critical locations throughout the system.
6. Design using projected precipitation trends to account for future climate change.

7. Select culvert sizes based on available roadway embankment cover.
8. Provide drainage swales through driveways to comfortably accommodate the tires and undercarriage of vehicles.
9. Develop plans recognizing the land use limitations, for example remove nuisance ponding from community amenity areas and from the foot of exterior staircases leading to residences.

4.2 Design Criteria

As per the guidelines for community drainage system planning, design, and maintenance in northern communities (CSA Group, 2015), the culvert design capacity prescribed by the CSA Group is:

- Size culverts to accept design flow at 80% capacity under free flow condition (1:10 year event).
- Size culverts to accept 1:100 design flow at 80% of available head at entrance.

In addition to the above requirements the proposed drainage system was developed to meet the following general criteria:

1. Ditches and swales were sized to convey the 10-year 24-hour storm event. The 10-year 24-hour storm event was selected as the critical 10-year event following a review of freshet snowmelt events and a number of rainstorm durations ranging from 1 hour to 24 hours. The goal was to provide sufficient capacity to handle the critical event. Tetra Tech has further upsized the culverts to add additional capacity to compensate for debris deposition blocking the culverts and limiting their capacity. Buried culverts and significant deposition was noted in the majority of culverts identified in the field visit described in Section 3.1.
2. Ditches were sized to maintain at least 100 mm of freeboard during the 10-year 24-hour storm event.
3. Swales were sized to maintain at least 50 mm of freeboard during the 10-year 24-hour storm event.

4.3 Design Scenarios

A rainfall-runoff model was created for the Grise Fiord community, where catchment areas are relatively small (less than 1 km^2). All of the drainage infrastructure in the community was designed using the rainfall-runoff model with the exception of culverts C30 and C31 which convey the Grise Fiord river and were modelled using a regional analysis approach due to its large catchment area. The regional analysis design approach is described in Section 2.3.2.1.

The rainfall-runoff model was run under five design storm scenarios as follows:

- 10-Year 1-Hour Rainfall;
- 10-Year 24-Hour Rainfall;
- 100-Year 1-Hour Rainfall;
- 100-Year 24-Hour Rainfall; and
- 100-Year Snowmelt.

To develop the 24-Hour storm distribution, hourly historical data extracted from the Iqaluit A weather station was used to develop a synthetic hyetograph which represented the intensity pattern likely to develop over the course of a 24-hour rainfall event.

The 1-hr storm intensities were developed using the Northern Quebec AES distribution. Computed short duration rainfall characteristics in the form of Intensity Duration Frequency (IDF) data for Grise Fiord was obtained from the online IDF_CC Tool v5.0 developed by Western University (Simonovic, Schardong, Gaur, & Sandink, 2018). The IDF_CC tool provides ungauged rainfall intensity-duration-frequency data. The IDF curves are calculated using historical data from nearby gauged locations. Climate change adjusted precipitation volumes for each of the scenarios were obtained using the adjustment factor as described in Section 2.3.2 of this report.

The snowmelt events were estimated by running a continuous model of Grise Fiord between 1985 and 2006. Annual peak freshet flowrates were generated over this time span. A statistical analysis was carried out on the annual flowrates to produce 10-year and 100-year snowmelt-driven return events.

Following an analysis of the peak flow rates for each design storm, Tetra Tech determined the 24-hour rainfall events to be the critical storm events. As an example, the 24-hour rainfall design storm flowrates in culvert C10 are summarized in Table 4-1. Peak flowrates are shown in culvert C10 as it is the largest culvert crossing in the community with the exception of culverts C30 and C31 which convey the Grise Fiord river and were modelled using a regional analysis approach described in Section 2.3.2.1.

Table 4-1: Rainfall-Runoff Model Design Storm Events

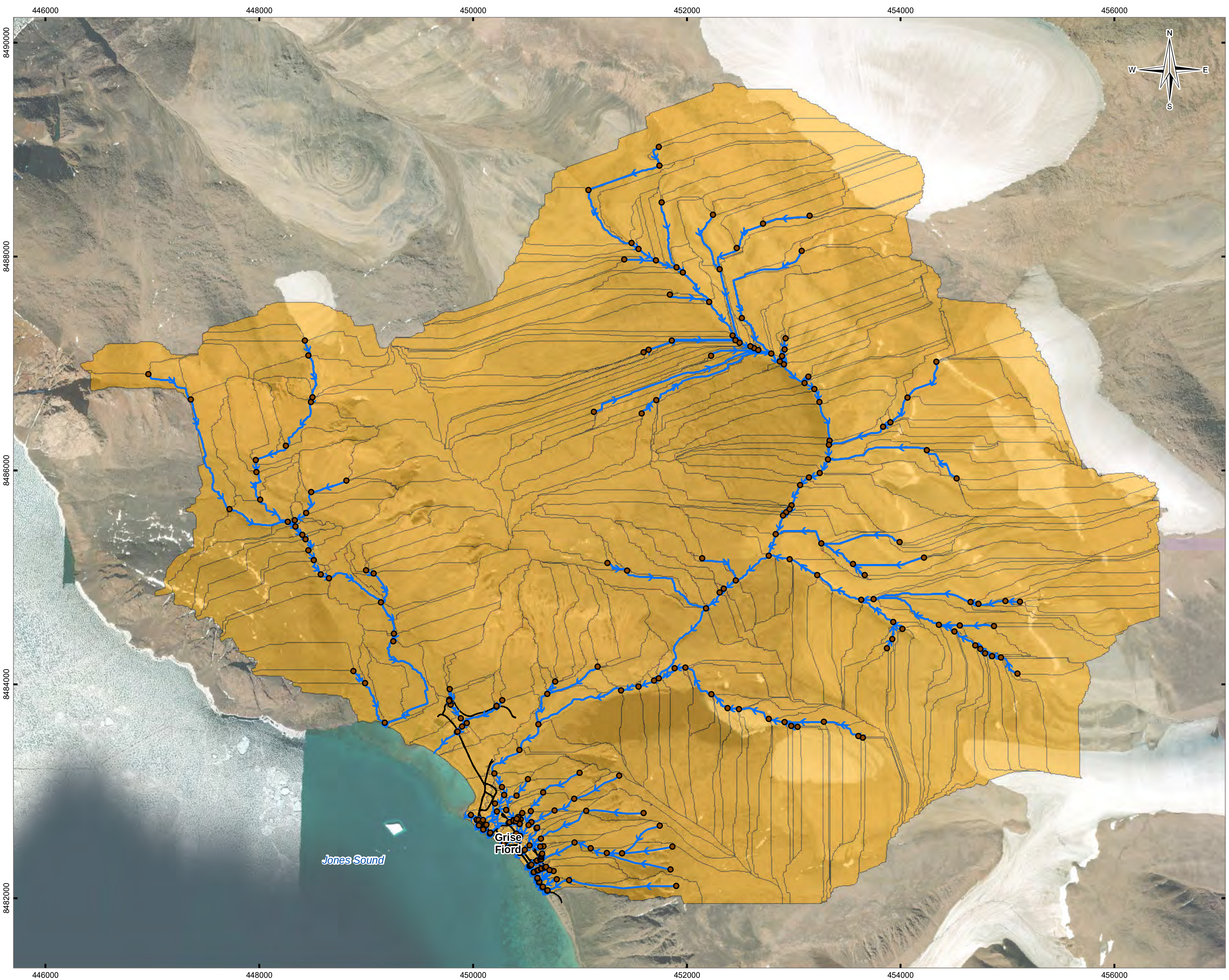
Design Storm Events	Peak Flow Rate (m^3/s) *
10-year 24-hour	1.12
100-year 24-hour	2.18

* Peak Flow Rate measured through culvert C10 in the PCSWMM model. All flow rates include the 28.3% climate change adjustment factor discussed in Section 2.3.2.

4.4 Modelling of System

A systems analysis approach was adopted to design the proposed drainage system for the Hamlet of Grise Fiord. PCSWMM, a stormwater modelling program, was used to develop the model of the drainage system. The model uses a node-link arrangement where links represent conduits, such as ditches and culverts; and junctions represent a point where two or more links are joined, according to how the drainage network operates.

In addition, the drainage area is split into subareas or subcatchments, which are the hydrologic units used to calculate flows. Flows calculated from a subcatchment area assigned to a junction, and then hydraulically routed through the drainage network. Through this approach, flows are aggregated through the system until discharged to an outfall point. Figure 4-1 shows the sub-catchments, junctions and conduits represented in the model. Input parameters for the subcatchments, junctions and conduits are presented in Appendix H.



LEGEND

- Junction
- Natural Drainage Path
- Subcatchment
- Gravel Road

NOTES
Base data source:
1. Grise Fiord road data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN
GRISE FIORD, NU

PCSWMM Model of Natural Drainage Paths

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:35,000
700 350 0 700
Metres

TETRA TECH

FILE NO.
WTRI03028-01_Subcatchments.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	DS	SL	ER	0

DATE	PROJECT NO.
December 1, 2021	ENG.WTRI03028-01

Figure 4-1

Although the typical process followed in developing a stormwater management plan includes the development of a hydrologic/hydraulic model of the existing system, the absence of a proper drainage system within the community led Tetra Tech to move directly to modelling the proposed system and using these results to size and identify the infrastructure upgrades required to convey the estimated flows.

After modelling the scenarios described in Section 4.3, Tetra Tech proposes that 16 of the existing culvert crossings be replaced and that 16 new culverts be added to the existing system (see Table 4-2). In addition, Tetra Tech is recommending that a formal system of swales and ditches be integrated into the community allowing for the systematic and effective conveyance of runoff. Table 1 in Appendix D shows the specifications and modelled performance of the proposed culverts for the 100-year 24-hour design scenario.

Tetra Tech is recommending that the proposed new culverts range in size between 450 mm to 1400 mm, with the exception of C30 and C31 which are proposed to be 3600 mm by 1200 mm box culverts with two barrels at each crossing. Further to this, all culverts being replaced will be 450 mm in diameter or larger. This sizing approach upholds the CSA recommended 450 mm minimum diameter criteria.

It should be noted that in certain cases swale profiles and site limitations will force the embedment of some culverts so as to meet the minimum depth of cover requirements set by the supplier. The minimum cover requirements must be met to ensure the structural integrity of the culvert. Figure 4-2 provides a schematic representation of the typical installation details where the integration of the minimum depth of cover requires culvert embedment.

Table 4-2: Summary of Recommended Culvert Actions

Recommended Culvert Action	Number of Culverts	Total Length (m)
EXISTING CULVERTS		
No Action Required	5	80
Abandon	6	133
Remove Debris	1	17
Repair	8	86
Replace / Upsize	16	126
Total Existing Culverts	**36**	**442**
NEW CULVERTS		
Within Existing Community	15	181
Servicing Future Community Expansion	1	15
Total New Culverts	**16**	**196**

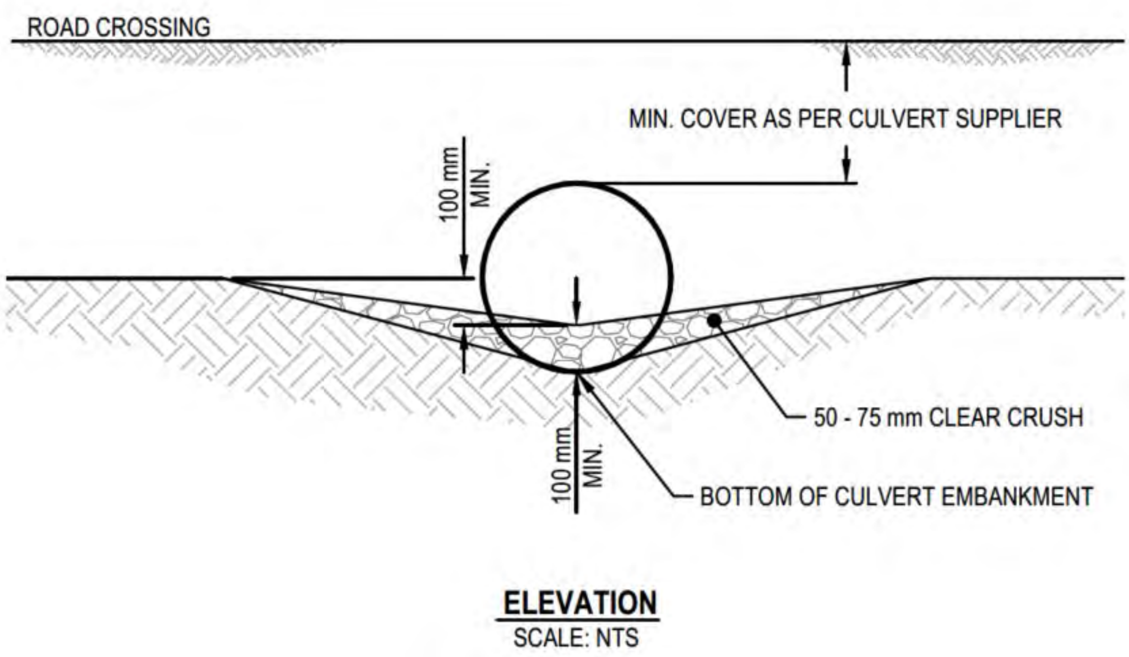


Figure 4-2: Typical Embedded Culvert Details

4.5 Drainage Recommendations

This section summarizes the recommended actions needed to upgrade the Level of Service provided by Grise Fiord's Drainage System. Currently, there are a number of deficiencies as identified in Section 3.0. Tetra Tech has developed the following series of recommendations which if implemented will remedy the previous issues identified throughout the community. The proposed improvements include the upgrading of culverts, ditches and swales.

4.5.1 Culverts

Table 1 in Appendix D provides a full inventory of Grise Fiord's existing culverts including recommended actions for each culvert. Tetra Tech's overarching culvert recommendations are provided below.

1. The minimum culvert size should be 450 mm as per the culvert size recommendations from CSA Group (2015) for de-icing purposes.

2. Cover over culverts shall meet the structural requirement set by the supplier. Tetra Tech recommends a minimum cover of 300 mm where vehicular traffic is likely to be present.

3. All newly installed culverts are to be Smooth Wall Steel Pipe (SWSP). The use of SWSP with a gauge of 10 to 12 mm will ensure the long-term durability. As detailed in Appendix E, the majority of corrugated steel pipes in Grise Fiord have failed to retain their structural integrity and are often damaged by maintenance equipment and road traffic.

   If CSP culverts are preferred, Tetra Tech recommends the use of a culvert end steel stiffener/sleeve to better protect the structural integrity of the culverts. A sample photo of a culvert end stiffener is included in Appendix

B. Note that Tetra Tech recommends a stiffener length equal to 2 times the culvert diameter. Details of a culvert end stiffener/sleeve are included in Figure 5-2 in Section 5.6.1.

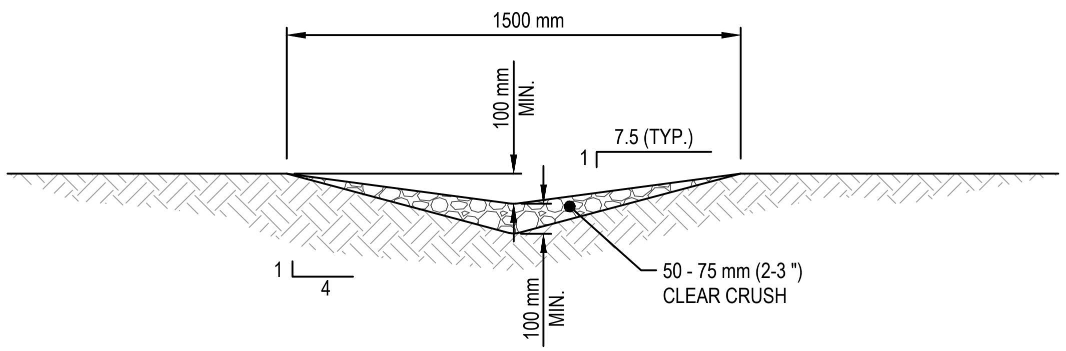
4. Culverts should be provided with high visibility marker poles to prevent damage during spring cleaning activities.
5. An annual maintenance program should be implemented to prepare the system for the spring freshet. This may include the steaming of specific culverts and/or the removal of debris limiting the capacity of the culvert crossings. Maintenance is further detailed in Section 5.6.
6. Based on the areas of erosion noted during our site visit and on water velocities modelled using PCSWMM, Tetra Tech recommends the use of riprap aprons for culvert inlets and outlets.
7. Culverts are to extend a minimum of one diameter past the embankment to protect against embankment erosion.
8. Headwall and end-wall side slopes are to be between 1.5H:1V to 2H:1V. Side slopes of 2H:1V are preferred where space allows.
9. Riprap headwalls and end-walls are recommended for erosion protection and slope stability. Where space does not allow for riprap protection, culvert inlets and outlets should include a concrete headwall alternative. Figure 4-5 shows typical riprap headwall and end-wall details.
10. Culvert headwalls and end-walls should be armored with riprap and include a non-woven geotextile lining underneath of the riprap layer. Headwalls protect road embankments from erosion and improve the stability of the slope, and should be installed on all culvert crossings in the community. However, recognizing budgetary constraints as well as the need to prioritize the most in-need crossings, headwall and end-wall protection is most critical on culverts larger than 1.0 m in diameter. A typical riprap headwall detail is shown in Figure 4-5.

4.5.2 Ditches and Swales

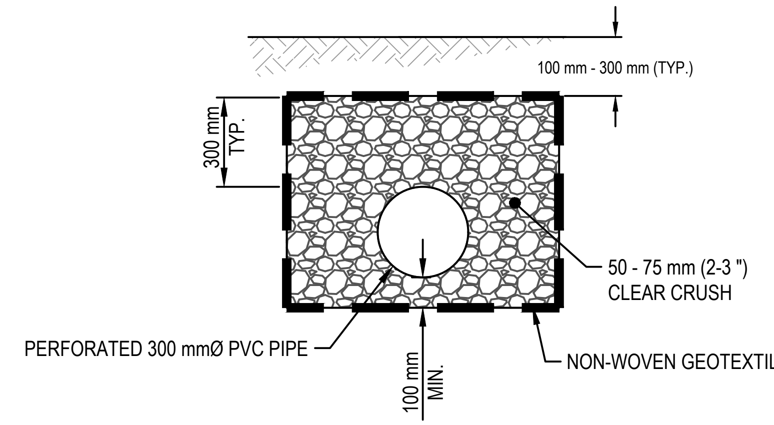
1. Open channels must include a revetment system for erosion protection, particularly in areas where permafrost can be impacted. Failure to do so may lead to hydraulic erosion, which in turn may lead to thermal degradation of the permafrost layer.
2. The slope of ditches and swales should be as gradual as possible with a minimum slope of 0.5% being maintained.
3. Ditches are to have a minimum bottom width of 750 mm, a minimum depth of 750 mm and side slopes between 1.5H:1V to 2H:1V. Flatter side slopes should be considered near schools and children's playgrounds.
4. Ditches are to be lined with a 10 kg class riprap layer having a minimum thickness of 350 mm. See Figure 4-4 for riprap gradation.
5. Ditches are to be lined with a non-woven geotextile between the existing soil and the specified riprap layer.
6. Swales are to have a minimum depth of 100 mm. Swale side slopes are to be a 7.5H:1V minimum to allow for vehicular traffic to safely cross without damage. Swales are to be lined with a 50-75 mm (2-3") clear crush layer having a minimum thickness of 100 mm in the centre of the swale.
7. Figure 4-4 includes typical cross section details for the proposed ditches and swales.

8. The community of Grise Fiord may wish to increase the active depth of the existing swales throughout the community by raising the road profiles. This may be necessary to fully formalize the proposed swale sections detailed in Figure 4-3.

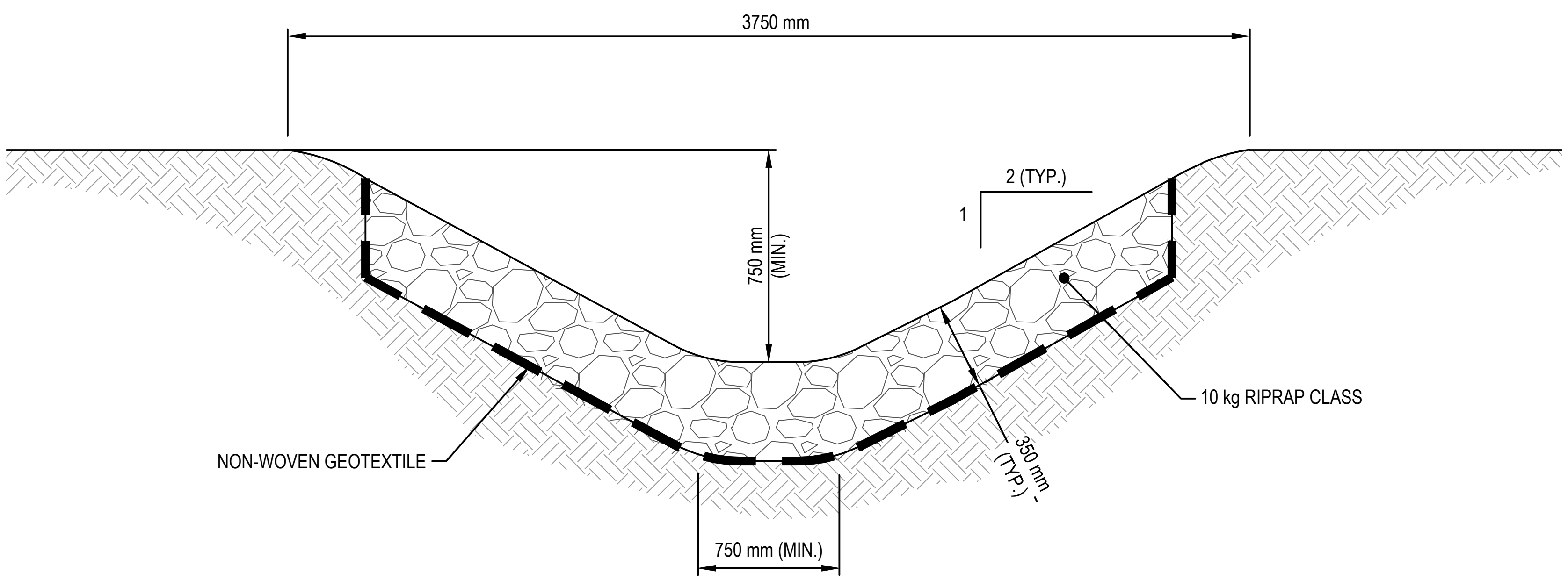
9. To the extent possible, ponding water nearby and underneath of buildings should be eliminated. Grading practices underneath buildings should promote the movement of water away from their footprints.



1 TYPICAL SWALE
FIG.1 SCALE: NTS



2 TYPICAL UNDERDRAIN
FIG.1 SCALE: NTS



3 TYPICAL DITCH
FIG.1 SCALE: NTS

10 kg RIPRAP CLASS			
ROCK GRADATION PERCENTAGE (kg)			
15 %	50 %	85 %	
1	10	30	
APPROXIMATE AVERAGE DIMENSIONS (mm)			
15 %	50 %	85 %	100 %
90	195	280	330

TYPICAL 50-75 mm (2-3") CLEAR CRUSH GRADATION
SCALE:NTS

LEGEND

NOTES

NUM	DATE	DWN	CKD	APR	DESCRIPTION
A	03/24/20	MJK	ER	DNM	ISSUED FOR REVIEW

REVISIONS

PROFESSIONAL SEAL

CLIENT

Nunavut

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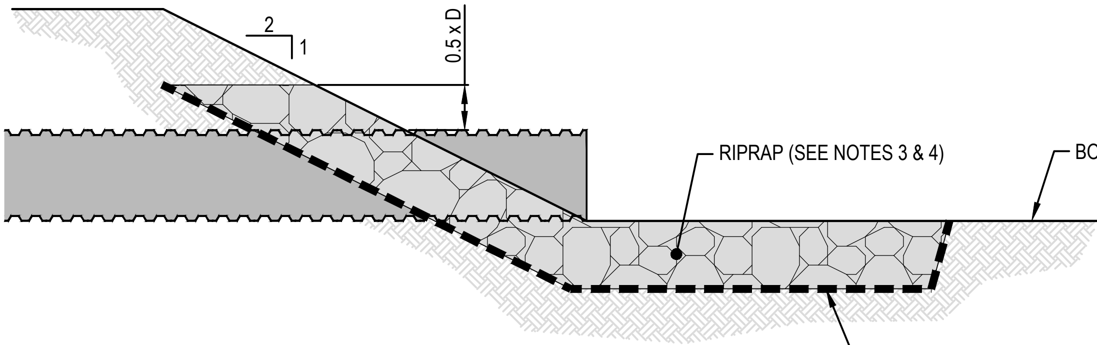
GRISE FIORD MASTER DRAINAGE PLAN

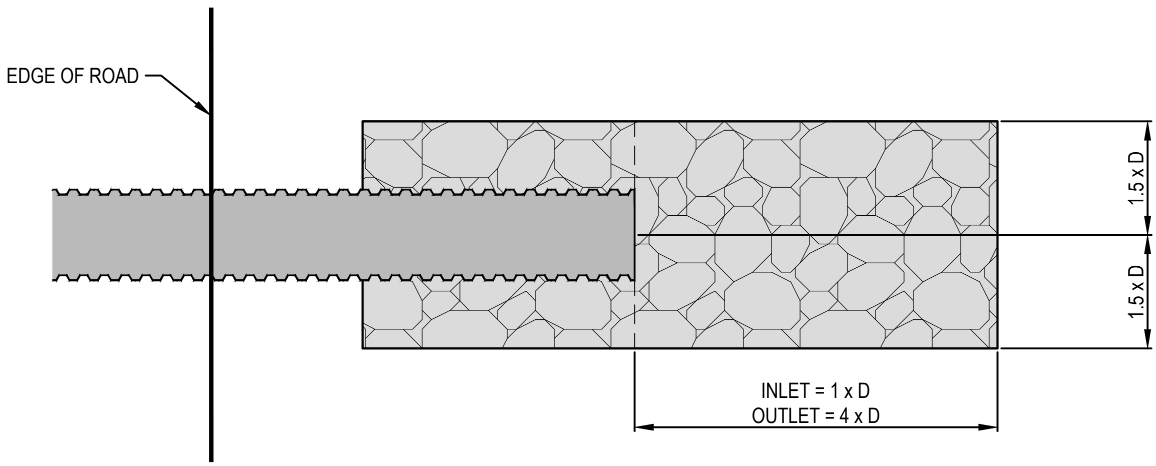
TYPICAL DITCHES AND SWALE DIAGRAMS

PROJECT NO.	OFFICE	DES	CKD	REV	DRAWING
WTRM03028-01	VANC	ER	ER	A	FIG.4-3
DATE	SHEET No.	DWN	APP	STATUS	
DEC. 17, 2021	- of -	ER	DNM	IFR	

C:\Users\Eric.Rothfels\OneDrive - Tetra Tech, Inc\Documents\Projects\Grise Fiord\CAD\WTRM03028-01_GF Drainage Project.dwg [FIG.4-4] December 13, 2021 - 5:57:07 pm (BY: ROTHFELS, ERIC)



SECTION



PLAN

1 CULVERT APRON DETAIL
SCALE: 1:50

NOTES:

1. D = Pipe Diameter
2. Riprap shall be 10 kg class or larger.
3. 10 kg class riprap layer shall be a minimum thickness of 350 mm.
4. 25 kg class riprap layer shall be a minimum thickness of 450 mm.
5. Riprap shall be placed in a controlled manner (no end dumping) to specified design slope.

ISSUED FOR REVIEW

SCALE 1:50
500 0 500 1000 2000mm

CLIENT

DRAINAGE PLANNING
GRISE FIORD, NU

TYPICAL CULVERT
RIPRAP PROTECTION DETAIL

PROJECT NO.	DWN	CKD	REV
ENG.WTRI03028	JDM	ER	A

OFFICE	DATE
VANC	DEC. 17, 2021

Figure 4-4

5.0 DRAINAGE MASTER PLAN

Based on our 2021 field investigation, background data review, and modeling work, Tetra Tech has developed the proposed upgrades for the existing drainage system and the planned community expansion areas. Features of the Master Drainage Plan include a Conceptual Drainage Design (Section 5.1), Grading Plan (Section 5.2), Construction Phasing (Section 5.4), and ongoing system maintenance (Section 5.6).

The proposed upgrades in combination with the outlined maintenance program, have been designed to convey the expected peak flows identified in Section 4.3 of this report as per CSA Northern Community Drainage Guidelines.

5.1 Conceptual Drainage Design

Tetra Tech has compiled all the existing and the proposed drainage infrastructure into a single conceptual drainage plan complete with recommended upgrades for existing infrastructure, flow routing improvements within the existing community and preliminary drainage recommendations for the future Hamlet expansion. The recommended system is comprised of ditches, swales and culverts and is laid out in Appendix K. Action categories have been created for both culverts and open channels. Tables 5-1 and 5-2 below outline and explain each action category.

Table 5-1: Culvert Action Categories and Descriptions

Action Category	Description
ABANDON	Culvert not functioning as intended and/or not necessary to the functioning of the drainage system. Complete removal of the culvert is preferred so to avoid future collapse of the pipe. Reuse of culvert may be possible if its structural integrity remains intact.
FUNCTIONING AS INTENDED	Culvert retains full capacity with no observed damage. No action required.
NOT ASSESSED	Culvert was not assessed by Tetra Tech staff during the 2019 site visit for due to one of the following: culvert was completely buried, culvert was not found, culvert was outside of the core community areas inspected by Tetra Tech staff.
RELOCATE	Culvert functioning as intended, but to be moved to a different location.
REMOVE DEBRIS	Culvert is blocked or partly blocked with sediment or debris. No damage observed. Sediment and/or debris to be cleared.
REPAIR	Culverts with damage where repair will restore full or near full capacity. Repair culvert as per Section 5.6.1 and clean out sediments as required.
REPLACE	Culverts damaged beyond repair to restore full capacity or culvert does not have sufficient capacity to convey the design flow events to CSA guidelines. In some cases, the culvert has been fully buried out of sight and assumed damaged beyond repair. This assessment can be revisited and revised as appropriate upon the culvert's excavation. **In some cases, repairs could still be completed to restore a reduced capacity if funding for replacement is not immediately available. Such culverts are noted as "Repair Possible" in Appendix D.**
UPSIZE	Culvert does not have sufficient capacity to convey the design flow events to CSA guidelines.

Table 5-2: Open Channel Action Categories and Descriptions

Action Category	Description
NEW DITCH	Install typical ditch as per Figure 4-4. This action applies to both existing and newly created overland flow paths.
NEW SWALE	Install typical swale as per Figure 4-4. This action applies to both existing and newly created overland flow paths.
WATERCOURSE	Stable stream or creek. No Action Required.

5.1.1 Drainage Design Recommendations

Recommendations in regard to the conceptual drainage design include the following:

1. As stated in Section 4.5.1, the Appendix D Culvert Summary Table details the recommended actions for each existing culvert. Several of the culverts which slated for replacement may also be replaced. Many of the culverts identified in the 2021 site visit have damaged ends. There were a number that were completely buried and we were not able to assess their condition. We recommend replacement in these cases; however, if the existing culvert is in good condition, unblocking it and repairing the damaged ends is possible. Where Tetra Tech indicated "Repair Possible," the culvert had sustained visible damage and/or was buried; however, the measured culvert size was determined to be adequate. In this case, repair may be a viable cost-saving alternative to replacement if the structural integrity of the culvert remains intact. A sleeve can be installed on damaged ends in this case as shown in Figure 5-2. Replacement and upgrade to solid steel pipe is still the recommended option for long-term durability.

2. Culvert C29 which drains the lake in the centre of the Hamlet was recognized as a key component to the proper functioning of the drainage system. Tetra Tech is proposing that a second culvert be added at this crossing for increased capacity and redundancy. This will help protect the community in the event that one of the culverts becomes blocked with ice and/or debris. We recommend that one of the culverts be installed slightly above the other. This way, water and debris will flow through only one culvert for the majority of the time, mitigating ice and debris blockages.

3. Tetra Tech recommends installing a series of new culverts and ditches instead of culvert C19 which is 55 m in length. The existing C19 culvert is badly damaged due to vehicle loads and a lack of cover. The proposed new culverts (C42, C43, and C44) are shorter in length which allows for easier access for maintenance. We recommend installing the new culverts lower than the existing culverts to provide sufficient cover depth to prevent damage from surface loads including heavy vehicle traffic.

4. Suprapermafrost groundwater (groundwater in the active layer) was noted to be surfacing around the Co-op store, causing overland flow drainage issues as well as potentially impacting the Co-op store's foundation.

    a. One potential solution to this issue is to dig the perimeter ditches behind the Co-op store deeper to try and intercept the suprapermafrost groundwater before it flows toward the store. The issue with this approach is that this would cause deeper soil to be exposed to warming summer air which melts the permafrost. In effect, this would cause the active layer thickness to increase, and the groundwater issue would persist deeper in the soil, underneath the deepened ditch.

    b. We believe a better solution is to install an underdrain system in the soil beneath the surface to mitigate damage to the permafrost layer. The underdrain would carry groundwater in the active layer away from the Co-op store and drain into the perimeter ditches. This is the proposed solution in the Conceptual Drainage Design map included in Appendix K. Details of the underdrain structure are to be provided in the detailed design phase. An example of a typical underdrain system is provided in Figure 4-4 in Section 4.5.2.

5. Culverts C30 and C31 downstream of the bridge did not meet the 10-year or the 100-year CSA culvert capacity requirements and were therefore determined to be undersized. Our preliminary recommendation for crossing C30 is to replace the existing CSP culverts with two (2) 3600 mm wide by 1200 mm rise reinforced concrete box culverts. Our preliminary recommendation for crossing C31 is to similarly replace the existing culverts with two (2) 3600 mm wide by 1200 mm rise reinforced concrete box culverts.

   Due to the large size of the proposed box culverts, Tetra Tech recommends confirming the sizing and design aspects such as coatings, embedment, and erosion protection in the detailed design phase. We recommend utilizing a 1D or 2D HEC-RAS model to analyze velocities and surcharge depths to support a detailed analysis to ensure the capacity is sufficient and to account for erosion and scour protection. Due to the proximity to the ocean, the presence of saline water should be expected, and a coating or treatment should be used to protect from the increased risk of corrosion. The extensive corrosion along the base of the existing culverts suggest that high salinity may be an issue.

6. As noted in Section 2.3.3, developing tension cracks were observed at the south end of the runway. The tension cracking is caused by riverbank erosion. Tetra Tech recommends the slope at the south end of the runway be remediated.

   To protect the runway, residential buildings, bridge, and culverts along the river from the risk of slope instability caused by erosion, a formal revetment system should be designed and constructed along the riverbank, from the toe of the runway to the C30 and C31 culvert crossing outlets.

5.2 Grading Plan

To aid in directing flows and reducing ponding, Tetra Tech has identified community areas where poor drainage conditions could be improved via regrading. Regrading locations are shown in Appendix J and are detailed below. Regrading locations work in conjunction with the Conceptual Drainage Design (Appendix K) to direct surface water towards drainage infrastructure where it is then conveyed through the community.

- Raising the road profile and adding a crown is recommended for all roadways in the Hamlet. However, recognizing budgetary constraints as well as the need to prioritize areas most in-need via phasing, Tetra Tech has included in the grading plan specific sections of roadways where raising the profile is most critical. These road sections were identified during the 2021 site visit as having a lot of ponding and/or overland flow. Crowning the road is a technique that can be used in combination with swales on the shoulders to prevent ponding and overland flow across roadways.
- For the areas highlighted as “Grade towards” or “Regrade to promote flow towards,” slope the grading areas in the direction indicated using cut and fill techniques to minimize the amount of fill material needed to be procured or hauled away. Grading the areas in the direction shown will move surface water into the drainage system where it will be conveyed safely through the community. Regrading these areas will reduce ponding in the community, increase access to buildings, and improve the drainage system performance following rainfall events and during the spring freshet. The particular areas highlighted were found during the 2021 site visit to have significant ponding water which in some cases restricts residents’ access to buildings.
- Lower the profile of the ditch beside the new hamlet office. This will allow surface water to be directed into the ditch via regrading of the parking area, to alleviate the ponding issues noted in this area during the 2021 site

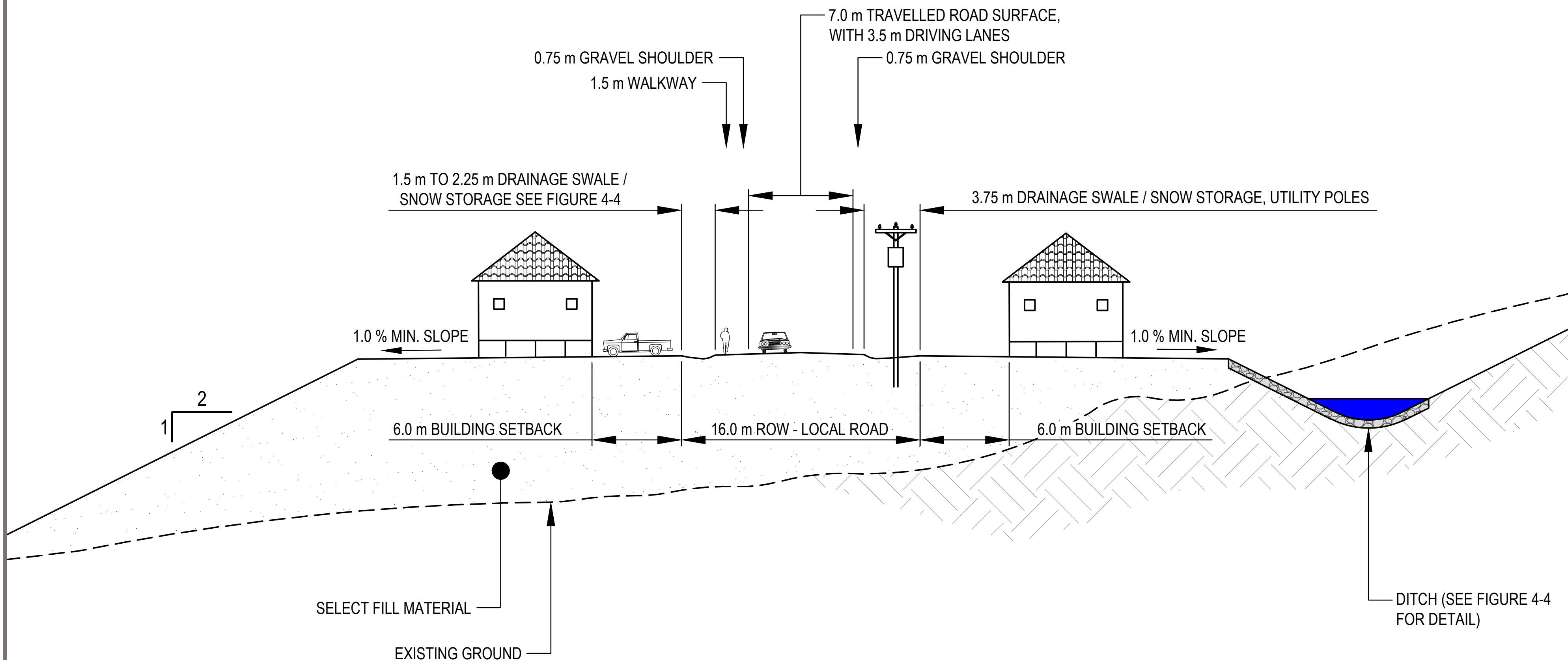
visit. Lowering the ditch profile will also decrease the risk of large flows in the ditch overflowing into the surrounding parking lot during high-flow events such as freshet.

5.3 Community Plan & Proposed Development Areas

At this stage we have provided drainage improvement recommendations based on the 2016 Grise Fiord Community Plan. Amendments to the 2016 Community Plan would likely carry revisions to the proposed drainage improvements.

To address the suitability of the community's proposed development areas, Tetra Tech has completed a development suitability map in Section 2.2.3 of this report. Both of the community's proposed development areas in the Southeast corner of the community have been designated as conditionally suitable for development, and would be deemed suitable following the installation of debris control structures due to their proximity to the landslide runout zones (Section 2.2.2.1). The debris control structures are to be specified by a rock engineering specialist. Specification of these debris control structures can be completed during a later detailed design phase at such a time when the future development buildings are planned to be constructed.

Specific to the new development grading, the use of gravel pads should be considered which include a 1% minimum slope directing water away from building footprints. Figure 5-1 provides details as to the recommended grades which may be considered at the time of development.



LEGEND

-

NOTES
-

0 20
Scale: 1: 400 (metres)

ISSUED FOR REVIEW

CLIENT
Nunavut

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GRISE FIORD MASTER DRAINAGE PLAN

ABOVE GRADE DEVELOPMENT DETAIL

PROJECT NO.	DWN	CKD	REV	
WTRI03028-01	AD	ER	0	Fig. 5-1
OFFICE	DATE			
VANC	DEC. 17, 2021			

5.4 Project Phasing

Tetra Tech has developed a phasing plan allowing CGS and the Hamlet to focus on the most critical elements of the proposed drainage plan first and consider postponing some of the less critical aspects until funding is available in future construction seasons. The phasing plan is included in Appendix L.

Tetra Tech has broken the work into four phases, with Phase 1 having the highest priority, Phase 3 having the lowest priority, and Phase 4 subject to future community expansion. For each Phase we have developed a Class "D" cost estimate to assist with future budgeting (see Section 5.5).

The phasing was developed based on the following criteria:

- Phase 1: Address Essential Service Areas
  - This phase is aimed at upgrading existing infrastructure around essential service areas including the Hamlet's Health Centre, Co-op Store, Grise Fiord Lodge, and the school.
  - Included in this phase is the repair of a section of the river embankment by the airport runway where a surface tension crack was observed.
- Phase 2: Address Community Service Areas and Main Watercourses
  - This phase is aimed at upgrading drainage infrastructure around common public use amenities and ensuring long-term capacity in the central watercourses running through Grise Fiord's developed area.
  - Common Public Use facilities protected under this phase includes the Community Learning Centre and the Church.
- Phase 3: Remaining Existing Infrastructure
  - This phase is aimed at upgrading the remaining existing infrastructure not addressed under Phases 1-2. It predominately covers the remaining residential areas outside of the Hamlets core.
  - Included in this phase is the installation of a revetment system along the bank of the river from the runway to the ocean outfall to protect the runway, the bridge, and the nearby residential buildings from erosion.
- Phase 4: Future community expansion infrastructure
  - This Phase is to be completed in conjunction with future community expansions and can be completed as required by the advancement of development.

Tetra Tech notes that separate phases could be combined, if desired. As discussed in Section 5.5, it is expected that the Hamlet would also benefit from efficiencies of scale when merging separate phases. Bulk material orders and reduced travel costs for skilled labour could lower the overall costs of the upgrades.

5.5 Construction Cost Estimate

Construction of the Grise Fiord Master Drainage Plan was broken into five phases, with Phase 1 having the highest priority, Phase 3 having the lowest priority, and Phase 4 denoting construction work to support future community expansion.

A Class "D" cost estimate was developed for each phase. The cost estimates are included in Appendix C. A summary of the cost estimates is shown in Table 5-3 below.

Phasing has been broken down to distribute the costs over a longer period of time to accommodate the availability of annual budgets. Combining phases will translate into greater savings as it will allow the Hamlet to take advantage of economies of scale.

Tetra Tech notes specifically that the potential exists to combine Phases 2 and 4 as their expected capital cost is reduced relative to the other Phases.

Tetra Tech has excluded the debris control structures and the river revetment system from the Class "D" cost estimate. The debris control structures are recommended to protect the future community expansion areas in the southeast of the community.

The river revetment system has not been included in the cost estimate due to this component being considered as additional works and not within the scope of this report. Detailed assessment of the river-bank velocities and scour potential would require 2-dimensional modeling of the river as well as a detailed inspection of the watercourse and banks to determine the bed material gradation and problem areas. We have integrated the revetment system into our conceptual drainage design map (Appendix K) and phasing plan (Appendix L) for consideration by the Hamlet.

Table 5-3: Summary of Phased Cost Estimate

	Phase				
	1	2	3	4	Total
Preliminaries	$56,984	$49,358	$82,411	$36,305	$225,059
Civil Works	$290,843	$214,583	$545,111	$84,050	$1,134,588
Miscellaneous	$15,000	$15,000	$15,000	$15,000	$60,000
Sub-total	**$362,828**	**$278,941**	**$642,523**	**$135,355**	**$1,419,647**
Project Contingencies: (40%)	$145,131	$111,577	$257,009	$54,142	$567,859
Total Estimated Construction Cost	**$507,959**	**$390,518**	**$899,532**	**$189,497**	**$1,987,505**

5.6 Ongoing System Maintenance

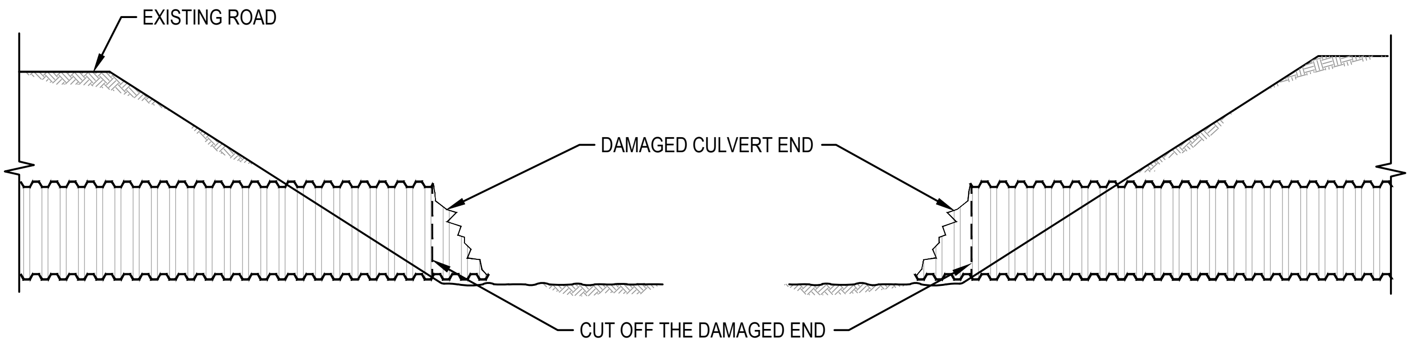
A properly maintained and monitored community drainage system is important in promoting the ongoing safety and well-being of a community. To ensure proper functioning of the drainage system, a program to maintain and monitor the system should be implemented.

5.6.1 Culvert Maintenance and Repair

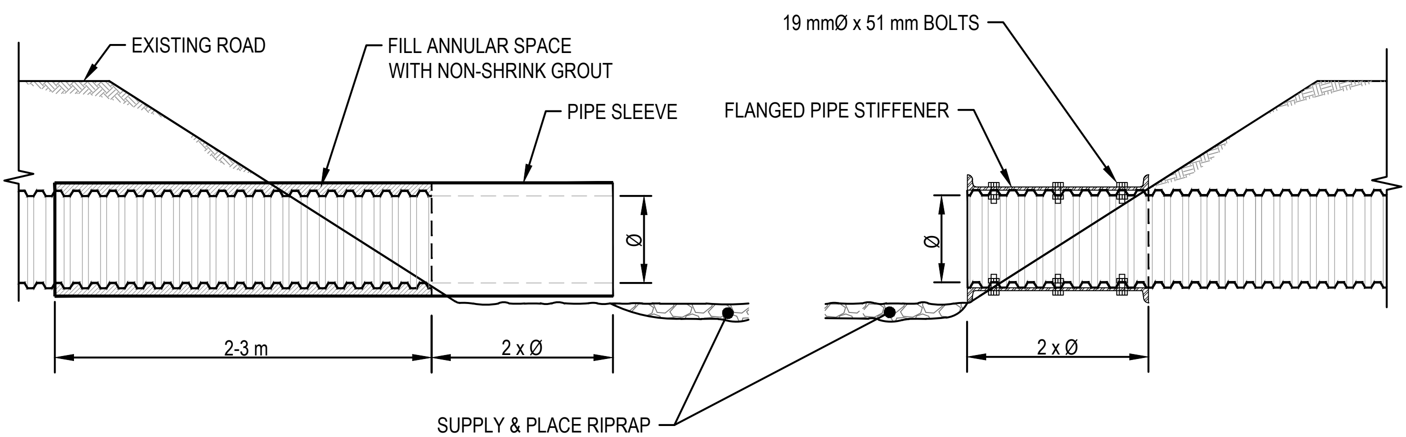
As per the guidelines for community drainage system planning, design, and maintenance in northern communities (CSA Group, 2015), culvert maintenance and repair guidelines are as follows:

- Culvert ends should be marked with a brightly painted posts installed vertically at the outlet and inlet. When lost or damaged, culvert marking posts shall be replaced.
- Spare culverts of each size shall be kept on hand to facilitate the timely repair and replacement of all culverts.

- Where culverts have suffered end damage but are otherwise in good condition, a SWSP sleeve should be added to reinstate the original length of the culvert. The annular space between the existing pipe and the SWSP sleeve should be grouted and sealed. Figure 5-2 provides a sketch covering the proposed repairs.
- After rain events and/or during spring melt, the inlets and outlets of the drainage system closest to the discharge location should be inspected for blockages including sediment and litter. If blockages exist they should be removed to allow for the conveyance of flows to the full capacity of the identified culverts.



BEFORE REPAIR



AFTER REPAIR

PIPE SLEEVE OPTION
SCALE: NTS

PIPE STIFFENER OPTION
SCALE: NTS

NOTE:

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GRISE FIORD MASTER DRAINAGE PLAN

DAMAGED CULVERT END REPAIR DETAILS

PROJECT NO.	DWN	CKD	REV
WTRI03028-01	MJK	ER	A

OFFICE	DATE
VANC	DEC. 17, 2021

FIG. 5-2

5.6.2 Snow Removal Management Plan

As per the guidelines for Community Drainage System Planning, Design, and Maintenance in Northern Communities (CSA Group, 2015), runoff from stockpiled snow should be prevented from re-entering the drainage system. Runoff from stockpile areas can overwhelm formalized and natural channels causing flooding.

To that end, Tetra Tech recommends that removed snow from roadways and driveways be safely deposited in one of the designated snow “Storage Zones” as shown in the Snow Removal Management Plan included in Appendix M. Further details are outlined below.

- The preferred Snow Storage Zones exist on boundary of the community to minimize water egress back into the drainage system.
- Limited storage has been allotted in the higher elevation portions of the community where snow melt from storage zones would re-enter the Hamlet’s drainage system, adding to the springtime melt flows passing through the system. Temporary Push Out Zones have been designated for the higher elevation areas. Culverts downstream of this storage have sufficient capacity to accept additional flow. These areas should be used sparingly; however, the preference remains for snow to be placed on the west side of the community’s boundary along the shoreline.

5.6.3 Culvert Thawing

Grise Fiord’s annual maintenance program should incorporate a culvert thawing strategy. Some options for thawing culverts are presented in Appendix G for consideration. Figure 5-3 below shows the proposed method for thawing ice inside culverts.

As per the project phasing diagrams shown in Appendix L, higher priority culverts should be thawed first. For example, culverts in Phase 1 zones should be thawed before culverts in Phase 2 zones. Within these phased zones de-thawing efforts should begin at the end of the drainage system and work upstream

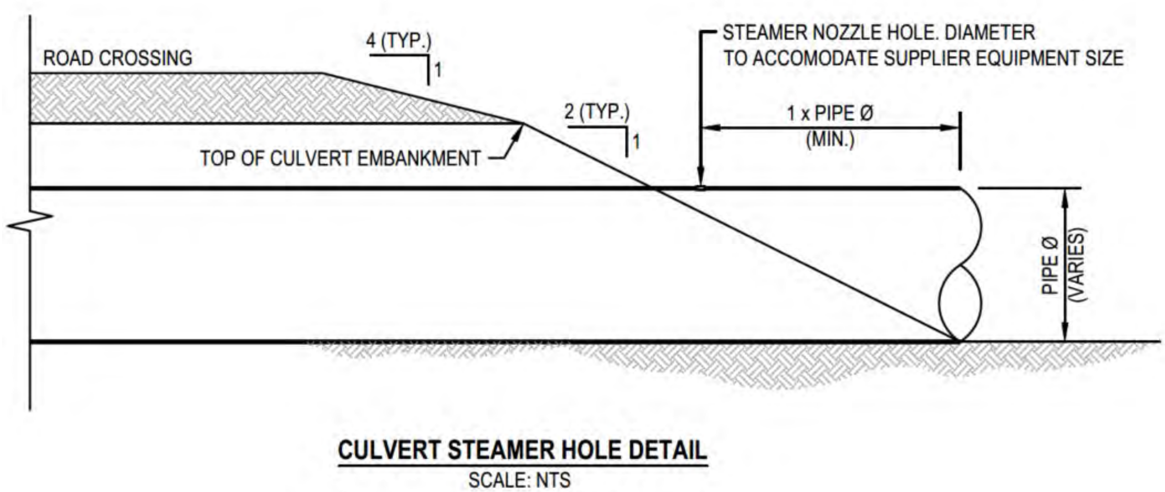

Figure 5-3: Culvert Thawing Detail

5.6.4 Maintenance Schedule

A recommended seasonal maintenance schedule as per the Guidelines for Community Drainage System Planning, Design, and Maintenance in Northern Communities (CSA Group, 2015), is presented as follows:

Spring:

- Visually inspect and thaw frozen culverts in order of their priority level, as discussed in Section 5.6.2. Note any damages to culverts.
- Remove debris from blocked or partially blocked culverts.
- Collect and dispose of litter if present.
- Following the spring freshet, inspect the drainage system to identify deficiencies for repair.

Summer:

- Repair washed out ditches, swales and riprap aprons as necessary. Ponding in ditches and swales should be identified and fixed with re-sloping and grading.
- A water pump can be used to flush blocked culverts free of sediment, rocks, and debris. Discharge of sediments into natural streams should be avoided and appropriate sediment and erosion control measures should be incorporated to protect the receiving water bodies.
- Repair damaged culvert ends. Replace or re-install culverts that have been shifted or damaged. Repair culverts in order of their priority level and the level of damage observed.

Fall:

- Complete repairs to the drainage system.
- Replace missing or damaged culvert marking posts.
- Create an inventory of materials required for the next year's maintenance program.

Winter:

- Monitor culverts and culvert marking posts.
- Implement the snow removal management plan as detailed in Section 5.6.2.

5.6.5 Inspection & Replacement Procedures

The climate and environment in Grise Fiord can lead to asset degradation at a faster pace than typical of southern environments. Yearly freeze-thaw cycles along with de-icing maintenance can cause damage premature of the intended installation lifespan for culverts, ditches and roads.

It is recommended that the Hamlet not follow a predetermined replacement schedule but rather ensure culverts and ditches are assessed on a yearly basis to determine if replacement or repairs are necessary. This approach takes into account the following considerations:

- Unlike with municipal infrastructure and utilities in other Canadian cities, which is often out of sight underground, Grise Fiord's culverts and road structures are accessible and can be easily inspected as necessary. Ongoing degradation and/or damage can be observed on a monthly or yearly basis allowing replacements to occur only if and when necessary based on observations.

- The possibility of a culvert failure without observable signs of damage or deterioration is unlikely. Further, the consequence of such a failure is low. Given this, pre-emptive asset replacement is financially inefficient. Culverts ditches should be retained while they remain fully serviceable to maximize cost savings.
- Damage occurring from maintenance and snow clearing activities is the largest source of asset deterioration. Any predetermined replacement schedules would be unable to predict yearly damages.

As an alternative to a set replacement schedule, Tetra Tech recommends that at a minimum once per year and in the Spring, the community foreman inspect and take inventory of all culverts within the Hamlet. During this inspection, the foremen is to assess for damage and signs of wear and document all findings within a culvert inventory sheet. As much of the culvert damage occurs over the spring (through de-icing and snow removal activities) this inspection should occur only once all snow and ice has melted. In some cases, damage will be repairable by installing a SSWP sleeve over the damaged end as detailed in Section 5.6.1. In other cases, the damage will be irreparable and necessitate a full replacement.

This decision should be made by the Hamlet foreman who has the best knowledge on the probability of success in repair versus replacement. Culverts of special concern are those with minimal cover. As a guideline, Tetra Tech recommends that culverts displaying the following issues be prioritized for replacement:

- Pipe deformation has occurred to the point where vertical deformation exceeds 10% of the original pipe diameter.
- Pipe deformation has occurred such that the culvert has holes or splits throughout its length allowing for leakage
- Corrosion is observed in the body of the pipe to the extent that small holes in the pipe wall are beginning to form.
- Damage to the pipe end is to the extent that installing a SWSP over the damaged pipe is not feasible.

Culverts which require replacement or repair should be flagged for service work to be completed during the late spring and summer of that year. Replacement should be in keeping with manufacturers specifications. Tetra Tech has included in Appendix J a complete inventory of all culverts and “large ditches” within the community. It is recommended that the Hamlet’s foremen work through this least in a sequential order when the yearly spring asset inspection is completed.

Critical Spares

Spare couplers, SWSP and repair clamps should be held within Grise Fiord’s reserve inventory at all times. As per CSA-S503-15 guidelines, at least 5% of culvert materials used throughout a community’s drainage system should be kept on hand in case critical, time-sensitive repairs or replacements are required.

Repairing a Washout

Following a culvert washout, exposed saturated ground should be covered with drain rock or pea sized gravel. This will help to minimize the amount of fines that are washed out from the roadway structure and moved into the downstream system. Once a replacement culvert is installed, riprap shall be used to armor the affected area. This should be done to prevent future washouts.

5.6.6 Gravel Road Construction Techniques

Current Hamlet Maintenance Practices and Issues:

Tetra Tech identified some issues with the Hamlet's gravel road network and maintenance practices during the site visit, including a lack of surface drainage and ditches, and the presence of surface defects, such as potholes and rutting. The Hamlet's current gravel road maintenance practices and snow ploughing operations appear to have reduced the thickness of the gravel road structure, removed gravel fines from the road surface, and reduced the roadway crown in numerous locations.

Design Criteria:

To achieve sufficient roadway drainage, crowning of the centre of the road should be completed to provide crossfall of 3-4%. This will facilitate drainage of water off the road surface and into adjacent ditches. Flat areas on the road surface can lead to ponding of water or sheet flow of water along the roadway. These issues can allow water to penetrate and weaken the road structure and subgrade (native soils below the road), and accelerate the loss of surface fines, resulting in development of surface failures (e.g. potholes, rutting, corrugation, etc.). These concerns can reduce the road's service life, and increase regular maintenance requirements. Conversely, crossfalls greater than 4% can lead to safety concerns for vehicles, particularly for large vehicles and during winter / frozen conditions.

One-way crossfall (superelevation) up to 4%, can be incorporated into the road cross section at curves by raising the outside edge of the roadway. In addition to providing surface drainage, superelevation provides better road geometry for vehicles manoeuvring through the curve. Vehicle speeds and the curvature of the roadway need to be considered with designing maximum superelevation values. The transition between regular two-way crossfall and superelevation should be gradual and graded to ensure continuous surface drainage is achieved.

Ditches should be provided along the length of the roadway to ensure continuous drainage is achieved. Ditches should be constructed to a depth a minimum of 300 mm below the bottom of the granular road structure and graded (minimum 0.5%) to eliminate low spots and prevent ponding of water. Ponding water has the potential to saturate the road structure and subgrade, which may result in road failures requiring significant maintenance or reconstruction.

Gravel roads should be surfaced with a minimum 100 mm thick layer of a Crushed Surfacing Gravel. A Crushed Surfacing Gravel has a higher percentage of fines (material finer than 0.075 mm) compared to a Crushed Base Gravel, and therefore performs better in gravel road surfacing applications. The higher fines content helps bind the granular material together and will better seal the road surface to limit material loss and ingress of water through the surface. Where the road needs to be raised to address geometric or drainage issues, or to increase ditch capacities, the Hamlet can utilize Crushed Base Gravel and/or a Pit Run material. The Crushed Base Gravel and Pit Run material should be placed and compacted in 150-200 mm thick layers prior to the placement of the Crushed Surfacing Gravel.

Sample gradation and specifications for Crushed Surfacing Gravel, Crushed Base Gravel and Pit Run material is included below for the Hamlet's reference.

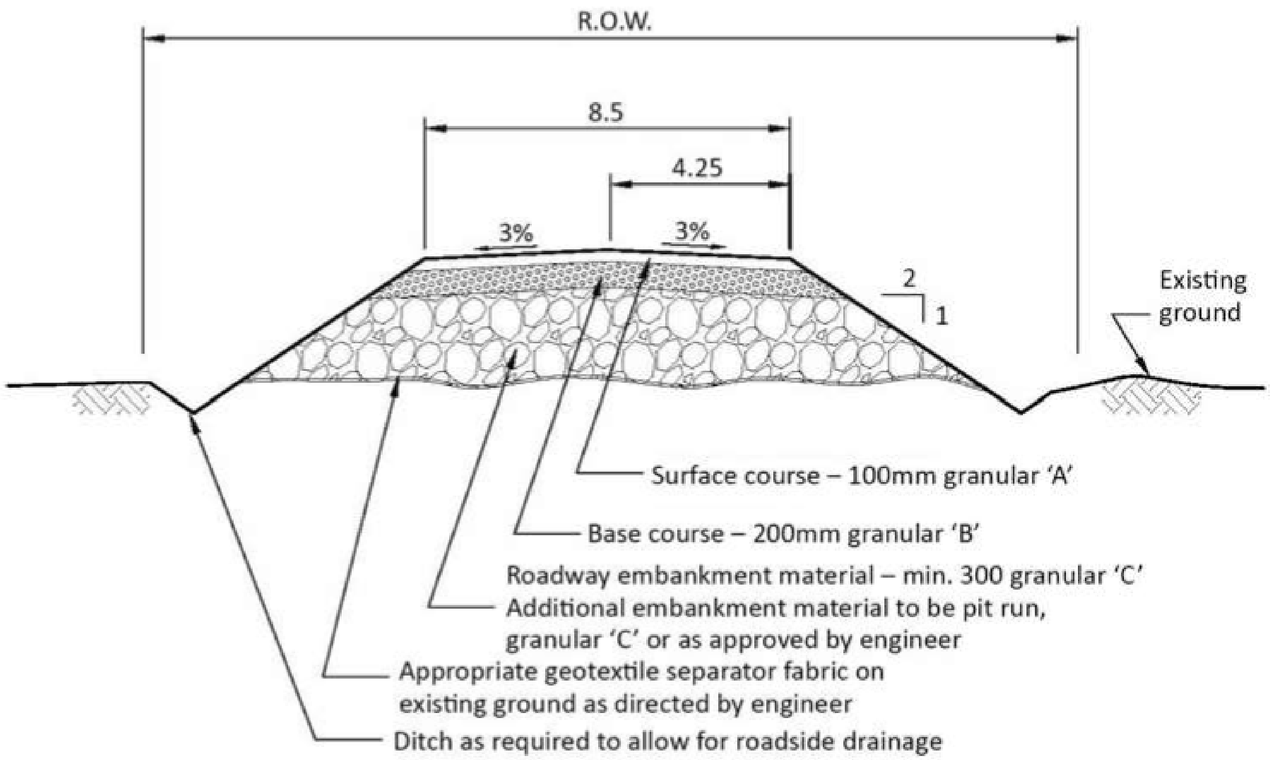

Figure 5-4: Typical Embankment Construction, NISI Northern Design Standard (CAN/CSA-S503-15)

Equipment:

It is understood the Hamlet's current maintenance practices involve dragging weighted tractor tires over the gravel roads to infill potholes and flatten other surface imperfections. However, this approach does not allow operators to control the crossfall, and over time has the potential to remove surface fines, reduce the overall road structure and flatten the road crown.

To make the roadway maintenance more effective and efficient, the following equipment is presented for consideration by the Hamlet:

- **Grader**: to reshape the gravel roads and evenly spread additional granular material. The angle of the grader's blade can be set during grading operations to ensure a consistent crossfall is achieved along the length of road. The grader can also be utilized to mix and dry granular stockpiles prior to placement onto the roads. Grader operators will require training so as not to damage the road or waste granular.
  - Alternatively, the Hamlet could utilize a bobcat (skid steer loader) to complete regrading of the gravel roads. Granular material can be placed along the centreline of the road and shaped by the bobcat to ensure minimum crossfall requirements are achieved. Bobcats have advantages over a grader in that they require less operator training, can be utilized in a variety of functions by the Hamlet, and have a lower capital cost. Additionally, bobcats can be equipped with tracks to enable its use in the winter i.e. for snow clearing operations.

- **Compactor**: necessary to achieve compaction of the granular road structure during placement. The Hamlet could consider use of a standalone rubber tire or steel drum roller machine, or utilize a roller towed behind the grader.
  - Conversely, compaction of the granular material can be achieved by wheel rolling the moisture conditioned material with construction equipment or other community vehicles during road maintenance or construction activities. The lift thickness of material placed may need to be reduced to ensure required density is achieved.
- **Gravel truck(s)**: for hauling of granular from the quarry / stockpile site to town.
- **Wheel loader**: to load granular material into trucks at the quarry / stockpile site.
- **Water truck**: used to moisture condition granular material to ensure it is placed and compacted at the optimum moisture content.
- **Gravel crusher and screen**: to manufacture and sort granular material. The Hamlet could consider purchasing their own gravel crusher unit, or hire a contractor to complete blasting, crushing and stockpiling of the various material types (e.g. crushed surfacing gravel, crushed base gravel, pit run, riprap, etc.) in a sufficient for the Hamlet's requirements for multiple years.

Construction / Maintenance Methodology:

Gravel road construction should be completed in the summer after spring thaw to ensure granular materials do not contain ice and/or frozen lumps, or are placed on snow, ice or frozen ground. Granular materials should be placed and compacted to the thicknesses and grades in accordance with the Design Criteria noted above. Each layer of granular material placed should be sufficiently compacted prior to placing subsequent granular layers of gravel such that there is no (or very limited) movement observable in the surface of the layer when trafficked by a loaded gravel truck. At culvert inlets and outlets, riprap erosion protection should be installed to ensure drainage flows do not erode the roadway granular structure.

The Hamlet should complete gravel road maintenance on a bi-annual or more frequent basis, with the associated maintenance costs included in the Hamlet's annual budget. Similar to road construction activities, gravel road maintenance should be completed in the summer months. Typically, gravel road maintenance should be completed at the following times:

- In spring shortly after freshet when road conditions are likely to be at their worst due to increase flows from snow melt. Resurfacing of gravel roads and addressing erosion issues may be required, in addition to regrading of roadways.
- Prior to the onset of winter to ensure roads are left in a suitable driving condition for the winter months. In addition, completing ditch and culvert maintenance will aid with drainage during spring thaw in the following year.

Hamlet personnel should assess the exact maintenance activities year-by-year as the requirements may vary by location, due to traffic volumes, nearby drainage features or other factors. In some locations, reworking / regrading of the existing gravels to re-establish drainage and crossfall may be satisfactory. In other areas, the Hamlet may need to import additional Crushed Surfacing Gravel to ensure a minimum thickness of 100 mm is maintained. When grading roadways, the grader or bobcat's operating speed should be limited to 5-10 km/h ensure a consistent grade is achieved.

When importing additional granular material, Hamlet personnel should mark spread distances for granular material unloaded from trucks to aid with even spreading of material by the grader or bobcat. The spread distance is the length a truckload of gravel will cover at the given road width and specified thickness.

Depending on the characteristics of the available granular material, the Hamlet may consider implementing a Dust Control program, should this be identified as an issue by Hamlet personnel, or the community's residents. There are numerous products and methods available for dust control, which are typically completed on an annual basis. Chloride products, such as Calcium Chloride, are common and typically involve applying the product to the road surface or intermixing into gravel to be incorporated into the road surface. The benefits of completing dust control extend beyond improving air quality for residents, and includes reduced loss of fines in the gravel surface and reduced maintenance / blading requirements.

Further guidance on gravel road construction and maintenance practices are detailed in the U.S. Department of Transportation, Federal Highway Administration Gravel Roads Construction & Maintenance Guide (August 2015) provides further guidance and information.

Granular Material Specifications:

The following material sample material specifications are provided for the Hamlet's reference:

- Crushed Surfacing Gravel shall be manufactured to conform to the following requirements:
  - Consist of hard durable particles free from clay lumps, frozen material, organic matter, and other deleterious materials. Cohesion of this aggregate is achieved by plastic fines.
  - When tested in accordance with ASTM C136, the material shall have a gradation conforming to the following gradation limits:

Gradation Limits: Crushed Surfacing Gravel	
Sieve Designation (mm)	**Percent Passing by Weight**
25	100
19	85 – 100
9.5	60 – 85
4.75	40 – 70
1.18	20 – 50
0.300	10 – 30
0.075	7 – 15

  - Liquid limit when tested in accordance with ASTM D4318, maximum 25.
  - Plasticity index when tested in accordance with ASTM D4318, maximum 6.
  - Los Angeles degradation when tested in accordance with ASTM C131/C131M, maximum percent loss by weight 25.
  - Fracture, at least 80% of particles by mass retained on 4.75 mm sieve to have at least one freshly fractured face.

- Pit Run material shall conform to the following requirements:
  - The material shall be well graded, granular material free from clay lumps, organic matter and other extraneous material, screened to remove all stones in excess of maximum 100 mm diameter.
  - When tested in accordance with ASTM C136/C136M, the material shall have a gradation conforming to the following gradation limits:

Gradation Limits: Pit Run	
Sieve Designation (mm)	**Percent Passing by Weight**
100	100
75	85 – 100
50	70 – 100
25	50 – 100
4.75	25 – 100
2.00	10 – 80
0.075	2 – 8

- Crushed Base Gravel shall be manufactured to conform with the following requirements:
  - The material shall consist of hard durable particles free from clay lumps, frozen material, organic matter, and other deleterious materials.
  - When tested in accordance with ASTM C136/C136M, the material shall have a gradation conforming to the following gradation limits:

Gradation Limits: Crushed Base Gravel	
Sieve Designation (mm)	**Percent Passing by Weight**
50	100
37.5	60 – 100
25	40 – 75
12.5	15 – 40
2.36	10 – 25
0.300	5 – 15
0.075	0 – 5

  - Liquid limit when tested in accordance with ASTM D4318, maximum 25.
  - Plasticity index when tested in accordance with ASTM D4318, maximum 6.
  - Los Angeles degradation when tested in accordance with ASTM C131/C131M, maximum percent loss by weight 35.
  - Fracture, at least 60% of particles by mass retained on 4.75 mm sieve to have at least one freshly fractured face.

6.0 CLOSURE

We trust this document meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech Canada Inc.

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APPENDIX A

TETRA TECH'S LIMITATIONS ON THE USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

HYDROTECHNICAL

1.1 USE OF DOCUMENT AND OWNERSHIP

This document pertains to a specific site, a specific development, and a specific scope of work. The document may include plans, drawings, profiles and other supporting documents that collectively constitute the document (the "Professional Document").

The Professional Document is intended for the sole use of TETRA TECH's Client (the "Client") as specifically identified in the TETRA TECH Services Agreement or other Contractual Agreement entered into with the Client (either of which is termed the "Contract" herein). TETRA TECH does not accept any responsibility for the accuracy of any of the data, analyses, recommendations or other contents of the Professional Document when it is used or relied upon by any party other than the Client, unless authorized in writing by TETRA TECH.

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Where TETRA TECH submits electronic file and/or hard copy versions of the Professional Document or any drawings or other project-related documents and deliverables (collectively termed TETRA TECH's "Instruments of Professional Service"), only the signed and/or sealed versions shall be considered final. The original signed and/or sealed electronic file and/or hard copy version archived by TETRA TECH shall be deemed to be the original. TETRA TECH will archive a protected digital copy of the original signed and/or sealed version for a period of 10 years.

Both electronic file and/or hard copy versions of TETRA TECH's Instruments of Professional Service shall not, under any circumstances, be altered by any party except TETRA TECH. TETRA TECH's Instruments of Professional Service will be used only and exactly as submitted by TETRA TECH.

Electronic files submitted by TETRA TECH have been prepared and submitted using specific software and hardware systems. TETRA TECH makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

1.3 STANDARD OF CARE

Services performed by TETRA TECH for the Professional Document have been conducted in accordance with the Contract, in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this Professional Document. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of the Professional Document.

If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

1.4 DISCLOSURE OF INFORMATION BY CLIENT

The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by third parties other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this report, at or on the development proposed as of the date of the Professional Document requires a supplementary exploration, investigation, and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

Unless expressly agreed to in the Services Agreement, TETRA TECH was not retained to investigate, address or consider, and has not investigated, addressed or considered any environmental or regulatory issues associated with the project.

1.8 LEVEL OF RISK

It is incumbent upon the Client and any Authorized Party, to be knowledgeable of the level of risk that has been incorporated into the project design, in consideration of the level of the hydrotechnical information that was reasonably acquired to facilitate completion of the design.

APPENDIX B

EXAMPLE CULVERT END STIFFENER

Photo 1: Example Culvert End Stiffener

APPENDIX C

PHASED COST ESTIMATES

Community and Government Services - Government of Nunavut

Class 'D' Cost Estimate - All Phases

Tetra Tech Project ENG.WTRI03028-01 - Grise Fiord Master Drainage Plan

Preliminary Estimate of Probable Costs		Total
Preliminaries		$225,059
Civil Works		$1,134,588
Miscellaneous		$60,000
	Sub-total	**$1,419,647**
Project Contingencies	40.0%	$567,859
	Total Estimated Construction Cost	**$1,987,505**

NMS Specs

Preliminaries			Unit	Est Quantity	Est. Unit Price	Est. Total
01 25 01	0-1	Mob / Demob, Temporary Facilities, Security, Quality Control, etc.	lump sum	1	$129,058.78	$129,059
01 35 14	0-2	Traffic Control, Barricades, and Temporary Signage	lump sum	1	$16,000.00	$16,000
01 71 00	0-3	Construction Surveys	lump sum	1	$80,000.00	$80,000
					Sub-total Preliminaries	**$225,059**

Civil Works			Unit	Est Quantity	Est. Unit Price	Est. Total
31 14 11	1-1	Excavation and Off-Site Disposal	cu.m	2,220	$30.00	$66,600
33 42 13	1-2	Supply and Install 300 mm PVC Pipe	m	95	$400.00	$38,062
33 42 13	1-3	Supply and Install 450 mm Steel Casing Culvert	m	135	$527.00	$71,145
33 42 13	1-4	Supply and Install 600 mm Steel Casing Culvert	m	35	$707.00	$24,745
33 42 13	1-5	Supply and Install 900 mm Steel Casing Culvert	m	60	$1,068.00	$64,080
33 42 13	1-6	Supply and Install 1200 mm Steel Casing Culvert	m	43	$1,770.00	$76,110
33 42 13	1-7	Supply and Install 1400 mm Steel Casing Culvert	m	37	$2,065.00	$76,405
33 42 13	1-8	Supply and Install 3.6 m x 1.2 m Concrete Box Culvert	m	48	$7,803.20	$374,553
33 42 13	1-9	Supply and Install 600 mm Steel Casing Sleeve	m	13	$707.00	$9,191
33 42 13	1-10	Supply and Install 800 mm Steel Casing Sleeve	m	6	$921.00	$5,526
31 37 10	1-11	Supply and Place 10 kg Class Riprap	cu. m	1,034	$100.00	$103,400
31 37 10	1-12	Supply and Place 50 - 75 mm Clear Crush (Swales)	cu. m	179	$100.00	$17,900
31 37 10	1-13	Supply and Place 19 mm Minus Crush (Road Grading)	cu. m	765	$90.00	$68,850
31 32 21	1-14	Supply and Place Non-Woven Geotextile	sq. m	3,901	$20.00	$78,020
02 41 13	1-15	Culvert Removal and Off-Site Disposal	each	30	$2,000.00	$60,000
					Sub-total Site Services	**$1,134,588**

Miscellaneous			Unit	Est Quantity	Est. Unit Price	Est. Total
01 35 43	2-1	Dewatering	lump sum	1	$20,000.00	$20,000
01 35 43	2-2	Sediments and Erosion Control Measures	lump sum	1	$40,000.00	$40,000
					Sub-total Miscellaneous	**$60,000**

Notes:

1 Quantities shown on this table are estimates and provided for reference only.

2 Estimated quantities do not account for spare culverts and materials.

Community and Government Services - Government of Nunavut

Class 'D' Cost Estimate - Phase 1

Tetra Tech Project ENG.WTRI03028-01 - Grise Fiord Master Drainage Plan

Preliminary Estimate of Probable Costs		Total
Preliminaries		$56,984
Civil Works		$290,843
Miscellaneous		$15,000
	Sub-total	**$362,828**
Project Contingencies	40.0%	$145,131
	Total Estimated Construction Cost	**$507,959**

NMS Specs						
Preliminaries			**Unit**	**Est Quantity**	**Est. Unit Price**	**Est. Total**
01 25 01	0-1	Mob / Demob, Temporary Facilities, Security, Quality Control, etc.	lump sum	1	$32,984.34	$32,984
01 35 14	0-2	Traffic Control, Barricades, and Temporary Signage	lump sum	1	$4,000.00	$4,000
01 71 00	0-3	Construction Surveys	lump sum	1	$20,000.00	$20,000
					Sub-total Preliminaries	**$56,984**
Civil Works			**Unit**	**Est Quantity**	**Est. Unit Price**	**Est. Total**
31 14 11	1-1	Excavation and Off-Site Disposal	cu.m	594	$30.00	$17,820
33 42 13	1-2	Supply and Install 300 mm PVC Pipe	m	95	$400.00	$38,062
33 42 13	1-3	Supply and Install 450 mm Steel Casing Culvert	m	29	$527.00	$15,283
33 42 13	1-4	Supply and Install 600 mm Steel Casing Sleeve	m	4	$707.00	$2,828
33 42 13	1-5	Supply and Install 900 mm Steel Casing Culvert	m	45	$1,068.00	$48,060
33 42 13	1-6	Supply and Install 1200 mm Steel Casing Culvert	m	43	$1,770.00	$76,110
31 37 10	1-7	Supply and Place 10 kg Class Riprap	cu. m	239	$100.00	$23,900
31 37 10	1-8	Supply and Place 50 - 75 mm Clear Crush (Swales, Underdrain)	cu. m	81	$100.00	$8,100
31 37 10	1-9	Supply and Place 19 mm Minus Crush (Road Grading)	cu. m	258	$90.00	$23,220
31 32 21	1-10	Supply and Place Non-Woven Geotextile	sq. m	1,173	$20.00	$23,460
02 41 13	1-11	Culvert Removal and Off-Site Disposal	each	7	$2,000.00	$14,000
					Sub-total Site Services	**$290,843**
Miscellaneous			**Unit**	**Est Quantity**	**Est. Unit Price**	**Est. Total**
01 35 43	2-1	Dewatering	lump sum	1	$5,000.00	$5,000
01 35 43	2-2	Sediments and Erosion Control Measures	lump sum	1	$10,000.00	$10,000
					Sub-total Miscellaneous	**$15,000**

Notes:

1 Quantities shown on this table are estimates and provided for reference only.

2 Estimated quantities do not account for spare culverts and materials.

Community and Government Services - Government of Nunavut

Class 'D' Cost Estimate - Phase 2

Tetra Tech Project ENG.WTRI03028-01 - Grise Fiord Master Drainage Plan

Preliminary Estimate of Probable Costs		Total
Preliminaries		$49,358
Civil Works		$214,583
Miscellaneous		$15,000
	Sub-total	**$278,941**
Project Contingencies	40.0%	$111,577
	Total Estimated Construction Cost	**$390,518**

NMS Specs						
Preliminaries			**Unit**	**Est Quantity**	**Est. Unit Price**	**Est. Total**
01 25 01	0-1	Mob / Demob, Temporary Facilities, Security, Quality Control, etc.	lump sum	1	$25,358.30	$25,358
01 35 14	0-2	Traffic Control, Barricades, and Temporary Signage	lump sum	1	$4,000.00	$4,000
01 71 00	0-3	Construction Surveys	lump sum	1	$20,000.00	$20,000
					Sub-total Preliminaries	**$49,358**
Civil Works			**Unit**	**Est Quantity**	**Est. Unit Price**	**Est. Total**
31 14 11	1-1	Excavation and Off-Site Disposal	cu.m	512	$30.00	$15,360
33 42 13	1-2	Supply and Install 450 mm Steel Casing Culvert	m	59	$527.00	$31,093
33 42 13	1-3	Supply and Install 600 mm Steel Casing Culvert	m	11	$707.00	$7,777
33 42 13	1-4	Supply and Install 600 mm Steel Casing Sleeve	m	6	$707.00	$4,242
33 42 13	1-5	Supply and Install 800 mm Steel Casing Sleeve	m	6	$921.00	$5,526
33 42 13	1-6	Supply and Install 1400 mm Steel Casing Culvert	m	37	$2,065.00	$76,405
31 37 10	1-7	Supply and Place 10 kg Class Riprap	cu. m	230	$100.00	$23,000
31 37 10	1-8	Supply and Place 50 - 75 mm Clear Crush (Swales)	cu. m	47	$100.00	$4,700
31 37 10	1-9	Supply and Place 19 mm Minus Crush (Road Grading)	cu. m	134	$90.00	$12,060
31 32 21	1-10	Supply and Place Non-Woven Geotextile	sq. m	821	$20.00	$16,420
02 41 13	1-11	Culvert Removal and Off-Site Disposal	each	9	$2,000.00	$18,000
					Sub-total Site Services	**$214,583**
Miscellaneous			**Unit**	**Est Quantity**	**Est. Unit Price**	**Est. Total**
01 35 43	3-1	Dewatering	lump sum	1	$5,000.00	$5,000
01 35 43	3-2	Sediments and Erosion Control Measures	lump sum	1	$10,000.00	$10,000
					Sub-total Miscellaneous	**$15,000**

Notes:

1 Quantities shown on this table are estimates and provided for reference only.

2 Estimated quantities do not account for spare culverts and materials.

Community and Government Services - Government of Nunavut

Class 'D' Cost Estimate - Phase 3

Tetra Tech Project ENG.WTRI03028-01 - Grise Fiord Master Drainage Plan

Preliminary Estimate of Probable Costs		Total
Preliminaries		$82,411
Civil Works		$545,111
Miscellaneous		$15,000
	Sub-total	**$642,523**
Project Contingencies	40.0%	$257,009
	Total Estimated Construction Cost	**$899,532**

NMS Specs						
Preliminaries			**Unit**	**Est Quantity**	**Est. Unit Price**	**Est. Total**
01 25 01	0-1	Mob / Demob, Temporary Facilities, Security, Quality Control, etc.	lump sum	1	$58,411.14	$58,411
01 35 14	0-2	Traffic Control, Barricades, and Temporary Signage	lump sum	1	$4,000.00	$4,000
01 71 00	0-3	Construction Surveys	lump sum	1	$20,000.00	$20,000
					Sub-total Preliminaries	**$82,411**
Civil Works			**Unit**	**Est Quantity**	**Est. Unit Price**	**Est. Total**
31 14 11	1-1	Excavation and Off-Site Disposal	cu.m	471	$30.00	$14,130
33 42 13	1-2	Supply and Install 450 mm Steel Casing Culvert	m	47	$527.00	$24,769
33 42 13	1-3	Supply and Install 600 mm Steel Casing Culvert	m	24	$707.00	$16,968
33 42 13	1-4	Supply and Install 600 mm Steel Casing Sleeve	m	3	$707.00	$2,121
33 42 13	1-5	Supply and Install 3.6 m x 1.2 m Concrete Box Culvert	m	48	$7,803.20	$374,553
31 37 10	1-6	Supply and Place 10 kg Class Riprap	cu. m	285	$100.00	$28,500
31 37 10	1-7	Supply and Place 50 - 75 mm Clear Crush (Swales)	cu. m	51	$100.00	$5,100
31 37 10	1-8	Supply and Place 19 mm Minus Crush (Road Grading)	cu. m	373	$90.00	$33,570
31 32 21	1-9	Supply and Place Non-Woven Geotextile	sq. m	870	$20.00	$17,400
02 41 13	1-10	Culvert Removal and Off-Site Disposal	each	14	$2,000.00	$28,000
					Sub-total Site Services	**$545,111**
Miscellaneous			**Unit**	**Est Quantity**	**Est. Unit Price**	**Est. Total**
01 35 43	2-1	Dewatering	lump sum	1	$5,000.00	$5,000
01 35 43	2-2	Sediments and Erosion Control Measures	lump sum	1	$10,000.00	$10,000
					Sub-total Miscellaneous	**$15,000**

Notes:

1 Quantities shown on this table are estimates and provided for reference only.

2 Estimated quantities do not account for spare culverts and materials.

Community and Government Services - Government of Nunavut

Class 'D' Cost Estimate - Phase 4

Tetra Tech Project ENG.WTRI03028-01 - Grise Fiord Master Drainage Plan

Preliminary Estimate of Probable Costs		Total
Preliminaries		$36,305
Civil Works		$84,050
Miscellaneous		$15,000
	Sub-total	**$135,355**
Project Contingencies	40.0%	$54,142
	Total Estimated Construction Cost	**$189,497**

NMS Specs						
Preliminaries			**Unit**	**Est Quantity**	**Est. Unit Price**	**Est. Total**
01 25 01	0-1	Mob / Demob, Temporary Facilities, Security, Quality Control, etc.	lump sum	1	$12,305.00	$12,305
01 35 14	0-2	Traffic Control, Barricades, and Temporary Signage	lump sum	1	$4,000.00	$4,000
01 71 00	0-3	Construction Surveys	lump sum	1	$20,000.00	$20,000
					Sub-total Preliminaries	**$36,305**
Civil Works			**Unit**	**Est Quantity**	**Est. Unit Price**	**Est. Total**
31 14 11	1-1	Excavation and Off-Site Disposal	cu.m	643	$30.00	$19,290
33 42 13	1-2	Supply and Install 900 mm Steel Casing Culvert	m	15	$1,068.00	$16,020
31 37 10	1-3	Supply and Place 10 kg Class Riprap	cu. m	280	$100.00	$28,000
31 32 21	1-4	Supply and Place Non-Woven Geotextile	sq. m	1,037	$20.00	$20,740
					Sub-total Site Services	**$84,050**
Miscellaneous			**Unit**	**Est Quantity**	**Est. Unit Price**	**Est. Total**
01 35 43	2-1	Dewatering	lump sum	1	$5,000.00	$5,000
01 35 43	2-2	Sediments and Erosion Control Measures	lump sum	1	$10,000.00	$10,000
					Sub-total Miscellaneous	**$15,000**

Notes:

1 Quantities shown on this table are estimates and provided for reference only.

2 Estimated quantities do not account for spare culverts and materials.

APPENDIX D

SUMMARY OF EXISTING AND PROPOSED CULVERTS

Table D-1: Proposed Culverts (100-Year Design Storm Event)

Name	Proposed Culvert Action	Culvert Type	Length (m)	Diameter (mm)	Number of Barrels	Max. Flow (m^3/s)	Max. Velocity (m/s)	Max/Full Flow (m/s/m/s)	Max/Full Depth (m/m)
C1	Upsize	SWSP	4.3	600	1	0.30	2.30	0.22	0.51
C2	Functioning as Intended	CSP	3.6	900	1	0.30	2.10	0.09	0.28
C3	Upsize	SWSP	6.0	600	1	0.31	2.27	0.23	0.54
C4	Upsize	SWSP	3.8	450	1	0.02	1.05	0.04	0.15
C5	Repair	CSP	4.1	600	1	0.13	1.73	0.13	0.30
C6	Repair	CSP	10.3	600	1	0.10	1.90	0.08	0.26
C7	Repair	CSP	8.3	750	1	0.10	1.85	0.08	0.18
C8	Repair	CSP	13.0	750	1	0.10	1.82	0.06	0.18
C9	Upsize	SWSP	5.8	1400	1	2.16	2.92	0.16	0.52
C10	Upsize	SWSP	9.5	1400	1	2.18	2.97	0.14	0.53
C11	Replace	SWSP	10.5	600	1	0.01	1.12	0.01	0.05
C12	Replace	SWSP	10.9	450	1	0.01	1.28	0.02	0.10
C13	Repair	CSP	23.0	600	1	0.01	0.76	0.03	0.10
C14	Upsize	SWSP	11.0	1400	1	2.19	1.94	0.27	0.81
C15	Upsize	SWSP	6.6	1400	1	2.19	2.98	0.25	0.53
C16	Abandon	Cast Iron	7.9	450	1	0.00	0.00	0.00	0.00
C17	Abandon	Cast Iron	6.1	450	1	0.00	0.00	0.00	0.00
C18	Functioning as Intended	Cast Iron	4.9	450	1	0.00	0.00	0.00	0.00
C19	Abandon	CSP	55.5	1200	1	0.58	1.98	0.13	0.31
C20	Abandon	Cast Iron	6.0	450	1	0.00	0.00	0.00	0.00
C21	Upsize	SWSP	9.0	1200	1	1.03	2.30	0.21	0.43
C22	Repair	CSP	11.9	600	1	0.02	1.63	0.02	0.09
C23	Abandon	CSP	39.6	450	1	0.00	0.00	0.00	0.02
C24	Functioning as Intended	CSP	8.6	900	1	0.14	2.13	0.03	0.17
C25	Repair	CSP	9.8	600	2	0.21	1.93	0.10	0.26
C26	Replace	SWSP	5.2	900	1	0.39	1.64	0.31	0.55
C27	Clean Out	CSP	16.6	800	2	0.39	0.94	0.12	0.70

Name	Proposed Culvert Action	Culvert Type	Length (m)	Diameter (mm)	Number of Barrels	Max. Flow (m^3/s)	Max. Velocity (m/s)	Max/Full Flow (m/s/m/s)	Max/Full Depth (m/m)
C28	Repair	CSP	4.6	600	1	0.02	0.61	0.05	0.17
C29	Functioning as Intended	CSP	39.6	900	1	0.57	2.38	0.35	0.42
C30	Upsize	Reinforced Concrete Box	12.0	3600 x 1200	2	13.00	1.37	1.00	1.11
C31	Upsize	Reinforced Concrete Box	12.5	3600 x 1200	2	12.06	1.39	1.00	1.03
C32	Functioning as Intended	CSP	22.8	900	1	0.05	1.81	0.02	0.09
C33	Upsize	SWSP	10.5	600	1	0.08	2.25	0.07	0.18
C34	Upsize	SWSP	5.6	450	1	0.09	1.59	0.32	0.39
C35	Upsize	SWSP	6.2	450	1	0.05	1.48	0.10	0.28
C36	Abandon	CSP	17.4	1000	1	0.00	0.00	0.00	0.00
C37	New Culvert	SWSP	12.0	450	1	0.02	1.31	0.05	0.12
C38	New Culvert	SWSP	17.1	450	1	0.01	1.84	0.02	0.07
C39	New Culvert	SWSP	39.2	900	1	0.47	2.59	0.28	0.33
C40	New Culvert	SWSP	6.9	450	1	0.01	0.57	0.01	0.14
C41	New Culvert	SWSP	11.9	450	1	0.03	2.08	0.06	0.15
C42	New Culvert	SWSP	9.8	1200	1	0.56	1.81	0.38	0.32
C43	New Culvert	SWSP	13.3	1200	1	0.56	2.27	0.17	0.27
C44	New Culvert	SWSP	10.4	1200	1	0.56	2.99	0.10	0.22
C45	New Culvert	SWSP	9.9	450	1	0.00	0.86	0.02	0.07
C46	New Culvert	SWSP	14.5	900	1	0.10	1.58	0.08	0.20
C47	New Culvert	SWSP	7.0	450	1	0.01	1.86	0.01	0.09
C48	New Culvert	SWSP	6.7	450	1	0.02	1.28	0.08	0.17
C49	New Culvert	SWSP	5.4	450	1	0.02	1.38	0.06	0.16
C50	New Culvert	SWSP	9.0	450	1	0.00	1.53	0.00	0.04
C51	New Culvert	SWSP	11.6	450	1	0.02	2.28	0.02	0.10
C52	New Culvert	SWSP	10.0	450	1	0.01	1.74	0.02	0.09

APPENDIX E

INVENTORY OF EXISTING CULVERTS

Table E-1: Culvert C1

Culvert Name	C1
Date Assessed	July 20, 2021
Diameter (mm)	400
Material	Corrugated steel
Condition	Damaged outlet
Recommended Action	Replace
Notes	Undersized
Inlet Photo	

Outlet Photo	

Table E-2: Culvert C2

Culvert Name	C2
Date Assessed	July 20, 2021
Diameter (mm)	900
Material	Corrugated Steel
Condition	Functioning as Intended
Recommended Action	
Notes	

Inlet Photo	
Outlet Photo	

Table E-3: Culvert C3

Culvert Name	C3
Date Assessed	July 20, 2021
Diameter (mm)	500
Material	Corrugated Steel

Condition	Damaged
Recommended Action	upsize
Notes	
Inlet Photo	

Outlet Photo	

Table E-4: Culvert C4

Culvert Name	C4
Date Assessed	July 20, 2021
Diameter (mm)	400
Material	Corrugated Steel
Condition	Blocked
Recommended Action	upsize
Notes	

Inlet Photo	
Outlet Photo	

Table E-5: Culvert C5

Culvert Name	C5
Date Assessed	July 20, 2021
Diameter (mm)	600
Material	Corrugated Steel
Condition	Damaged
Recommended Action	repair
Notes	Repair ends or replace
Inlet Photo	

Outlet Photo	

Table E-6: Culvert C6

Culvert Name	C6
Date Assessed	July 20, 2021
Diameter (mm)	600
Material	Corrugated Steel
Condition	Partially Damaged
Recommended Action	repair
Notes	Install lower to increase cover depth

Inlet Photo	

Outlet Photo	

Table E-7: Culvert C7

Culvert Name	C7
Date Assessed	July 20, 2021
Diameter (mm)	750
Material	Corrugated Steel
Condition	Partially Damaged
Recommended Action	repair
Notes	

Inlet Photo	

Outlet Photo	

Table E-8: Culvert C8

Culvert Name	C8
Date Assessed	July 20, 2021
Diameter (mm)	750
Material	Corrugated Steel
Condition	Partially Damaged
Recommended Action	repair
Notes	

Inlet Photo	

Outlet Photo	

Table E-9: Culvert C9

Culvert Name	C9
Date Assessed	July 20, 2021
Diameter (mm)	600
Material	Corrugated Steel
Condition	Partially Damaged
Recommended Action	upsize
Notes	Upsize to 2x1200mm or 1x1400mm

Inlet Photo	
Outlet Photo	

Table E-10: Culvert C10

Culvert Name	C10
Date Assessed	July 20, 2021
Diameter (mm)	750
Material	Corrugated Steel
Condition	Functioning as Intended
Recommended Action	upsize
Notes	Upsize to 2x1200mm or 1x1400mm
Inlet Photo	

Outlet Photo	

Table E-11: Culvert C11

Culvert Name	C11
Date Assessed	July 20, 2021
Diameter (mm)	
Material	Corrugated Steel
Condition	Damaged
Recommended Action	replace
Notes	Install lower to increase cover depth

Inlet Photo	
Outlet Photo	

Table E-12: Culvert C12

Culvert Name	C12
Date Assessed	July 20, 2021
Diameter (mm)	
Material	Corrugated Steel
Condition	Blocked
Recommended Action	replace
Notes	Buried outlet
Inlet Photo	
Outlet Photo	

Table E-13: Culvert C13

Culvert Name	C13
Date Assessed	July 20, 2021
Diameter (mm)	600
Material	Corrugated Steel
Condition	Partially Damaged
Recommended Action	repair
Notes	Repair Inlet. Install lower to increase cover depth
Inlet Photo	

Outlet Photo	

Table E-14: Culvert C14

Culvert Name	C14
Date Assessed	July 20, 2021
Diameter (mm)	450
Material	Corrugated Steel
Condition	Partially Damaged
Recommended Action	upsize
Notes	Upsize to 2x1200mm or 1x1400mm

Inlet Photo	
Outlet Photo	

Table E-15: Culvert C15

Culvert Name	C15
Date Assessed	July 20, 2021
Diameter (mm)	600
Material	Corrugated Steel
Condition	Partially Damaged

Recommended Action	upsize
Notes	Upsize to 2x1200mm or 1x1400mm
Inlet Photo	

Outlet Photo	

Table E-16: Culvert C16

Culvert Name	C16
Date Assessed	July 20, 2021
Diameter (mm)	100
Material	Cast Iron
Condition	Damaged
Recommended Action	upsize
Notes	

Inlet Photo	
Outlet Photo	

Table E-17: Culvert C17

Culvert Name	C17
Date Assessed	July 20, 2021

Diameter (mm)	100
Material	Cast Iron
Condition	Functioning as Intended
Recommended Action	upsize
Notes	
Inlet Photo	
Outlet Photo	

Table E-18: Culvert C18

Culvert Name	C18

Date Assessed	July 20, 2021
Diameter (mm)	100
Material	Cast Iron
Condition	Functioning as Intended
Recommended Action	
Notes	
Inlet Photo	
Outlet Photo	

Table E-19: Culvert C19

Culvert Name	C19

Date Assessed	July 20, 2021
Diameter (mm)	800
Material	Corrugated Steel
Condition	Damaged
Recommended Action	abandon
Notes	
Inlet Photo	

Outlet Photo	

Table E-20: Culvert C20

Culvert Name	C20
Date Assessed	July 20, 2021
Diameter (mm)	100
Material	Cast Iron
Condition	Damaged
Recommended Action	abandon
Notes	

Inlet Photo	
Outlet Photo	

Table E-21: Culvert C21

Culvert Name	C21
Date Assessed	July 20, 2021
Diameter (mm)	800
Material	Corrugated Steel
Condition	Functioning as Intended
Recommended Action	upsize
Notes	
Inlet Photo	

Outlet Photo	

Table E-22: Culvert C22

Culvert Name	C22
Date Assessed	July 20, 2021
Diameter (mm)	600
Material	Corrugated Steel
Condition	Partially Damaged
Recommended Action	repair
Notes	

Inlet Photo	
Outlet Photo	

Table E-23: Culvert C23

Culvert Name	C23
Date Assessed	July 20, 2021

Diameter (mm)	450
Material	Corrugated Steel
Condition	Blocked
Recommended Action	abandon
Notes	
Inlet Photo	

Outlet Photo	

Table E-24: Culvert C24

Culvert Name	C24
Date Assessed	July 20, 2021
Diameter (mm)	900
Material	Corrugated Steel
Condition	Functioning as Intended
Recommended Action	Functioning as Intended
Notes	

Inlet Photo	
Outlet Photo	

Table E-25: Culvert C25

Culvert Name	C25
Date Assessed	July 20, 2021
Diameter (mm)	600

Material	Corrugated Steel
Condition	Partially Damaged
Recommended Action	repair
Notes	Repair damaged outlet or replace
Inlet Photo	

Outlet Photo	

Table E-26: Culvert C26

Culvert Name	C26
Date Assessed	July 20, 2021
Diameter (mm)	800
Material	Corrugated Steel
Condition	Damaged
Recommended Action	replace
Notes	Install lower to increase cover depth

Inlet Photo	
Outlet Photo	

Table E-27: Culvert C27

Culvert Name	C27
Date Assessed	July 20, 2021
Diameter (mm)	800
Material	Corrugated Steel

Condition	Partially Blocked
Recommended Action	clean out
Notes	
Inlet Photo	

Outlet Photo	

Table E-28: Culvert C28

Culvert Name	C28
Date Assessed	July 20, 2021
Diameter (mm)	600
Material	Corrugated Steel
Condition	Partially Damaged
Recommended Action	repair
Notes	

Inlet Photo	
Outlet Photo	

Table E-29: Culvert C29

Culvert Name	C29

Date Assessed	July 20, 2021
Diameter (mm)	800
Material	Corrugated Steel
Condition	Functioning as Intended
Recommended Action	Functioning as Intended
Notes	
Inlet Photo	

Outlet Photo	

Table E-30: Culvert C30

Culvert Name	C30
Date Assessed	July 20, 2021
Diameter (mm)	1200
Material	Corrugated Steel
Condition	Partially Damaged
Recommended Action	upsize
Notes	

Inlet Photo	
Outlet Photo	

Table E-31: Culvert C31

Culvert Name	C31
Date Assessed	July 20, 2021
Diameter (mm)	1200
Material	Corrugated Steel
Condition	Functioning as Intended
Recommended Action	upsize

Notes	
Inlet Photo	
Outlet Photo	

Table E-32: Culvert C32

Culvert Name	C32
Date Assessed	July 20, 2021
Diameter (mm)	900
Material	Corrugated Steel
Condition	Functioning as Intended
Recommended Action	Functioning as Intended
Notes	

Inlet Photo	

Outlet Photo	

Table E-33: Culvert C33

Culvert Name	C33
Date Assessed	July 21, 2021
Diameter (mm)	450
Material	Corrugated Steel
Condition	Blocked
Recommended Action	upsize
Notes	

Inlet Photo	
Outlet Photo	

Table E-34: Culvert C34

Culvert Name	C34

Date Assessed	July 21, 2021
Diameter (mm)	300
Material	Corrugated Steel
Condition	Damaged
Recommended Action	upsize
Notes	Install lower to increase cover depth
Inlet Photo	
Outlet Photo	

Table E-35: Culvert C35

Culvert Name	C35
Date Assessed	July 21, 2021
Diameter (mm)	250
Material	Cast Iron
Condition	Functioning as Intended
Recommended Action	upsize
Notes	Install lower to increase cover depth
Inlet Photo	

Outlet Photo	

Table E-36: Culvert C36

Culvert Name	C36
Date Assessed	July 20, 2021
Diameter (mm)	
Material	Corrugated Steel
Condition	Buried
Recommended Action	abandon
Notes	

Inlet Photo	
Outlet Photo	

APPENDIX F

COMMUNITY PLANS AND BYLAW NO. 168

GRISE FIORD COMMUNITY PLAN

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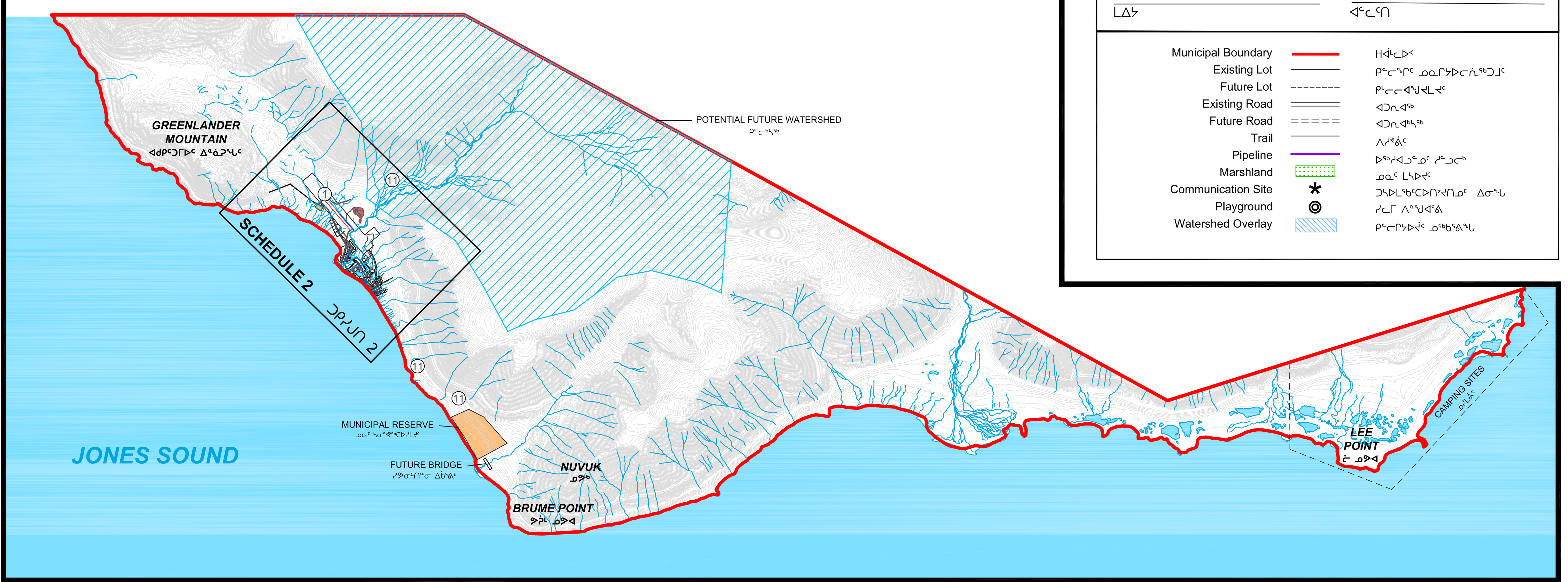
SCHEDULE 3: LAND USE & ZONING - MUNICIPAL BOUNDARY VIEW



READ a third time this ____ day of ______________, 2016 A.D.

______________ Mayor

______________ Senior Administrative Officer

______ ______________, 2016 A.D.

Municipal Boundary		ᕼᐋᒪᓚᐅᑉ
Existing Lot		
Future Lot		
Existing Road		
Future Road		
Trail		
Pipeline		
Marshland		
Communication Site	*	
Playground	◎	
Watershed Overlay		

COMMUNITY / COMMERCIAL

PERMITTED USES

- Automotive gas bar
- Bank
- Broadcasting studio
- Commercial recreation
- Communications facility
- Community freezer
- Community hall or centre
- Convenience store
- Correctional facility
- Craft studio
- Day care centre
- Educational facility
- Emergency and protective services
- Government office
- Group home
- Health care facility
- Hotel
- Office
- Park or playground
- Parking lot
- Personal service
- Place of worship
- Post office
- Restaurant
- Retail store
- Service and repair shop

CONDITIONAL USES

- Dwelling unit(s) in a non-residential building provided that the dwelling unit(s) are above the ground floor.
- Home occupation
- Planned Unit Development
- Staff housing
- Uses similar in character and purpose to those listed for this zone

INDUSTRIAL

PERMITTED USES

- Automotive gas bar
- Automotive repair, sales or facility
- Building supply or contractors shop
- Caretaker unit
- Communications facility
- Community freezer
- Heavy equipment and vehicle yard
- Manufacturing plant
- Outdoor storage
- Rental shop
- Warehouse

CONDITIONAL USES

- Barge staging and landing site with associated warehousing
- Food processing facility
- Fuel storage facility
- Hazardous goods storage
- Planned Unit Development
- Power generation facility
- Sewage treatment plant

OPEN SPACE

PERMITTED USES

- Archaeological site
- Beach shacks
- Boat storage
- Cemetery
- Dock
- Monument, cairn, or statue
- Park or playground
- Shed to store equipment for traditional, cultural, and recreational activities taking place in the Zone.
- Snow fence
- Sports field
- Washroom facility

CONDITIONAL USES

- Communications facility
- Dog teams
- Uses similar in character and purpose to those listed for this zone

TRANSPORTATION

PERMITTED USES

- Airport and related uses
- Communications facility
- Planned Unit Development
- Service shop
- Sea lift facility

NUNA

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PERMITTED USES

- Archaeological site
- Dog team
- Temporary tenting or camping

CONDITIONAL USES

- Beach shack
- Cabin
- Quarry
- Cemetery
- Commercial harvesting
- Communications facility
- Permanent hunting and fishing cabins or camps
- Resource exploration and development
- Snow fence
- Tourist facilities
- Wind turbine
- Land farm

RESIDENTIAL

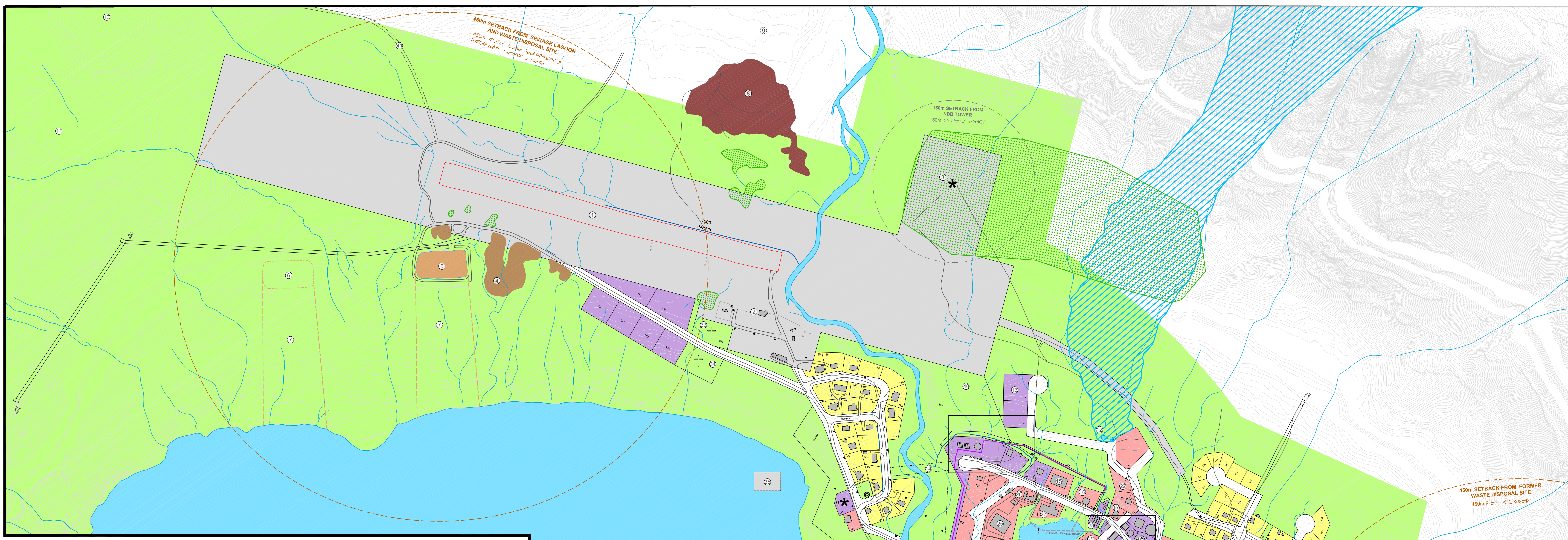
PERMITTED USES

- Dwelling, single-unit
- Dwelling, semi-detached or duplex
- Dwelling, rowhouse
- Dwelling, multi-unit
- Dwelling, apartment
- Park or playground

CONDITIONAL USES

- Bed and breakfast
- Craft studio
- Daycare centre
- Dwelling, mini home
- Elders facility
- Group home
- Home occupation
- Secondary suite
- Planned Unit Development

SCHEDULE 2: LAND USE & ZONING - COMMUNITY VIEW



Airstrip	1	Church	21
Airport	2	Future Community Freezer	22
NBD Tower	3	Wildlife Office	23
Waste Disposal Site	4	RCMP	24
Sewage Lagoon	5	New Hamlet Office	25
Future Secondary Sewage Lagoon	6	Future Health Centre	26
Wetland Treatment Area	7	Health Centre	27
Quarry	8	Power Plant	28
Canada Day Picnic Area	9	Ummimak School	29
Look Out Point	10	Co-op Hotel	30
Picnic Area	11	Community Centre / Gym	31
Water Intake	12	Community Freezer	32
Future Power Plant	13	Cemetery	33
Future Seasonal Bridge	14	Future Cemetery Expansion	34
Arctic Co-op	15	Potential Floating Dock	35
Hamlet Office	16	Proposed Breakwater	36
Firehall	17	Sealift	37
Water Tanks	18	Former Waste Disposal Site	38
Daycare	19	Camping Site	39
Housing Association	20	Monument	40
		Future Community Access Road	41

GRISE FIORD COMMUNITY PLAN

BY-LAW 65

MARCH 2016

FOTENN PLANNING & URBAN DESIGN

exp.

GRISE FIORD COMMUNITY PLAN

BY-LAW NO. 65

A By-law of the Hamlet of Grise Fiord in Nunavut Territory to adopt a General Plan pursuant to the provisions of the Planning Act, RSNWT, 1988, c. P-7, s.4.

WHEREAS the Council of the Hamlet of Grise Fiord has prepared a General Plan, referred to as the "Grise Fiord Community Plan", in accordance with the Planning Act:

NOW THEREFORE, the Council of the Hamlet of Grise Fiord, duly assembled, enacts as follows:

1. That the Community Plan of the Hamlet of Grise Fiord hereto annexed and marked as Appendix "A" to this By-law, shall hereby constitute the Community Plan of the Hamlet of Grise Fiord.
2. This By-law may be cited as the "Grise Fiord Community Plan."
3. This By-law shall come into full force and effect on the date of its Third Reading.
4. By-law No. 59 of the Hamlet of Grise Fiord is hereby repealed.

READ a first time this 8th day of March, 2016, A.D.

Mayor

A Senior Administrative Officer

After due notice and a Public Hearing, READ a second time this 25th day of October, 2016, A.D.

Mayor

A Senior Administrative Officer

APPROVED by the Minister of Community and Government Services this 27 day of APRIL, ~~2016~~, A.D. 2017

Minister

READ a third time this 27 day of June, ~~2016~~ 2017 A.D.

Mayor

Senior Administrative Officer

1 INTRODUCTION

1.1 Purpose of the Plan

The purpose of the Grise Fiord Community Plan is to outline Council's policies for managing the physical development of the Hamlet until 2035. The Community Plan was created through a community consultation process and reflects the needs and desires of the community. The Community Plan builds on previous plans, while incorporating new policies to address the challenges, issues and needs identified by the community.

1.2 Goals of the Community Plan

Community Plan policies emerge from the values of a community and its vision of how it would like to grow. The goals established for this Community Plan are:

1. To create a safe, healthy, functional and attractive community that reflects community values and culture.
2. To promote the Plan as a tool for making effective and consistent decisions regarding land use and development in the community.
3. To ensure an adequate supply of land for all types of uses to support the growth and change in the community.
4. To build upon community values of participation and unity to support community projects and local economic development.
5. To protect the natural beauty of "Nuna", by protecting viewpoints to the water, and retaining waterfront and lakeshore areas for public uses and traditional activities.

1.3 Administration of the Plan

The Community Plan is enacted by By-law. Changes to the Plan can be made by amending the By-law in accordance with the *Nunavut Planning Act*. The Community Plan should be reviewed and updated every five years as required by the *Nunavut Planning Act*. A Zoning By-law is also being enacted for the purpose of implementing regulations based on the policies of the Community Plan. All development must follow the intent of the Community Plan and Zoning By-law. The Community Plan includes Schedule 1 (Policy Plan Text), Schedule 2 (Land Use & Zoning Map – Community View), and Schedule 3 (Land Use & Zoning Map – Municipal Boundary).

2 COMMUNITY GROWTH & PHASING POLICIES

At the time of preparation of this Plan, the population of Grise Fiord was approximately 130 people. This Plan is based on a future population of approximately 170 people by 2035, however this number may increase or decrease based on the influence of various factors. These factors include economic development activity in the region, the natural rate of population growth, and in-migration from other communities. It is estimated that an additional 6 dwelling units will be required to meet the projected population growth, which can be accommodated on lands currently zoned for residential development. Sufficient land is also available for industrial uses in a new subdivision. Some additional land for community and commercial uses are required to accommodate future development. The policies of Council are:

a) Provide for a designated land supply to meet the needs of a population of approximately 170 people by 2035.
b) Identify sufficient land on the Community Plan to meet the needs of the projected 2035 population.
c) Review the Community Plan in 5 years, in 2021, to re-assess actual rates of growth and community needs.
d) Council will generally phase new community land development as follows:
   i. Infill and redevelopment on vacant or underused lots within the built-up area of the Hamlet;
   ii. Development of vacant lots in new subdivisions.
e) Phasing of development may change without amendment to this Plan.

3 GENERAL POLICIES

The following policies of Council apply to all development in the Hamlet:

a) The development of lots shall be subject to the following lot development policies:
   i. Buildings shall be sited to respect setbacks identified in the Zoning By-law.
   ii. All service connections to buildings with trucked services shall be easily accessed from the front yard on all lots and grouped together, where possible.
   iii. Building foundations should achieve an unobstructed gap of at least 0.8 metres between the ground and the underside of the building, wherever possible, to reduce problems associated with snow drifting.
   iv. Any building over 500 m^2 in gross floor area shall consider potential wind impacts on surrounding development. A wind study may be required by the Development Officer.
   v. Culverts are required and shall be installed across access driveways to lots.
   vi. On any portion of a lot where fill is introduced, drainage shall be directed towards the public road. Exceptions may be made by the Development Officer. Where possible, drainage ditches shall not be located in utility rights-of-way or easements.
   vii. Road widenings may be obtained, as required, at the time of development or redevelopment of a lot in situations where the road right-of-way is less than 16 metres wide.
b) Utilities or communication facilities shall be permitted in any land use designation. Other than designated rights-of-way or easements for utility or communication lines, easements alongside roadways, marked between the edge of the roadway and lot lines, will be used for distribution lines, with a minimum clearance, as specified in the Utility Corporation's Joint Use Agreement.

c) The Hamlet will pile snow in locations to minimize downwind snow drifting and where spring melt run-off can be properly channelled to drainage ditches or waterbodies.
d) The Hamlet shall avoid piling snow within 30.5 metres (100 feet) of any watercourse.
e) The Hamlet shall protect any cemeteries and sites of archaeological, ethnicographical, palaeontological or historical significance from disturbance. Any development in or near such sites shall follow the *Nunavut Archaeological and Palaeontological Regulations, 2001* of the *Nunavut Act* (Canada).
f) The Hamlet shall encourage development that minimizes emissions from fossil fuels, that are energy efficient and that consider alternative energy supply technology.
g) The Hamlet shall work with the Nunavut Planning Commission to ensure that the Community Plan and the future Nunavut Land Use Plan are compatible.
h) The Hamlet will seek opportunities to improve connectivity of walkways and other transportation corridors, where possible, to maximize safety and efficiency for users.

4 COMMUNITY DEVELOPMENT POLICIES

The following policies of Council shall guide Council's decision-making on issues of development and land uses:

a) Adequate housing is fundamental to public health, and the social well-being of the community. In addition to identifying new residential development areas, Council will encourage and pursue the development of new homes in the community.
b) The Hamlet will use new development and public spaces to celebrate Inuit culture and language.
c) Council will actively pursue property standards with lessees and property owners in the Hamlet to ensure that building stock, particularly housing stock, is being fully utilized and maintained.
d) Due to capacity, safety, and need for more developable land, Council will continue to actively pursue the relocation of the existing airport to the old airport site east of the existing townsite.
e) Facilities for youth, including the retention / relocation of the existing Youth Hall will be a priority for Council.
f) The Hamlet shall encourage development that minimizes emissions from fossil fuels, that are energy efficient and that consider alternative energy supply technology.
g) The Hamlet shall consider strategies to adapt to the future impacts of climate change, such as locating development away from low-lying coastal areas and protecting existing areas against erosion.

5 LAND USE DESIGNATION POLICIES

5.1 Residential

The Residential designation provides land for primarily residential uses, but also permits other small-scale conditional uses subject to the approval of Council. The policies of

Council are intended to maintain an adequate supply of land for residential development, to build safe and liveable neighbourhoods, and to protect residential areas from incompatible development. The policies of Council are:

a) The Residential designation will be used primarily for housing with all types of dwellings permitted. Other related residential uses such as a group home, a home occupation, or a bed and breakfast will be conditionally permitted.
b) Residential development will be phased so that a target minimum 3-year supply of vacant surveyed land, or approximately 0.5 hectares of vacant surveyed land, is available at any given time.

5.2 Community Use

The Community Use designation is intended to maintain an adequate supply of land for commercial and community uses, preferably in significant and important locations so that residents may enjoy easy access to public facilities and services. The policies of Council are:

a) The Community Use designation will be used primarily for:
   i. commercial uses, such as hotels, restaurants, retail stores, personal and business services, and offices;
   ii. public uses, such as community centres, churches, medical clinics, schools, and other institutional or community uses; and
   iii. government services.
b) Community facilities will be centrally located to ensure safe and convenient access by residents.
c) Commercial facilities will be located along main roads, where possible, to provide safe and convenient access by residents.
d) Residential uses will be permitted when located above a ground floor commercial or community use.
e) Council will encourage the re-use or redevelopment of existing sites within the built-up area of the Hamlet.

5.3 Open Space

The Open Space designation is intended to protect shoreline environments, maintain access to the sea and to reserve open spaces within the built-up area for recreational uses and cultural events. The policies of Council are:

a) The Open Space designation will be used primarily for parks, walking trails, dog teams and other forms of passive recreation.
b) A playground should be located within 300 metres walking distance from any residence in the community.
c) Unless otherwise noted, all Commissioner’s Land forming part of the 100-foot strip (30.5 metres) along the seashore measured from the ordinary high water mark will be designated Open Space.
d) Generally no development is permitted within 30 metres from the normal high water mark of any river or major creek. Council may consider the filling of a

waterbody where it is needed for future development provided that the appropriate approvals are obtained.

5.4 Industrial

The Industrial designation is intended to reserve land for economic development activities and support job creation. The designation is also intended to reduce the negative effects and dangers associated with industrial uses such as noise, dust, odours, truck travel and the storage of potentially hazardous substances by concentrating these uses on the periphery of the townsite. The policies of Council are:

a) Permitted uses in the Industrial designation will include all forms of manufacturing, processing, warehousing, and storage uses. Permitted uses will also include garages, power generation plants, and fuel storage.
b) Council will work with local businesses and government operations to identify opportunities to relocate non-conforming industrial uses (e.g. garages, warehouses, etc.) inside the village to the new industrial subdivision.

5.5 Transportation

The Transportation designation is intended to identify major transportation facilities, such as marinas and airports, and to ensure their safe and efficient operation. The policies of Council are:

a) The Transportation designation is intended primarily for transportation facilities, including marine facilities, the airport, and associated air navigation communications systems.
b) All development within the areas affected by the Grise Fiord Airport Zoning Regulations shall comply with those regulations. Development applications shall be referred to Nunavut Airports for review and approval where development is proposed adjacent to the airport and/or where development has the potential to interfere with airport operations.
c) All development within the 200-metre Influence Zone of the Non-Directional Beacon (NDB) Communications Site, as shown on Schedule 2: Land Use & Zoning Map – Community View, is subject to the approval of NAV CANADA.

5.6 Nuna

The Nuna designation applies to all unsurveyed land within the Municipal Boundary not designated by another land use. It is intended to protect the natural beauty and cultural resources of the land – 'Nuna' – while providing access for traditional, recreational and tourism activities. The Nuna designation also permits mineral exploration, quarrying, and local infrastructure projects such as landfills, soil remediation, water supply and treatment, and wastewater treatment to ensure proper separation of these activities from the townsite. The policies of Council are:

a) The Nuna designation generally permits traditional, tourism and recreational uses. Permitted uses also include dog teams, quarrying, mineral exploration, and local infrastructure projects.

b) Council shall ensure that development does not negatively impact wildlife, wildlife habitat and harvesting, and is consistent with the guiding principles of Inuit Qaujimajatuqangit (IQ).

5.7 Waste Disposal Overlay

The Waste Disposal Overlay identifies the required 450-metre setback from existing or former waste disposal sites. The policies of Council are:

a) The Hamlet shall generally prohibit the development of residential uses and uses involving food storage or food preparation within 450 metres of any existing or former waste disposal site, pursuant to the *General Sanitation Regulations* of the *Public Health Act* (Nunavut).
b) Despite Policy (a) above, the Hamlet may seek variances to the 450-metre waste disposal setback from the GN Environmental Health Officer for development proposed within the setback, as shown on Schedule 2: Land Use & Zoning Map – Community View. A letter from the Environmental Health Officer confirming the variance shall be obtained prior to the issuance of a Development Permit.

5.8 Watershed Overlay

The Watershed Overlay identifies the watershed of the Hamlet water source (glacial runoff) and is intended to restrict the uses of the underlying designation to protect the Hamlet water source. The policies of Council are:

a) No development is permitted in the Watershed Overlay, unless it can be demonstrated that the development will have no negative impact on the Hamlet water source.
b) Despite policy 4.8 a) above, uses accessory to the supply of water such as a pipeline, a pumping or monitoring station or road are permitted.

5.9 Municipal Reserve

The Municipal Reserve designation is intended to reserve the land for the future growth of the community. The policies of Council are:

a) The Municipal Reserve designation does not permit any development except temporary uses approved by Council.
b) Municipal Reserve lands shall be redesignated by amendment to this Plan prior to being used for community expansion.

APPENDIX G

CULVERT THAWING METHODS

Culvert Thawing

Culverts are subject to freezing during winter and spring. During winter, ground water can continuously feed streams which either flow through culverts or over roadways causing icing. During spring breakup, daytime melting must be carried through culverts.

When a culvert freezes it can no longer do the job it was designed to do and trapped water will begin to cause problems and ultimately, money.

What's the Solution?

To thaw culverts, a combination of hot water/steam and high pressure water in a mobile environment is the effective method.

Mobile Pressure Washers

To thaw culverts quickly, a skid style hot water pressure washer/steamer, also known as a truck mounted pressure washer is the equipment of choice.

Self-contained and designed to hold up under the toughest of conditions, skid mounted pressure washers/steamers can be bolted onto the back of a truck, on an open deck trailer or in an enclosed trailer.

Enclosed Trailer Mounted Pressure Washer

Open Deck Mounted Pressure Washer

Skid Mounted Presure Washer

Culvert Nozzles

Culvert nozzles are required to dig effectively through ice. The reverse jets on the fixed and rotary nozzles pull the hose through the tube or sewer line and blast debris from the line or tube wall.

Backward ports drive the nozzle forward and flush debris
Forward ports blast into pipe and break up clogs & debris
Physically small for cornering ability up to 4200 PSI
Corrosion resistant stainless steel construction
A wide range of orifice sizes are available for various pressure and flow applications

Rotating style adds extra agitation and surface cleaning

United States Patent [19]

Olsson

[11] Patent Number: 4,770,211

[45] Date of Patent: Sep. 13, 1988

[54] METHOD FOR THAWING OUT ROAD CULVERTS CHOKED WITH ICE

[76] Inventor: Lars-Uno Olsson, Heden 4084, S-780 53 Nås, Sweden

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[22] PCT Filed: Feb. 24, 1986

[86] PCT No.: PCT/SE86/00080

§ 371 Date: Oct. 24, 1986

§ 102(e) Date: Oct. 24, 1986

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[30] Foreign Application Priority Data

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[51] Int. Cl.[4] E03B 7/10; F16L 53/00

[52] U.S. Cl. 138/32; 138/28; 138/35

[58] Field of Search .... 138/26, 28, 32, 35; 254/262, 263, DIG. 14; 405/124, 130, 131; 137/301

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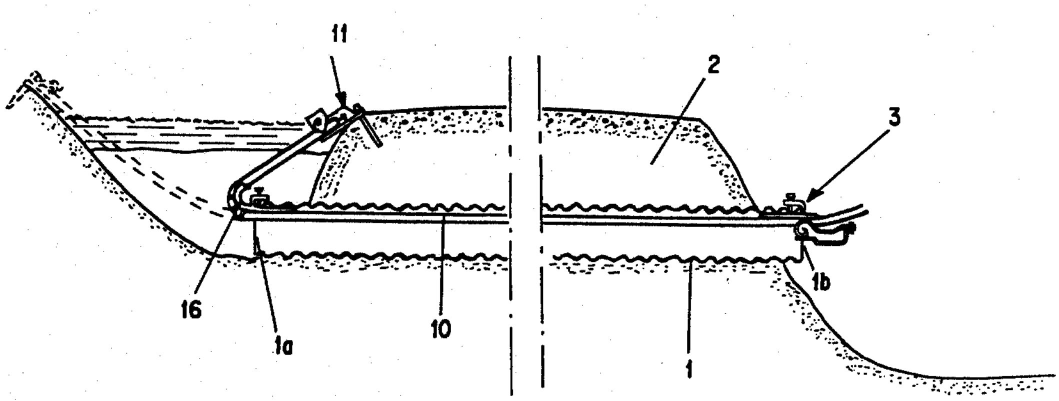
Attorney, Agent, or Firm—Witherspoon & Hargest

[57] ABSTRACT

Method for clearing a road culvert or the like which is choked with ice, wherein a substantially homogeneous rope of a material having at least a certain reversible extensibility is extended through the culvert from its inlet side to its outlet side and wherein the rope in its unloaded condition is clamped in connection with the outlet side and the inlet side respectively of the culvert so that the rope extends through the culvert.

4 Claims, 3 Drawing Sheets



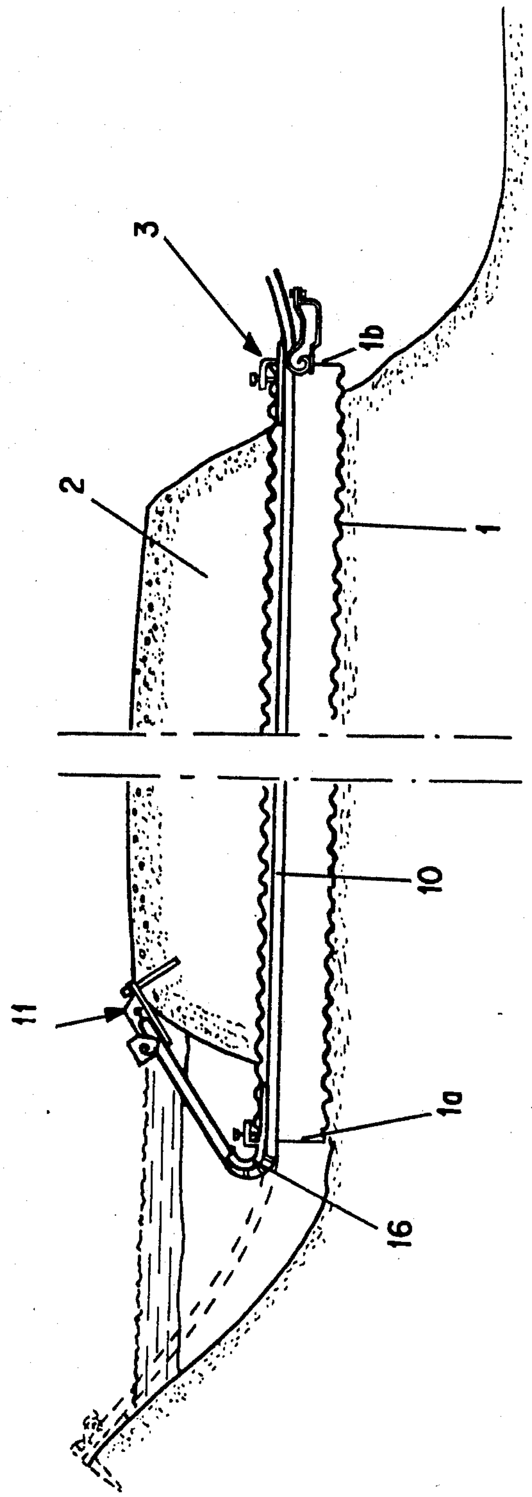


Fig. 1

Fig. 5

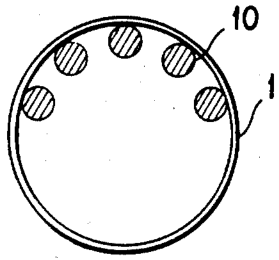
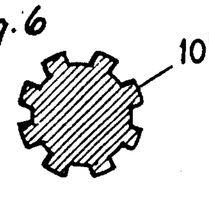


Fig. 6



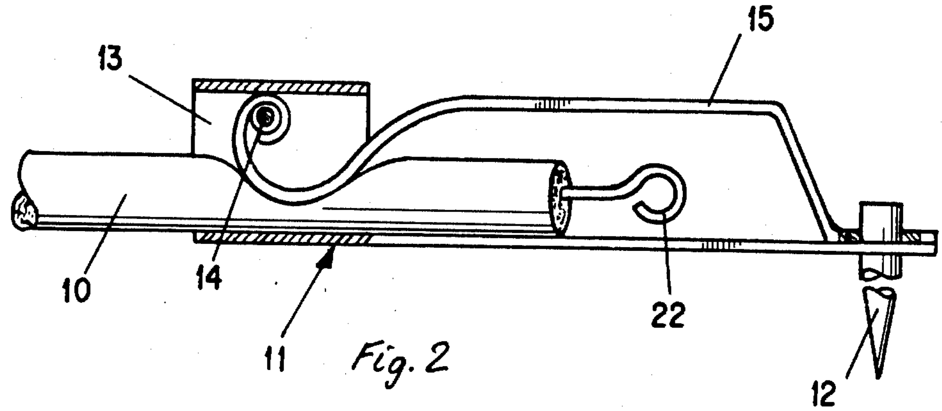


Fig. 2

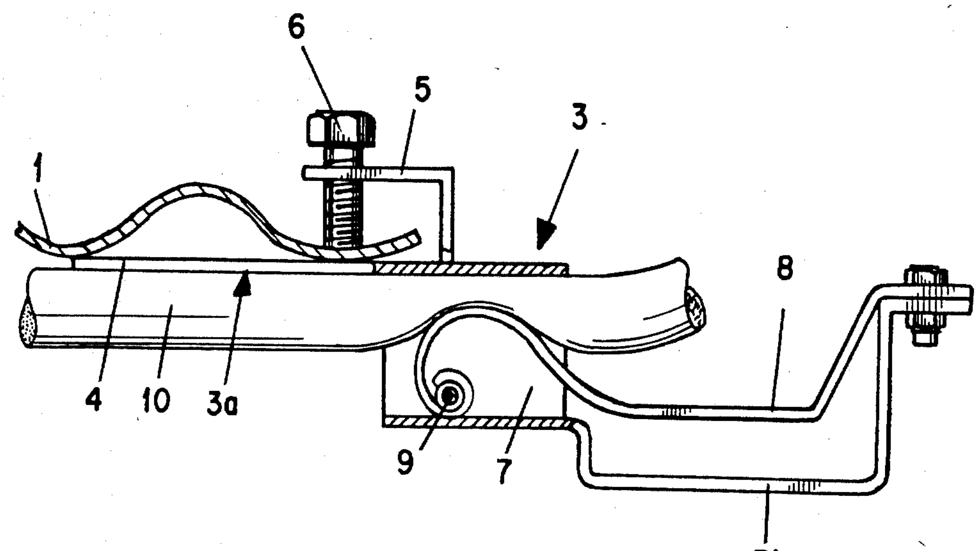
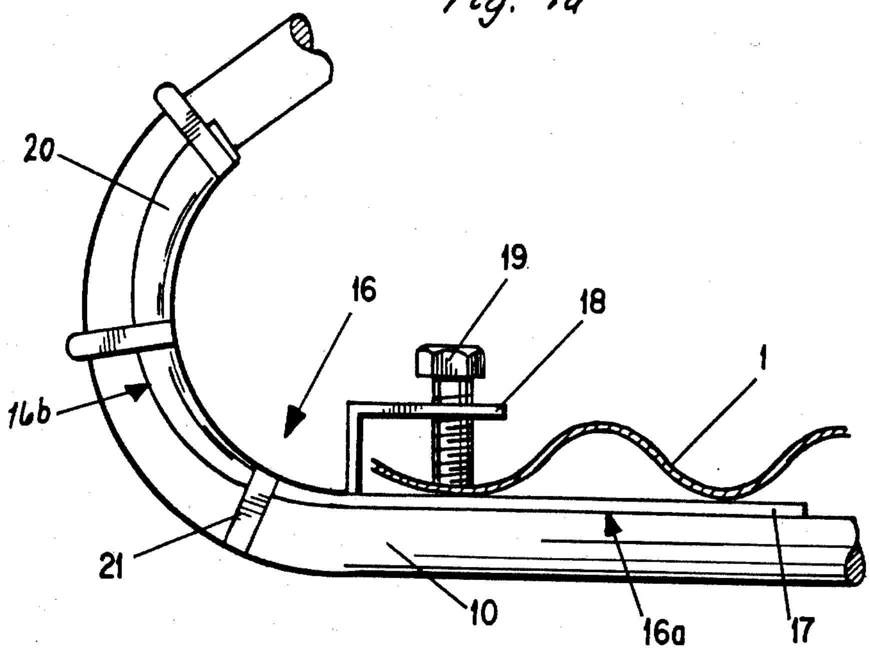


Fig. 3

Fig. 4a



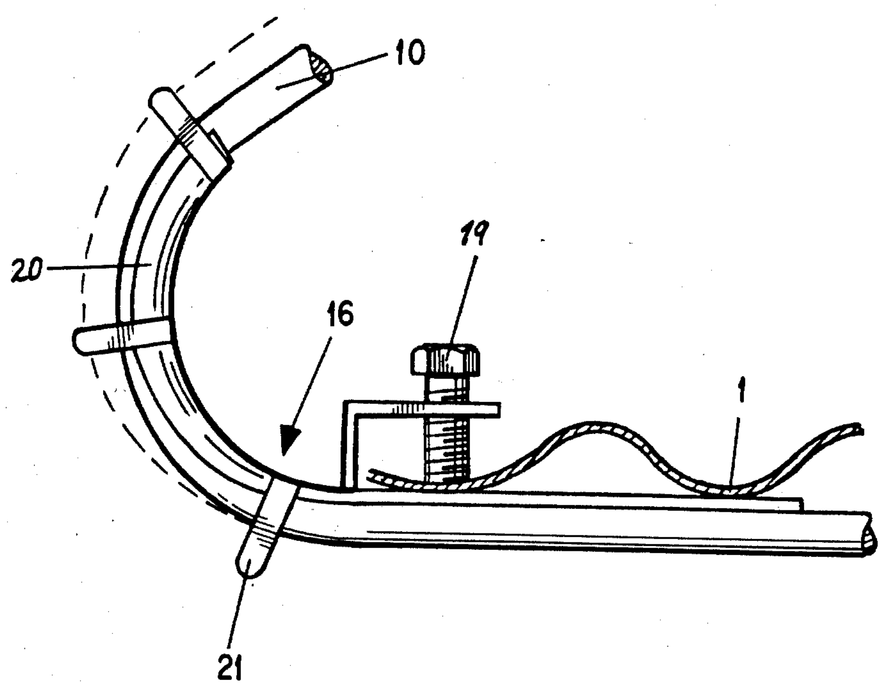


Fig. 4b

METHOD FOR THAWING OUT ROAD CULVERTS CHOKED WITH ICE

BACKGROUND OF THE INVENTION

The present invention relates to a method for thawing out road culverts choked with ice and also relates to an apparatus for carrying out said method.

A common problem in connection with winter maintenance is that road culverts become completely choked with ice, which makes it impossible to drain melted ice through the road culverts in warm weather, and especially by the spring flood. If such a road culvert that is completely choked with ice is not thawed out before the spring flood this may cause serious flooding and also a danger of parts of the road way being washed away.

In order to prevent the above mentioned, serious consequences of a road culvert choked with ice it is presently common practice to continously inspect road culverts which by experience are known to cause problems. When a road culvert choked with ice is found during such a periodical inspection, the procedure is presently to send out a clearing partrol, usually two persons, by car for thawing out the road culvert in question. Today steam generators are mostly used for thawing out road culverts in this manner, although attempts have also been made to use conventional building dryers. Already from the above it is clear that the thawing out of a road culvert in the conventional manner brings about relatively high costs which apart from transport costs also include wage costs for two persons and the cost for the steam generator.

Apart from the fact that the conventional clearing method discussed above is relatively expensive it also suffers from a number of more or less serious disadvantages that are clear from the following general description of the presently employed method using steam thawing. As indicated above a steam generator is transported out to the working place on a lorry or the like, and when the ends of the road culvert have been exposed the steam generator is started and is connected through hoses to steam pipes used for the thawing. In certain cases it is only necessary to thaw out a smaller passage through the culvert, whereupon the flow of water through this smaller passage continues to widen the passage in the ice until the culvert is completely cleared. In such a case it is, for obtaining the best result, absolutely necessary that the first thawing out of the smaller passage is carried out relatively close to the upper portion of the road culvert since the water will eat its way down through the ice towards the bottom of the culvert. Since road culverts may have a length of up to 15–20 meters, depending upon the width of the road, such a thawing out of a first small passage through the entire length of the road culvert is very difficult to achieve with a satisfactory result by means of a steam pipe. The reason for this is that if the steam pipe has such a length that it may reach through the entire length of the road culvert it will not be possible to keep it close to the upper portion of the road culvert throughout the entire length thereof and accordingly the steam pipe will deflect such that in the worst case it will leave the culvert close to its bottom. Accordingly it may also happen that the steam pipe will be stopped and cannot be brought through the entire length of the road culvert in case stones have fallen into the road culvert and remained therein on the bottom of the culvert.

In other cases it is not sufficient to thaw out only a smaller passage in the road culvert in order to avoid flooding, and therefore it will be necessary to clear the whole culvert in order to avoid the risk that a smaller passage is frozen again. It will also be realized that in the above discussed case where it proves impossible even to thaw out a first small passage in the road culvert by means of a steam pipe, it may become necessary to clear the whole culvert. In such a case when the whole culvert is to be cleared the procedure is such that a number of unperforated steam pipes, being upon in the outer end and having a length of approximately 3 meters are successively introduced from the outlet side of the culvert. When these unperforated pipes have been inserted to their full length they are withdrawn and are exchanged for perforated steam pipes which are fixed in position. Then steam is turned on to perform its thawing action until this length of the culvert may be cleared. This procedure is repeated until the culvert has been cleared throughout its length. The last portion of the length of the culvert is usually cleared from its inlet side, but it will be realized that if the culvert has a length of 10–15 meters and possibly even 20 meters it will be necessary for the persons performing the clearing to crawl into the culvert in order to be able to carry out a great deal of the work. Even if this work is not extremely risky it is cold and damp and generally unpleasant. Naturally such a clearing of a complete culvert is very time consuming, and especially so by larger culvert diameters and lengths.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a method and an apparatus by means of which the above discussed disadvantages in connection with conventional methods may be eliminated as far as possible.

This object is achieved by means of a method and an apparatus of the kind indicated in the enclosed patent claims. From the patent claims the characteristic features of the invention are also clear.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplifying embodiments of the invention are described more closely below in connection with the enclosed drawings, on which:

FIG. 1 is a schematic illustration of the principles of the present invention in connection with a road embankment with a road culvert, both in cross section,

FIG. 2 illustrates a ground attachment of the apparatus according to the invention.

FIG. 3 illustrates a culvert attachment of the apparatus according to the invention.

FIG. 4*a* illustrates an edge cover in combination with the rope in its unloaded condition.

FIG. 4*b* illustrates the edge cover according to FIG. 4*a*, but with the rope in its loaded condition.

FIG. 5 illustrates a modified embodiment with several apparatuses according to the invention positioned in a road culvert, and

FIG. 6 illustrates another embodiment of the rope having an alternative cross-sectional shape.

Although the invention is described herein with reference only to the clearing of a road culvert, it should be obvious that the invention with the same advantage may be used for thawing out other types of culverts for draining off melted ice and/or rain-water. An example of this may be culverts used in fields by farmers in order to prevent flooding of the fields.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1 schematically illustrates the use of the invention by a road culvert 1 extended through a road embankment 2 in order to conduct melted ice and/or rainwater from an inlet side 1*a* to an outlet side 1*b*. Mostly the outlet side 1*b* of the culvert is relatively freely accessible from the outside even if the road culvert 1 is completely choked with ice, and thus, for reasons which will be explained below, a culvert attachment 3 is positioned in connection with the outlet and 1*b* of the culvert. An embodiment of the culvert attachment 3 is illustrated in greater detail in FIG. 3 from which it is clear that the culvert attachment has a first portion 3*a* intended to be clamped to the culvert. In the illustrated embodiment the first portion 3*a* comprises an inner leg 4 and an outer leg 5 between which the culvert 1 is introduced and clamped by means of a bolt 6 engaging a threaded bore in the outer leg 5. The other portion 3*b* of the culvert attachment is formed integral with the first portion 3*a* and is at its outer end releasably connected to a clamping means 8, for instance by means of a screw-nut connection 8*a*. In the illustrated embodiment the clamping means 8 consists of a flat bar being bent into a helical shape in its free end for a pivotal mounting on a pin 9 being firmly connected to a plate secured to the culvert attachment substantially midway between its ends. Through the pivotal mounting of the clamping means 8 on the pin 9 a rope 10 that will be more closely described below may be released and clamped between the helical end of the clamping means 8 and a portion of the culvert attachment close to the middle thereof by swinging the clamping means 8 upwardly and downwardly respectively about the pin 9.

In connection with the inlet side 1*a* of the road culvert 1 and at a distance therefrom a ground attachment 11 is anchored in the road embarkment 2 or at some other suitable place in accordance with what will be discussed below. In FIG. 2 a suitable embodiment of the ground attachment 11 is illustrated which in one of its ends is provided with a peg 12 which is pointed in one of its ends and which is intended to be forced down into the ground for anchoring the ground attachment. In its other end the ground attachment 11 is provided with a plate 13 which essentially corresponds to the plate 7 on the culvert attachment of FIG. 3 and which accordingly is provided with a pin 14 for pivotal mounting of one end of a clamping means 15 which in turn corresponds to the clamping means 8 of FIG. 3. Thus, the clamping means 15 has a helically shaped end for mounting on the pin 14, and in its opposite end it is releasably attached to the ground attachment 11, preferably by means of a nut 15*a* screwed into a threaded upper portion of the anchoring peg 12. It will now be realized that in accordance with what has been described in connection with FIG. 3 the clamping means 15 is intended for releasably clamping the rope 10 between its helical end a portion of the ground attachment 11.

In the case illustrated in FIG. 1 where the ground attachment is anchored in connection with the road embankment 2 it also becomes necessary to provide an edge cover 16 at the inlet end 1*a* of the culvert, and this partly for guiding the rope 10 around the relatively sharp bend and at the same time also for protecting the rope. As is clear from FIGS. 4*a* and 4*b* the edge cover 16 in a suitable embodiment consists of a first portion 16*a* which to a great extent corresponds to the first portion 3*a* of the culvert attachment 3 and thus comprises an inner leg 17 and an outer leg 18 between which the culvert 1 is clamped by means of a bolt 19 screwed into a threaded bore in the outer leg 18. The other portion 16*b* of the edge cover provides the guiding proper for the rope 10 and for this purpose includes an upwardly bent guide rail 20 having a smooth curvature for deflecting the rope 10 between 90° and 180°, in the illustrated embodiment approximately 135°. For providing the best guiding the guide rail 20 has an inner, longitudinal groove having a shape essentially corresponding to that of the rope 10. For additionally securing and guiding the rope 10 in the guide rail 20 the latter is also provided with a number of guide loops 21 evenly distributed along the length of the guide rail, and through these loops the rope is threaded.

For reasons of clarity it should be mentioned that although the elongated means, which according to the invention is intended to be extended through a road culvert, herein is referred to as a rope this term is not intended to delimit the invention regarding the cross-sectional shape or surface of the elongated means. Although the rope in the illustrated embodiments has a substantially circular cross-sectional shape it is obvious that the term rope should also cover rectangular, triangular or other suitable cross-section shapes.

As mentioned above the rope 10 is intended to be extended through the road culvert 1 and to be clamped at the culvert attachment 3 as well as at the ground attachment 11. The rope is substantially solid or homogeneous (possibly with air bubbles contained in the material) and in the illustrated embodiments it has a basically circular sectional area. The rope is cut into a suitable length corresponding to the length of the road culvert to which it is to be attached. Characteristic of the rope is that it is manufactured from a material which at least to a certain degree may be reversibly extended, i.e. a material which when it is subject to a tension load undergoes a certain, not permanent, reduction in cross section. Thus, when the tension load is removed the rope shall resume its original shape. By an embodiment of the invention where a free passage is established through ice in the road culvert by simply pulling the rope out from the culvert, it is sufficient if the rope has a relatively low reversible extensibility sufficient for reducing the cross-sectional area of the rope to such a degree that it without problem is released from the surrounding ice. By another embodiment where the passage through the ice is established with the rope remaining in the culvert by extending the rope to such an extent that its cross-sectional area is greatly reduced, it must on the other hand be possible to subject the material to such a tension load that its cross-sectional area is substantially reduced to half without any danger of the material rupturing or breaking. A material that has been found suitable for the later embodiment and that complies with the requirements thereof is a synthetic rubber EPDM (SIS 1626-70).

In either or both of its ends the rope is provided with a hook 22 the function of which will be described below. In certain cases it may also be preferable to provide the free ends of the rope with a not shown web or stocking intended to protect the rope from external damage through for instance gravel and rocks.

According to an emboidment of the invention the clearing or thawing out of a road culvert is carried out in the following manner:

In good time before the winter, when the culvert is open, the above described equipment is installed, and when installed it can remain there year after year and it will not be necessary to dismount it unless some portion thereof is damaged. The assembly is carried out such that a culvert attachment **3** of the kind described above is clamped to the outlet side **1***b* of the culvert **1**. The ground attachment **11** may be secured by forcing the anchoring peg **12** into the ground by means of any suitable tool so that it is firmly anchored, and the anchoring may be carried out in alternative places depending upon the surrounding terrain. Hereby it is determining that the ground attachment shall be anchored at a spot where there is little danger that it will become covered by ice during winter. The reason for this is naturally that it must be easy to get hold of the end of the rope **10** being positioned in connecton therewith without having to expose said end by chopping off ice. Of importance for the positioning is also that the anchoring position must be as close as possible to the inlet end **1***a* of the culvert so that the length of the rope may be reduced. In view of this the positioning illustrated with full lines in FIG. **1** seems to be preferable in most cases, but it is also possible to position the ground attachment as illustrated with broken lines in FIG. **1**, in which case the rope will be extended obliquely upwardly in FIG. **1**.

As mentioned above the positioning of the ground attachment **11** illustrated with full lines in FIG. **1** also necessitates the mounting of an edge cover **16** at the inlet end **1***a* of the culvert for deflecting and guiding the rope **10**. By the alternative positioning illustrated with broken lines it would be possible to manage without any edge cover or with an edge cover of a simpler design. When the culvert attachment, the ground attachment and possibly an edge cover have been installed the rope **10** is extended through the culvert and, where appropriate, the rope is then threaded through the edge cover, and its ends are clamped to the culvert attachment and to the ground attachment respectively. The clamping is carried out in such a way that the clamping means **8** and **15** respectively is disengaged and is swung about the pin **9** and **14** respectively, whereupon the rope is installed in the respective attachment and is clamped in position by means of the clamping means which are secured by the nut **8***a* and **15***a* respectively. The rope **10** is clamped to the attachments in its substantially unloaded condition, i.e. without being subject to any essential tension load. However, especially in connection with longer road culverts it may be necessary to clamp the rope **10** when the same is subject to a certain, low tension load in order to make sure that the rope does not hang down towards the middle but runs close to the upper edge of the culvert **1** throughout its extension, and as discussed in the introduction this is essentially in order to make it possible for the water flowing through an opened passage to eat its way down in the ice so that the ice may be efficiently cleared away. The rope remains in the above described position and when it is discovered, during a routine inspection discussed above, that the culvert is completely choked with ice so that melted ice cannot be drained therethrough it will, by employing the invention, no longer be necessary to send out any special patrol for clearing the culvert, but in most cases the person carrying out the inspection may carry out the clearing by himself. By one embodiment the procedure is such that the rope is released at the culvert attachment **3** by the outlet side **1***b* of the culvert, possibly subsequent to exposing this side by removing snow, through disengaging the clamping means **8** and swinging the same about the pin **9**. The rope which in this embodiment should have a high reversible extensibility is then stretched or tensioned by hand from the outlet side **1***b* while remaining clamped at the ground attachment **11**, and through this tension load and due to the tensibility of the material the rope **10** is immediately released from the ice as its cross-sectional area is greatly reduced. Hereby a free passage for the melted ice is established around the circumference of rope and when this has been achieved the rope is clamped to the culvert attachment **3** again in its loaded condition so that the water may continue to flow in the passage in such a way that it wears its way through the ice and finally clears the whole culvert. When the culvert has been cleared the rope is released from the culvert attachment **3** again and is unloaded so that it resumes its original shape and finally it is clamped again so that the procedure may be repeated if the culvert should become choked with ice once more. As has been mentioned above it is obvious that the rope **10** by this embodiment should have as high a reversible extensibility as possible in order to establish the largest possible passage for the melted ice when it is stretched or tensioned. In this embodiment it may also be suitable if the rope has a rectangular cross-sectional shape in order to leave as wide a passage as possible for the melted ice to thereby ensure a positive clearing of the complete culvert.

When the ground attachment is positioned as illustrated with broken lines in FIG. **1** there is a danger that the reduction of the cross section of the rope at the end closest to the ground attachment, due to the great distance from the place where the tension load is applied, goes on so slowly that the water beginning to flow in freezes before sufficient flow has been established in order to keep the passage open. For that reason it may be preferable in all cases to use the variant illustrated with full lines in FIG. **1**, having an edge cover **16**. The reason for this is that when the rope is stretched about the edge cover the passage may be opened up more quickly by performing the tensioning or stretching in two different steps. In FIG. **4***a* the rope is illustrated guided about the edge cover in its unloaded condition, but in FIG. **4***b* the broken lines illustrate how the extension of the rope is blocked by the guide rail **20** of the edge cover so that the reduction of the cross-sectional area of the rope, when the rope is normally tensioned, has been fully established up to the guide rail and possibly a distance around the same, while the remaining portion of the rope still maintains its full cross-sectional dimension so that no melted ice or snow enters from above. At this state the rope is clamped at the culvert attachment **3** when in its loaded condition and the person moves to the ground attachment **11** and exposes the same when necessary. Then the rope is released at the ground attachment and since only a relatively short portion of the rope from the edge cover **16** and up to the ground attachment is unloaded this portion of the rope may quickly be stretched or tensioned so that a full flow through the established passage is immediately obtained and so that the above mentioned danger of freezing is elminated.

By certain road culverts which by experience are known to cause serious problems, or by road culverts having a large diameter it may suitable to provide several ropes **10** at a distance from each other in connection with the upper portion of the culvert, and for instance in the way schematicaly illustrated in FIG. **5**. Another alternative that may be considered in connection with larger road culverts is to employ thicker ropes therein, but in such a case it may be necessary to provide some kind of not shown auxiliary device having a gear mechanism for tensioning or stretching the rope.

In FIG. 6 a rope 10' is illustrated having an alternative cross-sectional shape with longitudinal grooves or channels. This rope is intended to be twisted in connection with the streching or tensioning thereof so that the grooves assume a screw line shape around the rope. Apart from the fact that this configuration establishes a somewhat larger passage for the melted ice it also gives the ice a non-uniform surface so that the melted ice more efficiently wears off the ice. This is even further emphasized if the grooves or channels initially are helically shaped in the rope.

In extremely difficult situations where the above described method is not sufficient or in cases where it is desirable to open up a culvert in spite of the fact that there is no water such as melted ice or snow present that can wear down through the ice during its flow through the culvert, it is in accordance with another embodiment also possible to use the invention together with a conventional steam unit or possibly together with a hot-air unit, such as a building dryer. For this purpose a hook 22 is provided in one or possibly both ends of the rope. By connecting a particular steam pipe (possibly a flexible steam hose), which is closed in one end and in said end is provided with a loop for engaging the hook 22 and which is perforated along a portion of its length, to the steam unit the complete culvert may be cleared from one side without the necessity for crawling into the culvert. This is achieved by hooking-up the loop of the steam pipe to the hook 22 of the rope, whereupon the steam pipe, through withdrawal of the rope, is pulled stepwise through the culvert as this is thawed out. Due to the fact that the steam pipe is pulled in through the passage established by the rope it will not be necessary to take up separate holes for the perforated steam pipe and moreover the complete culvert may be thawed out in one operation independent of the length of the culvert. This work is naturally speeded up even further if several ropes are installed in the culvert in accordance with FIG. 5, whereby a corresponding number of steam pipes may be used. It should be realized that by this embodiment it is, as mentioned, sufficient if the rope only has a certain reversible extensibility, since it is intended to establish a passage through the ice by being completely withdrawn from the culvert. Thus, the reduction of the cross-sectional area need only be sufficient to ensure that the rope is released from the ice.

Although preferred embodiments of the invention have been described and illustrated herein it should be obvious to those skilled in the art that a great number of changes and modifications may be carried out without departing from the scope of the invention. For instance it is possible to employ alternative designs for the culvert attachment, the ground attachment and the edge cover, both regarding their preferred clamping to the culvert, anchoring in the ground and clamping of the rope respectively. Thus, the scope of the invention should only be restricted by the enclosed patent claims.

I claim:

1. A method for clearing road culverts or the like having become choked with ice, comprising the steps of: extending a substantially homogenous rope of a material having at least a certain reversible extensibility through the culvert from its inlet side to its outlet side before it becomes choked with ice; clamping the rope in its unloaded condition in connection to the outlet side and inlet side of the culvert so that the rope extends through the culvert; and, once the culvert has become choked with ice, releasing the rope from its clamping in connection with the outlet side of the culvert; applying a tension load to the rope from the released end for reducing the cross-sectional area of the rope and thereby forming a free passage through the culvert around the circumference of the rope; clamping the rope again in connection with the outlet side of the culvert, in the loaded extended condition of the rope; and allowing a continuous flow of melted ice or snow in the passage formed around the circumference of the rope, thereby clearing the road culvert.

2. A method as described in claim 1, wherein a rope having a high reversible extensibility is used and wherein the rope is clamped close to the upper portion of the culvert.

3. A method as described in claim 2, wherein the rope in connection with the inlet side of the culvert is deflected from its extension within the culvert through an edge cover; the corresponding end of the rope is clamped at a distance from the inlet side of the culvert and both ends of the rope, one after the other, are released from the clamping, are tensioned or extended and clamped again.

4. A method for clearing road culverts or the like having become choked with ice, comprising the steps of: extending a substantially homogeneous rope of a material having at least a certain reversible extensibility through the culvert from its inlet side to its outlet side before it becomes choked with ice; clamping the rope in its unloaded condition in connection to the outlet side and the inlet side of the culvert so that the rope extends through the culvert; and, once the culvert has become choked with ice, releasing both ends of the rope at their respective clamping positions; connecting a steam pipe perforated along a portion of its length to one end of the rope; connecting the steam pipe to a steam unit; applying a tension load to the end of the rope not connected to the steam pipe, for reducing the cross-sectional area of the rope so that it is released from the ice; successively pulling the rope out from the culvert for forming a free passage through the culvert and successively pulling the steam pipe into the passage in the ice established by withdrawing the rope; thereby successively clearing the culvert by means of steam supplied from the steam unit.

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[54] **METHOD FOR THAWING FROZEN ROAD CULVERTS**

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[52] **U.S. Cl.** **219/213**; 219/549; 338/214

[58] **Field of Search** 219/213, 528, 219/544, 538, 546; 404/77, 79; 405/131, 128; 338/214

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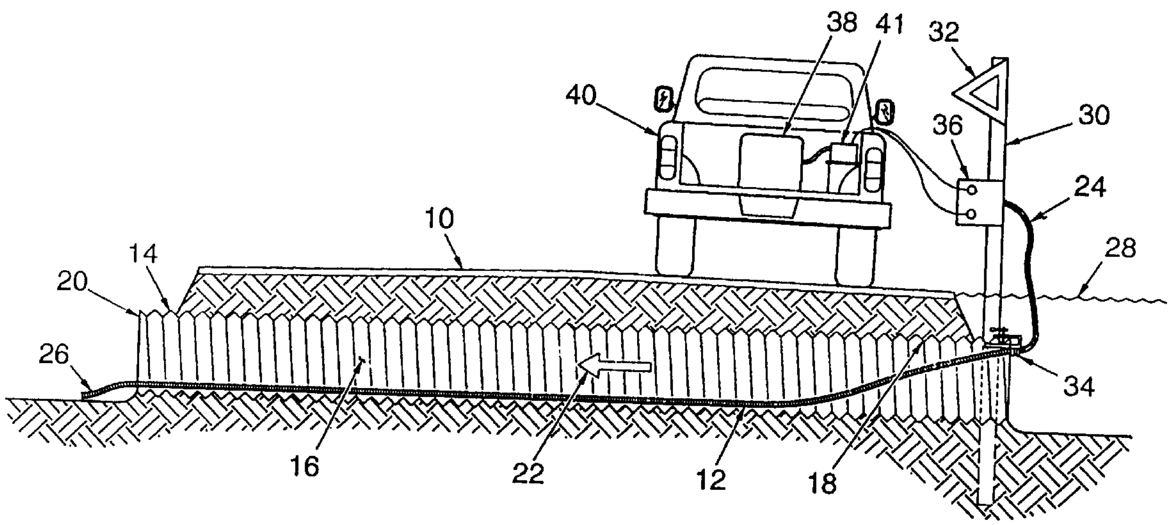
[57] **ABSTRACT**

A method for thawing frozen road culverts. The first step involves positioning an electrically conductive cable in a road culvert prior to an ice blockage occurring. A connection end of the electrically conductive cable is anchored in an accessible location. The second step involves connecting a power source to the connection end of the electrically conductive cable after an ice blockage of the road culvert has occurred and supplying power to the electrically conductive cable, such that energy generated by power flowing through the electrically conductive cable causes a flow path to be created through the ice blockage in the road culvert.

7 Claims, 2 Drawing Sheets



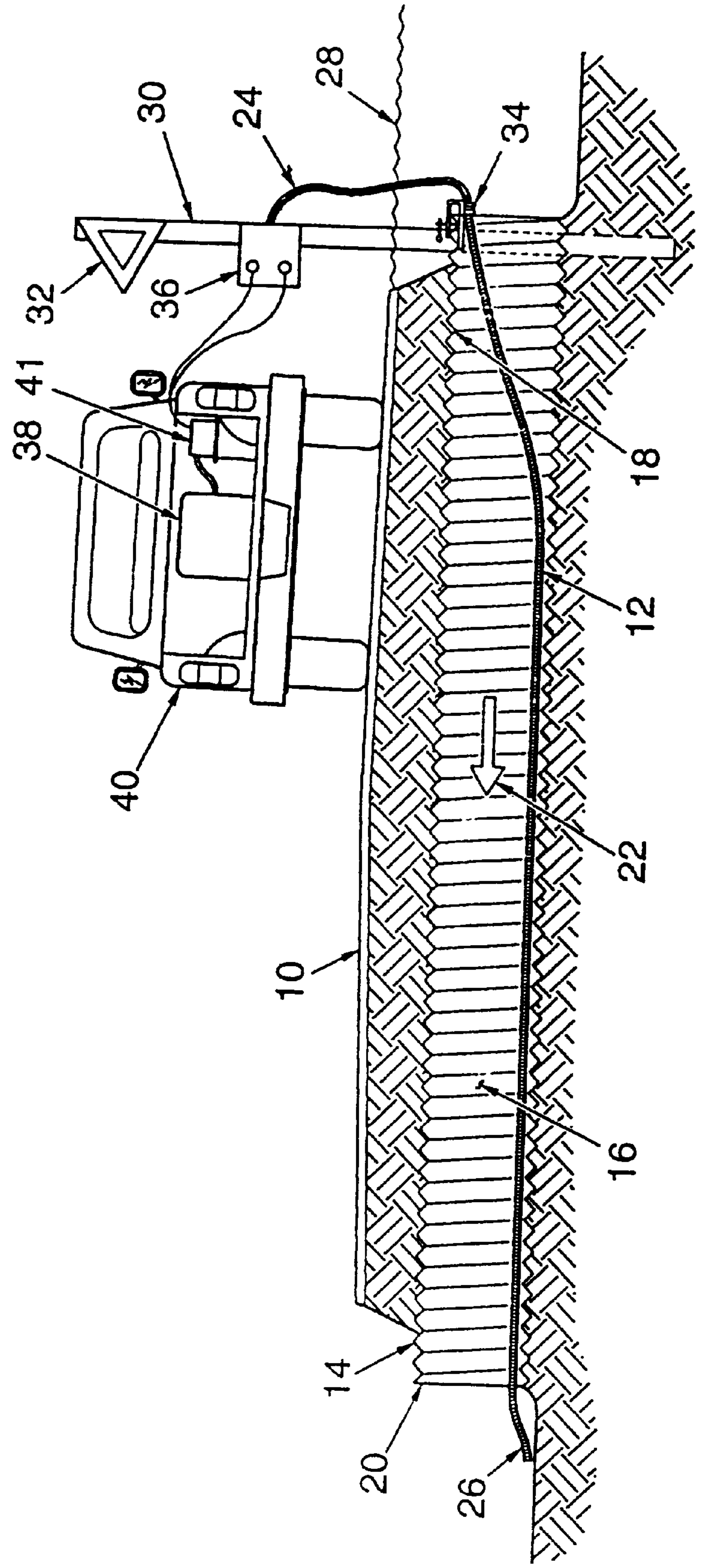


FIGURE 1

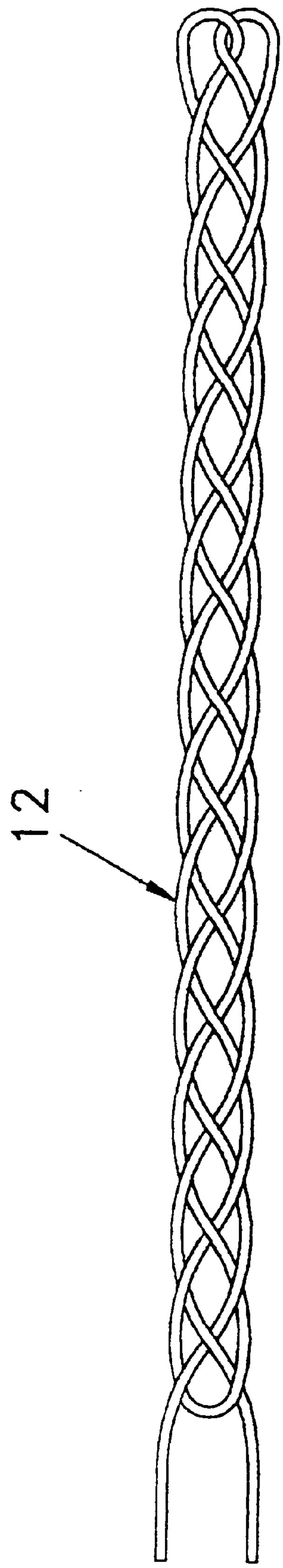


FIGURE 2

METHOD FOR THAWING FROZEN ROAD CULVERTS

FIELD OF THE INVENTION

The present invention relates to a method for thawing frozen road culverts.

BACKGROUND OF THE INVENTION

With the coming of spring every year there is a daily cycle of melting and freezing. The heat of the sun during the day causes snow to melt. As the sun goes down the temperature falls and water resulting from melting of the snow freezes.

Culverts are strategically placed under roads which are in a path followed by a flow of water from the melting snow. The culverts divert the flow of water so the road does not wash out. Unfortunately, the daily cycle of melting and freezing sometimes results in a culvert becoming blocked by an ice plug. If the ice plug is not removed in a timely fashion, the flow of water seeks an alternative path which often results in a washing out of portions of the road.

At the present time, steam truck crews are dispatched whenever it is noted that a culvert is plugged by ice. Removal of an ice plug from a culvert is generally a slow process. High pressure steam is injected into the ice plug, usually from a downstream side of the culvert, until a flow of water is restored. An ice plug that extends part way into a culvert generally can be removed by high pressure steam within three hours. Ice plugs that extend completely through a culvert can take considerably longer to remove.

The problem of road culverts plugging with ice has become so prevalent, that oversize culverts are frequently used for the express purpose of reducing the frequency of the problem.

SUMMARY OF THE INVENTION

What is required is a more time efficient method of thawing frozen road culverts.

According to one aspect of the present invention there is provided a method for thawing frozen road culverts. The first step involves positioning an electrically conductive cable in a road culvert prior to an ice blockage occurring. A connection end of the electrically conductive cable is anchored in an accessible location. The second step involves connecting a power source to the connection end of the electrically conductive cable after an ice blockage of the road culvert has occurred and supplying power to the electrically conductive cable, such that energy generated by power flowing through the electrically conductive cable causes a flow path to be created through the ice blockage in the road culvert.

According to another aspect of the present invention, there provided, a combination including a road culvert and an electrically conductive cable. The road culvert has an interior bore with an upstream end and a downstream end relative to normal water flow. The electrically conductive cable is positioned in the interior bore and extends substantially the length of the road culvert from the upstream end toward the downstream end. A connection end of the electrically conductive cable is anchored in an accessible location, such that a power source connectable to the connection end of the electrically conductive cable to supply power to energize the electrically conductive cable.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the invention will become more apparent from the following description in which reference is made to the appended drawings, wherein:

FIG. **1** is a front elevation view, in section, of a culvert that has been equipped with an electrically conductive cable in accordance with the teachings of the present method.

FIG. **2** is a detailed top plan view of a electrically conductive cable illustrated in FIG. **1**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred method for thawing frozen road culverts will now be described with reference to FIG. **1**.

The teachings of the preferred method, as will hereafter be further described, require that an electrically conductive cable **12** be positioned in a road culvert **14**. Road is generally indicated by reference numeral **10**. Road culvert **14** has an interior bore **16** with an upstream end **18** and a downstream end **20** relative to a direction of normal water flow as indicated by arrow **22**. Electrically conductive cable **12** has a connection end **24** and a remote end **26**. Beneficial results have been obtained using electrically conductive cable **12** made from #10 insulated copper wire, although in applications requiring higher temperatures wire made from alloys that can withstand higher temperatures may be used. Electrically conductive cable **12** is positioned in interior bore **16** of road culvert **14** and, preferably, extends substantially the length of road culvert **14** from upstream end **18** toward downstream end **20**. It is essential that electrically conductive cable **12** is positioned at upstream end **18**, for it is at upstream end **18** that a lockage by ice is most likely to occur. It is not always ssential that electrically conductive cable **12** reach all the ay to downstream end **20**. Each installation must be made having regard to surface topography and other conditions prevailing. Some road culverts become blocked at both ends, others are prone only to upstream blockage. Connection end **24** of electrically conductive cable **12** is anchored in an accessible location. When choosing an accessible location must bear in mind the conditions that will prevail when an ice blockage condition is encountered. There is likely to be an accumulation of water upstream of road culvert **14**, so the accessible location ispeferably above a high water mark generally indicated by reference numeral **28**. There is also likely to be an accumulation of snow on the ground, so connection end **24** is preferably a sufficient height to be above any accumulation of snow. In order to achieve this objective, it is preferred that connection end **24** be mounted onto a post **30**. Post **30** can be marked with a sign **32** or otherwise marked so as to be readily identified by work crews. In order to ensure that electrically conductive cable **12** does not shift after installation, it is preferred that electrically conductive cable **12** be clamped by means of clamp **34** to upstream end **18** of road culvert **14**. Connection end **24** of electrically conductive cable **12** is preferably is connected to a junction box **36**. A power source **38** is used to supply power to electrically conductive cable **12**. For safety reasons, a low voltage direct current power source which generates six to forty volts is preferred. It will be appreciated that the power required will vary with the gauge and length of electrically conductive cable **12** used. It is not viewed as being cost effective to have a power source at every installation. It is viewed as being more practical to take power source **38** to the particular road culvert that is blocked, it is, therefore, preferred that power source **38** be mounted on a truck **40**. For reasons of safety, it is preferred that power source **38** have a control box **41** which include features that control current and provide overcurrent protection with a breaker trip mechanism.

The use and operation of the above described combination in accordance with the teachings of the preferred method will now be described. The first step involves positioning electrically conductive cable **12** in road culvert **14** prior to an ice blockage occurring. Of course, after an ice blockage has occurred it is too late to insert electrically conductive cable **12**. Historical data can be used to select those of road culverts **14** that are most prone to ice blockage. Connection end **24** of electrically conductive cable **24** is anchored in an accessible location, such as post **30**. It is preferred that cable be secured to road culvert **14** at upstream end **18** by means of clamp **34**. Cable **24** is then laid through road culvert **14**.

The second step involves connecting power source **38** to connection end **24** of electrically conductive cable **12** after an ice blockage (not shown) of road culvert **14** has occurred. As low voltage power source **38** is truck mounted, truck **40** can be dispatched. The connection of power source **38** to connection end **24** of electrically conductive cable **12** is made through junction box **36**. Power source **38** provides power to electrically conductive cable **12**. Tests have shown that energy generated by electrically conductive cable **12** causes a flow path to be created through the ice blockage in the immediate vicinity of electrically conductive cable **12**. The resulting flow of water then tends to accelerate the process of removing the blockage by rapidly washing away the ice. A trickle of water through road culvert **14** generally occurs in as little as two minutes and normal flow through road culvert **14** is generally restored within ten minutes. The rapid clearing of the blockage is believed to be due to more than just the heat generated by power passing through electrically conductive cable **12**.

Referring to FIG. **2**, in addition to thermal energy, there is believed to be an eddy current induced. In order to enhance this effect cable **12** is looped lengthwise back and forth in boustrophedonic fashion. The loops are then twisted together in order to make cable **12** more compact and easier to handle. Regardless of what forces are at work, the energy generated can be objectively shown to clear an ice blockage in a remarkably short time.

It will be apparent to one skilled in the art that modifications may be made to the illustrated embodiment without departing from the spirit and scope of the invention as hereinafter defined in the Claims.

The embodiments of the invention in which an exclusine property or privilege is claimed are defined as follows:

1. A method for thawing frozen road culverts, comprising the steps of:

positioning an electrically conductive cable in a road culvert prior to an ice blockage occurring, with a connection end of the electrically conductive cable anchored in an accessible location;

dispatching a mobile low voltage power source to the road culvert when a blockage occurs; and

connecting the power source to the connection end of the electrically conductive cable and supplying power to the electrically conductive cable, such that energy generated by power flowing through the electrically conductive cable causes a flow path to be created through an ice blockage in the road culvert.

2. In combination:

a road culvert having an interior bore;

an electrically conductive cable positioned in the interior bore and extending substantially the length of the road culvert;

a connection end of the electrically conductive cable being anchored in an accessible location, such that a power source is connectable to the connection end of the electrically conductive cable to supply power to energize the electrically conductive cable; and

a mobile low voltage power source for supplying power to the electrically conductive cable.

3. The combination as defined in claim **2**, wherein the road culvert has with an upstream end and a downstream end relative to normal water flow, the cable extending from the upstream end toward the downstream end.

4. The combination as defined in claim **2**, wherein the cable is looped lengthwise back and forth in boustrophedonic fashion.

5. The combination as defined in claim **4**, wherein the cable is twisted.

6. A method for thawing frozen road culverts, comprising the steps of:

positioning an electrically conductive cable in a road culvert prior to an ice blockage occurring, with a connection end of the electrically conductive cable anchored in an accessible location outside the road culvert and an opposite end of the cable being unattended and extending completely through the road culvert and projecting out through the opposite end thereof;

dispatching a mobile low voltage power source to the road culvert when a blockage occurs in the road culvert; and

connecting the power source to the connection end of the electrically conductive cable and supplying electrical power to the electrically conductive cable, such that energy generated by the electrical power flowing through the electrically conductive cable causes a flow path to be created through the ice blockage in the road culvert thereby assisting with thawing of the road culvert.

7. The combination of claim **2** wherein the accessible location of the connection end of the cable is located outside the road culvert so as to be accessible.

* * * * *

APPENDIX H

PCSWMM MODEL PARAMETERS

Table H-1: Conduits PCSWMM Parameters

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Geom1 (m)	Geom2 (m)	Barrels	Slope (m/m)
C4	J489	J487	134.901	0.07	TRAPEZOIDAL	5	10	1	0.04084
C5	J482	J489	83.835	0.07	TRAPEZOIDAL	5	10	1	0.0457
C6	J472	J482	169.803	0.07	TRAPEZOIDAL	5	10	1	0.03752
C8	J580	J462	360.148	0.07	TRAPEZOIDAL	5	10	1	0.03843
C9	J416	J580	987.454	0.07	TRAPEZOIDAL	5	10	1	0.04887
C10	J476	J416	181.45	0.07	TRAPEZOIDAL	5	10	1	0.05648
C11	J559	J600	939.229	0.07	TRAPEZOIDAL	5	10	1	0.08464
C12	J313	J317	59.47	0.07	TRAPEZOIDAL	5	10	1	0.07667
C13	J562	J313	154.084	0.07	TRAPEZOIDAL	5	10	1	0.06402
C14	J601	J562	443.883	0.07	TRAPEZOIDAL	5	10	1	0.08366
C15	J595	J601	241.207	0.07	TRAPEZOIDAL	5	10	1	0.055
C17	J267	J595	208.222	0.07	TRAPEZOIDAL	5	10	1	0.05666
C18	J259	J267	50.103	0.07	TRAPEZOIDAL	5	10	1	0.05254
C19	J278	J259	49.257	0.07	TRAPEZOIDAL	5	10	1	0.04833
C20	J265	J278	49.145	0.07	TRAPEZOIDAL	5	10	1	0.04773
C21	J261	J265	230.219	0.07	TRAPEZOIDAL	5	10	1	0.05703
C22	J282	J254	117.123	0.07	TRAPEZOIDAL	5	10	1	0.07161
C23	J558	J282	167.893	0.07	TRAPEZOIDAL	5	10	1	0.06936
C25	J594	J558	142.997	0.07	TRAPEZOIDAL	5	10	1	0.07931
C26	J225	J594	48.412	0.07	TRAPEZOIDAL	5	10	1	0.07192
C28	J568	J191	117.108	0.07	TRAPEZOIDAL	5	10	1	0.05004
C29	J551	J568	292.069	0.07	TRAPEZOIDAL	5	10	1	0.08931
C30	J596	J176	135.674	0.07	TRAPEZOIDAL	5	10	1	0.06177
C31	J575	J596	120.999	0.03	TRAPEZOIDAL	2	3	1	0.0505
C32	J162	J575	46.163	0.03	TRAPEZOIDAL	2	3	1	0.06
C33	J174	J162	44.907	0.03	TRAPEZOIDAL	2	3	1	0.05791
C34	J590	J174	117.761	0.03	TRAPEZOIDAL	2	3	1	0.05895
C35	J586	J590	54.348	0.03	TRAPEZOIDAL	2	3	1	0.04749
C40	J129	J556	431.181	0.03	TRAPEZOIDAL	2	3	1	0.04871
C42	J563	J129	85.289	0.03	TRAPEZOIDAL	2	3	1	0.05712

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Geom1 (m)	Geom2 (m)	Barrels	Slope (m/m)
C44	J537	J563	215.211	0.03	TRAPEZOIDAL	2	3	1	0.04066
C48	J105	J118	96.492	0.03	TRAPEZOIDAL	2	3	1	0.02105
C50	J349	J601	221.589	0.03	TRAPEZOIDAL	2	3	1	0.06887
C57	J388	J600	212.652	0.03	TRAPEZOIDAL	2	3	1	0.08591
C59	J386	J388	105.312	0.03	TRAPEZOIDAL	2	3	1	0.10551
C60	J15	J105	796.529	0.03	TRAPEZOIDAL	2	3	1	0.01796
C63	J426	J386	423.047	0.03	TRAPEZOIDAL	2	3	1	0.16215
C66	J578	J555	117.521	0.03	TRAPEZOIDAL	2	3	1	0.09472
C67	J434	J426	235.584	0.03	TRAPEZOIDAL	2	3	1	0.24345
C71	J581	J595	539.755	0.03	TRAPEZOIDAL	2	3	1	0.09339
C73	J217	J594	583.924	0.03	TRAPEZOIDAL	2	3	1	0.13913
C77	J214	J217	90.761	0.03	TRAPEZOIDAL	2	3	1	0.18073
C78	J478	J436	343.115	0.03	TRAPEZOIDAL	2	3	1	0.23586
C82	J569	J581	413.739	0.03	TRAPEZOIDAL	2	3	1	0.05976
C85	J582	J478	164.948	0.03	TRAPEZOIDAL	2	3	1	0.20804
C86	J545	J590	800.532	0.03	TRAPEZOIDAL	2	3	1	0.06544
C87	J566	J578	788.779	0.03	TRAPEZOIDAL	2	3	1	0.09198
C88	J201	J214	342.605	0.03	TRAPEZOIDAL	2	3	1	0.1441
C95	J181	J586	850.579	0.03	TRAPEZOIDAL	2	3	1	0.08694
C96	J103	J596	500.867	0.03	TRAPEZOIDAL	2	3	1	0.06416
C98	J413	J566	185.057	0.03	TRAPEZOIDAL	2	3	1	0.06361
C99	J172	J181	62.044	0.03	TRAPEZOIDAL	2	3	1	0.09029
C105	J542	J430	183.161	0.03	TRAPEZOIDAL	2	3	1	0.01173
C106	J448	J582	83.19	0.03	TRAPEZOIDAL	2	3	1	0.17803
C107	J444	J582	375.551	0.03	TRAPEZOIDAL	2	3	1	0.13262
C108	J287	J581	809.801	0.03	TRAPEZOIDAL	2	3	1	0.11832
C109	J565	J580	391.742	0.03	TRAPEZOIDAL	2	3	1	0.04051
C110	J450	J448	64.315	0.03	TRAPEZOIDAL	2	3	1	0.13463
C111	J90	J545	346.701	0.03	TRAPEZOIDAL	2	3	1	0.08375
C114	J352	J542	173.171	0.03	TRAPEZOIDAL	2	3	1	0.04752

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Geom1 (m)	Geom2 (m)	Barrels	Slope (m/m)
C120	J438	J413	275.189	0.03	TRAPEZOIDAL	2	3	1	0.04964
C121	J188	J575	475.055	0.03	TRAPEZOIDAL	2	3	1	0.09194
C124	J292	J569	700.213	0.03	TRAPEZOIDAL	2	3	1	0.11731
C126	J428	J438	69.748	0.03	TRAPEZOIDAL	2	3	1	0.04882
C132	J35	J15	741.068	0.03	TRAPEZOIDAL	2	3	1	0.0406
C133	J330	J347	80.543	0.03	TRAPEZOIDAL	2	3	1	0.09251
C135	J378	J428	70.062	0.03	TRAPEZOIDAL	2	3	1	0.04453
C140	J511	J444	409.439	0.03	TRAPEZOIDAL	2	3	1	0.0764
C141	J308	J569	187.52	0.03	TRAPEZOIDAL	2	3	1	0.04283
C142	J382	J378	83.077	0.03	TRAPEZOIDAL	2	3	1	0.04552
C143	J244	J596	1299.104	0.03	TRAPEZOIDAL	2	3	1	0.11776
C144	J155	J568	95.623	0.03	TRAPEZOIDAL	2	3	1	0.30216
C146	J93	J90	419.359	0.03	TRAPEZOIDAL	2	3	1	0.19223
C147	J403	J382	93.108	0.03	TRAPEZOIDAL	2	3	1	0.06047
C150	J338	J330	272.971	0.03	TRAPEZOIDAL	2	3	1	0.09027
C151	J158	J586	605.779	0.03	TRAPEZOIDAL	2	3	1	0.08373
C153	J365	J566	202.225	0.03	TRAPEZOIDAL	2	3	1	0.06941
C155	J54	J563	734.664	0.03	TRAPEZOIDAL	2	3	1	0.04982
C156	J280	J562	478.071	0.03	TRAPEZOIDAL	2	3	1	0.33601
C160	J344	J338	139.96	0.03	TRAPEZOIDAL	2	3	1	0.07397
C162	J306	J559	995.715	0.03	TRAPEZOIDAL	2	3	1	0.37305
C166	J400	J403	259.53	0.03	TRAPEZOIDAL	2	3	1	0.06665
C167	J135	J556	404.184	0.03	TRAPEZOIDAL	2	3	1	0.05562
C168	J539	J555	420.966	0.03	TRAPEZOIDAL	2	3	1	0.0764
C173	J168	J551	93.359	0.03	TRAPEZOIDAL	2	3	1	0.05751
C176	J359	J365	336.792	0.03	TRAPEZOIDAL	2	3	1	0.07231
C181	J81	J93	458.226	0.03	TRAPEZOIDAL	2	3	1	0.28533
C182	J160	J168	91.131	0.03	TRAPEZOIDAL	2	3	1	0.07496
C185	J376	J539	172.203	0.03	TRAPEZOIDAL	2	3	1	0.24384
C187	J454	J511	50.132	0.03	TRAPEZOIDAL	2	3	1	0.07767

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Geom1 (m)	Geom2 (m)	Barrels	Slope (m/m)
C188	J111	J103	1208.163	0.03	TRAPEZOIDAL	2	3	1	0.12148
C189	J37	J35	254.358	0.03	TRAPEZOIDAL	2	3	1	0.07877
C191	J405	J542	55.98	0.03	TRAPEZOIDAL	2	3	1	0.06689
C193	J301	J306	225.578	0.03	TRAPEZOIDAL	2	3	1	0.28945
C194	J146	J160	128.574	0.03	TRAPEZOIDAL	2	3	1	0.08112
C195	J374	J376	118.034	0.03	TRAPEZOIDAL	2	3	1	0.11999
C198	J211	J244	223.638	0.03	TRAPEZOIDAL	2	3	1	0.10017
C199	J363	J539	129.458	0.03	TRAPEZOIDAL	2	3	1	0.08081
C204	J126	J537	302.151	0.03	TRAPEZOIDAL	2	3	1	0.03766
C205	J256	J237	467.675	0.03	TRAPEZOIDAL	2	3	1	0.0643
C207	J209	J596	1891.483	0.03	TRAPEZOIDAL	2	3	1	0.10334
C209	J411	J476	165.981	0.07	TRAPEZOIDAL	5	10	1	0.07072
C210	J600	J411	55.136	0.07	TRAPEZOIDAL	5	10	1	0.07175
C211	J317	J559	232.67	0.07	TRAPEZOIDAL	5	10	1	0.07726
C212	J254	J261	125.422	0.07	TRAPEZOIDAL	5	10	1	0.06124
C215	J207	J225	418.937	0.07	TRAPEZOIDAL	5	10	1	0.07683
C216	J191	J207	148.008	0.07	TRAPEZOIDAL	5	10	1	0.07084
C217	J176	J551	54.928	0.07	TRAPEZOIDAL	5	10	1	0.02726
C218	J149	J586	51.734	0.03	TRAPEZOIDAL	2	3	1	0.05978
C219	J556	J149	442.28	0.03	TRAPEZOIDAL	2	3	1	0.05181
C220	J118	J537	213.503	0.03	TRAPEZOIDAL	2	3	1	0.03125
C222	J328	J349	340.472	0.03	TRAPEZOIDAL	2	3	1	0.05257
C224	J555	J328	556.403	0.03	TRAPEZOIDAL	2	3	1	0.06344
C225	J436	J434	111.504	0.03	TRAPEZOIDAL	2	3	1	0.34679
C230	J347	J578	982.358	0.03	TRAPEZOIDAL	2	3	1	0.09352
C232	J170	J201	561.089	0.03	TRAPEZOIDAL	2	3	1	0.15022
C233	J354	J565	181.949	0.03	TRAPEZOIDAL	2	3	1	0.03654
C235	J361	J565	598.551	0.03	TRAPEZOIDAL	2	3	1	0.03222
C236	J237	J558	1003.935	0.03	TRAPEZOIDAL	2	3	1	0.17948
C239	J76	J545	714.616	0.03	TRAPEZOIDAL	2	3	1	0.07126

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Geom1 (m)	Geom2 (m)	Barrels	Slope (m/m)
C2	J77	J86	621.313	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C16	J78	J80	477.266	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C24	J79	J80	452.69	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C39	J80	J86	140.719	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C43	J2	J1	4.332	0.023	CIRCULAR	0.6	0	1	0
C47	J1	OF1	48.276	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C53	J4	J3	3.644	0.023	CIRCULAR	0.9	0	1	0
C56	J3	OF4	26.519	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C61	J6	J5	6.017	0.023	CIRCULAR	0.6	0	1	0
C62	J5	OF5	29.52	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C64	J8	J7	3.821	0.023	CIRCULAR	0.45	0	1	0
C68	J10	J9	4.113	0.023	CIRCULAR	0.6	0	1	0
C70	J9	OF2	35.75	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C72	J11	J10	36.275	0.03	TRAPEZOIDAL	1	1	1	0
C74	J12	J11	10.294	0.023	CIRCULAR	0.6	0	1	0
C76	J14	J13	8.258	0.023	CIRCULAR	0.75	0	1	0
C79	J13	J12	24.998	0.03	TRAPEZOIDAL	1	1	1	0
C80	J16	J14	30.877	0.03	TRAPEZOIDAL	1	1	1	0
C81	J17	J16	13.009	0.023	CIRCULAR	0.75	0	1	0
C84	J31	J30	10.929	0.023	CIRCULAR	0.45	0	1	0
C89	J30	J29	14.009	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C90	J29	J28	10.545	0.023	CIRCULAR	0.6	0	1	0
C93	J28	J27	18.36	0.03	TRAPEZOIDAL	1	1	1	0
C94	J27	J26	9.457	0.023	CIRCULAR	1.4	0	1	0
C97	J26	J25	28.606	0.03	TRAPEZOIDAL	1	1	1	0
C100	J25	J24	5.825	0.023	CIRCULAR	1.4	0	1	0
C101	J24	J21	61.22	0.03	TRAPEZOIDAL	1	1	1	0
C102	J21	J20	10.982	0.023	CIRCULAR	1.4	0	1	0
C104	J20	J19	6.421	0.03	TRAPEZOIDAL	1	1	1	0
C112	J19	J18	6.582	0.023	CIRCULAR	1.4	0	1	0

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Geom1 (m)	Geom2 (m)	Barrels	Slope (m/m)
C113	J18	OF3	41.714	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C115	J33	J32	9.036	0.023	CIRCULAR	1.2	0	1	0
C116	J36	J34	11.902	0.023	CIRCULAR	0.6	0	1	0
C117	J39	J38	6.754	0.023	CIRCULAR	1	0	1	0
C119	J23	J22	55.53	0.023	CIRCULAR	1.2	0	1	0.07631
C125	J43	J42	37.401	0.023	CIRCULAR	0.9	0	1	0.02562
C128	J45	J44	9.785	0.023	CIRCULAR	0.6	0	2	0
C131	J47	J46	16.605	0.023	CIRCULAR	0.8	0	2	0
C136	J51	J50	7.255	0.023	CIRCULAR	2.2	0	5	0
C139	J58	J57	9.966	0.023	CIRCULAR	2.2	0	5	0
C148	J62	J61	6.605	0.023	CIRCULAR	1.8	0	1	0
C149	J64	J63	55.556	0.023	CIRCULAR	1.8	0	1	0
C154	J70	J69	3.868	0.023	CIRCULAR	1	0	1	0
C159	J66	J65	4.028	0.023	CIRCULAR	1	0	1	0
C161	J68	J67	5.637	0.023	CIRCULAR	1	0	1	0
C163	J72	J71	4.445	0.023	CIRCULAR	1	0	1	0
C165	J74	J73	7.69	0.023	CIRCULAR	1	0	1	0
C170	J40	J84	36.785	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C171	J41	J40	2.555	0.023	CIRCULAR	1	0	1	0
C1_1	J75	J88	1011.461	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C1_2	J88	J2	232.369	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C41_1	J86	J89	162.773	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C41_3	J89	J91	164.513	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C178_1	J82	J92	538.405	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C178_2	J92	J87	531.807	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C1_3	J83	J94	480.159	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C1_5	J94	J95	222.539	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C1_6	J95	J41	246.901	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C169_2	J96	J84	152.023	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C169_3	J85	J97	405.936	0.03	TRAPEZOIDAL	1.5	2.5	1	0

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Geom1 (m)	Geom2 (m)	Barrels	Slope (m/m)
C169_4	J97	J96	222.546	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C175_1	J84	J98	132.415	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C175_2	J98	J33	33.85	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C179_1	J87	J99	128.541	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C179_2	J99	J23	81.041	0.03	TRAPEZOIDAL	1.5	2.5	1	0.01499
C41	J101	J100	8.595	0.023	CIRCULAR	0.9	0	1	0
C129	J100	J45	224.01	0.03	TRAPEZOIDAL	1	1	1	0
C65_2	J107	J101	40.478	0.03	TRAPEZOIDAL	1	1	1	0
C208	J113	J58	45.864	0.07	TRAPEZOIDAL	5	10	1	0.05082
C203_1	J57	J114	77.158	0.07	TRAPEZOIDAL	5	10	1	0.00504
C203_2	J114	OF10	81.963	0.07	TRAPEZOIDAL	5	10	1	0.0062
C3	J42	OF7	30.16	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C118_1	J34	J115	66.636	0.03	TRAPEZOIDAL	1.5	2.5	1	0.06365
C118_2	J115	J43	38.181	0.03	TRAPEZOIDAL	1	2.5	1	0.00537
C172_1	J394	J64	467.065	0.03	TRAPEZOIDAL	2	3	1	0.14385
C118	J63	J62	65.107	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C172	J61	OF12	299.629	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C91	J430	J64	72.073	0.03	TRAPEZOIDAL	1.5	2.5	1	0.78255
C213_1	J116	J117	192.973	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C213_2	J117	J106	206.264	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C213	J38	J99	190.427	0.03	TRAPEZOIDAL	1.5	2.5	1	0.07933
C157_1	J106	J119	97.92	0.03	TRAPEZOIDAL	1	1	1	0.05137
C157_2	J119	J47	188.448	0.03	TRAPEZOIDAL	1.5	2.5	1	0.05137
C157	J7	OF14	35.208	0.03	TRAPEZOIDAL	1.5	2.5	1	0.13347
C214	J44	OF8	24.463	0.03	TRAPEZOIDAL	1.5	2.5	1	0.19776
C206	J113	J51	54.125	0.07	TRAPEZOIDAL	5	10	1	0.04704
C179	J50	OF9	47.676	0.07	TRAPEZOIDAL	5	10	1	0.09509
C134	J48	J49	30.634	0.023	CIRCULAR	0.6	0	1	0
C137	J49	J99	115.491	0.03	TRAPEZOIDAL	1	1	1	-0.09151
C138	J53	J52	6.06	0.013	CIRCULAR	0.45	0	1	0

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Geom1 (m)	Geom2 (m)	Barrels	Slope (m/m)
C145	J234	J55	7.852	0.023	CIRCULAR	0.45	0	1	-0.52264
C178	J60	J108	39.621	0.023	CIRCULAR	0.45	0	1	0
C65_4	J122	J107	6.218	0.023	CIRCULAR	0.45	0	1	0.07272
C65_5	J123	J107	5.792	0.03	TRAPEZOIDAL	1	1	1	0.02314
C65_7	J124	J123	5.633	0.023	CIRCULAR	0.45	0	1	0.02326
C65	J121	J120	22.772	0.023	CIRCULAR	0.9	0	1	0
C180	J120	J112	25.162	0.03	TRAPEZOIDAL	1	1	1	0
C183	J112	J122	18.632	0.03	TRAPEZOIDAL	1	1	1	-999
C184	J109	J112	40.673	0.03	TRAPEZOIDAL	1	1	1	0
C169_1	J46	J125	30.296	0.03	TRAPEZOIDAL	1.5	2.5	1	0.09419
C169_6	J125	J127	5.514	0.023	CIRCULAR	0.8	0	1	0.09473
C169_7	J127	OF13	16	0.03	TRAPEZOIDAL	1.5	2.5	1	0.09416
C169	J128	J130	4.639	0.023	CIRCULAR	0.6	0	1	0
C190	J131	J132	10.463	0.023	CIRCULAR	0.6	0	1	0
C36	J133	J59	37.117	0.03	TRIANGULAR	0.2	1.5	1	0.08877
C38	J88	J4	276.168	0.03	TRAPEZOIDAL	1.5	2.5	1	0.11776
C45	J136	J27	31.929	0.03	TRAPEZOIDAL	1	1	1	0.02346
C51	J139	J140	12.049	0.023	CIRCULAR	0.45	0	1	0.04045
C52	J140	OF15	38.632	0.03	TRAPEZOIDAL	1.5	2.5	1	0.07473
C54	J132	OF16	141.618	0.03	TRAPEZOIDAL	1.5	2.5	1	0.20749
C58	J138	J142	28.143	0.03	TRIANGULAR	0.2	1.5	1	0
C69	J143	J33	38.305	0.03	TRIANGULAR	0.2	1.5	1	-0.16294
C192_1	J32	J145	44.947	0.03	TRAPEZOIDAL	1	1	1	0.02348
C192_2	J145	J115	44.003	0.03	TRAPEZOIDAL	1	1	1	0.02348
C103	J150	J148	43.096	0.03	TRIANGULAR	0.2	1.5	1	0
C127	J151	J153	17.151	0.03	TRAPEZOIDAL	1	1	1	0
C152	J156	J87	54.586	0.03	TRAPEZOIDAL	1	1	1	-0.41859
C41_2	J91	J159	266.517	0.03	TRAPEZOIDAL	1.5	2.5	1	0.13078
C122	J163	J161	65.498	0.03	TRAPEZOIDAL	1	1	1	0
C177	J161	J6	193.524	0.03	TRAPEZOIDAL	1.5	2.5	1	-0.01167

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Geom1 (m)	Geom2 (m)	Barrels	Slope (m/m)
C192	J165	J167	38.456	0.03	TRIANGULAR	0.2	1.5	1	0
C196	J167	OF18	29.529	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C197	J166	J169	41.1	0.03	TRIANGULAR	0.2	1.5	1	-0.16908
C49_2	J169	J139	41.409	0.03	TRIANGULAR	0.2	1.5	1	0.08448
C49_3	J152	J171	33.891	0.03	TRAPEZOIDAL	1.5	2.5	1	-0.13572
C49_4	J171	J27	64.186	0.03	TRAPEZOIDAL	1.5	2.5	1	-0.13573
C49	J159	J171	25.183	0.03	TRAPEZOIDAL	1.5	2.5	1	1.26688
C130_2	J173	J152	24.512	0.03	TRAPEZOIDAL	1	1	1	0
C130	J175	J151	23.999	0.03	TRAPEZOIDAL	1	1	1	0
C201_2	J220	J36	31.722	0.03	TRIANGULAR	0.2	1.5	1	-0.23476
C203	J179	J108	17.114	0.023	CIRCULAR	0.45	0	1	-0.5677
C221	J108	J182	36.161	0.03	TRAPEZOIDAL	1	1	1	0.2403
C202	J178	J179	46.012	0.03	TRIANGULAR	0.2	1.5	1	0
C55_2	J185	OF17	48.678	0.03	TRAPEZOIDAL	1.5	2.5	1	0.11682
C55	J130	J185	51.707	0.03	TRIANGULAR	0.2	1.5	1	0.0881
C65_1	J104	J189	52.463	0.03	TRAPEZOIDAL	1	1	1	0.01352
C65_8	J189	J124	63.107	0.03	TRAPEZOIDAL	1	1	1	0.0135
C228	J190	J102	49.626	0.03	TRAPEZOIDAL	1	1	1	-0.59964
C229	J193	J189	183.515	0.03	TRAPEZOIDAL	1	1	1	-0.09647
C231	J192	OF19	55.418	0.03	TRAPEZOIDAL	1.5	2.5	1	0
C65_6	J102	J194	59.658	0.03	TRAPEZOIDAL	1.5	2.5	1	0.07683
C65_9	J195	J122	35.313	0.03	TRAPEZOIDAL	1.5	2.5	1	-0.53747
C234	J194	J121	28.651	0.03	TRAPEZOIDAL	1	1	1	-0.02262
C237	J182	J115	103.681	0.03	TRAPEZOIDAL	1.5	2.5	1	0.01458
C238	J196	J159	34.419	0.03	TRAPEZOIDAL	1	1	1	0.06607
C164_3	J197	J198	14.486	0.023	CIRCULAR	0.75	0	1	0.07393
C164_4	J198	J17	7.851	0.03	TRAPEZOIDAL	1	1	1	0.07331
C164	J202	J203	4.864	0.013	CIRCULAR	0.45	0	1	0
C240	J199	J200	6.01	0.013	CIRCULAR	0.45	0	1	0
C241	J204	J205	17.367	0.023	CIRCULAR	1	0	1	0

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Geom1 (m)	Geom2 (m)	Barrels	Slope (m/m)
C242	J206	J208	39.164	0.023	CIRCULAR	0.9	0	1	0.02447
C243	J43	J206	2.041	0.01	CIRCULAR	1	0	1	0
C244	J208	J42	1.803	0.01	CIRCULAR	1	0	1	0
C200_1	J177	J210	17.171	0.03	TRIANGULAR	0.2	1.5	1	0.09719
C200_3	J232	J133	6.878	0.023	CIRCULAR	0.45	0	1	0.09935
C1_4	J22	J221	22.845	0.03	TRAPEZOIDAL	1.5	2.5	1	0.04272
C1_7	J221	OF6	30.011	0.03	TRAPEZOIDAL	1.5	2.5	1	0.04269
C253	J224	J226	17.398	0.01	CIRCULAR	1	0	1	0
C254	J226	J213	10.64	0.023	CIRCULAR	1.2	0	1	0
C245	J215	J144	13.113	0.01	CIRCULAR	1	0	1	-0.3501
C246	J216	J20	47.32	0.01	CIRCULAR	1	0	1	-0.05085
C247	J218	J31	22.828	0.01	CIRCULAR	1	0	1	-1.02066
C248	J219	J222	57.841	0.01	CIRCULAR	1	0	1	-0.22607
C186_1	J110	J222	45.659	0.03	TRAPEZOIDAL	1	1	1	0.09517
C186_2	J222	J36	58.1	0.03	TRAPEZOIDAL	1	1	1	0.09516
C186	J180	J107	34.049	0.01	CIRCULAR	1	0	1	-0.53449
C200	J186	J183	11.624	0.023	CIRCULAR	0.45	0	1	-999
C123	J154	J173	84.136	0.01	CIRCULAR	1	0	1	0.02622
C158	J157	J197	108.908	0.01	CIRCULAR	1	0	1	-0.12926
C1	J23	J147	0.966	0.01	CIRCULAR	1	0	1	-999
C92	J213	J22	0.868	0.01	CIRCULAR	1	0	1	-999
C226_2	J223	J128	120.403	0.03	TRIANGULAR	0.2	1.5	1	0.09855
C201	J183	OF20	129.272	0.01	CIRCULAR	1	0	1	0
C83	J148	J192	11.328	0.023	CIRCULAR	0.45	0	1	0.02959
C226	J147	J227	9.784	0.023	CIRCULAR	1.2	0	1	0
C249	J227	J228	13.4	0.01	CIRCULAR	1	0	1	0
C250	J228	J224	13.8	0.023	CIRCULAR	1.2	0	1	0
C251	J229	J228	21.562	0.01	CIRCULAR	1	0	1	0
C75_1	J144	J230	21.55	0.03	TRIANGULAR	0.2	1.5	1	0.01323
C75_2	J230	J145	24.178	0.03	TRIANGULAR	0.2	1.5	1	0.01394

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Geom1 (m)	Geom2 (m)	Barrels	Slope (m/m)
C75	J231	J230	40.635	0.01	CIRCULAR	1	0	1	-0.10012
C252	J164	J157	19.575	0.03	TRAPEZOIDAL	1	1	1	0.01988
C27	J210	J232	45.052	0.01	TRIANGULAR	0.2	1.5	1	0.01512
C175_3	J59	J134	26.895	0.03	TRIANGULAR	0.2	1.5	1	0.06105
C175_4	J134	J56	50.488	0.03	TRIANGULAR	0.2	1.5	1	0.06108
C175	J134	J212	7.042	0.01	CIRCULAR	0.45	0	1	9.22653
C256	J212	J21	41.861	0.01	CIRCULAR	1	0	1	-0.07354
C174	J56	J236	15.548	0.01	CIRCULAR	1	0	1	0.26075
C257	J236	J235	6.722	0.023	CIRCULAR	0.45	0	1	0
C258	J235	J238	17.583	0.01	CIRCULAR	1	0	1	0
C259	J238	J239	5.406	0.023	CIRCULAR	0.45	0	1	0
C260	J239	OF11	52.046	0.01	CIRCULAR	1	0	1	0
C37	J233	J236	36.436	0.01	CIRCULAR	1	0	1	0
C255	J240	J139	13.49	0.01	CIRCULAR	1	0	1	-0.21488
C49_6	J241	J169	29.674	0.03	TRIANGULAR	0.2	1.5	1	0.09454
C46_2	J141	J25	37.157	0.03	TRAPEZOIDAL	1	1	1	0.00474
C223_2	J242	J186	32.17	0.03	TRIANGULAR	0.2	1.5	1	0.0677
C227_1	J184	J243	18.556	0.03	TRIANGULAR	0.2	1.5	1	0.03268
C227_2	J243	J186	26.7	0.03	TRIANGULAR	0.2	1.5	1	0.03268
C46	J187	J243	20.381	0.01	CIRCULAR	1	0	1	-999
C7_1	J462	J137	260.819	0.07	TRAPEZOIDAL	5	10	1	0.04182
C7_2	J137	J472	144.741	0.07	TRAPEZOIDAL	5	10	1	0.04182
C7	J245	J249	41.738	0.01	CIRCULAR	1	0	1	0
C223	J249	J250	8.963	0.01	CIRCULAR	0.45	0	1	0
C227	J250	OF21	131.097	0.01	CIRCULAR	1	0	1	0
C261	J246	J247	40.775	0.01	CIRCULAR	1	0	1	0
C262	J247	J248	11.63	0.01	CIRCULAR	0.45	0	1	0
C263	J248	J242	32.996	0.01	CIRCULAR	1	0	1	-1.0991
C264	J251	J252	77.928	0.01	CIRCULAR	1	0	1	0
C265	J252	J253	10.576	0.01	CIRCULAR	0.45	0	1	0

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Geom1 (m)	Geom2 (m)	Barrels	Slope (m/m)
C266	J255	J128	36.368	0.01	CIRCULAR	1	0	1	-0.27046
C267	J253	J258	49.429	0.01	CIRCULAR	1	0	1	-0.20264
R1_3	J487	J258	72.796	0.07	TRAPEZOIDAL	5	10	1	0.04206
R1	J258	J113	169.056	0.07	TRAPEZOIDAL	5	10	1	0.04207

Table H-2: Junctions PCSWMM Parameters

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)
J15	451082.6	8488620	560.35	560.35
J35	451747.6	8488848	590.415	590.415
J37	451739.6	8489022	610.388	610.388
J54	451768.6	8488503	565.153	565.153
J76	452248.6	8488388	577.276	577.276
J81	453149.6	8488379	760.31	760.31
J90	452468.6	8488076	555.417	555.417
J93	452716.6	8488306	634.581	634.581
J103	452517.6	8487421	487.883	487.883
J105	451484.6	8488124	546.043	546.043
J111	453075.6	8488050	633.574	633.574
J118	451550.6	8488068	544.012	544.012
J126	451418.6	8487970	548.715	548.715
J129	451965.6	8487850	523.735	523.735
J135	451844.6	8487642	525.204	525.204
J146	452926.6	8487232	468.52	468.52
J149	452430.6	8487258	479.873	479.873
J155	453139.6	8486874	447.63	447.63
J158	451860.6	8487211	527.334	527.334
J160	452917.6	8487130	458.124	458.124
J162	452633.6	8487141	464.682	464.682
J168	452892.6	8487066	451.312	451.312
J170	454337.6	8487014	596.915	596.915
J172	451598.6	8487101	556.04	556.04
J174	452596.6	8487160	467.278	467.278
J176	452871.6	8487015	447.449	447.449
J181	451644.6	8487127	550.461	550.461
J188	452228.6	8487071	505.409	505.409
J191	453196.6	8486758	414.119	414.119
J201	454065.6	8486680	513.566	513.566

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)
J207	453242.6	8486637	403.66	403.66
J209	451133.6	8486546	650.237	650.237
J211	451580.6	8486529	630.036	630.036
J214	453907.6	8486448	464.703	464.703
J217	453837.6	8486406	448.561	448.561
J225	453338.6	8486277	371.567	371.567
J237	454247.6	8486188	534.142	534.142
J244	451716.6	8486655	607.745	607.745
J254	453146.6	8485932	336.806	336.806
J256	454526.5	8485923	564.151	564.151
J259	452931.6	8485607	311.311	311.311
J261	453061.6	8485861	329.139	329.139
J265	452983.6	8485670	316.032	316.032
J267	452903.6	8485577	308.682	308.682
J278	452963.6	8485635	313.689	313.689
J280	452146.6	8485175	398.92	398.92
J282	453245.6	8485973	345.172	345.172
J287	453991.6	8485326	442.246	442.246
J292	454220.6	8485182	453.357	453.357
J301	451260.6	8485133	625.076	625.076
J306	451443.6	8485062	562.357	562.357
J308	453667.6	8485020	379.798	379.798
J313	452347.6	8484891	236.805	236.805
J317	452309.6	8484855	232.259	232.259
J328	453221.6	8485019	316.756	316.756
J330	454729.5	8484750	461.961	461.961
J338	454983.5	8484775	486.502	486.502
J344	455119.5	8484770	496.826	496.826
J347	454657.5	8484767	454.542	454.542
J349	452965.6	8485168	298.881	298.881
J352	449783.6	8483953	54.785	54.785

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)
J354	450771.6	8484023	83.54	83.54
J359	454876.5	8484541	473.603	473.603
J361	451169.6	8484163	96.172	96.172
J363	454018.6	8484515	394.481	394.481
J365	454555.5	8484548	449.314	449.314
J374	453875.6	8484333	438.911	438.911
J376	453924.6	8484420	424.849	424.849
J378	454793.5	8484287	467.22	467.22
J382	454857.5	8484261	470.998	470.998
J386	451989.6	8484153	164.379	164.379
J388	451889.6	8484149	153.329	153.329
J394	450276.6	8483847	66.503	66.503
J400	455095.5	8484098	493.877	493.877
J403	454941.5	8484248	476.618	476.618
J405	449780.6	8483855	50.302	50.302
J411	451695.6	8484031	131.182	131.182
J413	454506.5	8484493	447.059	447.059
J416	451388.6	8483941	109.241	109.241
J426	452233.6	8483906	232.09	232.09
J428	454749.5	8484329	464.103	464.103
J430	449888.6	8483679	44.417	44.417
J434	452383.6	8483774	287.816	287.816
J436	452489.6	8483766	324.35	324.35
J438	454701.5	8484360	460.702	460.702
J444	453285.6	8483646	486.084	486.084
J448	452980.6	8483609	451.293	451.293
J450	453039.6	8483600	459.874	459.874
J454	453647.6	8483499	521.158	521.158
J462	450437.6	8483383	45.103	45.103
J472	450203.6	8483164	28.156	28.156
J476	451549.6	8483976	119.473	119.473

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)
J478	452769.6	8483675	403.115	403.115
J482	450272.6	8483035	21.916	21.916
J487	450209.6	8482881	12.876	12.876
J489	450295.6	8482963	18.041	18.041
J511	453608.6	8483513	517.276	517.276
J537	451714.6	8487962	537.343	537.343
J539	453933.6	8484580	384.054	384.054
J542	449792.6	8483807	46.566	46.566
J545	452308.6	8487878	526.481	526.481
J551	452911.6	8486989	445.952	445.952
J555	453633.6	8484789	351.985	351.985
J556	452210.6	8487574	502.758	502.758
J558	453321.6	8486102	356.789	356.789
J559	452180.6	8484709	214.337	214.337
J562	452461.6	8484969	246.649	246.649
J563	451906.6	8487896	528.599	528.599
J565	450696.6	8483909	76.896	76.896
J566	454359.6	8484554	435.312	435.312
J568	453102.6	8486814	419.972	419.972
J569	453555.6	8485124	371.774	371.774
J575	452670.6	8487122	461.917	461.917
J578	453748.6	8484794	363.067	363.067
J580	450614.6	8483622	61.039	61.039
J581	453261.6	8485316	347.093	347.093
J582	452917.6	8483644	436.712	436.712
J586	452458.6	8487214	476.786	476.786
J590	452495.6	8487192	474.208	474.208
J594	453331.6	8486236	368.094	368.094
J595	452833.6	8485401	296.902	296.902
J596	452792.6	8487090	455.814	455.814
J600	451739.6	8484053	135.128	135.128

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)
J601	452769.6	8485199	283.656	283.656
J1	450695.9	8482067	3.922	3.922
J2	450699.4	8482069	4.571	4.571
J3	450651.9	8482100	2.342	2.342
J4	450654.8	8482102	2.714	2.714
J5	450619.6	8482146	1.259	1.259
J6	450622.5	8482151	2.183	2.183
J7	450604.6	8482182	2.133	2.133
J8	450606.8	8482185	2.323	2.323
J9	450568.7	8482239	2.077	2.077
J10	450572	8482241	2.373	2.373
J11	450605.1	8482256	4.793	4.793
J12	450614.4	8482260	6.164	6.164
J13	450637.1	8482271	8.685	8.685
J14	450644.6	8482274	9.079	9.079
J16	450673.5	8482285	11.312	11.312
J17	450685.8	8482289	12.319	12.319
J18	450530.9	8482298	1.799	1.799
J19	450536.3	8482301	2.262	2.262
J20	450541.1	8482306	2.403	2.403
J21	450550.3	8482312	3.07	3.07
J22	450440.6	8482420	2.255	2.255
J23	450487.7	8482449	4.405	4.405
J24	450599.2	8482346	8.264	8.264
J25	450603.8	8482349	9.229	9.229
J26	450630.9	8482358	10.842	10.842
J27	450639.7	8482362	12.988	12.988
J28	450640.6	8482380	14.069	14.069
J29	450641	8482391	14.69	14.69
J30	450644.8	8482404	15.56	15.56
J31	450650.1	8482414	16.306	16.306

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)
J32	450430.3	8482545	5.488	5.488
J33	450438.1	8482550	5.949	5.949
J34	450403.5	8482591	5.417	5.417
J36	450407.3	8482602	7.25	7.25
J38	450597.5	8482652	23.042	23.042
J39	450601.4	8482657	23.563	23.563
J40	450547.8	8482708	23.343	23.343
J41	450550.1	8482709	23.602	23.602
J42	450291.5	8482507	2.287	2.287
J43	450316	8482538	3.244	4.244
J44	450159.9	8482600	1.634	1.634
J45	450163	8482609	2.55	2.55
J46	450113.7	8482673	2.186	2.186
J47	450127.5	8482683	3.005	3.005
J50	450058.8	8482683	0.818	0.818
J51	450063.6	8482692	1.362	1.362
J57	450040.2	8482730	1.748	1.748
J58	450050	8482728	1.498	1.498
J61	449854	8483553	37.939	37.939
J62	449860.2	8483555	38.262	38.262
J63	449901.2	8483603	42.3	42.3
J64	449945.9	8483635	44.048	44.048
J65	449733	8483778	46.538	46.538
J66	449736.4	8483780	46.707	46.707
J67	449783.3	8483840	49.359	49.359
J68	449779.4	8483844	50.023	50.023
J69	449922.3	8483714	45.497	45.497
J70	449923.3	8483718	45.515	45.515
J71	450223.9	8483790	62.497	62.497
J72	450224.2	8483794	62.782	62.782
J73	450357.6	8483713	65.511	65.511

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)
J74	450364	8483717	65.564	65.564
J75	451904.8	8482111	586.671	586.671
J77	451851.3	8482267	568.583	568.583
J78	451868.5	8482479	550.417	550.417
J79	451748.1	8482676	508.645	508.645
J80	451395.6	8482418	236.627	236.627
J82	451597.7	8482794	480.382	480.382
J83	451370.9	8483143	439.773	439.773
J84	450523.1	8482680	19.995	19.995
J85	451000.1	8483170	209.553	209.553
J86	451255	8482419	168.11	168.11
J87	450638.8	8482553	20.474	20.474
J88	450902.6	8482166	35.871	35.871
J89	451102.8	8482464	101.434	101.434
J91	450951.3	8482517	56.14	56.14
J92	451061.5	8482814	145.983	145.983
J94	450948.3	8482926	114.967	114.967
J95	450764.4	8482819	55.231	55.231
J96	450544.8	8482811	30.418	30.418
J97	450658.1	8482986	52.521	52.521
J98	450444	8482579	7.743	7.743
J99	450531.8	8482492	8.034	8.034
J100	450336.3	8482703	10.534	10.534
J101	450343.9	8482707	12.008	12.008
J102	450462.7	8482794	25.425	25.425
J104	450315.7	8482820	18.104	18.104
J106	450312.4	8482823	18.131	18.131
J107	450382.2	8482716	16.05	16.05
J113	450095.3	8482729	2.711	2.711
J114	449983.8	8482776	0.508	0.508
J116	450517.2	8483110	49.107	49.107

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)
J117	450410.9	8482958	33.361	33.361
J119	450227	8482808	10.041	10.041
J48	450663.7	8482484	18.688	18.688
J49	450643.2	8482474	18.277	18.277
J52	450491.4	8482362	2.61	2.61
J53	450496.2	8482366	2.943	2.943
J55	450510.8	8482373	3.637	3.637
J56	450517	8482379	3.923	3.923
J59	450586	8482357	8.64	8.64
J60	450352.5	8482694	11.401	11.401
J108	450357.3	8482654	8.053	8.053
J109	450438.7	8482694	17.329	17.329
J110	450440.4	8482689	17.08	17.08
J112	450405.8	8482717	17.327	17.327
J120	450429.6	8482720	19.299	19.299
J121	450447.3	8482734	21.312	21.312
J122	450387.8	8482719	16.603	16.603
J123	450382.3	8482722	16.418	16.418
J124	450381.1	8482727	16.587	16.587
J125	450102.2	8482645	2.17	2.17
J127	450098.5	8482641	2.014	2.014
J128	450067.2	8482840	9.495	9.495
J130	450062.7	8482841	9.433	9.433
J131	450001.5	8483253	29.076	29.076
J132	449991.7	8483250	27.816	27.816
J133	450619.5	8482372	11.878	11.878
J136	450658.9	8482336	13.106	13.106
J139	450568.6	8482262	2.834	2.834
J140	450557	8482259	2.368	2.368
J138	450381.9	8482612	6.426	6.426
J142	450364.9	8482591	3.048	3.048

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)
J143	450419.7	8482583	7.349	7.349
J144	450419.6	8482527	4.333	4.333
J145	450388.9	8482546	3.711	4.113
J148	450426.6	8482450	3.171	3.171
J150	450398.4	8482481	3.328	3.328
J151	450702.4	8482465	20.636	20.636
J152	450696.6	8482428	19.391	19.391
J153	450686.1	8482460	19.708	19.708
J154	450687.2	8482523	23.354	23.354
J156	450685.3	8482525	23.274	23.274
J159	450716.3	8482396	18.115	18.115
J161	450761.8	8482272	16.238	16.238
J163	450783.3	8482334	23.442	23.442
J164	450783.4	8482337	23.608	23.608
J165	450606.9	8482221	3.918	3.918
J167	450592.4	8482198	2.085	2.085
J166	450594.3	8482312	7.129	7.129
J169	450606.2	8482273	6.218	6.218
J171	450692.7	8482395	16.14	16.14
J173	450713.8	8482443	21.149	21.149
J175	450714	8482444	21.209	21.209
J177	450607.8	8482429	14.564	14.564
J178	450350.3	8482701	12.261	12.261
J179	450372.3	8482662	10.069	10.069
J182	450325	8482639	4.962	4.962
J184	450156.6	8482979	23.953	23.953
J186	450116.6	8482998	22.475	22.475
J185	450037.7	8482876	7.509	7.509
J189	450351.2	8482782	17.893	17.893
J190	450480.6	8482840	30.018	30.018
J193	450478.8	8482842	29.787	29.787

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)
J192	450419	8482444	2.885	2.885
J194	450427.4	8482755	21.904	21.904
J195	450413.8	8482741	20.542	20.542
J196	450739	8482370	20.384	20.384
J197	450692.1	8482309	13.08	13.08
J198	450690.1	8482294	12.533	12.533
J199	450596.8	8482421	13.308	13.308
J200	450591.6	8482419	12.958	12.958
J202	450481.3	8482385	2.931	2.931
J203	450477.3	8482382	2.744	2.744
J204	450426.4	8482755	21.845	21.845
J205	450414.2	8482742	20.67	20.67
J206	450314.1	8482539	3.392	3.392
J208	450289.9	8482508	2.354	2.354
J210	450600.5	8482413	13.239	13.239
J221	450423.9	8482406	1.699	1.699
J224	450462.4	8482437	3.704	3.704
J226	450448.1	8482428	3.09	3.09
J215	450423.9	8482536	6.436	6.436
J216	450511.8	8482342	2.793	2.793
J218	450638.2	8482433	16.616	16.616
J219	450417.3	8482698	16.388	16.388
J222	450439	8482646	14.774	14.774
J220	450391.3	8482631	9.113	9.113
J180	450417.2	8482700	16.512	16.512
J183	450104.8	8482999	21.474	21.474
J157	450774	8482354	23.219	23.219
J147	450487	8482450	4.405	4.405
J213	450439.5	8482422	2.351	2.351
J223	450102.7	8482955	19.927	19.927
J227	450479.1	8482456	4.362	4.362

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)
J228	450467.8	8482449	4.024	4.024
J229	450453	8482464	4.138	4.138
J230	450398.6	8482524	3.989	4.173
J231	450430.3	8482496	4.147	4.147
J232	450625.2	8482376	12.658	12.658
J134	450559.2	8482358	5.333	5.333
J212	450558.2	8482351	4.878	4.878
J235	450502	8482387	3.69	3.69
J236	450507.6	8482391	3.895	3.895
J238	450488	8482377	2.946	2.946
J239	450483.8	8482373	2.694	2.694
J233	450485	8482420	3.968	3.968
J234	450516.7	8482378	3.898	3.898
J240	450561.6	8482274	2.771	2.771
J241	450633.2	8482285	9.173	9.173
J141	450621.3	8482317	9.347	9.347
J242	450119.1	8483030	24.406	24.406
J187	450151.2	8483005	26.256	26.256
J243	450140.3	8482987	23.515	23.515
J137	450236.7	8483261	33.321	33.321
J245	450116.6	8483117	30.703	30.703
J246	450124.4	8483114	30.998	30.998
J247	450117.9	8483074	27.818	27.818
J248	450118.3	8483063	27.063	27.063
J249	450104.4	8483077	27.171	27.171
J250	450096.7	8483072	26.703	26.703
J251	450173.8	8482916	18.635	18.635
J252	450145.9	8482861	14.499	14.499
J253	450152.4	8482854	14.091	14.091
J255	450102.3	8482831	11.525	11.525
J258	450189.8	8482823	9.341	9.341

Table H-3: Subcatchments PCSWMM Parameters

Name	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	N Perv	Dstore Perv (mm)	Max. Infil. Rate (mm/hr)	Min. Infil. Rate (mm/hr)	Decay Constant (1/hr)
S1	J116	6.8101	177.897	382.811	40.33	0.12	5	0.75	0.25	4
S1_10	J25	0.1803	1008.525	1.788	20.295	0.12	5	0.75	0.25	4
S1_11	OF2	0.352	1008.525	3.49	20.295	0.12	5	0.75	0.25	4
S1_12	OF3	0.2521	1008.525	2.5	20.295	0.12	5	0.75	0.25	4
S1_2	J19	0.0808	1008.525	0.801	20.295	0.12	5	0.75	0.25	4
S1_3	J99	0.6674	1008.525	6.618	20.295	0.12	5	0.75	0.25	4
S1_5	J14	0.1517	1008.525	1.504	20.295	0.12	5	0.75	0.25	4
S1_8	OF6	0.8332	1008.525	8.262	20.295	0.12	5	0.75	0.25	4
S101	J170	26.8735	350.158	767.468	22.918	0.12	5	0.75	0.25	4
S104	J201	39.8021	899.935	442.277	27.772	0.12	5	0.75	0.25	4
S108	J170	11.4319	223.919	510.537	8.211	0.12	5	0.75	0.25	4
S111	J568	27.9743	986.684	283.518	28.486	0.12	5	0.75	0.25	4
S112	J191	30.1418	171.216	1760.455	27.144	0.12	5	0.75	0.25	4
S129	J170	24.1065	230.687	1044.987	9.627	0.12	5	0.75	0.25	4
S134	J214	24.0972	821.027	293.501	29.68	0.12	5	0.75	0.25	4
S141	J225	49.1344	1295.19	379.361	33.446	0.12	5	0.75	0.25	4
S146	J207	29.242	141.726	2063.277	27.841	0.12	5	0.75	0.25	4
S151	J214	14.0446	125.535	1118.78	21.051	0.12	5	0.75	0.25	4
S153	J594	11.7624	153.772	764.925	34.304	0.12	5	0.75	0.25	4
S154	J217	18.3066	193.032	948.371	26.043	0.12	5	0.75	0.25	4
S156	J558	20.8755	581.301	359.117	29.746	0.12	5	0.75	0.25	4
S158	J558	17.1449	356.725	480.62	27.338	0.12	5	0.75	0.25	4
S159	J237	14.1153	154.01	916.518	25.805	0.12	5	0.75	0.25	4
S160	J282	15.2287	676.064	225.255	33.715	0.12	5	0.75	0.25	4
S161	J237	17.8749	137.673	1298.359	17.452	0.12	5	0.75	0.25	4
S163	J265	16.1898	188.878	857.156	31.259	0.12	5	0.75	0.25	4
S164	J282	45.1891	272.094	1660.79	27.273	0.12	5	0.75	0.25	4
S165	J261	10.9773	105.377	1041.717	42.74	0.12	5	0.75	0.25	4
S166	J256	22.7061	191.606	1185.041	28.035	0.12	5	0.75	0.25	4

TETRA TECH

Name	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	N Perv	Dstore Perv (mm)	Max. Infil. Rate (mm/hr)	Min. Infil. Rate (mm/hr)	Decay Constant (1/hr)
S167	J259	22.1481	123.374	1795.2	18.69	0.12	5	0.75	0.25	4
S170	J265	24.5984	955.767	257.368	46.37	0.12	5	0.75	0.25	4
S171	J254	42.6463	227.419	1875.23	36.627	0.12	5	0.75	0.25	4
S172	J256	28.2193	158.405	1781.465	20.03	0.12	5	0.75	0.25	4
S175	J267	17.1183	107.221	1596.544	15.346	0.12	5	0.75	0.25	4
S177	J287	10.4804	89.138	1175.75	23.419	0.12	5	0.75	0.25	4
S178	J287	12.6068	89.725	1405.049	25.373	0.12	5	0.75	0.25	4
S181	J280	26.2842	183.153	1435.095	27.769	0.12	5	0.75	0.25	4
S183	J559	23.783	190.732	1246.933	43.091	0.12	5	0.75	0.25	4
S185	J595	22.1053	821.084	269.221	38.881	0.12	5	0.75	0.25	4
S187	J292	62.0983	217.245	2858.446	23.162	0.12	5	0.75	0.25	4
S188	J278	9.8346	164.791	596.792	24.475	0.12	5	0.75	0.25	4
S190	J562	36.5577	1228.626	297.549	46.957	0.12	5	0.75	0.25	4
S191	J581	14.1957	292.04	486.088	31.468	0.12	5	0.75	0.25	4
S192	J301	20.5297	201.48	1018.945	14.101	0.12	5	0.75	0.25	4
S193	J317	15.0362	156.985	957.811	50.356	0.12	5	0.75	0.25	4
S195	J601	23.3339	785.903	296.906	23.965	0.12	5	0.75	0.25	4
S197	J313	19.4909	160.06	1217.725	54.974	0.12	5	0.75	0.25	4
S198	J306	14.948	200.216	746.594	20.229	0.12	5	0.75	0.25	4
S2	J95	2.479	200.459	123.666	63.25	0.12	5	0.75	0.25	4
S200	J581	19.8965	603.76	329.543	20.315	0.12	5	0.75	0.25	4
S201	J308	26.0346	101.789	2557.703	21.71	0.12	5	0.75	0.25	4
S205	J328	35.5015	1160.466	305.925	24.263	0.12	5	0.75	0.25	4
S207	J578	27.0767	414.953	652.525	22.522	0.12	5	0.75	0.25	4
S209	J347	25.4996	136.517	1867.87	21.997	0.12	5	0.75	0.25	4
S210	J569	9.3918	344.925	272.285	18.671	0.12	5	0.75	0.25	4
S211	J349	28.9445	873.47	331.374	21.174	0.12	5	0.75	0.25	4
S212	J354	25.0905	296.354	846.639	89.534	0.12	5	0.75	0.25	4
S213	J349	15.0022	193.368	775.837	18.629	0.12	5	0.75	0.25	4
S215	J354	16.2554	237.701	683.859	72.812	0.12	5	0.75	0.25	4

Name	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	N Perv	Dstore Perv (mm)	Max. Infil. Rate (mm/hr)	Min. Infil. Rate (mm/hr)	Decay Constant (1/hr)
S216	J354	15.9174	171.919	925.866	80.832	0.12	5	0.75	0.25	4
S217	J352	31.197	213.644	1460.233	74.05	0.12	5	0.75	0.25	4
S218	J361	14.5428	169.093	860.047	86.871	0.12	5	0.75	0.25	4
S219	J559	13.1274	199.666	657.468	55.164	0.12	5	0.75	0.25	4
S221	J330	15.8651	82.806	1915.936	20.521	0.12	5	0.75	0.25	4
S223	J559	12.5891	725.233	173.587	55.945	0.12	5	0.75	0.25	4
S224	J328	23.0114	152.382	1510.113	24.363	0.12	5	0.75	0.25	4
S225	J361	20.7478	313.08	662.7	80.352	0.12	5	0.75	0.25	4
S227	J338	11.5069	105.855	1087.044	25.362	0.12	5	0.75	0.25	4
S229	J600	44.5853	1002.407	444.782	52.886	0.12	5	0.75	0.25	4
S230	J344	16.2932	163.133	998.768	21.479	0.12	5	0.75	0.25	4
S233	J578	27.8698	624.156	446.52	15.386	0.12	5	0.75	0.25	4
S234	J555	28.0418	669.101	419.097	24.045	0.12	5	0.75	0.25	4
S237	J344	15.4919	177.181	874.354	16.627	0.12	5	0.75	0.25	4
S240	J539	7.3042	381.014	191.704	23.556	0.12	5	0.75	0.25	4
S241	J405	15.8405	115.622	1370.025	44.033	0.12	5	0.75	0.25	4
S243	J566	16.7021	470.116	355.276	14.46	0.12	5	0.75	0.25	4
S244	J394	18.8207	256.581	733.519	64.236	0.12	5	0.75	0.25	4
S245	J363	26.7262	216.536	1234.261	19.75	0.12	5	0.75	0.25	4
S246	J365	10.7158	222.18	482.303	14.731	0.12	5	0.75	0.25	4
S247	J565	13.1335	350.075	375.162	31.853	0.12	5	0.75	0.25	4
S248	J359	22.275	177.972	1251.601	26.518	0.12	5	0.75	0.25	4
S250	J361	14.3139	266.868	536.366	47.302	0.12	5	0.75	0.25	4
S251	J363	24.0847	195.511	1231.885	17.985	0.12	5	0.75	0.25	4
S252	J413	10.4574	391.259	267.276	12.579	0.12	5	0.75	0.25	4
S253	J413	21.8844	220.501	992.485	15.547	0.12	5	0.75	0.25	4
S256	J376	9.2292	123.351	748.206	17.116	0.12	5	0.75	0.25	4
S259	J438	17.1513	143.507	1195.154	14.578	0.12	5	0.75	0.25	4
S261	J374	19.534	157.415	1240.924	17.671	0.12	5	0.75	0.25	4
S262	J428	11.3534	111.213	1020.87	14.242	0.12	5	0.75	0.25	4

Name	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	N Perv	Dstore Perv (mm)	Max. Infil. Rate (mm/hr)	Min. Infil. Rate (mm/hr)	Decay Constant (1/hr)
S264	J378	16.8049	220.598	761.788	19.193	0.12	5	0.75	0.25	4
S265	J382	11.8833	125.872	944.078	21.72	0.12	5	0.75	0.25	4
S266	J403	10.0457	419.162	239.662	29.495	0.12	5	0.75	0.25	4
S267	J403	21.9891	337.814	650.923	21.351	0.12	5	0.75	0.25	4
S268	J388	10.4797	113.714	921.584	29.399	0.12	5	0.75	0.25	4
S269	J400	35.2968	329.768	1070.352	18.519	0.12	5	0.75	0.25	4
S270	J386	26.0435	806.229	323.029	61.754	0.12	5	0.75	0.25	4
S271_2	OF12	2.8434	266.616	106.648	8.458	0.12	5	0.75	0.25	4
S271_3	J64	18.6975	266.616	701.289	8.458	0.12	5	0.75	0.25	4
S274	J542	3.2581	144.155	226.014	19.33	0.12	5	0.75	0.25	4
S275	J430	10.8946	165.179	659.563	12.401	0.12	5	0.75	0.25	4
S276_1	J600	23.02493	166.019	1386.886	38.474	0.12	5	0.75	0.25	4
S276_2	J87	3.6248	290.246	124.887	67.106	0.12	5	0.75	0.25	4
S276_5	J91	20.2519	290.246	697.749	67.106	0.12	5	0.75	0.25	4
S278_1	J411	14.30646	110.783	1291.395	33.897	0.12	5	0.75	0.25	4
S278_2	J487	1.9608	161.967	121.062	61.379	0.12	5	0.75	0.25	4
S278_3	J411	4.80E-05	110.783	0.004	33.897	0.12	5	0.75	0.25	4
S278_4	J94	15.7686	161.967	973.569	61.379	0.12	5	0.75	0.25	4
S278_6	J117	1.2526	161.967	77.337	61.379	0.12	5	0.75	0.25	4
S279_1	J102	0.7336	186.858	39.26	65.599	0.12	5	0.75	0.25	4
S279_2	J416	17.88514	434.025	412.076	53.724	0.12	5	0.75	0.25	4
S279_3	J92	20.8207	186.858	1114.253	65.599	0.12	5	0.75	0.25	4
S281_2	J580	39.41548	456.219	863.96	53.292	0.12	5	0.75	0.25	4
S281_3	J462	10.75603	193.413	556.117	75.688	0.12	5	0.75	0.25	4
S281_4	J89	59.2854	190.876	3105.964	53.243	0.12	5	0.75	0.25	4
S282_1	J476	17.1251	150.774	1135.812	40.163	0.12	5	0.75	0.25	4
S282_2	J476	0.001154	150.774	0.077	40.163	0.12	5	0.75	0.25	4
S284_1	J426	16.11763	925.136	174.219	44.046	0.12	5	0.75	0.25	4
S285_1	J426	22.31322	244.783	911.551	28.974	0.12	5	0.75	0.25	4
S288_1	OF12	9.150596	277.248	330.051	10.745	0.12	5	0.75	0.25	4

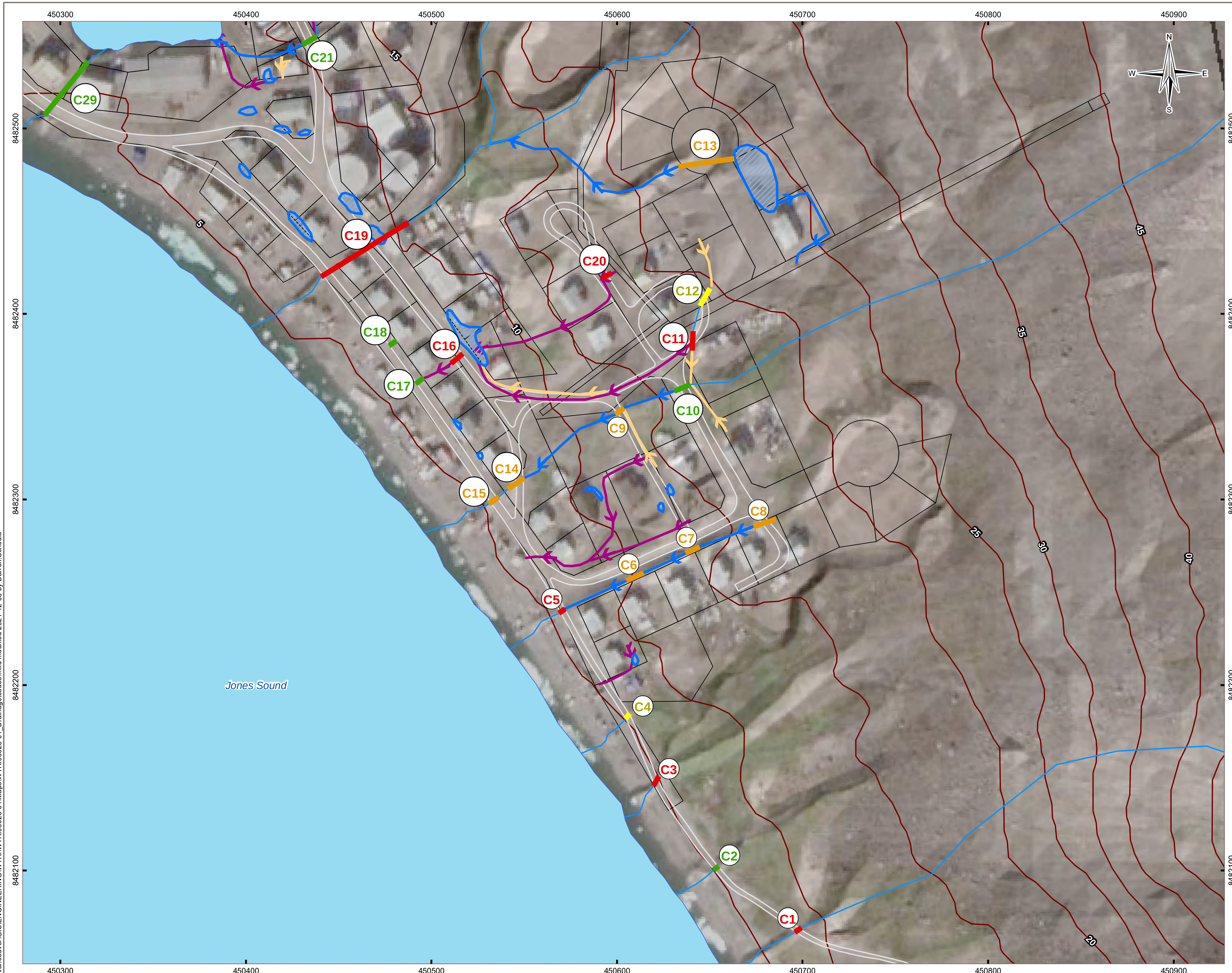
Name	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	N Perv	Dstore Perv (mm)	Max. Infil. Rate (mm/hr)	Min. Infil. Rate (mm/hr)	Decay Constant (1/hr)
S290	J478	32.4727	562.885	576.898	23.213	0.12	5	0.75	0.25	4
S291_1	J434	17.08198	174.879	976.789	29.063	0.12	5	0.75	0.25	4
S292_1	J436	13.74512	180.076	763.295	22.41	0.12	5	0.75	0.25	4
S292_2	J436	2.00E-05	180.076	0.001	22.41	0.12	5	0.75	0.25	4
S292_4	J436	0.010003	180.076	0.555	22.41	0.12	5	0.75	0.25	4
S293_1	J436	24.51254	149.61	1638.429	36.516	0.12	5	0.75	0.25	4
S293_3	J436	0.00648	149.61	0.433	36.516	0.12	5	0.75	0.25	4
S294	J462	12.9458	590.392	219.275	31.922	0.12	5	0.75	0.25	4
S296_1	J478	15.55704	168.573	922.867	19.424	0.12	5	0.75	0.25	4
S297	J444	22.4685	768.916	292.21	17.477	0.12	5	0.75	0.25	4
S298	J582	9.1587	335.702	272.822	20.861	0.12	5	0.75	0.25	4
S299	J444	14.2751	202.24	705.849	18.501	0.12	5	0.75	0.25	4
S3	J96	4.7196	271.115	174.081	51.049	0.12	5	0.75	0.25	4
S300	J448	17.6614	153.334	1151.825	21.298	0.12	5	0.75	0.25	4
S301	J450	42.9285	227.88	1883.82	17.655	0.12	5	0.75	0.25	4
S304	J511	15.1234	83.06	1820.78	13.715	0.12	5	0.75	0.25	4
S305	J454	34.3473	358.696	957.56	15.928	0.12	5	0.75	0.25	4
S309_1	J472	11.5608	219.452	526.803	31.993	0.12	5	0.75	0.25	4
S312_2	J482	3.9543	110.608	357.506	53.831	0.12	5	0.75	0.25	4
S316	J117	4.2955	154.617	277.816	45.472	0.12	5	0.75	0.25	4
S316_1	J489	1.4882	154.617	96.251	45.472	0.12	5	0.75	0.25	4
S322_1	J119	0.5861	505.911	11.585	10.502	0.12	5	0.75	0.25	4
S322_10	J51	0.296	505.911	5.851	10.502	0.12	5	0.75	0.25	4
S322_11	J58	0.2288	505.911	4.523	10.502	0.12	5	0.75	0.25	4
S322_2	J50	0.2733	505.911	5.402	10.502	0.12	5	0.75	0.25	4
S322_3	J47	1.1479	505.911	22.69	10.502	0.12	5	0.75	0.25	4
S322_4	J104	2.7825	505.911	55	10.502	0.12	5	0.75	0.25	4
S322_5	J45	2.4512	505.911	48.451	10.502	0.12	5	0.75	0.25	4
S322_6	J114	1.4635	505.911	28.928	10.502	0.12	5	0.75	0.25	4
S322_7	OF13	0.4163	505.911	8.229	10.502	0.12	5	0.75	0.25	4

Name	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	N Perv	Dstore Perv (mm)	Max. Infil. Rate (mm/hr)	Min. Infil. Rate (mm/hr)	Decay Constant (1/hr)
S325_2	J98	2.3135	314.408	73.583	15.233	0.12	5	0.75	0.25	4
S325_3	J84	1.5668	314.408	49.833	15.233	0.12	5	0.75	0.25	4
S325_5	OF7	1.8093	314.408	57.546	15.233	0.12	5	0.75	0.25	4
S326_2	J87	11.8649	227.634	521.227	62.599	0.12	5	0.75	0.25	4
S336_1	J4	2.2083	1017.851	21.696	19.687	0.12	5	0.75	0.25	4
S336_4	J2	1.5505	1017.851	15.233	19.687	0.12	5	0.75	0.25	4
S343_2	J88	18.4215	256.995	716.804	79.923	0.12	5	0.75	0.25	4
S343_3	J6	10.468	256.995	407.323	79.923	0.12	5	0.75	0.25	4
S4	J97	8.119	141.482	573.854	52.791	0.12	5	0.75	0.25	4
S6	J8	0.5523	854.114	6.466	32.546	0.12	5	0.75	0.25	4
S6_1	J99	1.2204	259.536	47.022	45.185	0.12	5	0.75	0.25	4
S6_2	J39	2.0525	259.536	79.083	45.185	0.12	5	0.75	0.25	4
S91	J155	32.7326	310.854	1052.99	42.638	0.12	5	0.75	0.25	4
S7	J176	1117.905	400	27947.63	19.813	0.12	5	0.75	0.25	4
S1_1	J133	0.3	1008.525	2.975	20.295	0.12	5	0.75	0.25	4
S1_13	J21	0.4058	1008.525	4.024	20.295	0.12	5	0.75	0.25	4
S1_14	J48	0.3964	1008.525	3.93	20.295	0.12	5	0.75	0.25	4
S303_3	OF16	5.5719	281.708	197.79	12.69	0.12	5	0.75	0.25	4
S325_8	J121	0.7206	314.408	22.919	15.233	0.12	5	0.75	0.25	4
S325_9	J112	0.2359	314.408	7.503	15.233	0.12	5	0.75	0.25	4
S325_4	J124	0.3202	314.408	10.184	15.233	0.12	5	0.75	0.25	4
S325_10	J101	0.1915	314.408	6.091	15.233	0.12	5	0.75	0.25	4
S325_11	J220	0.2718	314.408	8.645	15.233	0.12	5	0.75	0.25	4
S325_1	J178	0.3279	314.408	10.429	15.233	0.12	5	0.75	0.25	4
S325_12	J115	1.9677	314.408	62.584	15.233	0.12	5	0.75	0.25	4
S325_7	J36	0.5281	314.408	16.797	15.233	0.12	5	0.75	0.25	4
S325_13	J143	0.2246	314.408	7.144	15.233	0.12	5	0.75	0.25	4
S5_2	J173	0.3778	1008.525	3.746	20.295	0.12	5	0.75	0.25	4
S5_3	J31	0.2436	1008.525	2.415	20.295	0.12	5	0.75	0.25	4
S5_4	J171	1.478	1008.525	14.655	20.295	0.12	5	0.75	0.25	4

Name	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	N Perv	Dstore Perv (mm)	Max. Infil. Rate (mm/hr)	Min. Infil. Rate (mm/hr)	Decay Constant (1/hr)
S1_7	J177	0.2663	1008.525	2.64	20.295	0.12	5	0.75	0.25	4
S1_16	J27	0.2866	1008.525	2.842	20.295	0.12	5	0.75	0.25	4
S1_18	J159	3.4746	1008.525	34.452	20.295	0.12	5	0.75	0.25	4
S1_9	J164	3.5859	1008.525	35.556	20.295	0.12	5	0.75	0.25	4
S1_19	J161	1.011	1008.525	10.025	20.295	0.12	5	0.75	0.25	4
S1_4	J56	0.6825	1008.525	6.767	20.295	0.12	5	0.75	0.25	4
S1_20	J239	0.301	1008.525	2.985	20.295	0.12	5	0.75	0.25	4
S1_17	J23	1.4632	1008.525	14.508	20.295	0.12	5	0.75	0.25	4
S1_15	J148	0.1484	1008.525	1.471	20.295	0.12	5	0.75	0.25	4
S1_22	J224	0.2569	1008.525	2.547	20.295	0.12	5	0.75	0.25	4
S314_1	J128	0.6335	431.171	14.693	10.616	0.12	5	0.75	0.25	4
S303_5	J131	2.8746	281.708	102.042	12.69	0.12	5	0.75	0.25	4
S303_6	OF16	1.6766	281.708	59.516	12.69	0.12	5	0.75	0.25	4
S303	J137	3.8511	281.708	136.705	12.69	0.12	5	0.75	0.25	4
S322_9	J113	2.0346	505.911	40.217	10.502	0.12	5	0.75	0.25	4
S322_12	J252	0.3976	505.911	7.859	10.502	0.12	5	0.75	0.25	4
S314_2	J186	0.4322	431.171	10.024	10.616	0.12	5	0.75	0.25	4
S314_5	J247	0.6478	431.171	15.024	10.616	0.12	5	0.75	0.25	4
S314_4	J245	0.129	431.171	2.992	10.616	0.12	5	0.75	0.25	4
S314_6	OF10	3.7543	431.171	87.072	10.616	0.12	5	0.75	0.25	4
S1_21	J10	0.222	1008.525	2.201	20.295	0.12	5	0.75	0.25	4
S1_23	J139	0.5299	1008.525	5.254	20.295	0.12	5	0.75	0.25	4

APPENDIX I

DRAINAGE ISSUES MAP



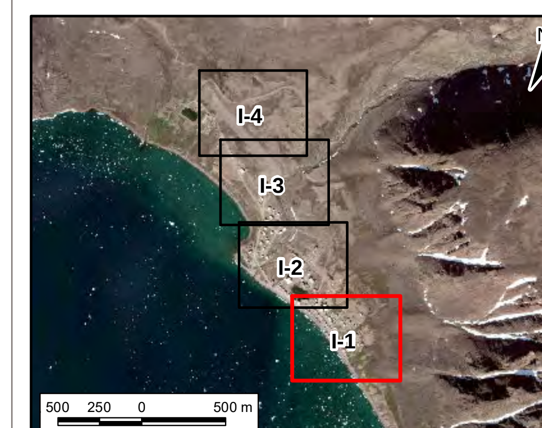
LEGEND

Culverts
- Functioning as Intended
- Blocked
- Partially Damaged
- Damaged

C## Culvert Number

Open Channels
- Overland Flow
- Existing Ditch
- Existing Swale
- Ponding
- Watercourse

Base Data
- Current Parcel
- Gravel Road
- Topographic Contour (5 m)
- Waterbody



NOTES
Base data source:
Imagery from Google Earth (2020)
Igloolik base data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN
GRISE FIORD, NU

Drainage Issues Based on July 20-22 Field Visit Observations

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:2,000

40 20 0 40

Metres

TETRA TECH

FILE NO.
WTRI03028-01_DrainageIssues.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	DS	SL	ER	0

DATE	PROJECT NO.
December 8, 2021	ENG.WTRI03028-01

Appendix I-1

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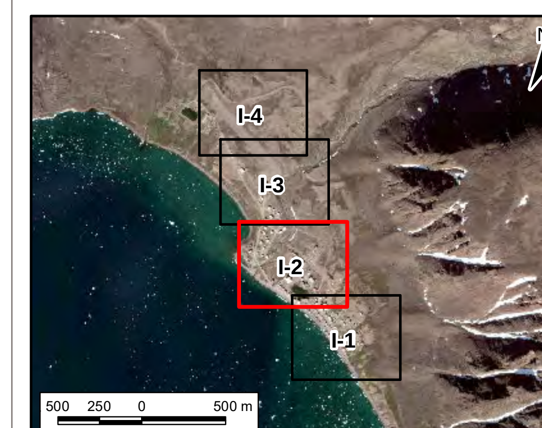
LEGEND

C## Culvert Number

Culverts
- Functioning as Intended
- Partially Blocked
- Blocked
- Partially Damaged
- Damaged
- Not Assessed

Open Channels
- Overland Flow
- Existing Ditch
- Existing Swale
- Ponding
- Erosion
- Watercourse

Base Data
- Current Parcel
- Gravel Road
- Topographic Contour (5 m)
- Waterbody



NOTES
Base data source:
Imagery from Google Earth (2020)
Igloolik base data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN
GRISE FIORD, NU

Drainage Issues Based on July 20-22 Field Visit Observations

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:2,000
40 20 0 40
Metres

FILE NO.
WTRI03028-01_DrainageIssues.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	DS	SL	ER	0

DATE	PROJECT NO.
December 8, 2021	ENG.WTRI03028-01

Appendix I-2

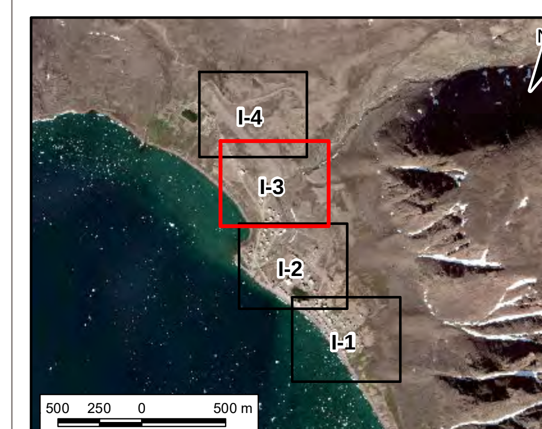
LEGEND

Culverts
- Blocked

C## Culvert Number

Open Channels
- Overland Flow
- Ponding
- Watercourse

Base Data
- Current Parcel
- Runway
- Gravel Road
- Topographic Contour (5 m)
- Waterbody



NOTES
Base data source:
Imagery from Google Earth (2020)
Igloolik base data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN
GRISE FIORD, NU

Drainage Issues Based on July 20-22 Field Visit Observations

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:2,000

40 20 0 40

Metres

TETRA TECH

FILE NO.
WTRI03028-01_DrainageIssues.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	DS	SL	ER	0

DATE	PROJECT NO.
December 8, 2021	ENG.WTRI03028-01

Appendix I-3

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LEGEND

Culverts

Not Assessed

Watercourse

Base Data

Current Parcel

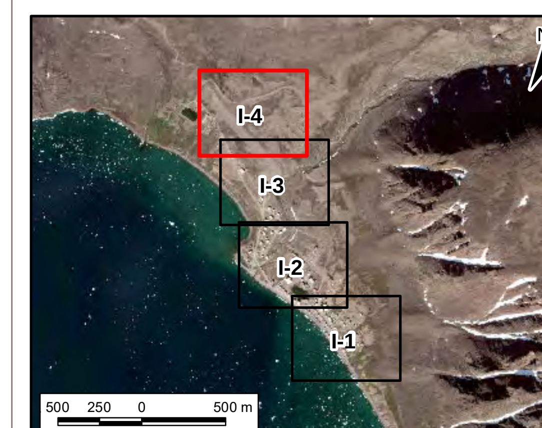
Runway

Gravel Road

Topographic Contour (5 m)

Waterbody

C## Culvert Number



NOTES
Base data source:
Imagery from Google Earth (2020)
Igloolik base data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN
GRISE FIORD, NU

Drainage Issues Based on July 20-22 Field Visit Observations

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:2,000

40 20 0 40

Metres

FILE NO.
WTRI03028-01_DrainageIssues.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	DS	SL	ER	0

DATE	PROJECT NO.
December 8, 2021	ENG.WTRI03028-01

Appendix I-4

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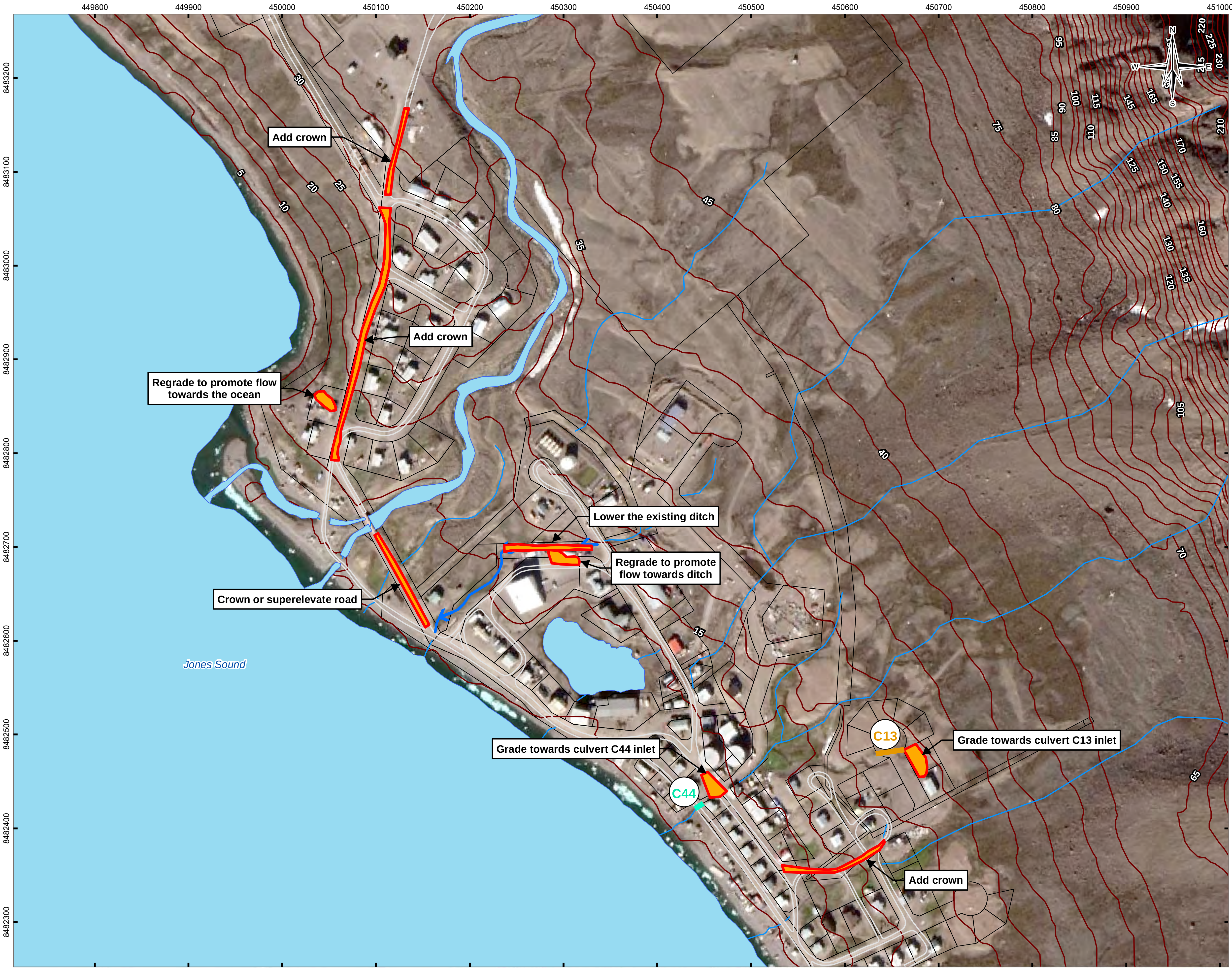
APPENDIX J

PROPOSED GRADING PLAN



LEGEND

- Grading Area
- Culvert C44 - New (Existing Community)
- Culvert C13 - Partially Damaged
- Existing Ditch
- Watercourse

Base Data

- Current Parcel
- Gravel Road
- Topographic Contour (5 m)
- Waterbody

NOTES
Base data source:
Imagery from Google Earth (2020)
Igloolik base data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN GRISE FIORD, NU

Proposed Grading Plan

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:4,000
80 40 0 80
Metres

FILE NO.
WTRI03028-01_GradingArea.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
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DATE	PROJECT NO.
December 8, 2021	ENG.WTRI03028-01

Appendix J

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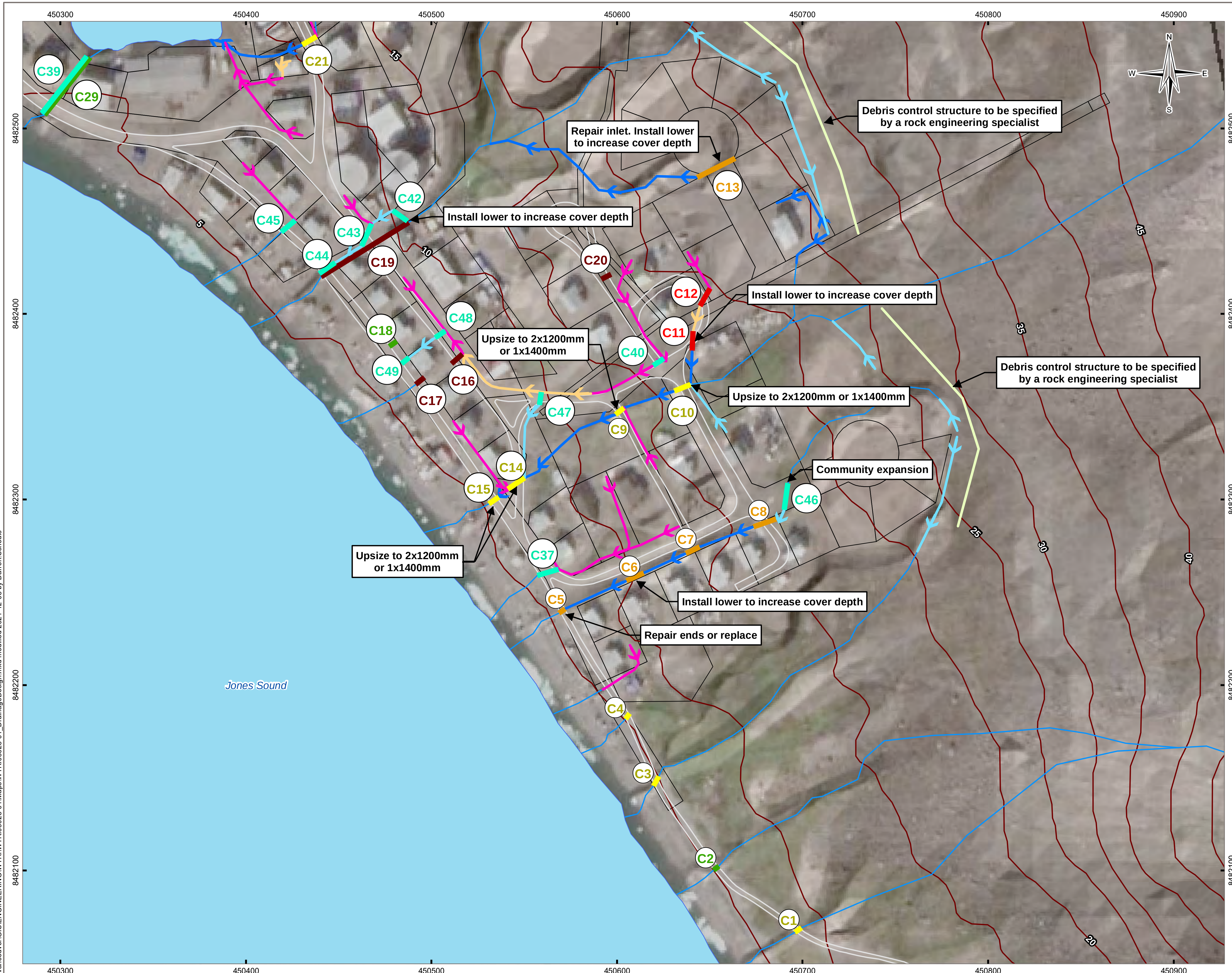
APPENDIX K

CONCEPTUAL DRAINAGE DESIGN



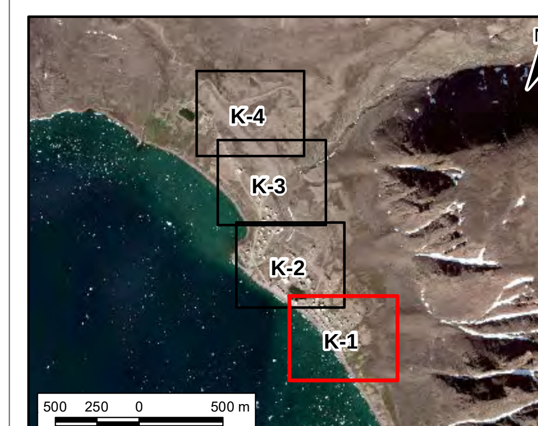
LEGEND

C## Culvert Number

Culverts
- Functioning as Intended
- Repair
- Upsize
- Abandon
- Replace
- New

Open Channels
- Existing Ditch
- New Ditch
- Existing Swale
- New Swale
- Debris Control Structure
- Watercourse

Base Data
- Current Parcel
- Gravel Road
- Topographic Contour (5 m)
- Waterbody



NOTES
Base data source:
Imagery from Google Earth (2020)
Igloolik base data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN
GRISE FIORD, NU

Conceptual Drainage Design

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:2,000
40 20 0 40
Metres

TETRA TECH

FILE NO.
WTRI03028-01_DrainageDesign.mxd

OFFICE	DWN	CKD	APVD	REV
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DATE
December 8, 2021

PROJECT NO.
ENG.WTRI03028-01

Appendix K-1

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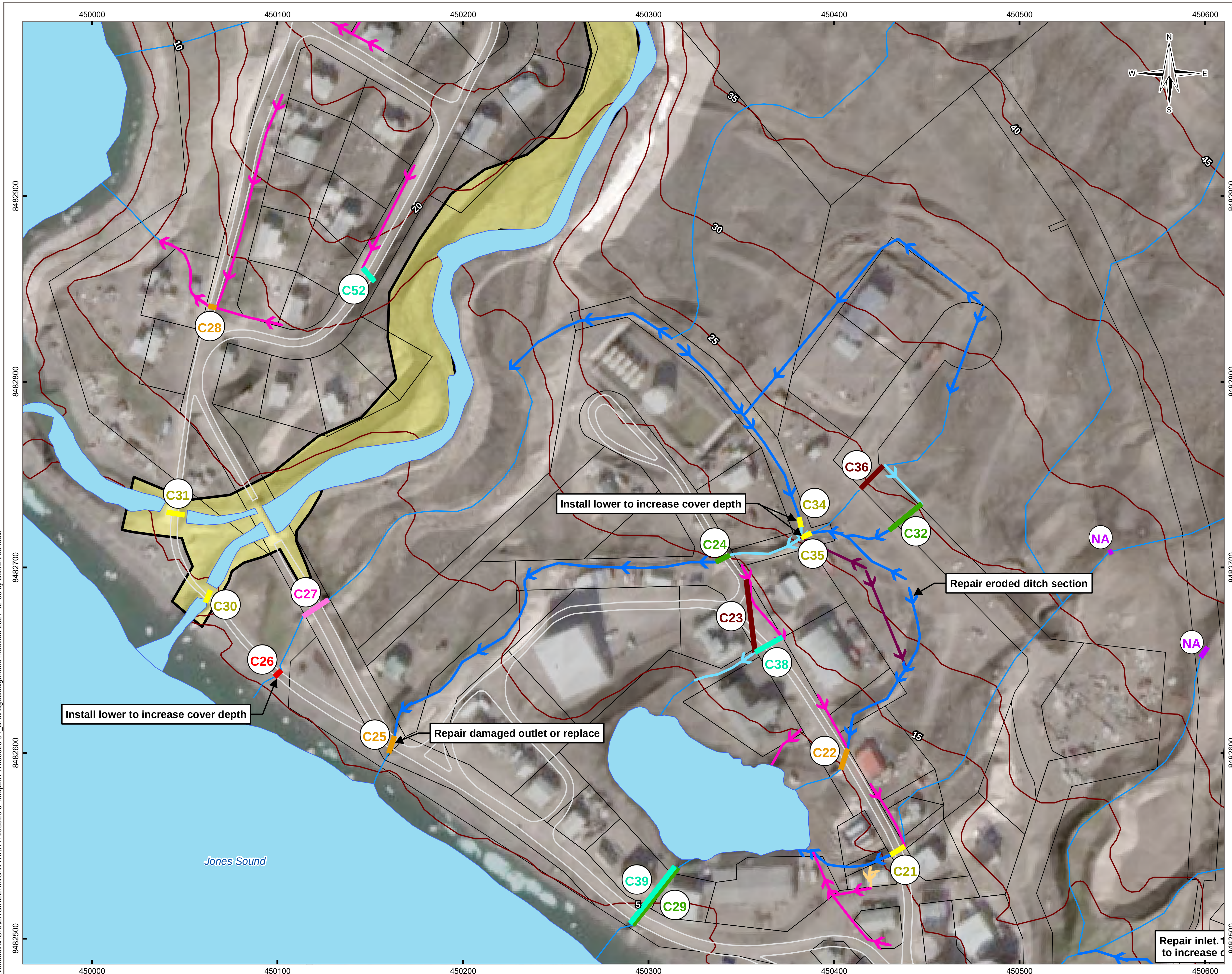

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LEGEND

C## Culvert Number

Culverts
- Functioning as Intended
- Clean Out
- Repair
- Upsize
- Abandon
- Replace
- New
- Not Assessed

Open Channels
- Existing Ditch
- New Ditch
- Existing Swale
- New Swale
- Underdrain
- Watercourse
- Formalize Revetment System

Base Data
- Current Parcel
- Gravel Road
- Topographic Contour (5 m)
- Waterbody

K-4
K-3
K-2
K-1
500 250 0 500 m

NOTES
Base data source:
Imagery from Google Earth (2020)
Igloolik base data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN GRISE FIORD, NU

Conceptual Drainage Design

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:2,000
40 20 0 40
Metres

FILE NO.
WTRI03028-01_DrainageDesign.mxd

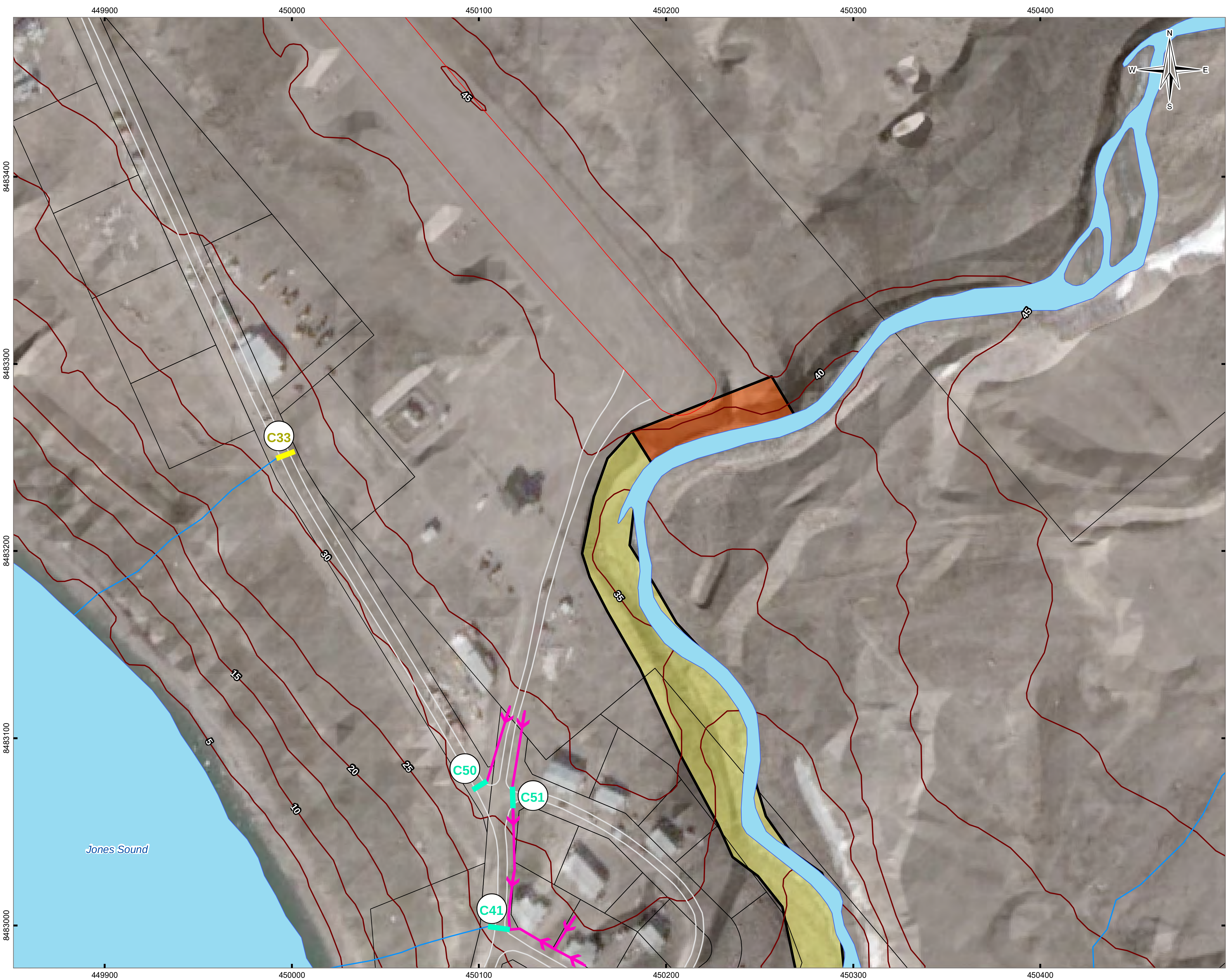
TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	DS	SL	ER	0

DATE
December 8, 2021

PROJECT NO.
ENG.WTRI03028-01

Appendix K-2



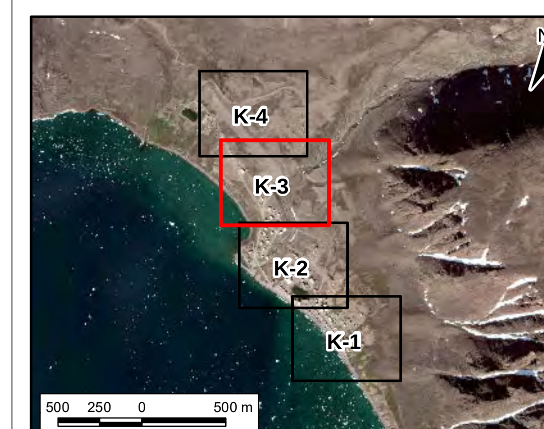
LEGEND

Culverts
- Upsize
- New

C## Culvert Number

Open Channels
- New Swale
- Watercourse
- Remediate Slope and Formalize Revetment System
- Formalize Revetment System

Base Data
- Current Parcel
- Runway
- Gravel Road
- Topographic Contour (5 m)
- Waterbody



NOTES
Base data source:
Imagery from Google Earth (2020)
Igloolik base data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN
GRISE FIORD, NU

Conceptual Drainage Design

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:2,000
40 20 0 40
Metres

FILE NO.
WTRI03028-01_DrainageDesign.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	DS	SL	ER	0

DATE
December 8, 2021

PROJECT NO.
ENG.WTRI03028-01

Appendix K-3

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LEGEND

C## Culvert Number

Culverts

Not

Watercourse

Base Data

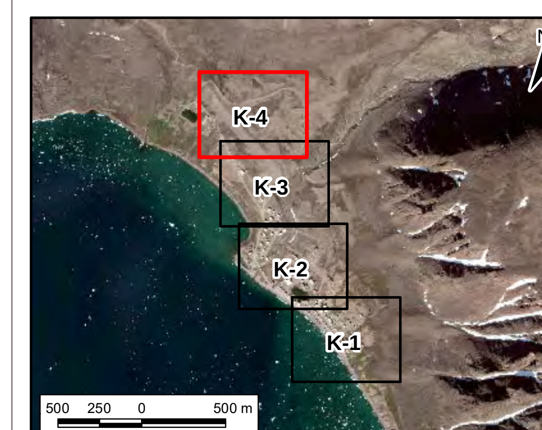
Current Parcel

Runway

Gravel Road

Topographic Contour (5 m)

Waterbody



NOTES
Base data source:
Imagery from Google Earth (2020)
Igloolik base data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN GRISE FIORD, NU

Conceptual Drainage Design

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:2,000

40 20 0 40

Metres

TETRA TECH

FILE NO.
WTRI03028-01_DrainageDesign.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	DS	SL	ER	0

DATE
December 8, 2021

PROJECT NO.
ENG.WTRI03028-01

Appendix K-4

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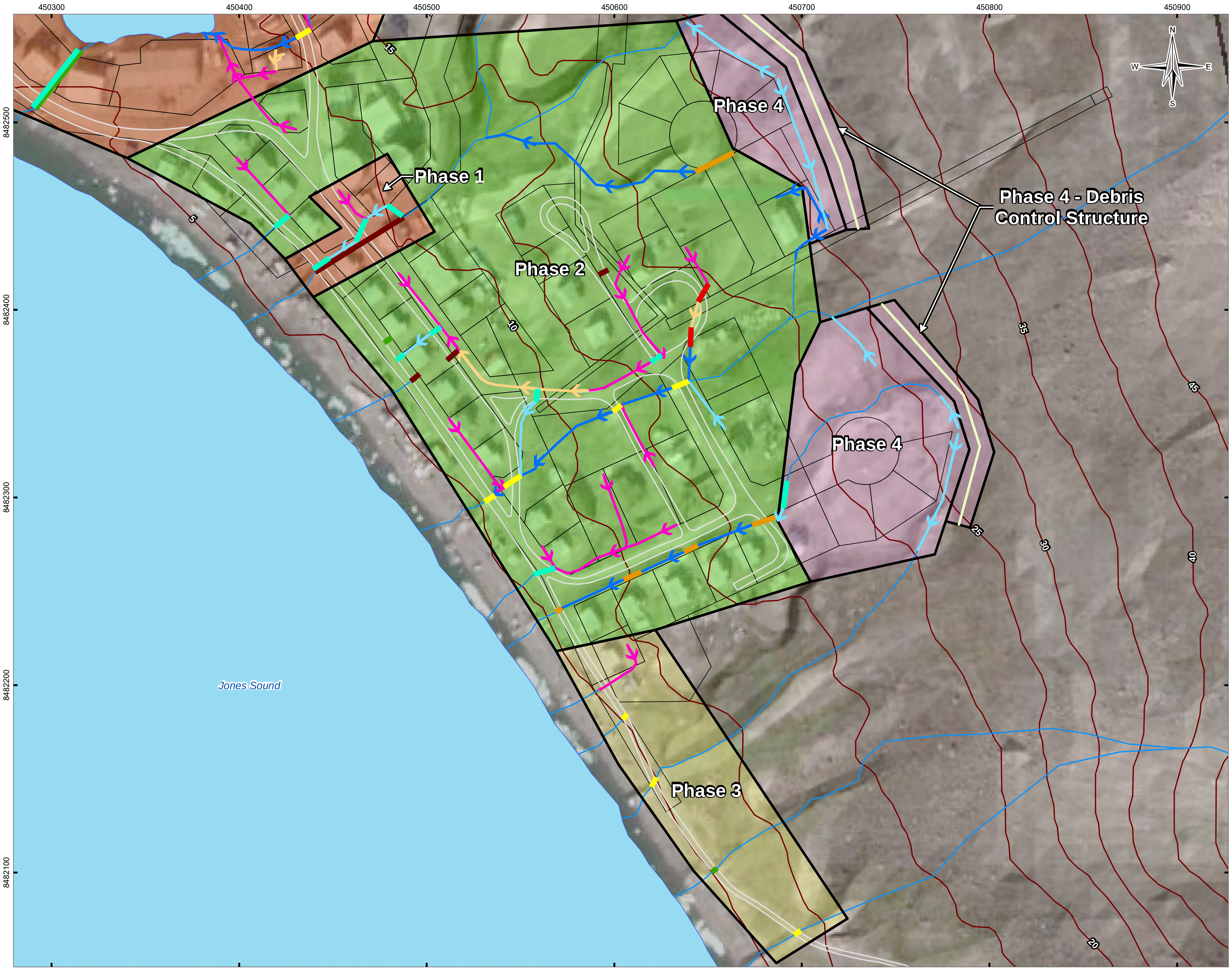
APPENDIX L

PROPOSED PHASING PLAN



LEGEND

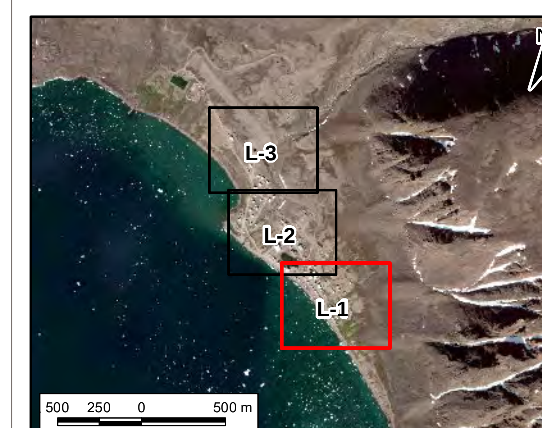
Culverts
- Functioning as Intended
- Repair
- Upsize
- Abandon
- Replace
- New

C## Culvert Number

Open Channels
- Existing Ditch
- New Ditch
- Existing Swale
- New Swale
- Debris Control Structure
- Watercourse

Project Phasing
- Phase 1 - High Priority
- Phase 2 - Mid Priority
- Phase 3 - Low Priority
- Phase 4 - Community Expansion

Base Data
- Current Parcel
- Gravel Road
- Topographic Contour (5 m)
- Waterbody



NOTES
Base data source:
Imagery from Google Earth (2020)
Igloolik base data from Government of Nunavut

STATUS
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MASTER DRAINAGE PLAN
GRISE FIORD, NU

Project Phasing

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:2,000
40 20 0 40
Metres

FILE NO.
WTRI03028-01_ProjectPhasing.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	DS	SL	ER	0

DATE
December 10, 2021

PROJECT NO.
ENG.WTRI03028-01

Appendix L-1

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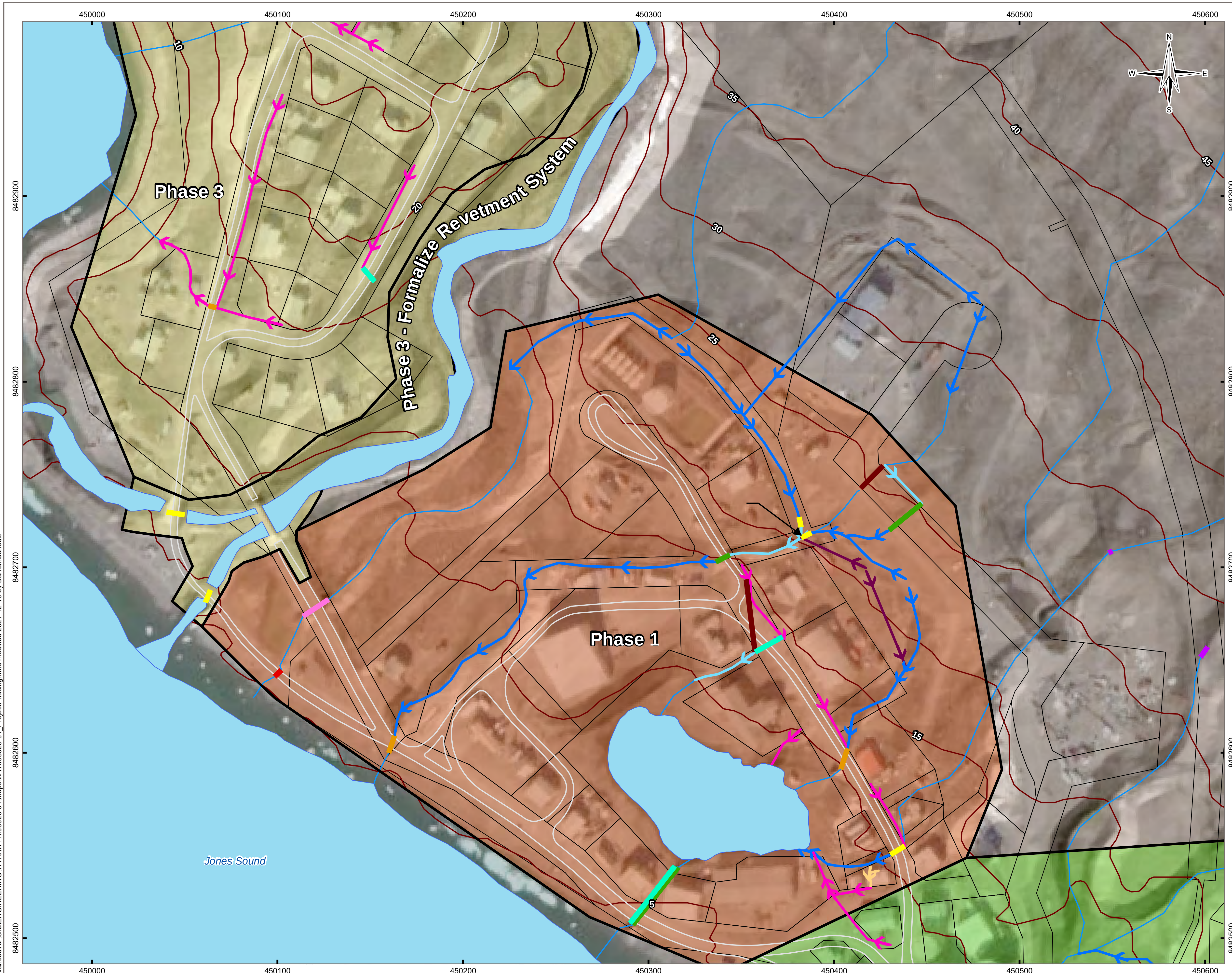


LEGEND

Culverts

- Functioning as Intended
- Clean Out
- Repair
- Upsize
- Abandon
- Replace
- New
- Not Assessed

C## Culvert Number

Open Channels

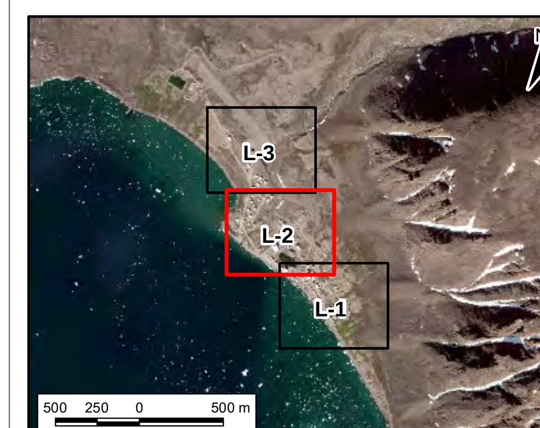
- Existing Ditch
- New Ditch
- Existing Swale
- New Swale
- Underdrain
- Watercourse

Project Phasing

- Phase 1 - High Priority
- Phase 2 - Mid Priority
- Phase 3 - Low Priority

Base Data

- Current Parcel
- Gravel Road
- Topographic Contour (5 m)
- Waterbody



NOTES
Base data source:
Imagery from Google Earth (2020)
Igloolik base data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN
GRISE FIORD, NU

Project Phasing

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:2,000
40 20 0 40
Metres

TETRA TECH

FILE NO.
WTRI03028-01_ProjectPhasing.mxd

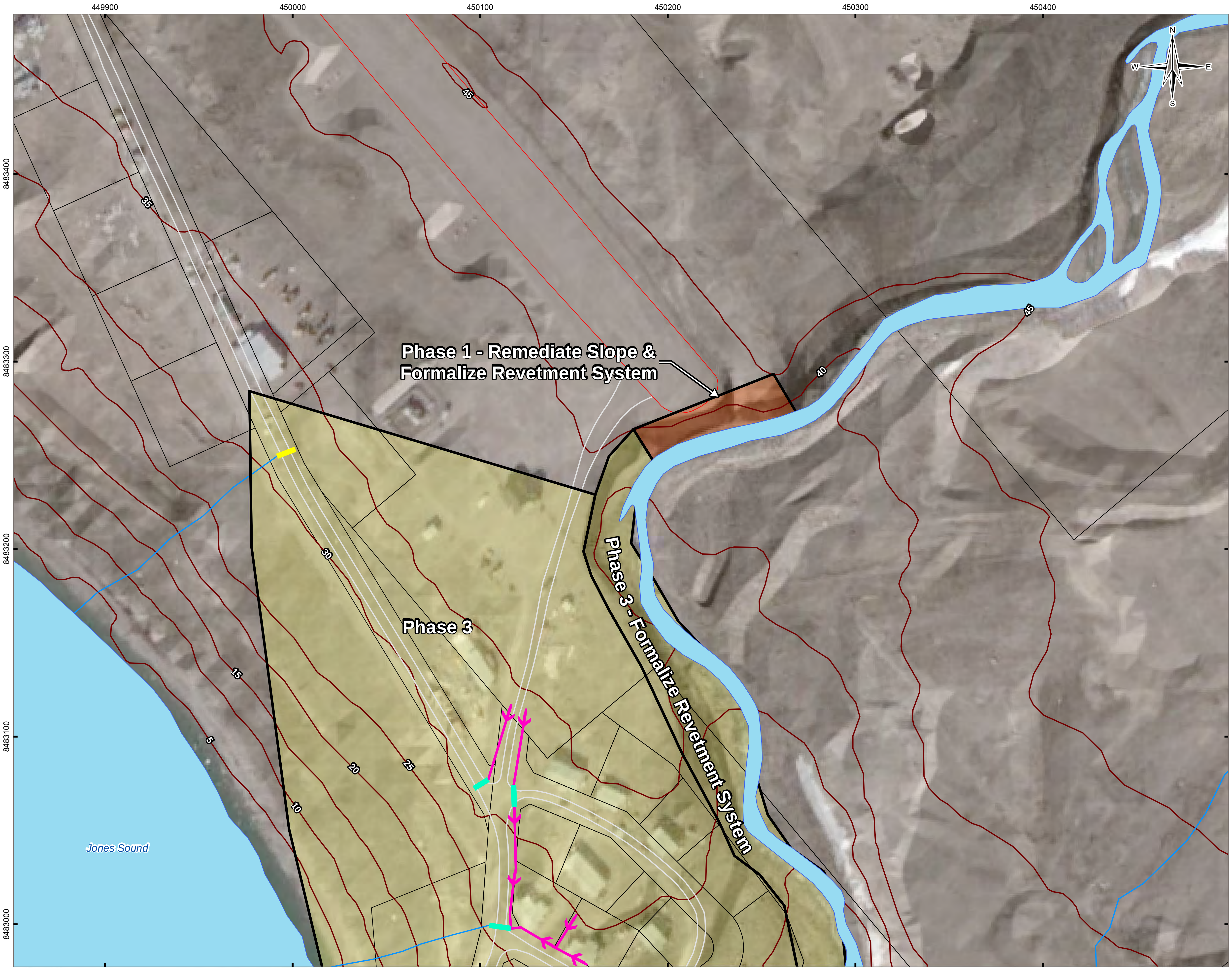
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	DS	SL	ER	0

DATE
December 10, 2021

PROJECT NO.
ENG.WTRI03028-01

Appendix L-2

Q:\Vancouver\GIS\ENGINEERING\WTRI\WTRI03028-01\Maps\WTRI03028-01_ProjectPhasing.mxd modified 2021-12-10 by Darren.Schouls



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LEGEND

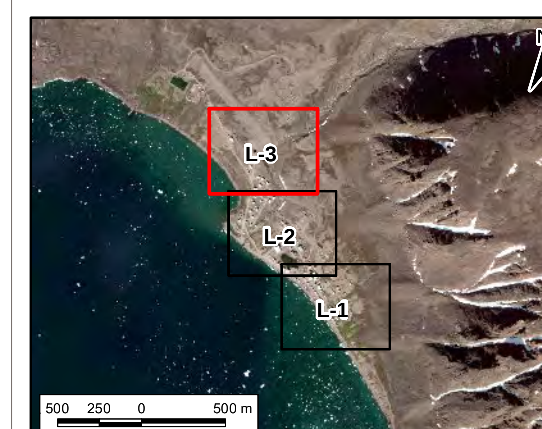
C## Culvert Number

Culverts
- Upsize
- New

Open Channels
- New Swale
- Watercourse

Project Phasing
- Phase 1 - High Priority
- Phase 3 - Low Priority

Base Data
- Current Parcel
- Runway
- Gravel Road
- Topographic Contour (5 m)
- Waterbody



NOTES
Base data source:
Imagery from Google Earth (2020)
Igloolik base data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN
GRISE FIORD, NU

Project Phasing

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:2,000
40 20 0 40
Metres

FILE NO.
WTRI03028-01_ProjectPhasing.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	DS	SL	ER	0

DATE	PROJECT NO.
December 10, 2021	ENG.WTRI03028-01

Appendix L-3

APPENDIX M

SNOW REMOVAL MANAGEMENT PLAN

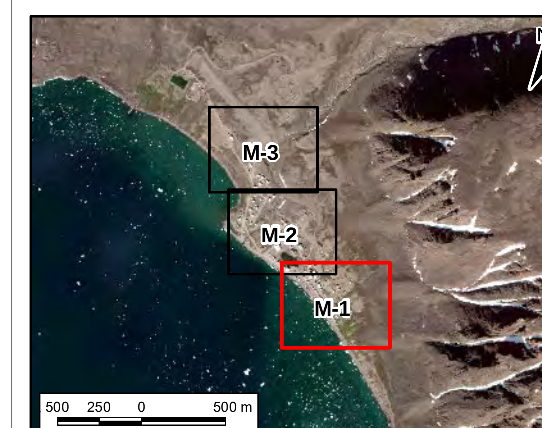
LEGEND

Snow Deposition

- Storage Zone
- Push Out Zone
- No Deposition Zone
- Watercourse

Base Data

- Current Parcel
- Gravel Road
- Topographic Contour (5 m)
- Waterbody



NOTES
Base data source:
Imagery from Google Earth (2020)
Igloolik base data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN GRISE FIORD, NU

Snow Removal Management Plan

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:2,000
40 20 0 40
Metres

TETRA TECH

FILE NO.
WTRI03028-01_SnowDeposition.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	DS	SL	ER	0

DATE
December 8, 2021

PROJECT NO.
ENG.WTRI03028-01

Appendix M-1

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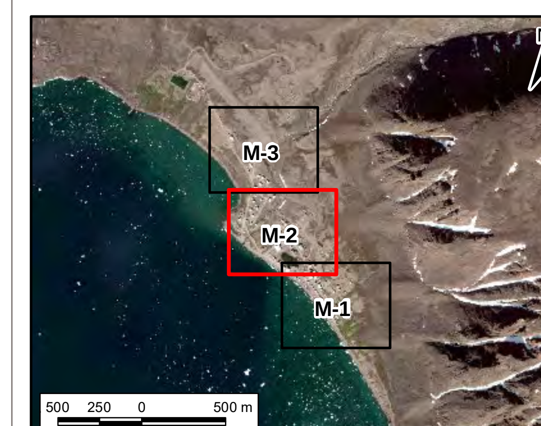
LEGEND

Snow Deposition
- Storage Zone
- Push Out Zone
- No Deposition Zone
- Watercourse

Base Data
- Current Parcel
- Gravel Road
- Topographic Contour (5 m)
- Waterbody



NOTES
Base data source:
Imagery from Google Earth (2020)
Igloolik base data from Government of Nunavut

STATUS
ISSUED FOR REVIEW

MASTER DRAINAGE PLAN
GRISE FIORD, NU

Snow Removal Management Plan

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:2,000
40 20 0 40
Metres

TETRA TECH

FILE NO.
WTRI03028-01_SnowDeposition.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	DS	SL	ER	0

DATE	PROJECT NO.
December 8, 2021	ENG.WTRI03028-01

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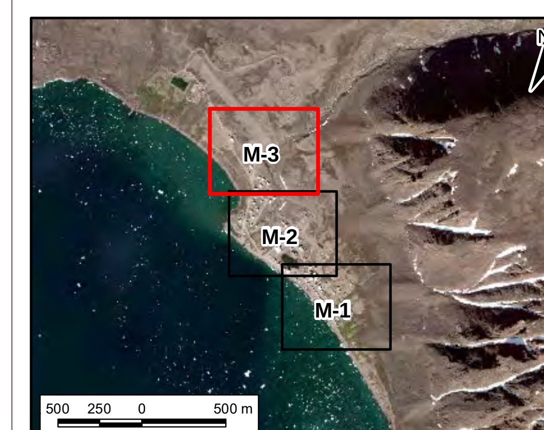
LEGEND

Snow Deposition

- Storage Zone
- Watercourse

Base Data

- Current Parcel
- Runway
- Gravel Road
- Topographic Contour (5 m)
- Waterbody



NOTES
Base data source:
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STATUS
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MASTER DRAINAGE PLAN
GRISE FIORD, NU

Snow Removal Management Plan

PROJECTION	DATUM	CLIENT
UTM Zone 17	NAD83	Nunavut

Scale: 1:2,000

40 20 0 40
Metres

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TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	DS	SL	ER	0

DATE	PROJECT NO.
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