Hamlet of Kugluktuk Master Drainage Plan



PRESENTED TO

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

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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

This report and its contents are intended for the sole use of Government of Nunavut and their agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Government of Nunavut, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on the Use of this Document attached in the Appendix or Contractual Terms and Conditions executed by both parties.

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) was retained by the Department of Community and Government Services (CGS), Government of Nunavut to develop a Drainage Master Plan for the Hamlet of Kugluktuk (Kugluktuk). CGS and Kugluktuk require a drainage study be conducted in Kugluktuk, for both the existing town site and planned future subdivisions identified in the Community Plan. This project follows a recommendation made in the Kugluktuk Climate Change Adaptation Plan (Johnson, K. & E. Arnold 2010).

The Terms of Reference (ToR) state that "Kugluktuk is currently in the latter stages of updating its Community Plan (By-law No. 290) and Zoning By-laws (By-law No. 291). The 2016 Census population of 1491 people is projected to grow to approximately 2000 people by 2036. When combined with pre-existing demand for housing, the population projection was used to estimate that 244 new housing units will be required by 2036. Future housing will require stable and well-drained soils upon which to be located. In order to ensure that the Hamlet of Kugluktuk has sufficient and suitable development land to accommodate future population growth forecast in the Community Plan, it is necessary for qualified personnel to conduct a drainage study for planned future subdivisions. It is also useful to review and evaluate drainage for the existing townsite in Kugluktuk, for the purpose of improving existing drainage works because there are known to be issues with seasonal drainage throughout town."

This report presents the results of the analyses and site inspections conducted by Tetra Tech, and presents a summary of recommendations to improve the existing drainage system as well as proposed drainage infrastructure for the proposed development areas. The development of this document followed guidance from the Community drainage system planning, design, and maintenance in northern communities (CSA Group, 2015).

Tetra Tech adopted a systems analysis approach to develop the Master Drainage Plan for Kugluktuk. This approach consisted of the following steps:

- Review of background information
- Site visit
- Inventory of existing drainage issues
- Development of a stormwater model to assess the drainage system for existing and proposed development conditions
- Recommendations

2.0 REVIEW OF BACKGROUND INFORMATION

The purpose of this task was to collect, compile and process all information related to the drainage system of the Hamlet of Kugluktuk, made available by officials from the Government of Nunavut and the Hamlet, and also from publicly available reports and data.

Beckstead, G. & L.B. Smith (1985) provided an overview of geotechnical and drainage constraints related to the urban development in Kugluktuk.

Base map data for communities were made available by CGS. This includes cadastral information, water bodies, contours, building, and transportation information, and satellite Imagery, including:

- 2017 Satellite Imagery (.tif)

- 2017 Digital Elevation Models (Bare earth and surface models available in .tif and .asc formats)
- 2017 Building footprint, infrastructure, and transportation vector datasets (AutoCAD .dwg and ESRI File Geodatabase or Shapefile formats)
- 2017 Hydrology (water bodies and watercourses) vector datasets (AutoCAD .dwg and ESRI File Geodatabase and Shapefile formats)
- 2017 Contours vector datasets (AutoCAD .dwg and ESRI File Geodatabase and Shapefile formats)
- 2017 Cadastral vector datasets (AutoCAD .dwg and ESRI File Geodatabase and Shapefile formats)

2.1 Climate

The climate in Kugluktuk is typical of the Arctic region, characterized by low precipitation and winter temperatures predominating for eight months of the year (Beckstead, G. & L.B. Smith 1985). Figure 2-1 shows climate normal for the period 1981 to 2010. The monthly mean, daily maximum and daily minimum temperatures in February are -27.7°C, -23.4°C, and -32°C respectively, as shown in Table 2-1. The same temperatures in July are 10.9°C, 15.6°C, and 6.1°C, respectively. The annual mean daily temperature is -10.3C. Extreme maximum and minimum temperatures are 34.9C and -47.3C.

Total annual precipitation is 247.2 mm, with an annual rainfall volume of 144.5 mm and a total snow depth of 182.1 cm. The maximum daily rainfall on record is 118.3 mm, which occurred on July 21, 2007. As a point of comparison, Beckstead, G. & L.B. Smith (1985) reported a maximum daily precipitation of 57.2 mm (See Table 2-2). Smith, I.R. (2013) included a photo (Figure 2-2 below) of the significant erosion that occurred in Kaivoina Street during that event. The actual location of the erosion is shown in Figure 3-4 where is depicted as “2007 Avulsion”.

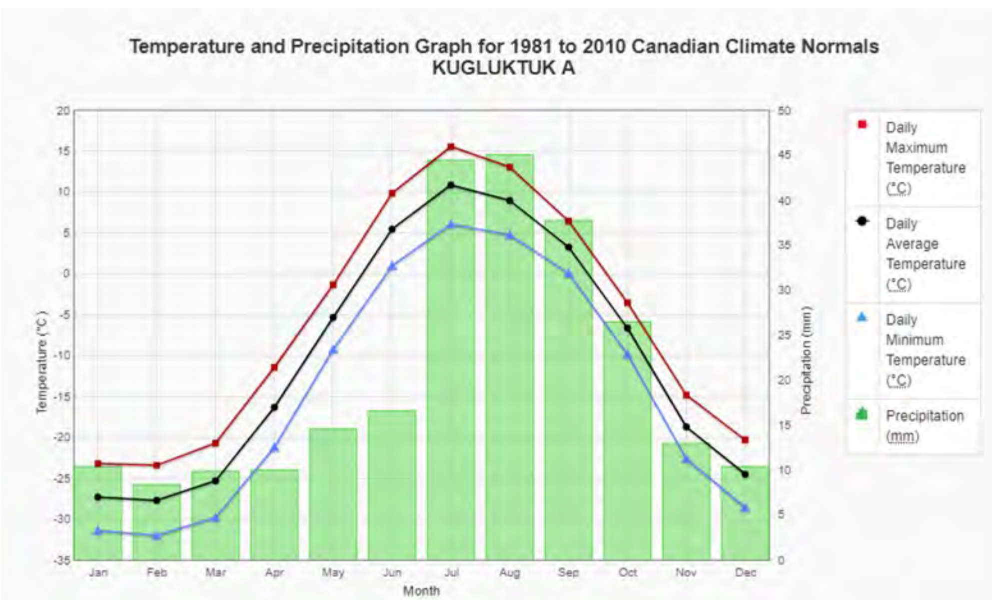


Figure 2-1: Temperature and Precipitation (1981-2010). Kugluktuk A. (source: Environment Canada)

Figure 2-2: Erosion in Kugluktuk During July 21, 2007 Storm Event. (source: Smith, I.R. 2013)

Table 2-1: Climate Normals 1981-2010 Station Data. Station Name: Kugluktuk A. Source: Environment Canada

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature													
Daily Average (°C)	-27.3	-27.7	-25.3	-16.3	-5.3	5.5	10.9	9	3.3	-6.6	-18.7	-24.5	-10.3
Standard Deviation	3.6	3.7	3.1	3.4	3	1.7	1.8	1.7	1.7	1.8	4	3.4	1.4
Daily Maximum (°C)	-23.2	-23.4	-20.7	-11.4	-1.3	9.9	15.6	13.1	6.5	-3.5	-14.8	-20.3	-6.1
Daily Minimum (°C)	-31.4	-32	-29.8	-21.2	-9.2	1	6.1	4.8	0.1	-9.8	-22.6	-28.6	-14.4
Extreme Maximum (°C)	0.8	-1.2	-0.1	9.8	19.8	31.1	34.9	29.2	22.6	13.8	2.8	-0.5	
Date (yyyy/dd)	1981/16	1980/07	1999/22	2010/22	1994/24	1996/25	1989/15	2000/01	1994/01	2003/01	1983/03	2006/10	
Extreme Minimum (°C)	-47.3	-47.2	-47	-40.2	-30.2	-12.1	-0.8	-4.4	-18.9	-35.4	-41	-44.5	
Date (yyyy/dd)	2004/15	1998/20	1979/05	2008/02	1983/03	2000/01	2002/30	1995/29	2000/26	1996/29	1985/24	1977/12	
Precipitation													
Rainfall (mm)	0.1	0	0	0.1	4.3	14.6	44.4	44.9	31.4	4.7	0	0	144.5
Snowfall (cm)	19.6	16.3	19.4	18.2	16.2	2.1	0	0.2	7.7	35	25.5	21.9	182.1
Precipitation (mm)	10.4	8.4	9.9	10	14.6	16.6	44.5	45.1	37.8	26.5	13	10.4	247.2
Average Snow Depth (cm)	31	35	39	40	24	2	0	0	0	8	19	26	19
Median Snow Depth (cm)	31	35	39	41	23	1	0	0	0	8	18	26	18
Snow Depth at Month-end (cm)	32	37	41	36	11	0	0	0	2	15	23	30	19
Extreme Daily Rainfall (mm)	2	0	0	7.4	20.6	27.4	**118.3**	53.7	28.8	19.3	0.2	0.4	
Date (yyyy/dd)	2003/05	1978/06	1978/01	1980/27	1992/27	1987/13	2007/21	1982/12	1983/07	1980/08	2000/02	2005/30	
Extreme Daily Snowfall (cm)	**26.2**	24.6	10.6	19.6	21.2	13	0.4	5	13.5	23	12.4	26	
Date (yyyy/dd)	1988/01	1981/21	2008/08	2008/10	2004/09	1991/05	1985/07	1986/23	1981/22	1981/29	1981/06	1994/25	
Extreme Daily Precipitation (mm)	25.8	9.1	8	16	21.8	27.4	**118.3**	53.7	28.8	23	12.4	14.8	
Date (yyyy/dd)	1988/01	1981/21	2010/07	1980/30	1978/25	1987/13	2007/21	1982/12	1983/07	1981/29	1981/06	1994/25	
Extreme Snow Depth (cm)	80	92	104	107	**128**	64	3	0	23	43	49	73	
Date (yyyy/dd)	1993/30	1993/22	1991/31	1991/03	1993/08	1993/01	1986/01	1978/01	1981/24	1995/29	1992/30	1994/26	

Table 2-2: Climate Normals 1981-2010 Station Data. Station Name: Kugluktuk A. Source: Environment Canada

TABLE 4.1

CLIMATIC DATA SUMMARY FOR COPPERMINE (N.W.T.)
(A.E.S. STA. 2200900)
LAT. 67° 50'N.; LONG. 115° 07' W.

MEASUREMENTS	UNITS	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN RAINFALL	mm	102.7	0.0	0.0	0.0	T	3.5	14.3	25.3	38.2	18.6	2.8	T	0.0
MEAN SNOWFALL	cm	100.7	9.2	6.4	10.4	10.2	8.1	2.6	0.5	0.4	5.3	21.0	15.1	11.5
TOTAL PRECIPITATION	mm	202.3	9.3	6.2	9.8	11.0	12.0	17.0	25.8	38.6	24.0	23.2	14.3	11.1
STANDARD DEVIATION OF TOTAL PRECIPITATION	mm	53.5	6.2	5.2	7.4	12.4	9.0	14.2	15.7	25.6	13.3	13.3	8.1	6.3
NUMBER OF DAYS WITH MEASURABLE RAINFALL	-	37.0	0	0	0	0	2	6	9	10	8	2	0	0
NUMBER OF DAYS WITH MEASURABLE SNOWFALL	-	75	9	6	8	7	6	2	*	*	4	12	12	9
NUMBER OF DAYS WITH MEASUREABLE PRECIPITATION	-	109	9	7	8	7	7	7	9	10	11	13	12	9
GREATEST RAINFALL IN 24 HOURS	mm	63.5	0.0	0.0	T	3.8	18.8	63.5	34.3	57.2	21.1	14.0	0.5	T
Years of Record			45	46	45	46	46	46	46	46	46	47	47	45
GREATEST SNOWFALL IN 24 HOURS	cm	25.9	22.9	20.3	14.5	19.8	15.5	25.9	14.0	4.6	13.0	20.6	16.8	25.7
Years of Record			45	46	45	46	46	46	46	46	46	47	47	45
GREATEST PRECIPITATION IN 24 HOURS	mm	63.5	22.9	20.3	14.5	21.3	18.8	63.5	34.3	57.2	22.9	20.6	16.8	25.7
Years of Record			45	46	45	46	46	46	46	46	46	47	47	45
MEAN DAILY MAXIMUM TEMPERATURE	°C	- 7.8	-26.4	-27.3	-22.9	-12.7	-1.5	7.3	13.8	12.3	5.2	-3.5	-15.8	-22.0
MEAN DAILY MINIMUM TEMPERATURE	°C	-15.3	-33.8	-34.9	-31.3	-22.3	-9.2	0.2	5.6	5.0	-0.3	-9.6	-23.4	-29.8
MEAN DAILY TEMPERATURE	°C	-11.6	-30.1	-31.1	-27.1	-17.5	-5.3	3.8	9.7	8.7	2.5	-6.6	-19.7	-25.9
STANDARD DEVIATION OF MEAN DAILY TEMPERATURE	°C	1.0	2.3	2.8	3.1	3.3	2.5	1.9	1.4	1.7	1.7	2.7	2.0	3.6
EXTREME MAXIMUM TEMPERATURE	°C	32.2	-2.8	1.1	-1.7	7.8	23.3	27.8	32.2	29.4	26.1	13.9	4.4	4.4
Years of Record			45	46	45	46	45	45	45	45	45	4.7	46	46
EXTREME MINIMUM TEMPERATURE	°C	-50.0	-47.8	-50.0	-48.9	-43.9	-31.1	-15.0	-0.6	-3.3	-20.0	-33.3	-41.1	-45.0
Years of Record			46	46	46	46	46	46	46	45	46	47	46	46

LEGEND:
T = TRACE
* = LESS THAN 0.5 DAYS

SOURCE: ENVIRONMENT CANADA, CLIMATIC NORMALS (1981 a,b)

2.1.1 Climate change

Smith, I.R. (2013) presented a summary of perceived sensitivities to climate change in Kugluktuk, including the following:

1. Landscape hazards, in the context of climate change appear to be of low risk;
2. Warming could have a potential influence on thaw subsidence in the alluvial terrace sediments;
3. Urban development in areas of beach ridges need to take into account the potential presence of buried ice, which is deduced to be present to observations of thermokarst[1] terrain along the beach front regions in the port facility;
4. Stream diversions along the western edge of the airport runway need to take into account permafrost impacts. Armouring with larger rock is required to avoid hydraulic erosion, which may in turn lead to thermal erosion;
5. Climate warming could lead to melting of the upper sections of the ice wedges underlying most of the airport;
6. Some areas east of the airport terminal pad show evidence of thermokarst, suggesting that the ice wedge polygons may have significant ice contents below them. Any development considerations in this area would have to first assess subsurface ice content;
7. Reductions in sea ice and increased wave action may accelerate shore erosion, particularly in the eastern part of the town, where there is a fairly steep shore profile;
8. Sea level rise in Kugluktuk could be up to 50 cm over the 2010 – 2100 period, possibly leading to flooding of low-lying terrain;
9. Kugluktuk's fresh water source is Coppermine River. There are concerns that the salinity wedge may contaminate temporarily the Hamlet's water supply;
10. Insufficient urban drainage capacity has been highlighted as a significant issue, particularly in light of the erosion observed during the July 21, 2007 event (see Figure 2-2, Figure 3-4). There are concerns that uncontrolled runoff may lead to further erosion;
11. Surface ponding of water is another issue of concern. If ponding is allowed to occur near building pads, it can result in ice formation, which in turn can lead to differential heave of the building above it; and
12. Changes in snow amount and wind direction and strength may change snow drift patterns. Such changes need to be considered in building design and community planning.

[1] A land surface found in Arctic areas characterised by very irregular terrain of marshy hollows and small hummocks formed as ice-rich permafrost thaws.

2.2 Surficial Geology

Smith, I.R. (2013) presented a detailed representation of the surficial geology for Kugluktuk, as shown in Figure 2-3. Bedrock outcrops are prominent throughout the town. The majority of unconsolidated sediments within the town are related to submersion of the landscape during deglaciation, and its subsequent isostatic uplift. A prominent, flat delta terrace, upon which the airport runway was built, is situated ~30 m above sea level and is considered to have formed ~6000 years ago (Smith, I.R. 2013).

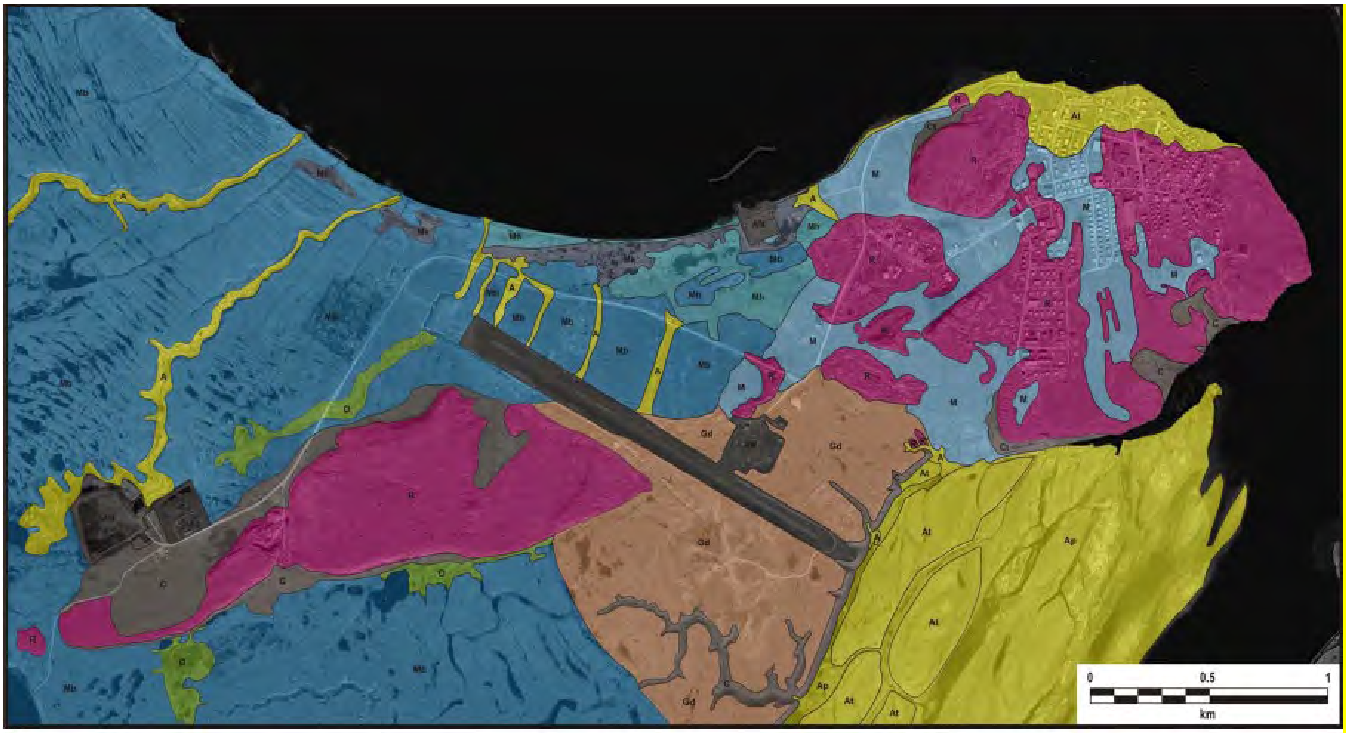
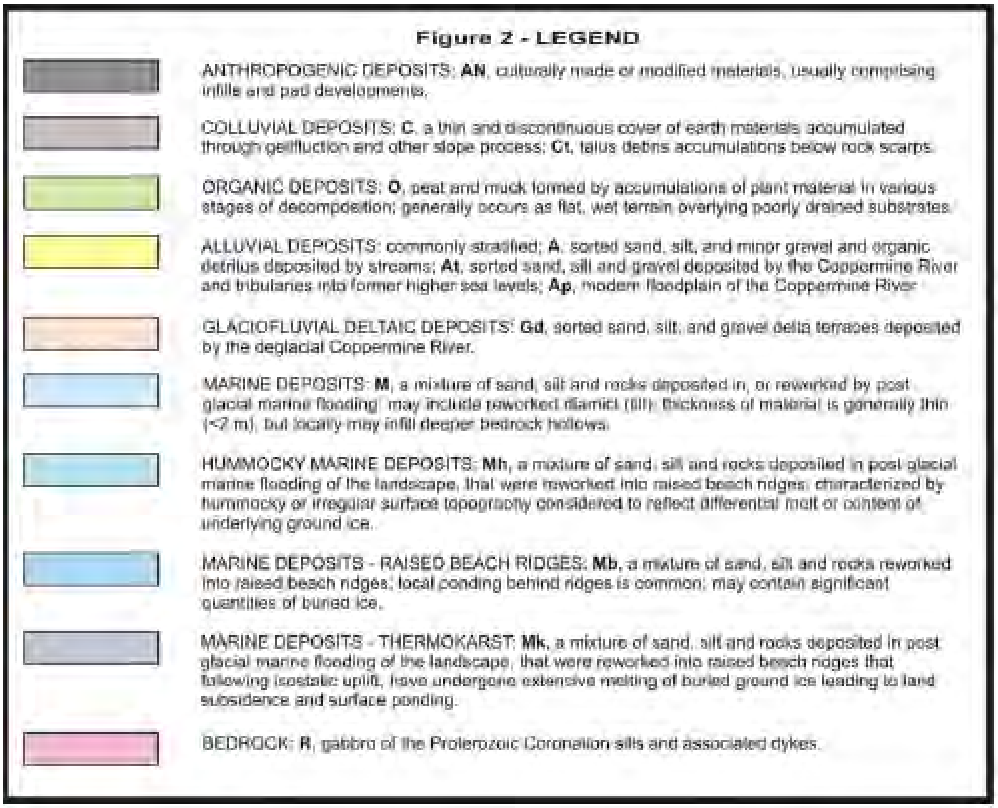


Figure 2-3: Surficial Geology in the Kugluktuk Area



2.3 Drainage

The drainage patterns of the Hamlet of Kugluktuk follow the natural relief, however the construction of fill pads for houses and road embankments have modified the natural drainage, likely leading to an increase in surface runoff volume and peak flows. The surface drainage system is conformed primarily by ditches, swales and culverts. Figure 2-4 shows the drainage basins for Kugluktuk.

Q:\Vancouver\Transportation\TRN_WTRM\TRN.WTRM03098 - Kugluktuk\GIS\Maps\Figures\WTRM03098-01_Figure2-4_Drainage Basins.mxd modified 12/20/2018 by Mauricio.Herrera

LEGEND

- Flow_Direction
- Proposed Development
- Existing & Proposed Development
- Drainage Basins
- Lakes
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Basins Hamlet of Kugluktuk

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:10,851

Metres

TETRA TECH

FILE NO.
WTRM03098-01_Figure2-4_Drainage Basins.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0

DATE	PROJECT NO.
December 20, 2018	TRN.WTRM03098-01

Figure 2-4

3.0 INVENTORY OF EXISTING DRAINAGE SYSTEM AND ISSUES

A critical task in the development of a Drainage Master Plan is the inventory of all critical infrastructure. This process included the location and description of the physical assets that conform the drainage system, including key geometric characteristics and conditions. 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 of the drainage system.

3.1 Site Visit

A site visit was conducted from July 24 to 26, 2018 by two Tetra Tech staff, Mark Aylward-Nally and Mauricio Herrera. The purpose of the site visit was to:

- Meet with representatives from the Government of Nunavut, and from Kugluktuk;
- Conduct a walkthrough inspection of the drainage system of the Hamlet; and
- Conduct informal interviews with local residents regarding known drainage issues.

3.1.1 Meeting with Government Representatives

Upon arrival to Kugluktuk on July 24, 2018, a meeting with government representatives was held at the Department of Community Government and Services Planning, and Land Division. The meeting was attended by:

- Robert Chapple, Director, Planning and Lands, Government of Nunavut;
- William Patch, Manager of Community Planning, Government of Nunavut;
- Representative from the Hamlet;
- Mark Aylward-Nally, Hydrotechnical Engineer, Tetra Tech; and
- Mauricio Herrera, Senior Hydrotechnical Engineer, Tetra Tech.

During the meeting, government officials provided valuable information on areas of concern regarding the drainage system as summarized in Table 3-1. This information was documented and mapped.

3.1.2 Walkthrough Inspection

A walkthrough of Kugluktuk was conducted from July 24 to July 26, 2018. The objective of the site visit was to:

- Develop an understanding of the drainage patterns through the town;
- Identify main drainage routes and key infrastructure assets;
- Get GPS points of key infrastructure locations, for instance upstream and downstream culvert ends;
- Measure culvert dimensions and document culvert conditions;
- Identify areas of ponding;

- Record a photo inventory of key elements of the drainage infrastructure;
- Identify drainage outlet locations; and
- Conduct Informal Interviews with Hamlet residents.

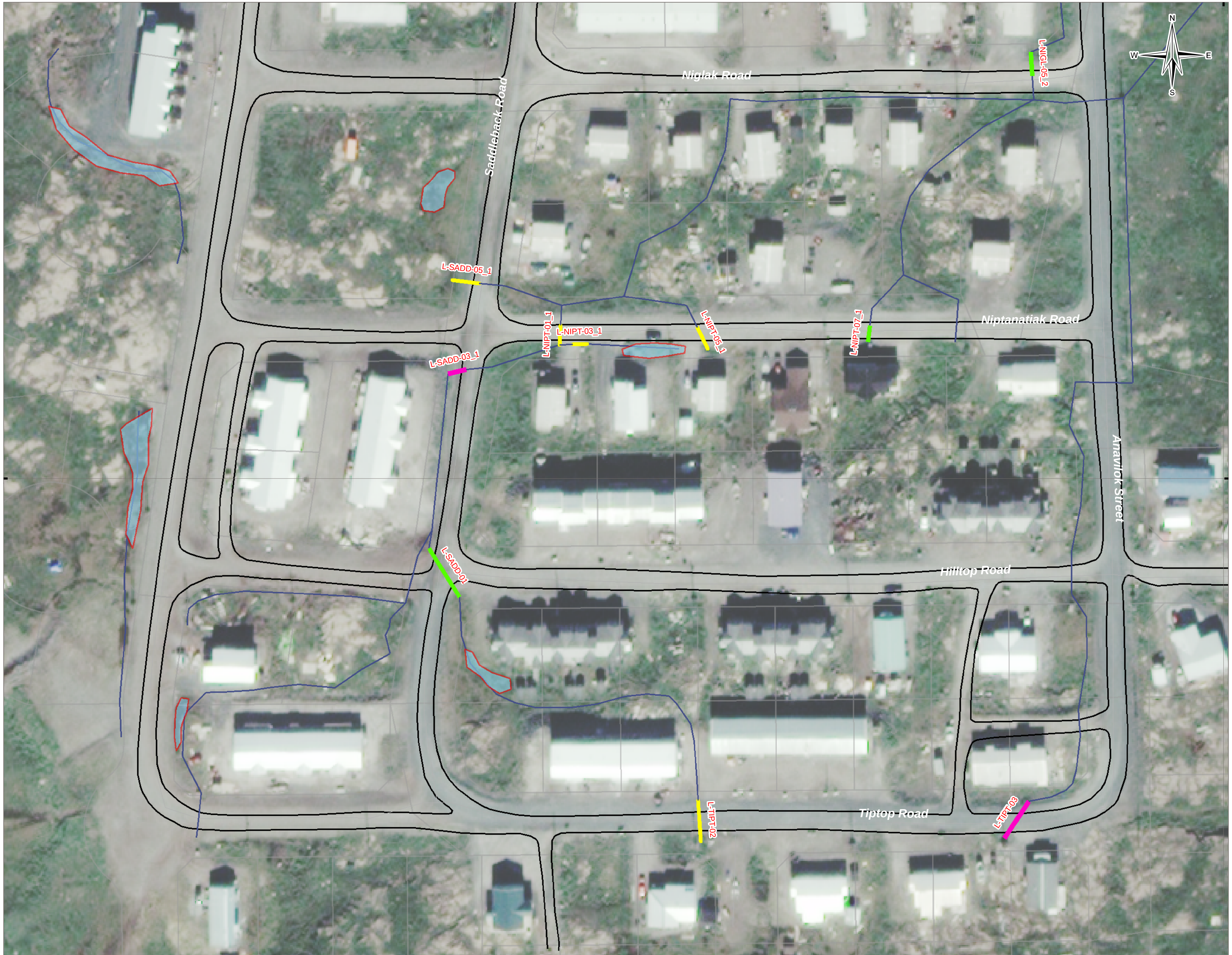
The Photos section includes several photos taken during the site visit.

Table 3-1: Kugluktuk Drainage Issues

Issue	Cause
Spring flooding	Culvert blocked by ice/snow
Damaged culvert inlet/outlet	Damage caused by excavator cleaning snow and/or ice during spring
Road washout	Extreme rain event in July 2007, lack of capacity of the drainage system
Ponding	Blocked culverts, poor grading, vegetation overgrowth, lack of an outlet.
Erosion	Velocity threshold for erosion is exceeded

3.1.3 Development of the Georeferenced Map

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 line shapefile. Each line represents either an open channel (ditch or swale) or a culvert. A naming convention was developed and every asset was named in the shapefile. Connectivity of the drainage system was developed for the most part using data from the site visit, and supplemented with mapping data provided by the government. A polygon shapefile was created to mark areas with drainage issues identified during the site visit. Those were ponding areas, damaged culverts, insufficient ditches and erosion issues. Figures 3-1 to 3-8 show the documented drainage issues. Figure 3-9 shows the full drainage network including all mapped assets.



LEGEND

Drainage Conveyance (Ditch or Culvert)

ISSUES

- Blocked Completely
- Blocked Inlet
- Overland Flow
- Partially Blocked
- Unfinished Ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Issues
Site Visit July 24-26, 2018.
Tiptop Road to Niglak Road

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:1,215
25 12.5 0 25
Metres

TETRA TECH

FILE NO.
WTRM03098-01_Figure3-1_Drainage Issues.mxd

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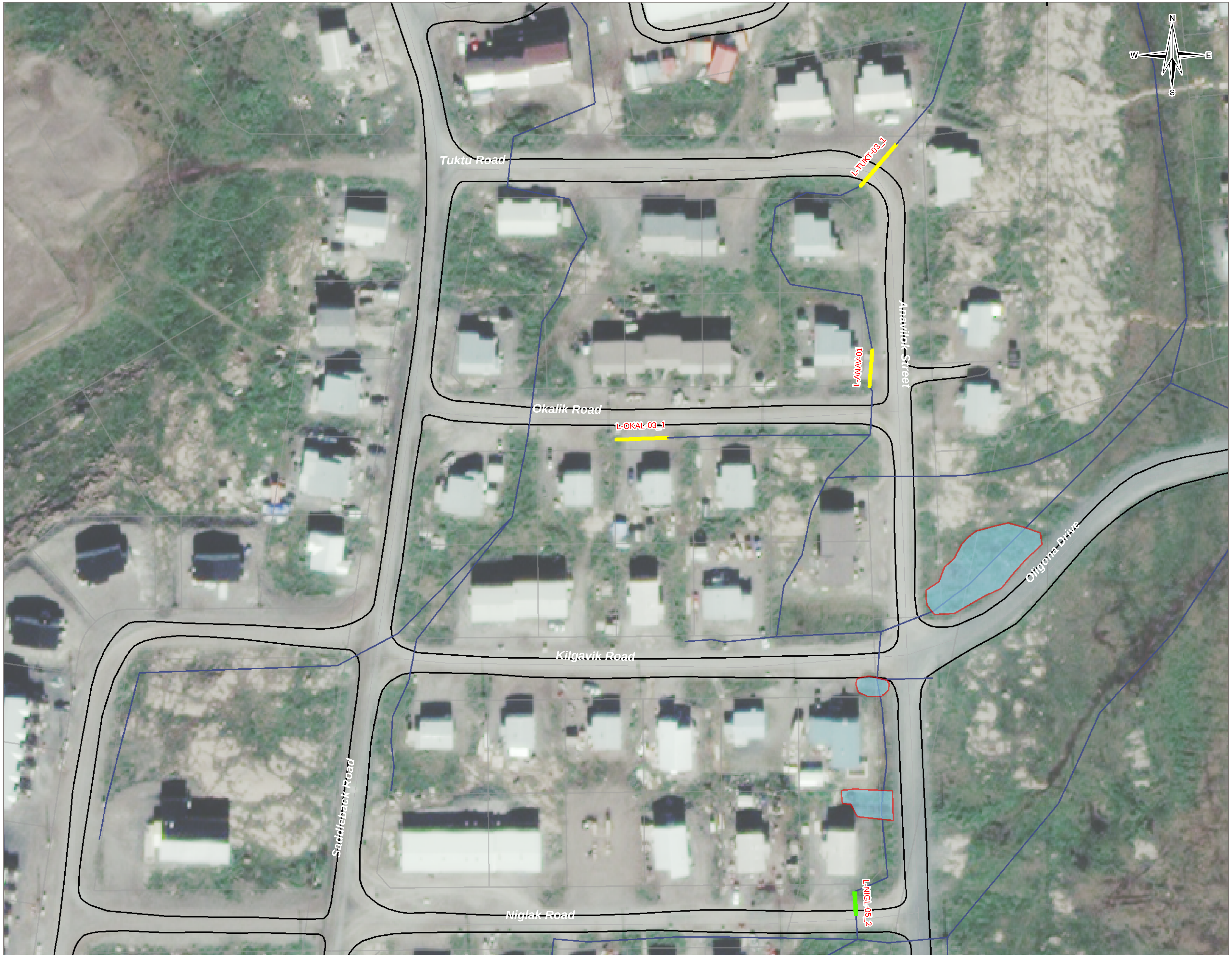
DATE	PROJECT NO.
March 5, 2019	TRN.WTRM03098-01

Figure 3-1



LEGEND

- Drainage Conveyance (Ditch or Culvert)

ISSUES

- Blocked Completely
- Blocked Inlet
- Overland Flow
- Partially Blocked
- Unfinished Ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
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HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Issues Site Visit July 24-26, 2018. Tuktu Road to Niglak Road

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:1,215
25 12.5 0 25
Metres

TETRA TECH

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WTRM03098-01_Figure3-2_Drainage Issues.mxd				
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DATE	PROJECT NO.			
March 5, 2019	TRN.WTRM03098-01			

Figure 3-2

LEGEND

- Drainage Conveyance (Ditch or Culvert)

ISSUES

- Blocked Completely
- Blocked Inlet
- Overland Flow
- Partially Blocked
- Unfinished Ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Issues Site Visit July 24-26, 2018. Umingmak Street to Tuktu Road

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:1,215
25 12.5 0 25
Metres

FILE NO.
WTRM03098-01_Figure3-3_Drainage Issues.mxd

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TETRA TECH

Figure 3-3

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LEGEND

- Drainage Conveyance (Ditch or Culvert)

ISSUES

- Blocked Completely
- Blocked Inlet
- Overland Flow
- Partially Blocked
- Unfinished Ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Issues Site Visit July 24-26, 2018. Hikok Drive to Umingmak Street

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:1,215
25 12.5 0 25
Metres

FILE NO.
WTRM03098-01_Figure3-4_Drainage Issues.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0

DATE	PROJECT NO.
March 5, 2019	TRN.WTRM03098-01

Figure 3-4

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LEGEND

- Drainage Conveyance (Ditch or Culvert)

ISSUES

- Blocked Completely
- Blocked Inlet
- Overland Flow
- Partially Blocked
- Unfinished Ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Issues
Site Visit July 24-26, 2018.
Arctic Ocean shoreline to Hikok Drive

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:1,215
25 12.5 0 25
Metres

FILE NO.
WTRM03098-01_Figure3-5_Drainage Issues.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0

DATE	PROJECT NO.
March 5, 2019	TRN.WTRM03098-01

Figure 3-5

Q:\Vancouver\Transportation\TRN_WTRM\TRN.WTRM03098 - Kugluktuk\GIS\Maps\Figures\WTRM03098-01_Figure3-5_Drainage Issues.mxd modified 3/5/2019 by mauricio.herrera

LEGEND

- Drainage Conveyance (Ditch or Culvert)

ISSUES

- Blocked Completely
- Blocked Inlet
- Overland Flow
- Partially Blocked
- Unfinished Ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Issues Site Visit July 24-26, 2018. Arctic Ocean shoreline to Inuit Street

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:1,165
25 12.5 0 25
Metres

TETRA TECH

FILE NO.
WTRM03098-01_Figure3-6_Drainage Issues.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0

DATE	PROJECT NO.
March 5, 2019	TRN.WTRM03098-01

Figure 3-6

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LEGEND

Drainage Conveyance (Ditch or Culvert)

ISSUES

- Blocked Completely
- Blocked Inlet
- Overland Flow
- Partially Blocked
- Unfinished Ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Issues Site Visit July 24-26, 2018. Coronation Drive to Kugluktuk Drive

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:1,737
25 12.5 0 25
Metres

TETRA TECH

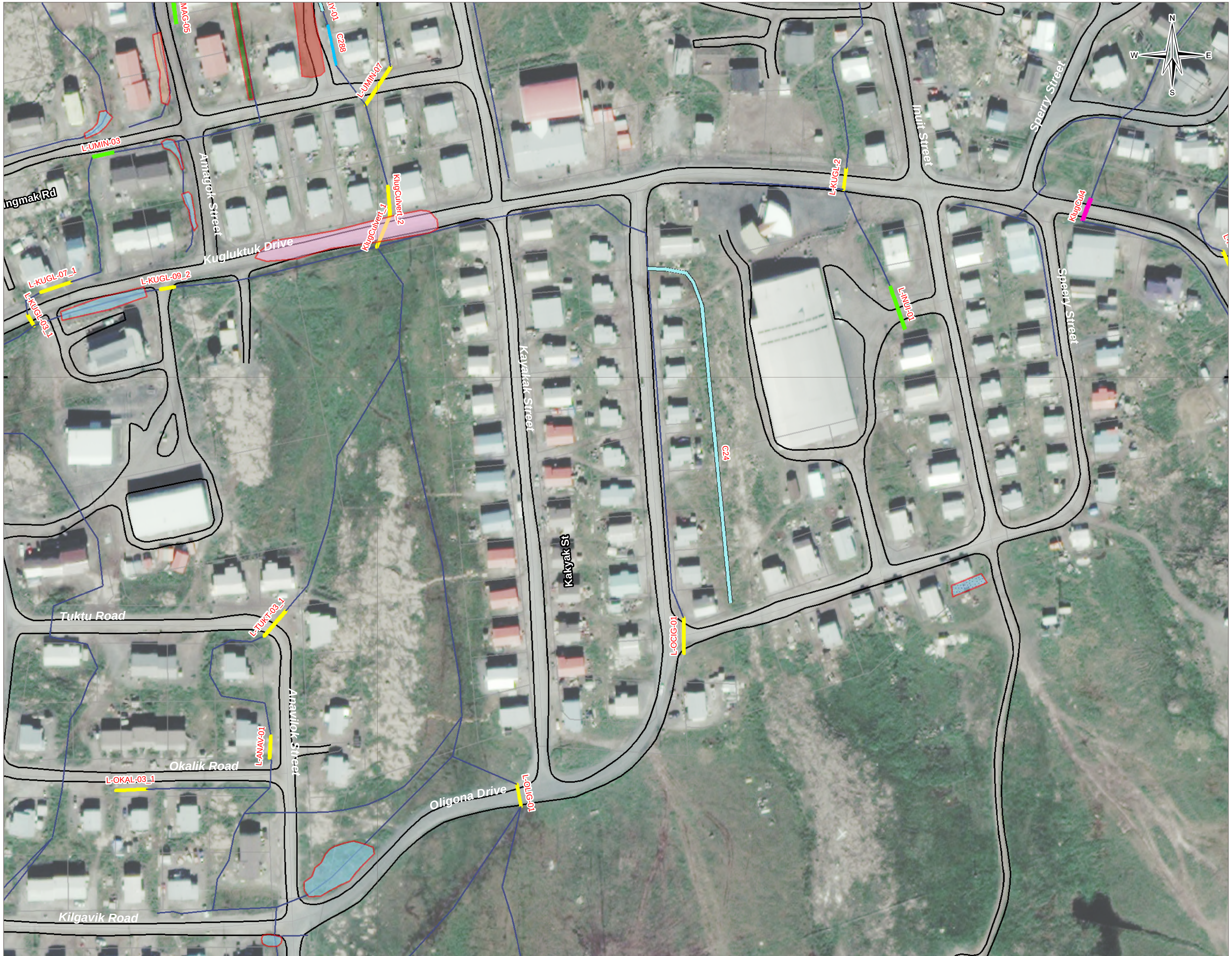
FILE NO.
WTRM03098-01_Figure3-7_Drainage Issues.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0

DATE	PROJECT NO.
March 5, 2019	TRN.WTRM03098-01

Figure 3-7

580000



580000

7524500

7524500

LEGEND

- Drainage Conveyance (Ditch or Culvert)

ISSUES

- Blocked Completely
- Blocked Inlet
- Overland Flow
- Partially Blocked
- Unfinished Ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Issues Site Visit July 24-26, 2018. Kugluktuk Drive to Oligona Drive

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:2,000
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
WTRM03098-01_Figure3-8_Drainage Issues.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0
DATE	PROJECT NO.			
March 5, 2019	TRN.WTRM03098-01			

Figure 3-8

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LEGEND

- Drainage Conveyance (Ditch or Culvert)

Type

- Culvert
- Culvert Infilled with Sediment
- Ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Infrastructure Hamlet of Kugluktuk

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:5,000
25 12.50 25
Metres

TETRA TECH

FILE NO.
WTRM03098-01_Figure3-9_Drainage Infrastructure.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0

DATE	PROJECT NO.
March 5, 2019	TRN.WTRM03098-01

Figure 3-9

4.0 ASSESSMENT OF EXISTING DRAINAGE SYSTEM

A systems analysis approach was adopted to assess the current conditions of the drainage system of the Hamlet of Kugluktuk. PCSWMM, a state-of-the-art stormwater 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 hydrological units used to calculate flows. Flows calculated from a subcatchment are assigned to a junction, and then move to the connecting links, to then conduct the hydraulic routing through the drainage network. With 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 Tables 1, 2 and 3 in the Tables Appendix.

4.1 Modeling Scenarios and Results

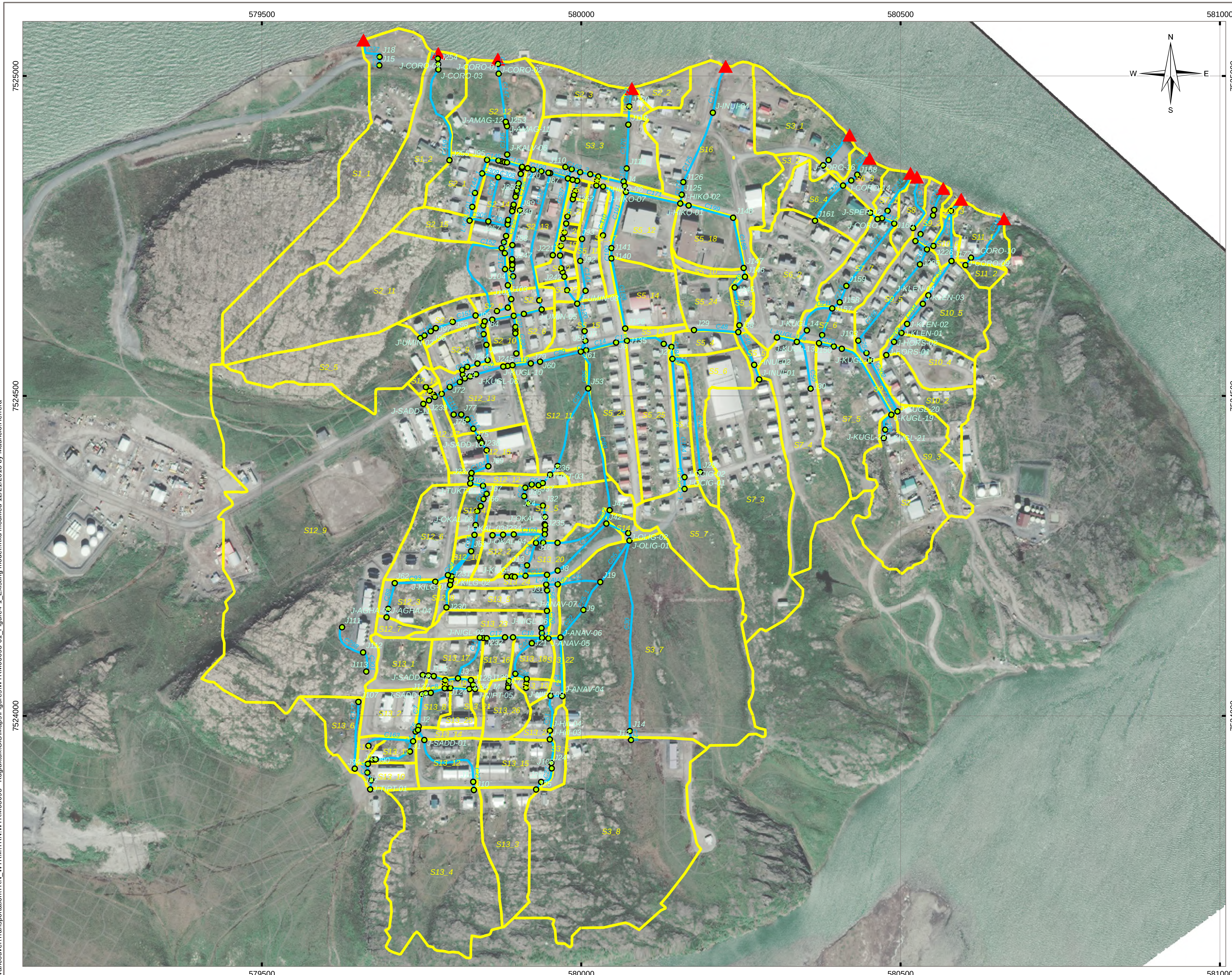
Based on the severity of the July, 2007 rainstorm event, and the damage it caused, a decision was made to test the drainage system with the model using summer storm events, rather than spring freshet scenarios. To this effect, five storms were selected to run the model, the 5-year 1-hr, 5-year 24-hr, 100-year 1hr, 100-year 24hr and the 2007 24hr event, as summarized in Table 4-1. 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."*

Taking the above into consideration, the system was first tested using the 5-year 1hr and 24-hr events. The purpose was to determine, in addition to known choke points (i.e. blocked culverts), where else the system would not be able to safely convey these two storm events with a 5-year return period. Subsequently, the model was run with the 100-year, 1hr and 24hr, as well as with the July 21, 2007 storm event. The 24-hr storm distributions used to create the hyetographs were developed, for the 1-hr events using the AES distribution for Northern Quebec, and for the 24-hr events from extreme northern precipitation events, using a pattern from historical hourly data from the Inuvik Station. Modeling results are presented in Figure 4-2. The figure shows areas where flooding would be expected for the 5-yr 1hr, 100-yr 24hr and for the 2007 event. From the modeling results, it was determined that system would flood under the 5-year events at various locations, and at some other locations for the larger events. In reality, for the larger events, flooding would be spread to a wider area given that excess runoff would overtop the roads and continue moving downstream.

Table 4-1: Kugluktuk Storm Events

Storm Events	Volume (mm)
5-year 1 hr	12.8
5-year 24-hr	37.5
100-year 1hr	23.3
100-year 24hr	67.4
2007 24hr	118.3



LEGEND

- Junctions
- Outfalls
- Conduits
- Subcatchments
- Lot Boundary

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

PCSWMM Model Existing Conditions Hamlet of Kugluktuk

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:5,819

25 12.5 0 25
Metres

FILE NO.
WTRM03098-01_Figure4-1_Existing model.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0

DATE	PROJECT NO.
December 21, 2018	TRN.WTRM03098-01

Figure 4-1

Q:\Vancouver\Transportation\TRN_WTRM\TRN.WTRM03098 - Kugluktuk\GIS\Maps\Figures\WTRM03098-01_Figure4-2_Modeling Results.mxd modified 12/21/2018 by Mauricio.Herrera

LEGEND

Hours Flooded- 2007 Event
- 0.00 - 1.21
- 1.22 - 4.89
- 4.90 - 6.87
- 6.88 - 8.02
- 8.03 - 9.31
- 9.32 - 11.35
- 11.36 - 13.87
- 13.88 - 16.23
- 16.24 - 21.88
- 21.89 - 38.12

5-year 1hr
- 0.00 - 0.20
- 0.21 - 0.74
- 0.75 - 1.41
- 1.42 - 2.13
- 2.14 - 2.88

100-year 1-hr
- 0.00 - 0.31
- 0.32 - 1.00
- 1.01 - 1.96
- 1.97 - 3.52
- 3.53 - 5.49

- Outfalls
- Conduits
- Road
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

PCSWMM Model Results Hamlet of Kugluktuk

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:4,965
100 50 0 100
Metres

FILE NO.
WTRM03098-01_Figure4-2_Modeling Results.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0

DATE
December 21, 2018

PROJECT NO.
TRN.WTRM03098-01

Figure 4-2

5.0 DRAINAGE MASTER PLAN

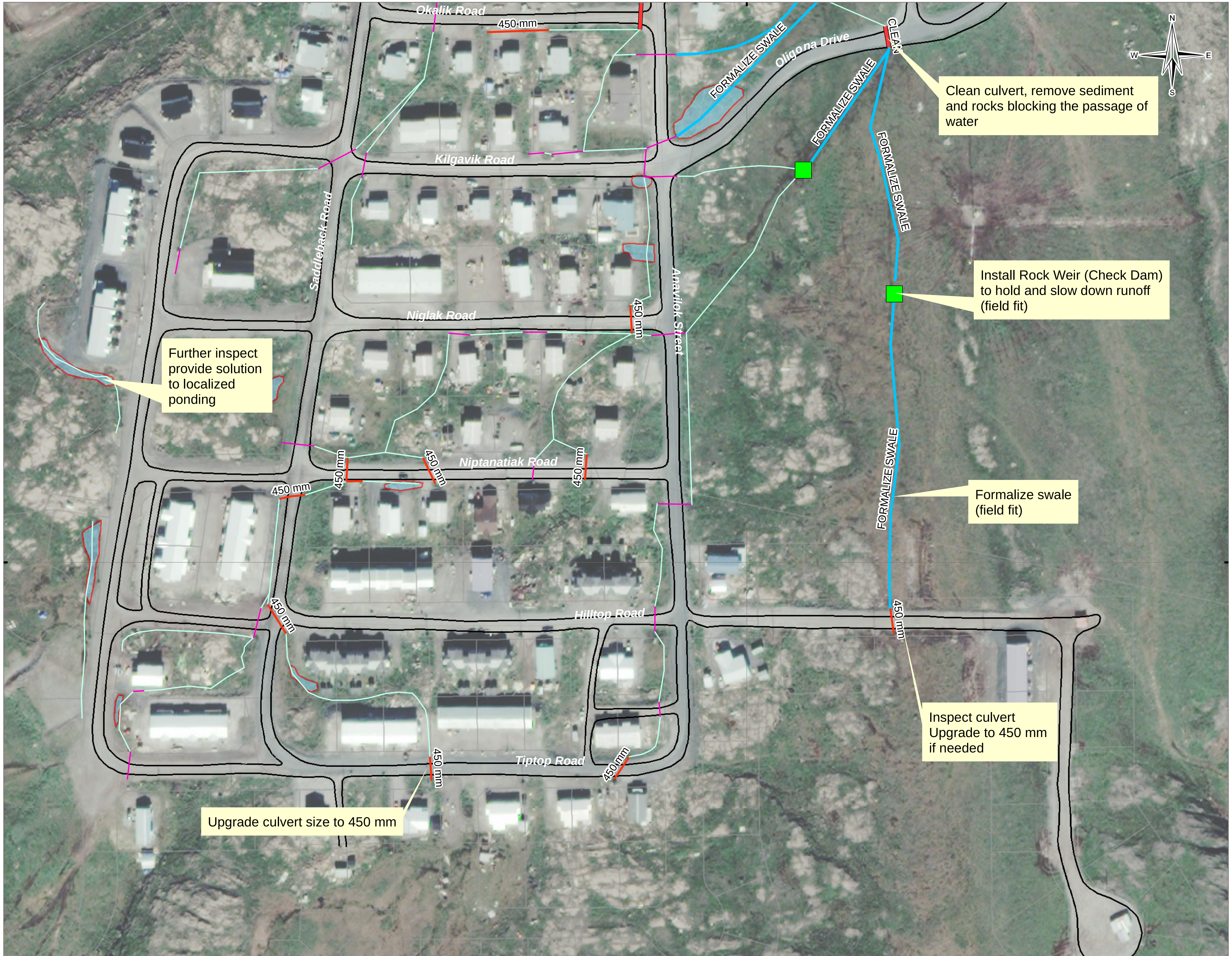
This section presents a summary of recommended actions to upgrade the Level of Service of the drainage system of the Hamlet of Kugluktuk. Currently, there are a number of deficiencies as identified in Section 3.0. The development of the Drainage Master Plan was based on the following premises:

- Minimum culvert size should be 450 mm, as per recommendation from CSA Group (2015);
- Redundancy in the drainage system is required considering challenging conditions of Northern communities, as summarized by CSA Group (2015);
- Open channels must have a revetment 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 erosion;
- To the extent possible, ponding water should not be allowed;
- Culverts should be provided with high visibility markers to prevent damage during spring cleaning activities; and
- An annual maintenance program should incorporate a culvert thawing strategy. Some options are presented in Appendix C for consideration.

5.1 Existing Development

Based on the issues identified in the field, and on the modeling results, a number of upgrades are proposed for the existing drainage system as shown in Figures 5-1 to 5-4. A key element in the plan is to increase redundancy in the drainage system. For instance, a series of check dams are proposed along the green corridor, as shown in Figures 5-1 and 5-2. The objective of these structures, is to slow down and hold runoff temporarily to mitigate peak flows and reduce the risk of flooding along the downstream system. Furthermore, a new 450 mm CSP pipe is proposed at the Kugluktuk Dr. crossing, if possible to be installed 1 foot above the ditch invert. Similarly, an additional 450 mm CSP pipe is proposed at the Umingmak Street crossing, discharging into an upgraded ditch/culvert system on the east side of Kaivoina Street.

With the proposed upgrades, and maintaining culverts clear of debris and sediment, the system should be able to safely pass an event similar to the July, 2007.



LEGEND

- Rock Weirs (Check Dams)

Recommendation

- Culvert
- Increase culvert size
- increase size, d/s riprap
- Ditch
- Formalize swale/ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Infrastructure Hamlet of Kugluktuk

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:2,016
25 12.5 0 25
Metres

TETRA TECH

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OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0
DATE	PROJECT NO.			
December 21, 2018	TRN.WTRM03098-01			

Figure 5-1

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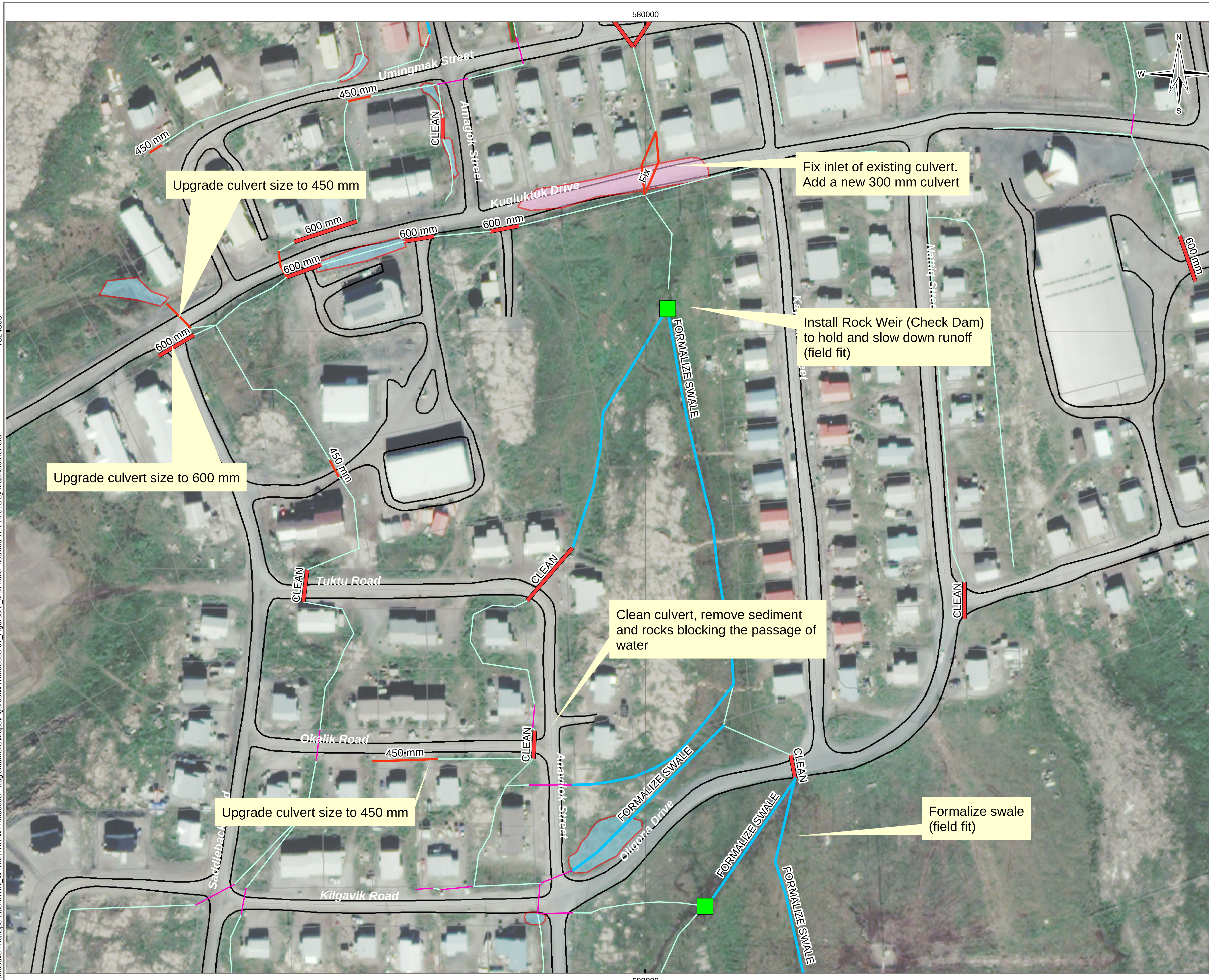

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LEGEND

- Rock Weirs (Check Dams)

Recommendation

- Culvert
- Increase culvert size
- increase size, d/s riprap
- Ditch
- Formalize swale/ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Infrastructure Hamlet of Kugluktuk

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:1,898
25 12.5 0 25
Metres

FILE NO.
WTRM03098-01_Figure5-2_MDP.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0

DATE	PROJECT NO.
December 21, 2018	TRN.WTRM03098-01

Figure 5-2

LEGEND

- Rock Weirs (Check Dams)

Recommendation

- Culvert
- Increase culvert size
- increase size, d/s riprap
- Ditch
- Formalize swale/ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Infrastructure Hamlet of Kugluktuk

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:1,898
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
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OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0
DATE	PROJECT NO.			
March 5, 2019	TRN.WTRM03098-01			

Figure 5-3

LEGEND

- Rock Weirs (Check Dams)

Recommendation

- Culvert
- Increase culvert size
- increase size, d/s riprap
- Ditch
- Formalize swale/ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK
MASTER DRAINAGE PLAN

Drainage Infrastructure
Hamlet of Kugluktuk

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:1,898
25 12.5 0 25
Metres

FILE NO.
WTRM03098-01_Figure5-4_MDP.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0

DATE	PROJECT NO.
December 21, 2018	TRN.WTRM03098-01

Figure 5-4

5.2 Community Plan (Proposed Development Areas)

As mentioned in the Introduction, the Kugluktuk 2016 Census population of 1491 people is projected to grow to approximately 2000 people by 2036. When combined with pre-existing demand for housing, the population projection was used to estimate that 244 new housing units will be required by 2036. To address this, a Community Plan has been prepared, as shown in Appendix B. A drainage plan for the proposed developments is presented in Figures 5-5 to 5-9. The drainage follows the natural terrain, however grading will need to be fined tuned in conjunction with the grading for the building pads and roads. The system is composed of ditches and culverts, with outlet locations as shown, following the natural terrain. The following design characteristics are recommended:

- Ditches should be as flat as possible, but not flatter than 0.5%
- Ditches to have a minimum bottom width of 0.5 metres, a maximum depth of 0.5 m and side slopes of 3:1.
- Culvert sizes vary from 450 mm to 600 mm as shown in the Figures.

LEGEND

- <all other values>
- Culvert
- Ditch
- Outfalls
- Rock Weirs (Check Dams)
- Development_Existing
- Development_New

Recommendation

- Culvert
- Increase culvert size
- increase size, d/s riprap
- Ditch
- Formalize swale/ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Master Plan
Community Plan
Hamlet of Kugluktuk

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:7,552
Metres

TETRA TECH

FILE NO.				
WTRM03098-01_Figure5-5_MDP-dev.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0
DATE	PROJECT NO.			
December 21, 2018	TRN.WTRM03098-01			

Figure 5-5

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LEGEND

- <all other values>
- Culvert
- Ditch
- Outfalls
- Rock Weirs (Check Dams)
- Development_Existing
- Development_New

Recommendation

- Culvert
- Increase culvert size
- increase size, d/s riprap
- Ditch
- Formalize swale/ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Master Plan Community Plan Hamlet of Kugluktuk

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:3,289
25 12.5 0 25
Metres

FILE NO.
WTRM03098-01_Figure5-6_MDP-dev.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0

DATE	PROJECT NO.
December 21, 2018	TRN.WTRM03098-01

Figure 5-6

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LEGEND

- <all other values>
- Culvert
- Ditch
- Outfalls
- Rock Weirs (Check Dams)
- Development_Existing
- Development_New

Recommendation

- Culvert
- Increase culvert size
- increase size, d/s riprap
- Ditch
- Formalize swale/ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Master Plan Community Plan Hamlet of Kugluktuk

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:3,490
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
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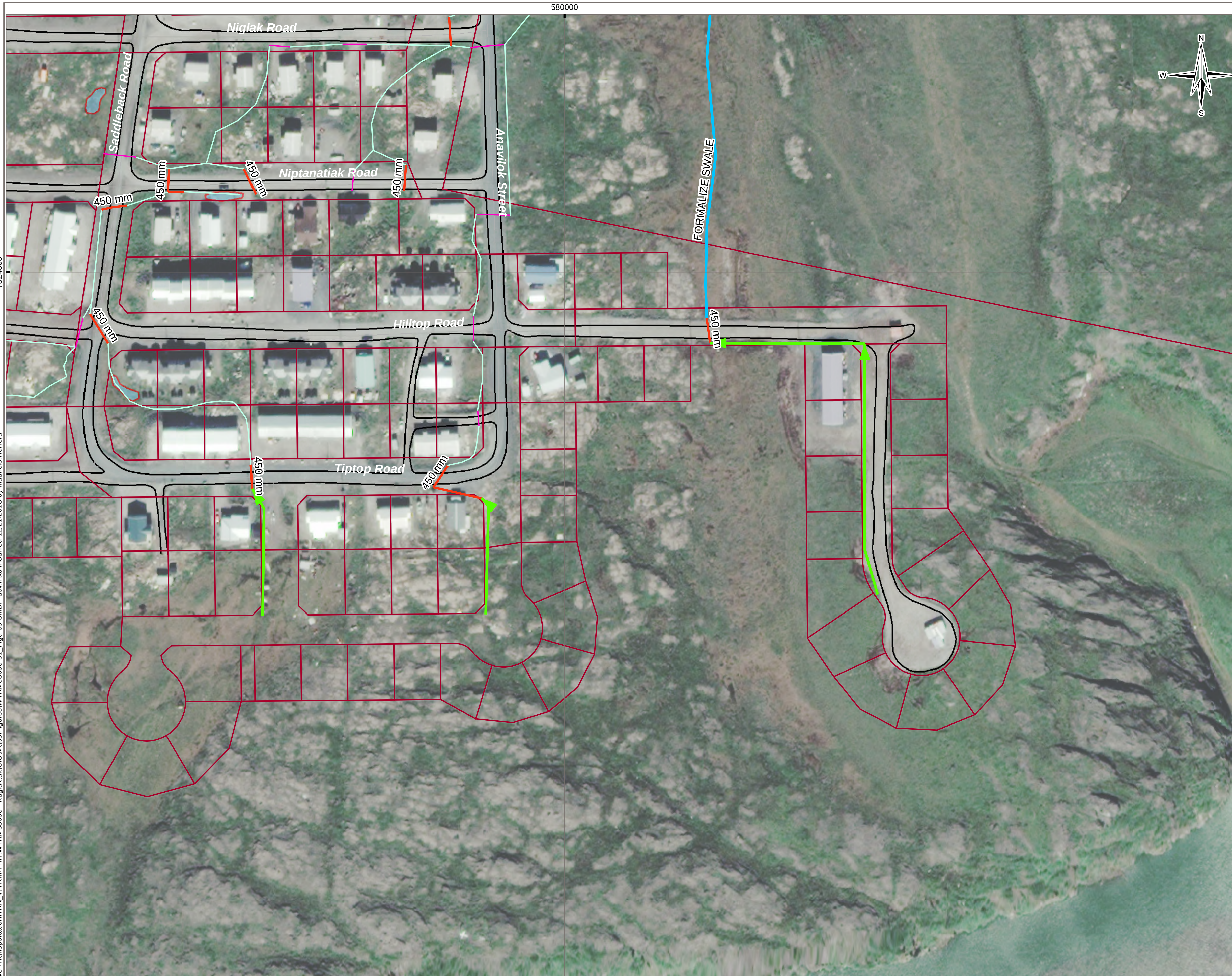
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0
DATE	PROJECT NO.			
December 21, 2018	TRN.WTRM03098-01			

Figure 5-7



LEGEND

- <all other values>
- Culvert
- Ditch
- Outfalls
- Rock Weirs (Check Dams)
- Development_Existing
- Development_New

Recommendation

- Culvert
- Increase culvert size
- increase size, d/s riprap
- Ditch
- Formalize swale/ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK MASTER DRAINAGE PLAN

Drainage Master Plan Community Plan Hamlet of Kugluktuk

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:2,051
25 12.5 0 25
Metres

FILE NO.
WTRM03098-01_Figure5-8MDP-dev.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0

DATE	PROJECT NO.
December 21, 2018	TRN.WTRM03098-01

Figure 5-8

LEGEND

- <all other values>
- Culvert
- Ditch
- Outfalls
- Rock Weirs (Check Dams)
- Development_Existing
- Development_New

Recommendation

- Culvert
- Increase culvert size
- increase size, d/s riprap
- Ditch
- Formalize swale/ditch
- road_segment_1
- 2007 Avulsion
- Anecdotal Flooding
- Erosion
- Overland Flow
- Ponding
- Ponding/Oily Water
- Potential Overtopping
- Shallow Swale
- Lot Boundary
- Road

NOTES
Base data source:
Imagery from ESRI; DigitalGlobe (2011).

STATUS
ISSUED FOR REVIEW

HAMLET OF KUGLUKTUK
MASTER DRAINAGE PLAN

Drainage Master Plan
Community Plan
Hamlet of Kugluktuk

PROJECTION	DATUM	CLIENT
UTM Zone 11	NAD83	Nunavut

Scale: 1:2,448
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
WTRM03098-01_Figure5-9MDP-dev.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MH	MAN	MH	0
DATE	PROJECT NO.			
December 21, 2018	TRN.WTRM03098-01			

Figure 5-9

Q:\Vancouver\Transportation\TRN_WTRM\TRN.WTRM03098 - Kugluktuk\GIS\Maps\Figures\WTRM03098-01_Figure5-9MDP-dev.mxd modified 12/21/2018 by Mauricio.Herrera

6.0 CLOSURE

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

Respectfully submitted,
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TABLES

Table 1: Subcatchment PCSWMM Model Parameters

Name	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)	N Imperv	N Perv	Dstore Imperv (mm)	Dstore Perv (mm)	Drying Time (days)	Curve Number
S8	OF9	0.3908	51.079	76.509	7.018	10	0.01	0.1	0.05	0.05	7	82
S16	J-INUI-04	3.6007	347.57	103.595	4.756	10	0.01	0.1	0.05	0.05	7	82
S2_2	J121	0.3472	7.577	458.253	8.905	25	0.01	0.1	0.05	0.05	7	82
S2	J-KUGL-21	2.0655	57.536	358.995	10.198	5	0.01	0.1	0.05	0.05	7	82
S9_3	J-KUGL-20	0.9155	25.964	352.6	9.466	5	0.01	0.1	0.05	0.05	7	82
S9_4	J-KUGL-17	0.1493	4.234	352.6	5.039	25	0.01	0.1	0.05	0.05	7	82
S9_2	J-CORO-07	0.3369	9.555	352.6	9.443	10	0.01	0.1	0.05	0.05	7	82
S9_5	J193	1.2644	35.859	352.6	10.022	25	0.01	0.1	0.05	0.05	7	82
S10_2	J-HORS-01	0.8872	30.928	286.858	7.15	10	0.01	0.1	0.05	0.05	7	82
S10_4	J-HORS-02	0.7779	27.118	286.858	5.828	5	0.01	0.1	0.05	0.05	7	82
S11_1	OF7	0.6574	87.318	75.288	14.992	10	0.01	0.1	0.05	0.05	7	82
S11_2	J-CORO-09	0.1795	23.842	75.288	14.849	25	0.01	0.1	0.05	0.05	7	82
S7_3	J-INUI-01	3.8295	80.127	477.929	5.055	10	0.01	0.1	0.05	0.05	7	82
S7_4	J30	2.4482	51.225	477.929	4.675	10	0.01	0.1	0.05	0.05	7	82
S7_5	J-KUGL-15	1.7001	35.572	477.929	9.382	10	0.01	0.1	0.05	0.05	7	82
S7_6	J157	0.4772	9.985	477.929	6.467	25	0.01	0.1	0.05	0.05	7	82
S7_1	J-CORO-12	0.2877	6.02	477.929	9.327	10	0.01	0.1	0.05	0.05	7	82
S7_7	J-CORO-11	0.9479	19.833	477.929	8.046	25	0.01	0.1	0.05	0.05	7	82
S6_2	J161	2.1986	96.126	228.72	5.991	25	0.01	0.1	0.05	0.05	7	82
S6_3	J168	0.3914	17.113	228.72	11.658	10	0.01	0.1	0.05	0.05	7	82
S6_4	J-CORO-13	0.9251	40.447	228.72	7.366	25	0.01	0.1	0.05	0.05	7	82
S3_1	J-CORO-16	1.4879	65.512	227.118	6.832	10	0.01	0.1	0.05	0.05	7	82
S3_2	J-CORO-15	0.3953	17.405	227.118	4.99	25	0.01	0.1	0.05	0.05	7	82
S5_5	J-INUI-02	0.1868	5.106	365.864	5.414	25	0.01	0.1	0.05	0.05	7	82
S5_4	J29	0.3443	9.411	365.864	7.094	25	0.01	0.1	0.05	0.05	7	82
S5_6	J28	1.0726	29.317	365.864	10.164	25	0.01	0.1	0.05	0.05	7	82
S5_7	J-OCIG-01	1.4893	40.706	365.864	7.334	10	0.01	0.1	0.05	0.05	7	82
S5_8	J-NATT-01	0.5058	13.825	365.864	4.803	25	0.01	0.1	0.05	0.05	7	82
S5_9	J146	0.236	6.45	365.864	3.785	25	0.01	0.1	0.05	0.05	7	82
S5_13	J136	0.1395	3.813	365.864	6.424	25	0.01	0.1	0.05	0.05	7	82
S5_12	J-HIKO-07	0.9908	27.081	365.864	7.486	10	0.01	0.1	0.05	0.05	7	82
S5_14	J140	0.9451	25.832	365.864	7.304	25	0.01	0.1	0.05	0.05	7	82
S5_15	J6	0.8115	22.18	365.864	4.611	25	0.01	0.1	0.05	0.05	7	82
S5_11	J93	0.6576	17.974	365.864	7.318	25	0.01	0.1	0.05	0.05	7	82
S5_17	J264	0.3211	8.776	365.864	5.846	25	0.01	0.1	0.05	0.05	7	82
S2_5	J-UMIN-01	2.1035	45.903	458.253	11.564	20	0.01	0.1	0.05	0.05	7	82
S2_7	J99	0.4902	10.697	458.253	4.381	25	0.01	0.1	0.05	0.05	7	82

Name	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)	N Imperv	N Perv	Dstore Imperv (mm)	Dstore Perv (mm)	Drying Time (days)	Curve Number
S2_4	J-UMIN-06	0.2466	5.381	458.253	4.61	25	0.01	0.1	0.05	0.05	7	82
S2_8	J101	0.2353	5.135	458.253	5	25	0.01	0.1	0.05	0.05	7	82
S2_9	J84	0.5594	12.207	458.253	4.474	25	0.01	0.1	0.05	0.05	7	82
S2_6	J-AMAG-03	0.3627	7.915	458.253	3.72	25	0.01	0.1	0.05	0.05	7	82
S2_10	J-AMAG-04	0.3384	7.385	458.253	4.102	25	0.01	0.1	0.05	0.05	7	82
S2_11	J104	4.4061	96.15	458.253	9.383	20	0.01	0.1	0.05	0.05	7	82
S2_13	J220	1.2144	26.501	458.253	4.193	25	0.01	0.1	0.05	0.05	7	82
S2_14	J-KALV-05	0.8529	18.612	458.253	6.12	25	0.01	0.1	0.05	0.05	7	82
S2_1	J-KALV-02	0.682	14.883	458.253	5.957	25	0.01	0.1	0.05	0.05	7	82
S2_15	J-KALV-01	0.4755	10.376	458.253	10.552	25	0.01	0.1	0.05	0.05	7	82
S2_12	J-CORO-02	1.939	42.313	458.253	4.29	10	0.01	0.1	0.05	0.05	7	82
S2_3	J120	0.8137	17.757	458.253	7.407	25	0.01	0.1	0.05	0.05	7	82
S5_16	J120	0.1387	3.791	365.864	11.407	25	0.01	0.1	0.05	0.05	7	82
S3_3	J119	1.7346	42.424	408.877	3.122	25	0.01	0.1	0.05	0.05	7	82
S3_4	J-KAIY-13	0.3082	7.538	408.877	6.239	25	0.01	0.1	0.05	0.05	7	82
S12_2	J-OKAL-04	0.4652	7.359	632.143	3.329	25	0.01	0.1	0.05	0.05	7	82
S12_5	J35	1.5122	23.922	632.143	7.312	25	0.01	0.1	0.05	0.05	7	82
S13_3	J25	1.2583	125.83	100	6.093	10	0.01	0.1	0.05	0.05	7	82
S13_4	J10	3.8166	381.66	100	7.693	10	0.01	0.1	0.05	0.05	7	82
S13_6	J107	0.6217	62.17	100	4.557	25	0.01	0.1	0.05	0.05	7	82
S13_2	J-HILL-02	0.6423	64.23	100	4.38	25	0.01	0.1	0.05	0.05	7	82
S13_10	J23	0.3577	35.77	100	3.851	25	0.01	0.1	0.05	0.05	7	82
S13_9	J91	0.1124	11.24	100	4.921	25	0.01	0.1	0.05	0.05	7	82
S13_11	J-HILL-01	0.2566	25.66	100	3.112	25	0.01	0.1	0.05	0.05	7	82
S13_12	J-SADD-01	0.7377	73.77	100	7.171	25	0.01	0.1	0.05	0.05	7	82
S13_8	J-SADD-03	0.276	27.6	100	4.438	25	0.01	0.1	0.05	0.05	7	82
S13_14	J-SADD-02	0.1699	16.99	100	4.404	25	0.01	0.1	0.05	0.05	7	82
S13_15	J24	0.8651	86.51	100	6.778	25	0.01	0.1	0.05	0.05	7	82
S13_1	J-SADD-05	0.6941	69.41	100	4.49	25	0.01	0.1	0.05	0.05	7	82
S13_17	J232	0.4923	49.23	100	4.105	25	0.01	0.1	0.05	0.05	7	82
S13_19	J3	0.1456	14.56	100	4.104	25	0.01	0.1	0.05	0.05	7	82
S13_16	J-NIGL-03	0.3421	34.21	100	4.623	25	0.01	0.1	0.05	0.05	7	82
S13_18	J-ANAV-05	0.4277	42.77	100	6.178	25	0.01	0.1	0.05	0.05	7	82
S13_5	J31	0.5675	56.75	100	4.341	25	0.01	0.1	0.05	0.05	7	82
S13_23	J-NIGL-06	0.7921	79.21	100	4.704	25	0.01	0.1	0.05	0.05	7	82
S13_24	J-KILG-03	0.2428	24.28	100	4.077	25	0.01	0.1	0.05	0.05	7	82
S12_3	J-SADD-07	0.6066	9.596	632.143	5.595	25	0.01	0.1	0.05	0.05	7	82
S12_7	J-AGHA-03	0.1624	2.569	632.143	6.304	25	0.01	0.1	0.05	0.05	7	82
S12_8	J231	0.1076	1.702	632.143	5.449	25	0.01	0.1	0.05	0.05	7	82

Name	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)	N Imperv	N Perv	Dstore Imperv (mm)	Dstore Perv (mm)	Drying Time (days)	Curve Number
S12_6	J-TUKT-01	1.1795	18.659	632.143	8.963	25	0.01	0.1	0.05	0.05	7	82
S12_4	J68	0.3422	5.413	632.143	6.683	25	0.01	0.1	0.05	0.05	7	82
S12_10	J63	0.2691	4.257	632.143	5.099	25	0.01	0.1	0.05	0.05	7	82
S12_9	J-SADD-11	13.946	220.615	632.143	10.388	0	0.01	0.1	0.05	0.05	7	82
S12_12	J236	0.341	5.394	632.143	6.842	25	0.01	0.1	0.05	0.05	7	82
S12_11	J61	2.1516	34.037	632.143	8.309	10	0.01	0.1	0.05	0.05	7	82
S12_13	J-KUGL-05	1.1889	18.807	632.143	6.376	25	0.01	0.1	0.05	0.05	7	82
S12_15	J-SADD-10	0.8079	12.78	632.143	5.672	25	0.01	0.1	0.05	0.05	7	82
S12_14	J-KUGL-01	0.1172	1.854	632.143	3.34	25	0.01	0.1	0.05	0.05	7	82
S10_5	J-KLEN-04	1.3251	46.194	286.858	13.868	10	0.01	0.1	0.05	0.05	7	82
S5_19	J-KAIY-05	0.0607	1.659	365.864	6.622	25	0.01	0.1	0.05	0.05	7	82
S5_20	J-KAIY-07	0.0692	1.891	365.864	9.434	25	0.01	0.1	0.05	0.05	7	82
S5_1	J-KAIY-10	0.0915	2.501	365.864	4.446	25	0.01	0.1	0.05	0.05	7	82
S5_21	J-KAIY-09	0.1164	3.182	365.864	3.867	25	0.01	0.1	0.05	0.05	7	82
S10_3	J180	0.0488	1.701	286.858	10.684	10	0.01	0.1	0.05	0.05	7	82
S10_6	J226	0.211	7.356	286.858	8.341	10	0.01	0.1	0.05	0.05	7	82
S5_2	J-KAIY-03	0.2403	6.568	365.864	6.498	25	0.01	0.1	0.05	0.05	7	82
S5_22	J261	0.1476	4.034	365.864	7.253	25	0.01	0.1	0.05	0.05	7	82
S12_1	J-KUGL-02	0.0521	0.824	632.143	5.83	25	0.01	0.1	0.05	0.05	7	82
S12_17	J71	0.319	5.046	632.143	7.312	25	0.01	0.1	0.05	0.05	7	82
S5_18	J148	0.9032	24.687	365.864	6.067	30	0.01	0.1	0.05	0.05	7	82
S5_10	J147	0.1505	4.114	365.864	6.947	25	0.01	0.1	0.05	0.05	7	82
S5_24	J29	0.7527	20.573	365.864	5.826	10	0.01	0.1	0.05	0.05	7	82
S14_1	J41	0.1701	4.102	414.681	3.527	25	0.01	0.1	0.05	0.05	7	82
S13_20	J42	1.0097	100.97	100	6.709	25	0.01	0.1	0.05	0.05	7	82
S13_22	J-ANAV-06	0.1047	10.47	100	7.282	25	0.01	0.1	0.05	0.05	7	82
S3_5	J108	0.2742	7.062	388.257	8.128	25	0.01	0.1	0.05	0.05	7	82
S3_7	J9	8.1356	209.542	388.257	5.323	0	0.01	0.1	0.05	0.05	7	82
S3_8	J12	6.8183	175.613	388.257	7.644	10	0.01	0.1	0.05	0.05	7	82
S5_23	J6	1.3754	37.593	365.864	4.222	25	0.01	0.1	0.05	0.05	7	82
S5_25	J135	1.578	43.131	365.864	4.479	25	0.01	0.1	0.05	0.05	7	82
S13_21	J-NIPT-05	0.1027	10.27	100	5.065	25	0.01	0.1	0.05	0.05	7	82
S13_25	J234_M	0.2618	26.18	100	4.831	25	0.01	0.1	0.05	0.05	7	82
S13_26	J-NIPT-07	0.5674	56.74	100	5.456	25	0.01	0.1	0.05	0.05	7	82
S13_13	J-NIPT-09	0.1527	15.27	100	6.435	25	0.01	0.1	0.05	0.05	7	82
S13_27	J-ANAV-03	0.3595	35.95	100	6.07	25	0.01	0.1	0.05	0.05	7	82
S1_1	J15	3.4651	133.15	260.241	7.568	20	0.01	0.1	0.05	0.05	7	82
S1_2	J255	2.2688	87.181	260.241	6.99	20	0.01	0.1	0.05	0.05	7	82

Table 2: Junctions PCSWMM Model Parameters

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)
J-SADD-01	579754.494	7523962.008	39.548
J-NIGL-06	579937.902	7524137.002	31.155
J-KILG-07	579945.246	7524205.091	29.496
J-KILG-08	579946.447	7524220.349	29.136
J-TUKT-04	579962.978	7524390.292	22.731
J-Hill-03	579950.993	7523962.971	38.328
J-Hill-04	579951.121	7523976.805	37.898
J-NATT-01	580141.629	7524576.504	17.822
J-NATT-02	580129.411	7524581.048	17.195
J-OCIG-01	580161.967	7524354.359	24.224
J-OCIG-02	580161.85	7524372.952	23.735
J-INUI-01	580278.872	7524525.412	22.065
J-INUI-02	580271.032	7524548.371	20.955
J-KUGL-12	580247.86	7524610.288	18.725
J-KUGL-13	580337.817	7524584.378	19.123
J-KUGL-14	580353.623	7524602.314	18.059
J-KUGL-15	580408.105	7524573.616	19.77
J-KUGL-16	580395.662	7524577.315	19.51
J-KUGL-17	580452.274	7524555.231	22.314
J-KUGL-18	580446.893	7524566.89	21.222
J-KUGL-19	580485.68	7524470.369	25.088
J-KUGL-20	580495.321	7524475.638	24.934
J-KUGL-21	580473.797	7524434.272	27.078
J-KUGL-22	580476.151	7524446.94	26.132
J-KLEN-01	580501.548	7524598.457	18.824
J-KLEN-02	580510.231	7524612.406	16.946
J-KLEN-03	580535.168	7524643.655	15.562
J-KLEN-04	580543.924	7524656.909	13.715
J-CORO-05	580519.752	7524762.472	5.835
J-CORO-06	580531.459	7524752.674	5.788
J-ANGU-01	580551.224	7524782.1	4.339
J-ANGU-02	580552.889	7524790.772	3.616
J-CORO-07	580523.391	7524741.887	6.872
J-CORO-09	580601.884	7524704.184	9.619
J-CORO-10	580610.587	7524715.947	8.649
J-HORS-01	580477.796	7524563.803	21.964
J-HORS-02	580489.885	7524584.312	20.595
J-CORO-11	580471.288	7524777.541	6.435

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)
J-CORO-12	580479.726	7524789.143	5.28
J-SPER-01	580452.939	7524786.162	6.357
J-SPER-02	580464.099	7524776.117	6.554
J-CORO-13	580410.189	7524828.477	3.686
J-CORO-14	580423.041	7524836.457	3.596
J-CORO-15	580379.159	7524860.418	4.71
J-CORO-16	580387.525	7524868.585	4.628
J-HIKO-01	580168.383	7524797.644	8.26
J-HIKO-02	580155.295	7524800.623	7.746
J-UMIN-07	579993.708	7524643.968	11.053
J-UMIN-08	580006.881	7524664.034	10.328
J-ANAV-03	579952.333	7524031.155	36.61
J-ANAV-04	579970.753	7524030.786	35.385
J-ANAV-05	579948.833	7524120.676	31.266
J-ANAV-06	579967.805	7524122.334	30.458
J-ANAV-07	579946.622	7524163.778	30.425
J-ANAV-08	579963.333	7524205.488	29.097
J-ANAV-09	579940.728	7524270.246	28.423
J-ANAV-10	579963.016	7524270.246	28.133
J-OLIG-01	580075.858	7524273.619	23.542
J-OLIG-02	580073.716	7524285.35	23.299
J9	580003.552	7524165.339	27.587
J24	579953.263	7523926.066	40.443
J41	580044.719	7524321.269	21.769
J42	580039.536	7524300.179	22.055
J53	580011.1	7524511.576	16.035
J58	580007.954	7524571.344	13.196
J59	580005.324	7524601.181	11.639
J60	579935.726	7524553.309	13.689
J61	579999.535	7524569.028	12.74
J79	579921.126	7524550.541	14.352
J92	579998.79	7524710.879	8.665
J93	580001.421	7524745.088	6.266
J-HIKO-04	580023.935	7524828.711	3.905
J110	579975.314	7524857.522	4.069
J-HIKO-05	580026.882	7524842.685	3.747
J-KAIY-13	579998.475	7524849.631	4.36
J-HIKO-03	580014.156	7524846.414	4.24
J-HIKO-08	580066.668	7524834.915	3.771
J118	580071.252	7524855.421	3.477

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)
J119	580074.068	7524923.938	1.875
J120	580075.491	7524952.546	1.641
J-HIKO-07	580070.455	7524818.594	5.278
J-HIKO-06	580034.505	7524827.041	4.912
J125	580157.563	7524814.297	7.561
J126	580159.928	7524834.059	5.868
J-INUI-04	580206.176	7524942.477	2.926
J135	580071.963	7524586.159	14.832
J136	580069.255	7524605.296	14.112
J140	580047.38	7524714.786	9.042
J141	580047.38	7524730.942	8.138
J146	580256.62	7524686.155	16.066
J147	580254.557	7524699.909	14.795
J148	580238.053	7524778.305	10.06
J150	580372.574	7524582.432	18.947
J151	580377.425	7524595.044	18.28
J157	580393.173	7524636.491	15.743
J158	580405.011	7524646.265	14.483
J159	580415.305	7524671.762	11.762
J160	580490.128	7524769.328	6.289
J161	580366.247	7524773.633	7.973
J168	580432.365	7524845.614	3.108
J177	580579.916	7524710.545	9.099
J180	580579.372	7524788.874	4.074
J193	580433.96	7524586.335	18.738
J205	580530.572	7524705.481	8.471
J206	580541.62	7524728.965	7.35
J226	580551.714	7524734.21	7.352
J-KAIY-01	579971.009	7524693.514	8.448
J-KAIY-02	579968.994	7524699.457	8.278
J-KAIY-03	579966.979	7524719.302	7.011
J-KAIY-04	579968.188	7524734.009	6.374
J-KAIY-05	579971.311	7524745.694	5.737
J-KAIY-06	579973.829	7524755.062	5.419
J-KAIY-07	579976.549	7524769.165	5.28
J-KAIY-08	579978.564	7524780.246	5.126
J-KAIY-09	579986.824	7524807.444	4.57
J-KAIY-10	579990.753	7524819.733	4.304
J-KAIY-11	579993.775	7524836.052	4.333
J-KAIY-12	579979.269	7524839.578	4.88

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)
J242	579973.59	7524686.324	8.786
J-KAIY-14	579985.327	7524854.111	4.143
J94	579645.716	7523917.174	41.819
J107	579651.377	7524021.661	41.396
J111	579625.718	7524138.196	38.998
J112	579658.7	7524098.87	38.86
J113	579663.774	7524069.059	40.089
J-KUGL-13a	580306.618	7524591.372	19.129
J108	579953.92	7523917.568	40.813
J8	579963.222	7524226.995	28.703
J10	579831.973	7523883.832	44.45
J11	579831.094	7523896.801	44.602
J25	579929.45	7523884.696	43.489
J26	579937.374	7523896.507	42.608
J27	580143.043	7524557.673	18.003
J28	580186.688	7524380.836	23.631
J29	580176.673	7524602.767	19.061
J38	580246.225	7524599.538	19.058
J30	580359.319	7524511.152	23.028
J254	579776.075	7525018.474	1.121
J255	579794.008	7524868.208	5.316
J-CORO-03	579776.498	7525009.935	1.224
J-CORO-04	579775.645	7525027.135	0.889
J106	579879.091	7524740.094	8.262
J100	579868.273	7524632.281	12.485
J101	579885.344	7524637.783	12.076
J102	579890.564	7524651.186	11.625
J103	579885.203	7524672.772	11.339
J104	579880.829	7524697.885	10.268
J105	579880.688	7524722.856	9.144
J220	579916.272	7524855.668	4.65
J241	579814.855	7524533.016	16.724
J244	579837.733	7524550.485	16.611
J246	579897.142	7524602.608	12.923
J247	579892.178	7524708.946	9.818
J248	579885.352	7524771.107	5.742
J249	579893.172	7524793.567	5.168
J250	579898.454	7524815.714	4.627
J251	579829.578	7524795.366	5.877
J252	579875.591	7524866.453	4.166

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)
J253	579882.993	7524924.93	3.16
J256	579898.575	7524566.209	14.285
J257	579854.731	7524772.751	5.937
J258	579870.221	7524841.688	4.005
J62	579708.206	7524207.239	35.491
J82	579851.712	7524579.736	14.705
J83	579847.325	7524596.438	14.115
J84	579847.157	7524609.935	13.639
J87	579951.55	7524848.046	4.491
J88	579892.321	7524735.49	7.838
J89	579904.561	7524789.91	5.324
J95	579852.864	7524868.745	4.236
J96	579764.718	7524601.101	17.163
J97	579772.477	7524605.898	16.958
J98	579799.001	7524615.633	16.281
J99	579834.836	7524625.509	14.096
J-AGHA-03	579695.357	7524153.678	37.248
J-AGHA-04	579697.981	7524166.953	36.87
J-AMAG-01	579897.113	7524597.643	13.122
J-AMAG-02	579897.173	7524607.794	12.72
J-AMAG-03	579910.406	7524627.993	12.551
J-AMAG-04	579894.642	7524625.01	12.205
J-AMAG-05	579893.5	7524686.708	10.473
J-AMAG-06	579891.966	7524698.247	10.118
J-AMAG-07	579892.451	7524704.541	9.949
J-AMAG-08	579891.886	7524713.659	9.504
J-AMAG-09	579875.747	7524730.927	9.01
J-AMAG-10	579882.606	7524749.729	7.475
J-AMAG-11	579883.899	7524921.393	3.16
J-AMAG-12	579882.149	7524928.223	2.269
J-AMAG-13	579892.144	7524788.735	5.373
J-AMAG-14	579894.276	7524798.751	5.096
J-AMAG-15	579884.937	7524767.687	5.914
J-AMAG-16	579885.809	7524774.876	5.578
J-AMAG-17	579900.81	7524825.28	4.358
J-AMAG-18	579902.206	7524831.671	4.075
J-AMAG-19	579905.317	7524846.73	3.845
J-AMAG-20	579907.239	7524856.033	3.702
J-AMAG-21	579897.315	7524811.089	4.679
J-AMAG-22	579899.628	7524820.484	4.536

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)
J-CORO-01	579871.036	7525003.47	0.993
J-CORO-02	579870.06	7525018.596	0.923
J-HIKO-09	579937.69	7524851.022	4.551
J-HIKO-10	579948.797	7524848.514	4.476
J-HIKO-11	579924.963	7524853.445	4.495
J-HIKO-12	579907.62	7524857.881	3.713
J-KALV-01	579825.379	7524774.006	6.99
J-KALV-02	579833.815	7524816.918	5.127
J-KALV-03	579870.519	7524867.707	4.274
J-KALV-04	579880.288	7524865.292	3.859
J-KALV-05	579884.08	7524864.688	3.666
J-KALV-06	579884.287	7524877.159	3.469
J-KUGL-04	579813.751	7524540.555	16.96
J-KUGL-07	579821.8	7524545.203	16.703
J-KUGL-08	579853.651	7524555.762	15.553
J-SADD-07	579771.785	7524209.519	33.41
J-UMIN-01	579748.249	7524590.319	17.551
J-UMIN-02	579754.729	7524594.403	17.449
J-UMIN-03	579849.015	7524616.516	13.334
J-UMIN-04	579860.785	7524619.097	13.028
J-UMIN-05	579938.104	7524634.93	12.114
J-UMIN-06	579934.428	7524649.176	11.109
J1	579732.107	7523944.012	40.743
J115	579760.898	7524062.818	36.912
J123	579786.904	7524049.235	36.335
J124	579790.936	7524043.164	36.438
J128	579830.836	7524048.513	36.32
J129	579886.268	7524049.135	36.378
J13	579915.223	7524235.12	30.021
J145	580240.46	7524669.307	16.692
J16	579929.285	7524269.918	28.733
J17	579897.043	7524065.533	35.41
J2	579745.597	7523983.52	38.849
J21	579922.893	7524113.114	32.034
J22	579665.469	7523911.091	41.805
J221	579955.614	7524719.851	7.61
J229	579914.203	7524050.46	36.089
J23	579666.176	7523924.484	41.525
J230	579789.152	7524169.387	35.223
J231	579796.051	7524211.336	33.109

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)
J232	579846.726	7524121.485	34.21
J233	579938.378	7524129.209	31.275
J234	579877.819	7524282.698	29.735
J234_M	579824.981	7524041.797	36.438
J235	579943.431	7524290.647	28.186
J236	579951.356	7524376.81	23.722
J237	579827.383	7524370.987	24.518
J238	579842.141	7524430.348	21.145
J239	579761.968	7524492.794	19.034
J240	579763.048	7524507.758	18.245
J243	579826.709	7524530.502	16.483
J245	579885.054	7524546.772	15.435
J260	579986.592	7524837.798	4.873
J261	579978.134	7524664.763	10.482
J262	579988.829	7524813.715	4.427
J263	580025.206	7524836.129	3.828
J264	580034.554	7524750.896	7.165
J3	579807.29	7524058.516	35.805
J31	579946.897	7524195.76	29.534
J32	579940.237	7524328.358	25.935
J33	579917.338	7524331.862	26.335
J34	579910.956	7524342.998	25.965
J35	579912.583	7524356.513	25.489
J36	579922.594	7524361.268	25.073
J37	579933.48	7524360.392	25
J63	579828.001	7524257.257	31.007
J64	579837.488	7524319.635	27.218
J65	579842.918	7524327.662	26.805
J66	579847.169	7524338.737	26.255
J67	579851.99	7524346.867	25.855
J68	579846.253	7524359.339	25.195
J69	579854.692	7524389.921	22.862
J70	579851.99	7524414.972	21.827
J71	579781.951	7524503.158	17.32
J72	579794.517	7524513.692	17.023
J73	579810.225	7524521.638	16.729
J75	579831.341	7524448.416	20.255
J76	579821.946	7524462.879	19.306
J77	579812.428	7524470.543	18.841
J78	579800.561	7524470.543	18.681

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)
J90	579675.899	7523931.532	41.152
J91	579667.049	7523952.88	40.979
J-AGHA-01	579673.088	7523931.376	41.215
J-AGHA-02	579678.551	7523931.68	41.09
J-ANAV-01	579942.743	7524299.191	27.833
J-ANAV-02	579943.667	7524310.664	27.253
J-HILL-01	579737.113	7523959.929	40.15
J-HILL-02	579740.931	7523975.323	39.703
J-KILG-01	579794.799	7524204.616	33.518
J-KILG-02	579797.26	7524217.826	32.583
J-KILG-03	579883.487	7524217.247	30.985
J-KILG-04	579891.929	7524217.909	30.728
J-KILG-05	579896.178	7524217.122	30.618
J-KILG-06	579912.945	7524218.824	30.111
J-KUGL-01	579757.089	7524513.794	18.515
J-KUGL-02	579769.242	7524501.483	17.965
J-KUGL-05	579818.012	7524527.368	16.524
J-KUGL-06	579835.531	7524533.681	16.279
J-KUGL-09	579878.152	7524545.629	15.055
J-KUGL-10	579892.605	7524548.022	14.922
J-NIGL-01	579841.308	7524121.927	34.278
J-NIGL-02	579852.33	7524121.027	33.978
J-NIGL-03	579880.841	7524122.567	33.17
J-NIGL-04	579893.323	7524122.567	32.64
J-NIGL-05	579938.836	7524121.718	31.364
J-NIPT-01	579786.557	7524043.053	36.468
J-NIPT-02	579787.264	7524055.646	36.045
J-NIPT-03	579795.327	7524043.274	36.408
J-NIPT-05	579834.081	7524041.819	36.66
J-NIPT-06	579827.385	7524055.63	35.94
J-NIPT-07	579885.68	7524043.913	36.419
J-NIPT-08	579886.877	7524054.552	36.238
J-NIPT-09	579913.721	7524043.701	36.396
J-OKAL-01	579943.108	7524283.566	28.46
J-OKAL-02	579943.753	7524297.696	27.885
J-OKAL-03	579861.439	7524282.082	30.097
J-OKAL-04	579894.62	7524283.33	29.372
J-OKAL-05	579832.964	7524282.507	30.405
J-OKAL-06	579834.846	7524297.989	29.423
J-SADD-02	579744.621	7523977.684	39.404

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)
J-SADD-03	579750.872	7524033.746	37.359
J-SADD-04	579764.726	7524035.853	36.887
J-SADD-05	579752.12	7524063.758	37.199
J-SADD-06	579769.235	7524061.924	36.64
J-SADD-08	579791.425	7524219.811	32.587
J-SADD-09	579844.37	7524426.198	21.282
J-SADD-10	579839.793	7524434.721	20.887
J-SADD-11	579752.985	7524487.436	19.102
J-SADD-12	579770.978	7524498.169	17.695
J-TIPT-01	579669.89	7523884.832	41.857
J-TIPT-02	579671.496	7523899.184	41.835
J-TUKT-01	579826.382	7524362.973	25.128
J-TUKT-02	579828.412	7524379.217	23.891
J-TUKT-03	579939.905	7524363.527	24.698
L-NIPT-10	579914.707	7524057.511	35.604
J127	579756.736	7524035.057	37.249
J4	580068.429	7524827.898	4.422
J5	579845.082	7524847.572	4.354
J6	580054.817	7524583.29	14.331
J7	580006.681	7524585.789	12.144
J12	580078.319	7523962.079	32.926
J14	580076.415	7523976.043	32.483
J15	579684.01	7525016.551	1.18
J18	579684.614	7525029.818	0.704
J19	580030.068	7524208.907	25.994

Table 3: Conduits PCSWMM Model Parameters

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Diameter	Geom2 (m)	Slope (m/m)
L-Hill-03	J-Hill-03	J-Hill-04	13.838	0.023	CIRCULAR	0.45	0	0.031
L-NATT-01	J-NATT-01	J-NATT-02	13.04	0.023	CIRCULAR	0.5	0	0.048
L-OCIG-01	J-OCIG-01	J-OCIG-02	18.6	0.023	FILLED_CIRCULAR	0.4	0.2	0.026
L-INUI-01	J-INUI-01	J-INUI-02	24.269	0.023	FILLED_CIRCULAR	0.3	0.28	0.046
L-KUGL-13	J-KUGL-13	J-KUGL-14	23.915	0.023	CIRCULAR	0.3	0	0.045
L-KUGL-15	J-KUGL-15	J-KUGL-16	12.986	0.023	FILLED_CIRCULAR	0.5	0.1	0.020
L-KUGL-17	J-KUGL-17	J-KUGL-18	12.845	0.023	FILLED_CIRCULAR	0.5	0.4	0.085
L-RIV-1	J-KUGL-19	J-KUGL-20	10.99	0.023	FILLED_CIRCULAR	0.5	0.48	0.014
L-KUGL-21	J-KUGL-21	J-KUGL-22	12.889	0.018	CIRCULAR	0.3	0	0.074
L-KLEN-01	J-KLEN-01	J-KLEN-02	16.437	0.023	CIRCULAR	0.5	0	0.115
L-KLEN-03	J-KLEN-03	J-KLEN-04	15.89	0.023	CIRCULAR	0.5	0	0.117
L-ANGU-01	J-ANGU-01	J-ANGU-02	8.833	0.023	CIRCULAR	0.5	0	0.082
L-CORO-07	J-CORO-07	J-CORO-06	13.476	0.024	CIRCULAR	0.4	0	0.081
L-CORO-09	J-CORO-09	J-CORO-10	14.637	0.023	CIRCULAR	0.4	0	0.066
L-HORS-01	J-HORS-01	J-HORS-02	23.814	0.023	CIRCULAR	0.27	0	0.058
L-CORO-11	J-CORO-11	J-CORO-12	14.351	0.023	CIRCULAR	0.5	0	0.081
L-SPER-01	J-SPER-01	J-SPER-02	15.02	0.023	CIRCULAR	0.3	0	-0.013
L-CORO-13	J-CORO-13	J-CORO-14	15.133	0.023	CIRCULAR	0.3	0	0.006
L-CORO-15	J-CORO-15	J-CORO-16	11.695	0.023	FILLED_CIRCULAR	0.4	0.12	0.007
L-HIKO-01	J-HIKO-01	J-HIKO-02	13.427	0.023	FILLED_CIRCULAR	0.4	0.39	0.038
L-UMIN-07	J-UMIN-07	J-UMIN-08	24.012	0.028	FILLED_CIRCULAR	0.6	0.3	0.030
L-ANAV-03	J-ANAV-03	J-ANAV-04	18.43	0.023	CIRCULAR	0.48	0	0.067
L-ANAV-05	J-ANAV-05	J-ANAV-06	19.051	0.023	CIRCULAR	0.4	0	0.042
L-ANAV-07	J-KILG-07	J-ANAV-08	18.098	0.023	CIRCULAR	0.46	0	0.002
L-ANAV-09	J-ANAV-09	J-ANAV-10	22.295	0.023	CIRCULAR	0.5	0	0.013
L-OLIG-01	J-OLIG-01	J-OLIG-02	33.209	0.023	FILLED_CIRCULAR	0.6	0.2	0.030
C22	J-ANAV-06	J9	55.94	0.035	TRAPEZOIDAL	1	1	0.051
C54	J-ANAV-04	J-ANAV-06	91.624	0.035	TRAPEZOIDAL	1	1	0.054
C71	J-OLIG-02	J42	15.741	0.035	TRAPEZOIDAL	1	1	0.027
C72	J42	J41	21.725	0.035	TRAPEZOIDAL	1	1	-0.003
C89	J60	J61	65.739	0.035	TRAPEZOIDAL	1	1	0.010
C90	J58	J61	8.734	0.035	TRAPEZOIDAL	1	1	0.052
KlugCul2	J79	J60	14.865	0.023	CIRCULAR	0.4	0	0.045
C120	J59	J-UMIN-07	44.35	0.028	TRAPEZOIDAL	2.1	1	0.013
C141	J-UMIN-08	J92	47.554	0.035	TRAPEZOIDAL	0.9	1	0.035
C142	J92	J93	34.322	0.035	TRAPEZOIDAL	0.9	1	0.070
C143	J93	J-HIKO-04	86.629	0.035	TRAPEZOIDAL	0.9	1	0.027
L-HIKO-03	J-KAIY-13	J-HIKO-03	16.013	0.023	CIRCULAR	0.7	0	0.007

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Diameter	Geom2 (m)	Slope (m/m)
C164	J-HIKO-03	J-HIKO-05	13.266	0.035	TRAPEZOIDAL	1	2	0.037
C170	J118	J119	68.597	0.035	TRAPEZOIDAL	1.5	1	0.023
CoroCul	J119	J120	28.653	0.023	CIRCULAR	0.5	0	0.008
C172	J120	J121	28.487	0.035	TRAPEZOIDAL	2.1	1	0.054
L-HIKO-06	J-HIKO-06	J-HIKO-04	10.704	0.023	CIRCULAR	0.4	0	0.095
HikokCul8	J-HIKO-02	J125	13.866	0.023	FILLED_CIRCULAR	0.4	0.35	0.013
C174	J125	J126	19.909	0.035	TRAPEZOIDAL	1	1	0.085
C189	J136	J140	111.691	0.035	TRAPEZOIDAL	1	1	0.045
C190	J140	J141	16.161	0.035	TRAPEZOIDAL	1	1	0.056
C191	J141	J-HIKO-07	90.668	0.035	TRAPEZOIDAL	1	1	0.032
SamHCul	J146	J147	13.912	0.023	CIRCULAR	0.6	0	0.092
C198	J147	J148	80.141	0.035	TRAPEZOIDAL	1	1	0.059
C199	J148	J-HIKO-01	72.327	0.035	TRAPEZOIDAL	1	1	0.025
C202	J-KUGL-20	J-KUGL-17	90.518	0.033	TRAPEZOIDAL	0.3	1.1	0.029
C203	J-HORS-02	J-KLEN-01	18.339	0.05	TRAPEZOIDAL	1	0.5	0.097
C204	J-KLEN-02	J-KLEN-03	39.993	0.033	TRAPEZOIDAL	1	1	0.035
KlugCul4	J150	J151	13.518	0.023	FILLED_CIRCULAR	0.3	0.24	0.049
C205	J-KUGL-16	J150	23.655	0.035	TRAPEZOIDAL	1	1	0.024
C212	J151	J157	44.352	0.035	TRAPEZOIDAL	1	1	0.057
AnguCul	J157	J158	15.357	0.023	CIRCULAR	0.5	0	0.082
C213	J158	J159	27.506	0.035	TRAPEZOIDAL	1	1	0.099
C214	J159	J160	122.994	0.033	TRAPEZOIDAL	1	1	0.045
C215	J160	J-CORO-11	20.558	0.035	TRAPEZOIDAL	1	1	-0.007
C216	J-SPER-02	J-CORO-11	7.331	0.035	TRAPEZOIDAL	1	1	0.016
C225	J-CORO-14	J168	13.072	0.033	TRAPEZOIDAL	2.1	1	0.037
C236	J-KLEN-04	J177	64.613	0.035	TRAPEZOIDAL	1	1	0.072
C237	J177	J180	78.356	0.035	TRAPEZOIDAL	1	1	0.064
C254	J-KUGL-18	J193	25.992	0.018	TRAPEZOIDAL	1	1	0.096
C267	J205	J206	25.961	0.033	TRAPEZOIDAL	1	1	0.043
C268	J206	J-CORO-07	22.352	0.035	TRAPEZOIDAL	1	1	0.021
C269	J-CORO-06	J-ANGU-01	35.805	0.045	TRAPEZOIDAL	1	1	0.041
C279	J-KUGL-19	J-KUGL-15	133.236	0.035	TRAPEZOIDAL	1	1	0.040
L-KAIY-01	J-KAIY-01	J-KAIY-02	6.278	0.035	TRAPEZOIDAL	1	6	0.000
L-KAIY-03	J-KAIY-03	J-KAIY-04	14.762	0.035	TRAPEZOIDAL	1	6	0.000
L-KAIY-05	J-KAIY-05	J-KAIY-06	9.704	0.023	CIRCULAR	0.4	0	0.000
L-KAIY-07	J-KAIY-07	J-KAIY-08	11.266	0.03	CIRCULAR	0.15	0	0.000
L-KAIY-09	J-KAIY-09	J-KAIY-10	12.906	0.023	CIRCULAR	0.4	0	0.000
C137	J242	J-KAIY-01	7.642	0.035	TRAPEZOIDAL	1	0.5	0.000
C138	J-KAIY-02	J-KAIY-03	19.953	0.035	TRAPEZOIDAL	1	6	0.000
C295	J-KAIY-04	J-KAIY-05	12.099	0.035	TRAPEZOIDAL	1	1.5	0.000

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Diameter	Geom2 (m)	Slope (m/m)
C296	J-KAIY-06	J-KAIY-07	14.367	0.035	TRAPEZOIDAL	1.5	1	0.000
C297	J-KAIY-08	J-KAIY-09	28.434	0.035	TRAPEZOIDAL	1	1	0.000
C299	J-KAIY-10	J-KAIY-11	16.602	0.035	TRAPEZOIDAL	2.1	1	0.000
C300	J-KAIY-12	J87	28.993	0.035	TRAPEZOIDAL	0.5	1	-0.157
L-KAIY-13	J-KAIY-11	J-KAIY-13	14.374	0.023	CIRCULAR	0.4	0	-0.318
C163_1	J110	J-KAIY-14	10.581	0.035	TRAPEZOIDAL	1	2	-0.012
C163_2	J-KAIY-14	J-KAIY-13	13.894	0.035	TRAPEZOIDAL	1	2	-0.012
L-KAIY-14	J-KAIY-12	J-KAIY-14	15.75	0.023	CIRCULAR	0.15	0	-0.276
C177	J94	J107	104.937	0.035	TRAPEZOIDAL	2	1	0.004
C298	J111	J112	63.08	0.035	TRAPEZOIDAL	2	1	0.002
C301	J113	J112	32.446	0.035	TRAPEZOIDAL	2	1	0.037
L-KUGL-13a	J-KUGL-13a	J-KUGL-13	32.084	0.018	TRAPEZOIDAL	0.3	0.6	0.000
L-ANAV-04	J108	J24	8.526	0.023	CIRCULAR	0.58	0	0.043
C47	J24	J-Hill-03	38.61	0.035	TRAPEZOIDAL	1	1	0.055
C51	J-Hill-04	J-ANAV-03	55.891	0.035	TRAPEZOIDAL	1	1	0.023
C20	J-NIGL-06	J-ANAV-07	33.967	0.035	TRAPEZOIDAL	1	1	0.022
C56	J-ANAV-07	J-KILG-07	41.616	0.035	TRAPEZOIDAL	1	1	0.022
L-ANAV-08	J-KILG-08	J8	18.036	0.023	CIRCULAR	0.5	0	0.024
C21	J8	J42	105.906	0.05	TRAPEZOIDAL	1	1	0.063
C67	J-ANAV-10	J41	101.944	0.035	TRAPEZOIDAL	1	1	0.059
C85	J53	J61	61.971	0.035	TRAPEZOIDAL	1	1	0.053
C220	J161	J-CORO-13	70.865	0.035	TRAPEZOIDAL	2.1	1	0.061
C171	J-HIKO-02	J-HIKO-07	86.755	0.035	TRAPEZOIDAL	1.603	0.548	0.028
C221	J-CORO-16	OF3	51.565	0.05	TRAPEZOIDAL	2.1	1	0.090
C228	J168	OF4	34.088	0.05	TRAPEZOIDAL	2.1	1	0.092
L-TIPT-02	J10	J11	13	0.023	FILLED_CIRCULAR	0.4	0.2	0.004
C23	J11	J-SADD-01	127.514	0.038	TRAPEZOIDAL	0.5	1	0.038
L-TIPT-03	J25	J26	14.228	0.023	CIRCULAR	0.15	0	0.062
C27	J26	J108	31.041	0.035	TRAPEZOIDAL	1	1	0.058
C188	J-NATT-02	J135	61.293	0.018	TRAPEZOIDAL	0.4	1	0.039
C184_1	J-OCIG-02	J27	186.429	0.018	TRAPEZOIDAL	0.5	0.5	0.029
C184_2	J27	J-NATT-01	18.89	0.018	TRAPEZOIDAL	0.5	0.5	0.029
C24	J28	J27	197.707	0.038	TRAPEZOIDAL	0.5	1	-0.093
C46	J-INUI-02	J38	56.922	0.035	TRAPEZOIDAL	0.5	1	0.033
L-KUGL-2	J38	J-KUGL-12	10.878	0.023	FILLED_CIRCULAR	0.3	0.25	0.031
C48	J29	J38	69.712	0.018	TRAPEZOIDAL	0.5	0.3	0.000
C49	J-KUGL-12	J146	83.235	0.035	TRAPEZOIDAL	0.5	0.5	0.032
C211	J-KUGL-14	J157	64.788	0.035	TRAPEZOIDAL	1	1	0.036
C50	J30	J-KUGL-13	80.4	0.018	TRAPEZOIDAL	0.3	0.3	-0.245
C266	J193	J205	153.463	0.033	TRAPEZOIDAL	1	1	0.067

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Diameter	Geom2 (m)	Slope (m/m)
C201	J-KUGL-22	J-KUGL-19	29.271	0.033	TRAPEZOIDAL	0.6	0.5	0.036
C292	J226	J180	61.732	0.035	TRAPEZOIDAL	1	1	0.053
C242	J180	OF6	24.437	0.035	TRAPEZOIDAL	1	1	0.169
C231	J-CORO-12	OF5	71.085	0.04	TRAPEZOIDAL	1	1	0.074
C275	J-ANGU-02	OF8	36.873	0.035	TRAPEZOIDAL	1	1	0.099
C245	J-CORO-10	OF7	87.696	0.045	TRAPEZOIDAL	1	1	0.099
C280	J-CORO-05	OF9	93.093	0.035	TRAPEZOIDAL	1	1	0.063
C175	J126	J-INUI-04	118.098	0.035	TRAPEZOIDAL	0.5	2	0.025
C159	J255	J-CORO-03	155.825	0.035	TRAPEZOIDAL	1	2	0.026
C2	J-CORO-04	O-CORO-03	8.42	0.035	TRAPEZOIDAL	1.5	1	0.106
L-CORO-03_1	J-CORO-03	J254	8.552	0.023	CIRCULAR	0.25	0	0.019
L-CORO-03_2	J254	J-CORO-04	8.674	0.023	CIRCULAR	0.35	0	0.019
C1	J-CORO-02	O-CORO-01	8.341	0.035	TRAPEZOIDAL	1	4	0.111
C121	J-AMAG-02	J-AMAG-04	17.406	0.035	TRAPEZOIDAL	1	1	0.030
C124	J-KUGL-04	J-KUGL-07	9.298	0.035	TRAPEZOIDAL	1	1	0.028
C125	J-KUGL-08	J82	24.059	0.035	TRAPEZOIDAL	1	1	0.035
C126	J82	J83	17.275	0.035	TRAPEZOIDAL	1	1	0.034
C127	J83	J84	13.503	0.035	TRAPEZOIDAL	1	1	0.035
C128	J84	J-UMIN-03	6.84	0.035	TRAPEZOIDAL	1	1	0.045
C129	J-UMIN-04	J-AMAG-04	34.38	0.035	TRAPEZOIDAL	1	1	0.024
C133	J-AMAG-06	J-AMAG-07	6.314	0.035	TRAPEZOIDAL	0.3	3	0.027
C134	J-AMAG-08	J88	21.843	0.035	TRAPEZOIDAL	1	1	0.076
C135	J88	J89	55.798	0.035	TRAPEZOIDAL	2.1	1	0.045
C136	J89	J-HIKO-11	64.168	0.035	TRAPEZOIDAL	2.1	1	0.012
C137_1	J-AMAG-10	J-AMAG-15	18.115	0.035	TRAPEZOIDAL	1	1	0.052
C137_4	J-AMAG-16	J-AMAG-13	15.243	0.035	TRAPEZOIDAL	1	1	0.055
C138_1	J-AMAG-18	J-AMAG-19	15.381	0.035	TRAPEZOIDAL	1	1	0.023
C138_2	J-AMAG-14	J-AMAG-21	12.711	0.035	TRAPEZOIDAL	1	1	0.017
C138_5	J-AMAG-20	J-HIKO-12	1.888	0.035	TRAPEZOIDAL	1	1	0.023
C138_6	J-AMAG-22	J-AMAG-17	4.942	0.023	TRAPEZOIDAL	1	1	0.018
C139	J-HIKO-12	J-KALV-05	24.513	0.035	TRAPEZOIDAL	2	2	0.002
C140	J-KALV-04	J-KALV-05	3.839	0.035	TRAPEZOIDAL	1	1	0.050
C145	J95	J-KALV-03	17.692	0.035	TRAPEZOIDAL	1	1	-0.002
C146	J-KALV-06	J-AMAG-11	44.25	0.05	TRAPEZOIDAL	1	2	0.007
C147	J-AMAG-12	J-CORO-01	76.087	0.035	TRAPEZOIDAL	1	1	0.017
C148	J-UMIN-02	J96	12.031	0.035	TRAPEZOIDAL	1	1	0.024
C149	J96	J97	9.126	0.035	TRAPEZOIDAL	1	1	0.022
C150	J97	J98	28.263	0.035	TRAPEZOIDAL	1	1	0.024
C151	J98	J99	37.183	0.035	TRAPEZOIDAL	1	1	0.059
C152	J99	J-AMAG-09	183.495	0.035	TRAPEZOIDAL	1	1	0.028

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Diameter	Geom2 (m)	Slope (m/m)
C153	J100	J101	22.36	0.035	TRAPEZOIDAL	0.3	6	0.023
C154	J101	J102	14.388	0.023	TRAPEZOIDAL	0.3	6	0.031
C155	J102	J103	22.249	0.023	TRAPEZOIDAL	0.3	6	0.013
C156	J103	J104	25.499	0.023	TRAPEZOIDAL	0.3	6	0.042
C157	J104	J105	24.98	0.023	TRAPEZOIDAL	0.3	6	0.045
C158	J105	J-AMAG-09	9.5	0.023	TRAPEZOIDAL	0.3	6	0.014
C160	J-HIKO-09	J-HIKO-11	12.961	0.035	TRAPEZOIDAL	1.5	2	0.004
C161	J87	J-HIKO-10	2.792	0.035	TRAPEZOIDAL	1.5	1	0.005
C304	J256	J-AMAG-01	33.062	0.035	TRAPEZOIDAL	1	2	-0.432
C305	J-KALV-01	J257	30.04	0.035	TRAPEZOIDAL	1	1	0.035
C306	J-AMAG-15	J257	31.044	0.035	TRAPEZOIDAL	1	1	0.019
C307	J257	J258	70.679	0.035	TRAPEZOIDAL	1	1	0.027
C308	J258	J-AMAG-18	34.365	0.035	TRAPEZOIDAL	1	1	-0.010
C309	J258	J5	25.839	0.035	TRAPEZOIDAL	1	1	-0.023
C88	J-AGHA-04	J62	41.577	0.035	TRAPEZOIDAL	1	4	0.033
C93	J62	J-SADD-07	63.641	0.035	TRAPEZOIDAL	1	4	0.033
L-AGHA-03	J-AGHA-03	J-AGHA-04	13.537	0.023	CIRCULAR	0.27	0	0.028
L-AMAG-01_1	J-AMAG-01	J246	4.967	0.023	CIRCULAR	0.47	0	0.040
L-AMAG-01_2	J246	J-AMAG-02	5.188	0.023	CIRCULAR	0.5	0	0.040
L-AMAG-03	J-AMAG-04	J-AMAG-03	16.05	0.023	CIRCULAR	0.4	0	-0.022
L-AMAG-05	J-AMAG-05	J-AMAG-06	11.644	0.023	CIRCULAR	0.05	0	0.031
L-AMAG-07_1	J-AMAG-07	J247	4.415	0.023	CIRCULAR	0.075	0	0.049
L-AMAG-07_2	J247	J-AMAG-08	4.724	0.023	CIRCULAR	0.01	0	0.049
L-AMAG-09_1	J-AMAG-09	J106	9.76	0.023	CIRCULAR	0.3	0	0.077
L-AMAG-09_2	J106	J-AMAG-10	10.259	0.023	CIRCULAR	0.4	0	0.077
L-AMAG-11_1	J-AMAG-11	J253	3.652	0.023	CIRCULAR	0.3	0	0.043
L-AMAG-11_2	J253	J-AMAG-12	3.4	0.023	CIRCULAR	0.4	0	0.225
L-AMAG-13_1	J-AMAG-13	J249	4.943	0.023	CIRCULAR	0.35	0	0.032
L-AMAG-13_2	J249	J-AMAG-14	5.302	0.023	CIRCULAR	0.3	0	0.032
L-AMAG-15_1	J-AMAG-15	J248	3.447	0.023	CIRCULAR	0.27	0	0.043
L-AMAG-15_2	J248	J-AMAG-16	3.797	0.023	CIRCULAR	0.35	0	0.043
L-AMAG-17	J-AMAG-17	J-AMAG-18	6.545	0.023	CIRCULAR	0.35	0	0.036
L-AMAG-19	J-AMAG-19	J-AMAG-20	9.503	0.023	CIRCULAR	0.4	0	0.023
L-AMAG-21_1	J-AMAG-21	J250	4.765	0.023	CIRCULAR	0.35	0	0.017
L-AMAG-21_2	J250	J-AMAG-22	4.913	0.023	CIRCULAR	0.35	0	0.018
L-CORO-01	J-CORO-01	J-CORO-02	15.163	0.023	CIRCULAR	0.35	0	0.005
L-HIKO-10	J-HIKO-10	J-HIKO-09	11.39	0.023	CIRCULAR	0.4	0	-0.007
L-HIKO-11_1	J-HIKO-11	J220	8.973	0.023	CIRCULAR	0.35	0	0.044
L-HIKO-11_2	J220	J-HIKO-12	8.933	0.023	CIRCULAR	0.27	0	0.044
L-KALV-01_1	J-KALV-01	J251	21.776	0.023	CIRCULAR	0.01	0	0.043

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Diameter	Geom2 (m)	Slope (m/m)
L-KALV-01_2	J251	J-KALV-02	21.971	0.023	CIRCULAR	0.05	0	0.043
L-KALV-03_1	J-KALV-03	J252	5.226	0.023	CIRCULAR	0.37	0	0.041
L-KALV-03_2	J252	J-KALV-04	4.84	0.023	CIRCULAR	0.26	0	0.041
L-KALV-05	J-KALV-05	J-KALV-06	12.477	0.023	CIRCULAR	0.4	0	0.016
L-KUGL-03_1	J241	J-KUGL-05	6.472	0.023	CIRCULAR	0.25	0	0.031
L-KUGL-03_2	J-KUGL-04	J241	7.621	0.023	CIRCULAR	0.35	0	0.031
L-KUGL-07_1	J-KUGL-07	J244	16.791	0.023	CIRCULAR	0.4	0	0.034
L-KUGL-07_2	J244	J-KUGL-08	16.775	0.023	CIRCULAR	0.25	0	0.034
L-UMIN-01	J-UMIN-01	J-UMIN-02	7.662	0.014	CIRCULAR	0.1	0	0.013
L-UMIN-03	J-UMIN-03	J-UMIN-04	12.053	0.023	CIRCULAR	0.01	0	0.025
L-UMIN-05	J-UMIN-05	J-UMIN-06	14.717	0.023	CIRCULAR	0.4	0	0.068
C10	J-NIPT-02	J3	20.237	0.023	TRAPEZOIDAL	1	1	0.012
C100	J66	J67	9.81	0.05	TRAPEZOIDAL	1	4	0.053
C101	J67	J68	13.732	0.05	TRAPEZOIDAL	1	4	0.018
C102	J68	J-TUKT-01	20.208	0.05	TRAPEZOIDAL	1	4	0.006
C103	J-OKAL-04	J-OKAL-01	48.504	0.035	TRAPEZOIDAL	1	4	0.019
C104	J-TUKT-02	J69	28.385	0.035	TRAPEZOIDAL	1	2	0.036
C105	J69	J70	25.205	0.035	TRAPEZOIDAL	1	2	0.041
C106	J70	J-SADD-09	13.572	0.035	TRAPEZOIDAL	1	2	0.040
C107	J-KUGL-02	J71	12.823	0.035	TRAPEZOIDAL	1	1	0.050
C108	J-SADD-12	J71	12.058	0.035	TRAPEZOIDAL	1	1	0.031
C109	J71	J72	16.402	0.035	TRAPEZOIDAL	1	1	0.018
C110	J72	J73	17.609	0.035	TRAPEZOIDAL	1	1	0.017
C111	J73	J-KUGL-05	9.671	0.035	TRAPEZOIDAL	1	1	0.021
C114	J-SADD-10	J75	16.098	0.035	TRAPEZOIDAL	1	2	0.039
C115	J75	J76	17.252	0.035	TRAPEZOIDAL	1	2	0.055
C116	J76	J77	12.224	0.035	TRAPEZOIDAL	1	2	0.038
C117	J77	J78	11.871	0.035	TRAPEZOIDAL	1	2	0.013
C118	J78	J71	37.564	0.035	TRAPEZOIDAL	1	2	0.036
C119	J-KUGL-10	J79	28.641	0.035	TRAPEZOIDAL	1	2	0.028
C16	J-NIPT-06	J3	20.308	0.023	TRAPEZOIDAL	1	1	0.007
C163	J91	J-HILL-01	76.639	0.035	TRAPEZOIDAL	1	2	0.011
C17	J-NIGL-02	J-NIGL-03	28.562	0.035	TRAPEZOIDAL	1	1	0.028
C18	J-NIGL-04	J-NIGL-05	45.536	0.035	TRAPEZOIDAL	1	1	0.028
C26	J-KILG-04	J-KILG-05	4.322	0.035	TRAPEZOIDAL	1	2	0.025
C287	J221	J-KAIY-12	122.19	0.035	TRAPEZOIDAL	1	4	0.000
C288	J261	J242	22.042	0.035	TRAPEZOIDAL	1	4	0.000
C3	J-AGHA-02	J1	56.972	0.035	TRAPEZOIDAL	1	3	-0.004
C302	J230	J-KILG-01	36.505	0.05	TRAPEZOIDAL	1	3	-2.318
C303	J234_M	J-NIPT-03	29.7	0.035	TRAPEZOIDAL	1	1	0.001

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Diameter	Geom2 (m)	Slope (m/m)
C310	J264	J-HIKO-06	87.682	0.035	TRAPEZOIDAL	1	6	0.026
C33	J16	J-ANAV-09	11.452	0.035	TRAPEZOIDAL	1	1	0.027
C34	J16	J-OKAL-01	19.433	0.035	TRAPEZOIDAL	1	4	0.014
C35	J-NIPT-08	J17	14.969	0.035	TRAPEZOIDAL	1	4	0.055
C36	L-NIPT-10	J17	19.406	0.035	TRAPEZOIDAL	1	4	0.010
C4	J1	J-HILL-01	18.475	0.035	TRAPEZOIDAL	1	3	0.063
C41	J21	J-NIGL-05	18.122	0.035	TRAPEZOIDAL	1	4	0.037
C42	J-NIGL-05	J-ANAV-05	10.054	0.035	TRAPEZOIDAL	1	4	0.010
C43	J-TIPT-02	J22	13.35	0.035	TRAPEZOIDAL	1	1	0.002
C44	J22	J23	13.416	0.035	TRAPEZOIDAL	1	1	0.021
C45	J23	J-AGHA-01	9.764	0.035	TRAPEZOIDAL	1	1	0.032
C5	J-HILL-02	J2	9.435	0.035	TRAPEZOIDAL	1	1	0.091
C57	J31	J-KILG-07	9.479	0.035	TRAPEZOIDAL	1	2	0.004
C58	J-OKAL-02	J-ANAV-01	1.803	0.035	TRAPEZOIDAL	1	4	0.029
C59	J-ANAV-02	J32	18.029	0.05	TRAPEZOIDAL	1	4	0.073
C6	J-SADD-02	J2	5.918	0.023	TRAPEZOIDAL	1	1	0.094
C60	J32	J33	23.173	0.05	TRAPEZOIDAL	1	4	-0.017
C61	J33	J34	12.84	0.05	TRAPEZOIDAL	1	4	0.029
C62	J34	J35	13.616	0.05	TRAPEZOIDAL	1	4	0.035
C63	J35	J36	11.086	0.05	TRAPEZOIDAL	1	4	0.038
C64	J36	J37	10.925	0.05	TRAPEZOIDAL	1	4	0.007
C65	J37	J-TUKT-03	7.151	0.05	TRAPEZOIDAL	1	4	0.042
C7	J2	J-SADD-03	50.519	0.023	TRAPEZOIDAL	1	1	0.030
C8	J-SADD-04	J-NIPT-01	22.996	0.035	TRAPEZOIDAL	1	4	0.018
C9	J-SADD-06	J-NIPT-02	19.097	0.023	TRAPEZOIDAL	1	1	0.031
C92	J-KUGL-06	J-KUGL-09	44.278	0.035	TRAPEZOIDAL	1	2	0.028
C94	J-SADD-08	J63	52.363	0.05	TRAPEZOIDAL	1	4	0.030
C95	J-KILG-02	J63	50.015	0.05	TRAPEZOIDAL	1	4	0.032
C96	J63	J-OKAL-05	25.741	0.05	TRAPEZOIDAL	1	4	0.023
C97	J-OKAL-06	J64	25.06	0.05	TRAPEZOIDAL	1	4	0.110
C98	J64	J65	17.132	0.05	TRAPEZOIDAL	1	4	0.045
C99	J65	J66	14.467	0.05	TRAPEZOIDAL	1	4	0.050
L-AGHA-01_1	J-AGHA-01	J90	2.816	0.023	CIRCULAR	0.15	0	0.023
L-AGHA-01_2	J90	J-AGHA-02	2.659	0.023	CIRCULAR	0.4	0	0.023
L-ANAV-01	J-ANAV-01	J-ANAV-02	11.514	0.023	CIRCULAR	0.27	0	0.050
L-HIKO-04_1	J-HIKO-04	J263	6.444	0.023	CIRCULAR	0.5	0	0.012
L-HIKO-04_2	J263	J-HIKO-05	6.769	0.023	CIRCULAR	0.4	0	0.012
L-HIKO-07_1	J-HIKO-07	J4	9.525	0.023	CIRCULAR	0.01	0	0.090
L-HIKO-07_2	J4	J-HIKO-08	7.238	0.023	CIRCULAR	0.25	0	0.090
L-HILL-01	J-HILL-01	J-HILL-02	15.866	0.023	CIRCULAR	0.27	0	0.028

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Diameter	Geom2 (m)	Slope (m/m)
L-KAIY-09_1	J-KAIY-09	J262	6.586	0.023	CIRCULAR	0.3	0	0.000
L-KAIY-09_2	J262	J-KAIY-10	6.32	0.023	CIRCULAR	0.4	0	0.000
L-KAIY-11_1	J-KAIY-11	J260	7.394	0.023	CIRCULAR	0.25	0	0.000
L-KAIY-11_2	J260	J-KAIY-12	7.539	0.023	CIRCULAR	0.2	0	-0.001
L-KILG-01_1	J-KILG-01	J231	6.838	0.023	CIRCULAR	0.45	0	0.070
L-KILG-01_2	J231	J-KILG-02	6.603	0.023	CIRCULAR	0.35	0	0.070
L-KILG-03	J-KILG-03	J-KILG-04	8.471	0.023	CIRCULAR	0.37	0	0.030
L-KILG-05	J-KILG-05	J-KILG-06	16.859	0.023	CIRCULAR	0.4	0	0.030
L-KILG-07	J-KILG-07	J-KILG-08	15.31	0.023	CIRCULAR	0.4	0	0.024
L-KUGL-01_1	J-KUGL-01	J240	8.485	0.023	CIRCULAR	0.12	0	0.032
L-KUGL-01_2	J240	J-KUGL-02	8.82	0.023	CIRCULAR	0.38	0	0.032
L-KUGL-05_1	J-KUGL-05	J243	9.248	0.023	CIRCULAR	0.4	0	0.013
L-KUGL-05_2	J243	J-KUGL-06	9.381	0.023	CIRCULAR	0.4	0	0.013
L-KUGL-09_1	J-KUGL-09	J245	6.998	0.023	CIRCULAR	0.32	0	-0.007
L-KUGL-09_2	J245	J-KUGL-10	7.656	0.023	CIRCULAR	0.2	0	-0.007
L-NIGL-01_1	J-NIGL-01	J232	5.437	0.023	CIRCULAR	0.45	0	0.027
L-NIGL-01_2	J232	J-NIGL-02	5.625	0.023	CIRCULAR	0.5	0	0.027
L-NIGL-03	J-NIGL-03	J-NIGL-04	12.486	0.023	CIRCULAR	0.45	0	0.042
L-NIGL-05_1	J-NIGL-05	J233	7.507	0.023	CIRCULAR	0.45	0	0.014
L-NIGL-05_2	J233	J-NIGL-06	7.81	0.023	CIRCULAR	0.01	0	0.014
L-NIPT-01_1	J-NIPT-01	J123	6.193	0.023	CIRCULAR	0.325	0	0.034
L-NIPT-01_2	J123	J-NIPT-02	6.423	0.023	CIRCULAR	0.5	0	0.033
L-NIPT-03_1	J-NIPT-03	J124	4.395	0.023	CIRCULAR	0.2	0	-0.007
L-NIPT-03_2	J124	J-NIPT-01	4.382	0.023	CIRCULAR	0.01	0	-0.007
L-NIPT-05_1	J-NIPT-05	J128	7.442	0.023	CIRCULAR	0.115	0	0.047
L-NIPT-05_2	J128	J-NIPT-06	7.912	0.023	CIRCULAR	0.27	0	0.047
L-NIPT-07_1	J-NIPT-07	J129	5.257	0.023	CIRCULAR	0.2	0	0.017
L-NIPT-07_2	J129	J-NIPT-08	5.452	0.023	CIRCULAR	0.55	0	0.017
L-NIPT-09_1	J-NIPT-09	J229	6.778	0.023	CIRCULAR	0.45	0	0.057
L-NIPT-09_2	J229	L-NIPT-10	7.071	0.023	CIRCULAR	0.35	0	0.057
L-OKAL-01_1	J-OKAL-01	J235	7.091	0.023	CIRCULAR	0.45	0	0.041
L-OKAL-01_2	J235	J-OKAL-02	7.058	0.023	CIRCULAR	0.5	0	0.041
L-OKAL-03_1	J-OKAL-03	J234	16.397	0.023	CIRCULAR	0.35	0	0.022
L-OKAL-03_2	J234	J-OKAL-04	16.819	0.023	CIRCULAR	0.15	0	0.022
L-OKAL-05	J-OKAL-05	J-OKAL-06	15.601	0.023	CIRCULAR	0.4	0	0.063
L-SADD-01	J-SADD-01	J-SADD-02	18.532	0.023	CIRCULAR	0.075	0	0.008
L-SADD-03_1	J-SADD-03	J127	6.011	0.023	CIRCULAR	0.01	0	0.039
L-SADD-03_2	J127	J-SADD-04	8.032	0.023	CIRCULAR	0.26	0	0.029
L-SADD-05_1	J-SADD-05	J115	8.831	0.023	CIRCULAR	0.35	0	0.033
L-SADD-05_2	J115	J-SADD-06	8.388	0.023	CIRCULAR	0.45	0	0.032

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Diameter	Geom2 (m)	Slope (m/m)
L-SADD-07	J-SADD-07	J-SADD-08	22.181	0.023	CIRCULAR	0.27	0	0.037
L-SADD-09_1	J-SADD-09	J238	4.713	0.023	CIRCULAR	0.25	0	0.041
L-SADD-09_2	J238	J-SADD-10	4.964	0.023	CIRCULAR	0.27	0	0.041
L-SADD-11_1	J-SADD-11	J239	10.462	0.023	CIRCULAR	0.27	0	0.067
L-SADD-11_2	J239	J-SADD-12	10.495	0.023	CIRCULAR	0.38	0	0.067
L-TIPT-01	J-TIPT-01	J-TIPT-02	14.443	0.023	CIRCULAR	0.27	0	0.002
L-TUKT-01_1	J-TUKT-01	J237	8.079	0.023	CIRCULAR	0.5	0	0.076
L-TUKT-01_2	J237	J-TUKT-02	8.296	0.023	CIRCULAR	0.47	0	0.076
L-TUKT-03_1	J-TUKT-03	J236	17.544	0.023	CIRCULAR	0.3	0	0.056
L-TUKT-03_2	J236	J-TUKT-04	17.806	0.023	CIRCULAR	0.5	0	0.056
C11	J3	J-NIGL-01	76.864	0.035	TRAPEZOIDAL	1	4	0.020
C40	J17	J21	58.525	0.035	TRAPEZOIDAL	1	4	0.058
C31	J13	J16	37.931	0.035	TRAPEZOIDAL	1	4	0.034
C29	J-KILG-06	J13	16.461	0.035	TRAPEZOIDAL	1	1	0.005
C12	J-KILG-06	J-KILG-08	33.548	0.035	TRAPEZOIDAL	1	4	0.029
C168	J-HIKO-08	J118	22.362	0.035	TRAPEZOIDAL	1.5	1	0.013
C165	J-HIKO-05	J-HIKO-08	40.813	0.035	TRAPEZOIDAL	1.5	1	-0.001
C132	J-UMIN-06	J87	203.843	0.035	TRAPEZOIDAL	0.5	1	0.032
C144_1	J-KALV-02	J5	32.67	0.035	TRAPEZOIDAL	1	1	0.016
C144_2	J5	J95	22.565	0.035	TRAPEZOIDAL	1	1	0.016
C87	J-TUKT-04	J53	132.692	0.035	TRAPEZOIDAL	1	1	0.051
C178	J-INUI-04	OF2	76.039	0.035	TRAPEZOIDAL	1	1	0.039
C13	J135	J6	17.39	0.023	CIRCULAR	0.5	0	1.634
C14	J6	J58	48.379	0.035	TRAPEZOIDAL	1	1	0.023
C15	J-AMAG-03	J-UMIN-05	28.563	0.01	TRAPEZOIDAL	0.5	1	0.015
C83	J41	J53	193.603	0.035	TRAPEZOIDAL	1	1	0.032
C19	J-UMIN-07	J261	25.989	0.03	TRAPEZOIDAL	1	2	0.470
KlugCulvert_1	J61	J7	18.226	0.023	CIRCULAR	0.3	0	0.033
KlugCulvert_2	J7	J59	15.457	0.023	CIRCULAR	0.6	0	0.033
C28	J12	J14	14.097	0.023	CIRCULAR	0.4	0	0.000
C30	J14	J-OLIG-01	301.421	0.035	TRAPEZOIDAL	1	2	0.030
C32	J15	J18	13.286	0.023	CIRCULAR	0.6	0	0.000
C37	J18	OF1	48.013	0.035	TRAPEZOIDAL	1	2	0.000
C25_1	J9	J19	51.62	0.028	TRAPEZOIDAL	1	1	0.031
C25_2	J19	J-OLIG-01	79.447	0.028	TRAPEZOIDAL	1	1	0.031
C25	J-ANAV-08	J19	67.542	0.035	TRAPEZOIDAL	1	1	0.046

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.

Any unauthorized use of the Professional Document is at the sole risk of the user. TETRA TECH accepts no responsibility whatsoever for any loss or damage where such loss or damage is alleged to be or, is in fact, caused by the unauthorized use of the Professional Document.

Where TETRA TECH has expressly authorized the use of the Professional Document by a third party (an “Authorized Party”), consideration for such authorization is the Authorized Party’s acceptance of these Limitations on Use of this Document as well as any limitations on liability contained in the Contract with the Client (all of which is collectively termed the “Limitations on Liability”). The Authorized Party should carefully review both these Limitations on Use of this Document and the Contract prior to making any use of the Professional Document. Any use made of the Professional Document by an Authorized Party constitutes the Authorized Party’s express acceptance of, and agreement to, the Limitations on Liability.

The Professional Document and any other form or type of data or documents generated by TETRA TECH during the performance of the work are TETRA TECH’s professional work product and shall remain the copyright property of TETRA TECH.

The Professional Document is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of TETRA TECH. Additional copies of the Document, if required, may be obtained upon request.

1.2 ALTERNATIVE DOCUMENT FORMAT

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

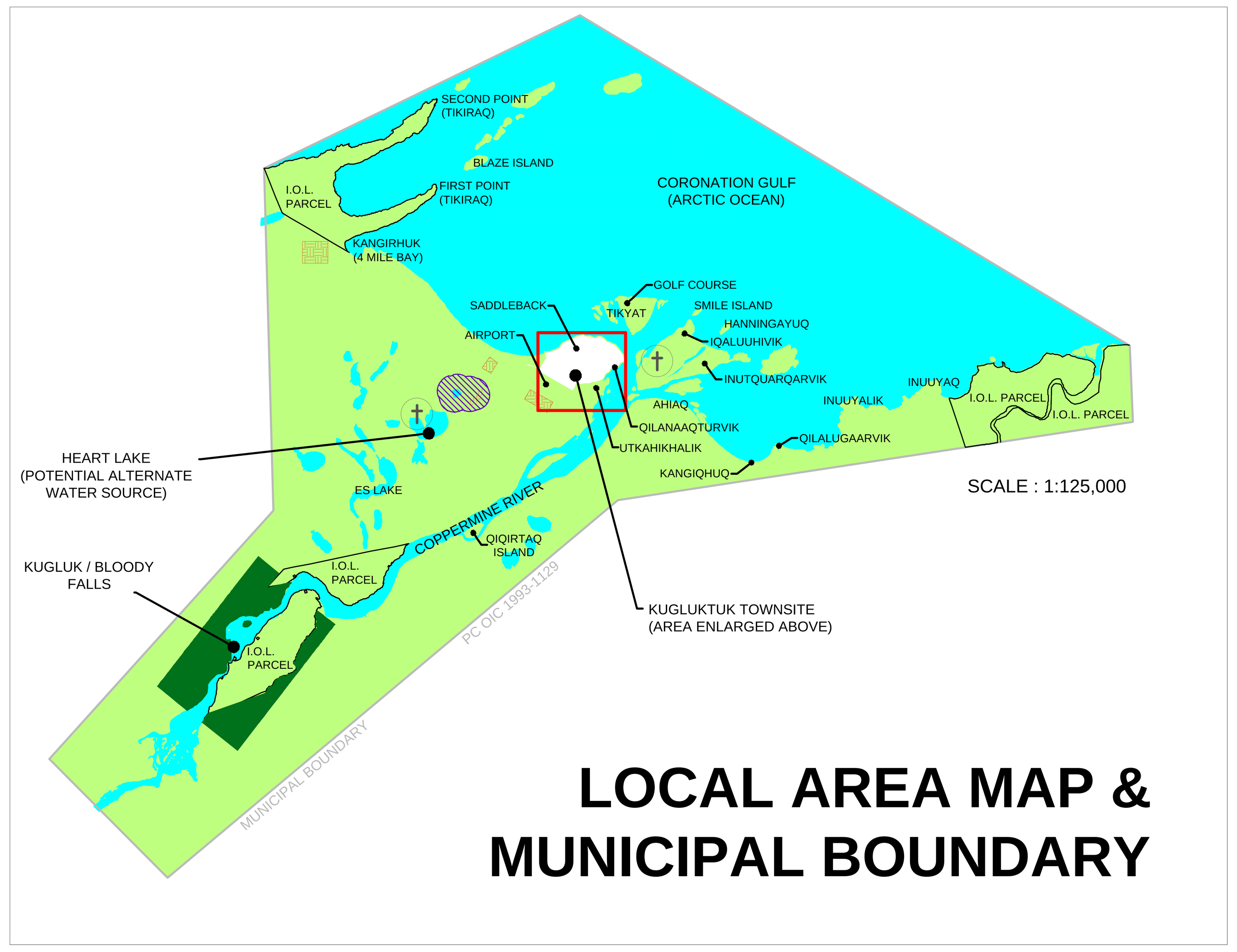
KUGLUKTUK COMMUNITY PLAN & ZONING MAP

SCHEDULE 2:
KUGLUKTUK COMMUNITY PLAN & ZONING MAP

LEGEND

- EXISTING ROAD
- EXISTING TRAIL
- EXISTING LEGAL SURVEY LINE / LOT LINE (2016)
- SKETCH LOT / PROPOSED LOT LINE
- ELEVATION CONTOUR LINE (5 METRE INTERVAL)
- WATERBODY
- STREAM
- BUILDING FOOTPRINT
- CHURCH
- CEMETERY

1	HAMLET BUILDING	16	POST OFFICE
2	RECREATION COMPLEX	17	CO-OP STORE
3	ULU HERITAGE CENTRE	18	NORTHERN STORE
4	KUGLUKTUK HIGH SCHOOL	19	JMS SUPPLIES LTD.
5	JIMMY HIKOK ILIHAKVIK	20	CONVENIENCE STORE
6	ELDERS' CENTRE	21	AVIAK'S STORE
7	HEALTH CENTRE	22	KIKIAK CONTRACTING
8	PRE-NATAL CENTRE	23	AIRPORT TERMINAL
9	ILAVUT CENTRE	24	POWER / WATER FACILITY
10	FIRE HALL	25	TANK FARM
11	R.C.M.P. DETACHMENT	26	FIRST AIR CARGO
12	COPPERMINE INN	27	HOUSING OFFICE
13	ENOKHOK INN	28	GAS STATION
14	K.I.A. OFFICE	29	FUTURE SITE FOR NEW POWER PLANT
15	H.T.O. OFFICE	30	FUTURE SITE FOR CONTINUING CARE CENTRE



LOCAL AREA MAP & MUNICIPAL BOUNDARY

ZONING SUMMARY

RESIDENTIAL (R)

Permitted Uses:

- Dwelling, Single-Unit
- Dwelling, Semi-Detached or Duplex
- Dwelling, Row house
- Park or Playground
- Any accessory building which is related to the main use or building and follows the rules in section 5 of the Zoning By-law.

Conditionally Permitted Uses:

- Dwelling, Multi-Unit
- Dwelling, Mini Home
- Bed and Breakfast
- Craft Studio
- Day Care Centre
- Elders Facility
- Group Home
- Home Occupation
- Secondary Suite

COMMERCIAL (C)

Permitted Uses:

- Office
- Restaurant
- Bank
- Gas station
- Convenience Store
- Retail Store
- Craft Studio
- Day Care Centre
- Hotel
- Office
- Personal Service
- Restaurant
- Any accessory building which is related to the main use or building and is allowed in section 5 of the Zoning By-law.

Conditionally Permitted Uses:

- Dwelling unit above the ground floor in a non-residential building
- Business in a home
- Accessory dwelling

COMMUNITY USE (CU)

Permitted Uses:

- Church
- Communications Facility
- Community Hall or Centre
- School or College
- Elders Facility
- Fire Hall
- Government Office
- Group Home
- Health Care Facility
- Parking Lot
- Police Station
- Post Office
- Any accessory building which is related to the main use or building and is allowed in section 5 of the Zoning By-law.

Conditionally Permitted Uses:

- Cemetery
- Accessory dwelling

OPEN SPACE (OS)

Permitted Uses:

- Archaeological site
- Monument, cairn, or statue
- Park or playground
- Sports field
- Washroom facility
- Shed to store equipment for traditional, cultural, and recreational activities taking place in the Zone.

INDUSTRIAL (I)

Permitted Uses:

- Automotive Repair, Sales or Facility
- Building Supply or Contractors Shop
- Dwelling unit for a person who is taking care of a nearby building or lot
- Outdoor storage
- Rental Shop
- Warehouse
- Communications facility
- Any accessory building which is related to the main use or building and is allowed in section 5 of the Zoning By-law.

Conditionally Permitted Uses:

- Barge staging and landing site with associated warehousing
- Hazardous Goods storage
- Power plant
- Tank farm

TRANSPORTATION (T)

Permitted Uses :

- Airport and related uses
- Communications Facility
- Marine Transportation and related uses

FUTURE DEVELOPMENT (FD)

The Future Development Zone refers to lands reserved for the future growth of the community and that might have environmental barriers to development. No development is allowed in this zone.

NUNA (N)

Permitted Uses:

- Archaeological Site
- Dog Team
- Temporary tenting or camping

Conditionally Permitted Uses:

- Beach Shack
- Quarry
- Cemetery
- Commercial Harvesting
- Communications Facility
- Permanent hunting and fishing cabins or camps
- Resource exploration and development
- Snow fence
- Tourist facilities
- Wind Turbine
- Any accessory building allowed in section 5 of the Zoning By-law.

PARK RESERVE (PR)

Nunavut Parks, for the Government of Nunavut, will administer the lands at Bloody Falls established as a Territorial Park or identified as a Park Reserve. As such, Nunavut Parks will establish Management Zones and regulate the use and development of the park area for the benefit of the residents of Kugluktuk and visitors to the area. Nunavut Parks will administer the development and use of the land with consultation and direction from Hamlet Council in the planning process for development within those lands.

DEVELOPMENT CONSTRAINT OVERLAY (DC)

This zone is intended to show development barriers to development on specified sites. Development Constraint overlays sit "above" zones and add additional development restrictions. Development in these areas must follow the rules of the overlay(s) and the rules of the zone underneath.

ARCHAEOLOGICAL RESERVE (DC-AR)

To protect Archaeological sites from destruction, no development may occur in this Overlay.

AVIATION BEACON SETBACK (DC-AB)

A 200 metre radius setback is established around the Non-Directional Beacon (NDB) towers, as required by Transport Canada regulations. No development is allowed within this overlay.

QUARRY RESERVE (DC-QR)

This overlay contains sites close to the built-up area that have been identified as containing granular resources that must be protected for future extraction. Only Pits, Quarries, and Asphalt Pits are allowed in this overlay.

SCHOOL RESERVE (DC-SR)

The School Reserve contains sites that have been identified for a future school. A school is the only permanent permitted use on the site, but parks and recreation facilities are also permitted on the site in the interim.

WASTE DISPOSAL SETBACK (DC-WD)

Waste Disposal Sites are conditionally permitted in this overlay. No houses or commercial buildings involving food storage or preparation are allowed within 450 metres of a Waste Disposal Site.

WATERFRONT RESERVE (DC-WR)

Permitted Uses in this overlay include: Beach Shacks, Boat Storage, Dock, Temporary Outdoor Storage of sealift equipment during sealift, and Snow Fence.

APPENDIX C

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

US005986237A

United States Patent [19]

Sterling et al.

[11] **Patent Number: 5,986,237**

[45] **Date of Patent: Nov. 16, 1999**

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

[75] Inventors: **Robert Laurel Sterling**, Grande Prairie; **Rudiger Schmidt**, Wainwright, both of Canada

[73] Assignee: **Iceworm International Inc.**, Alberta, Canada

[21] Appl. No.: **08/936,825**

[22] Filed: **Sep. 25, 1997**

[51] **Int. Cl.**^{6} **H05B 1/00**; H01C 3/06

[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

[56] **References Cited**

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Primary Examiner—Teresa Walberg

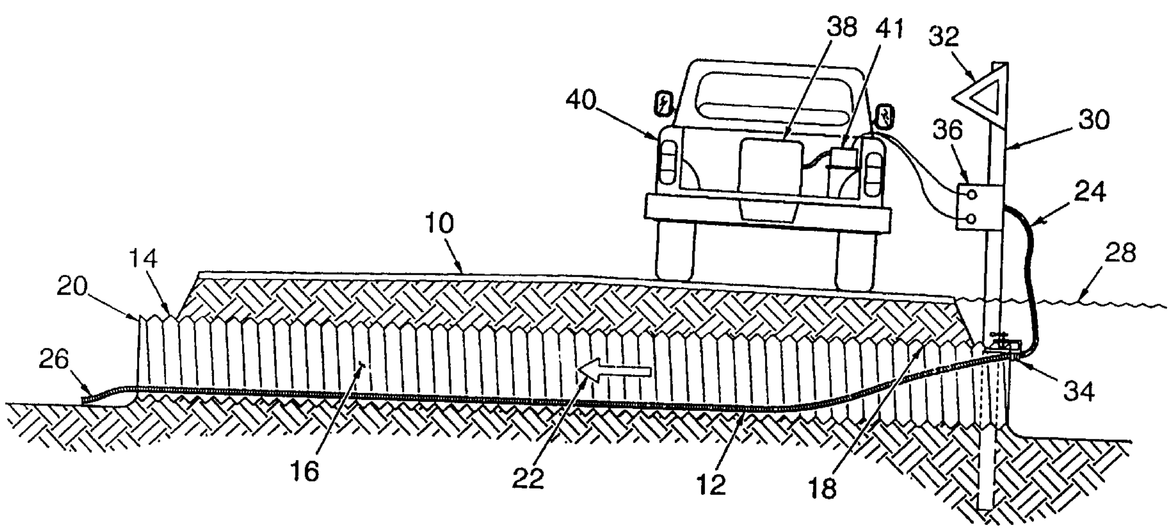
Assistant Examiner—Thor S. Campbell

Attorney, Agent, or Firm—Davis and Bujold

[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



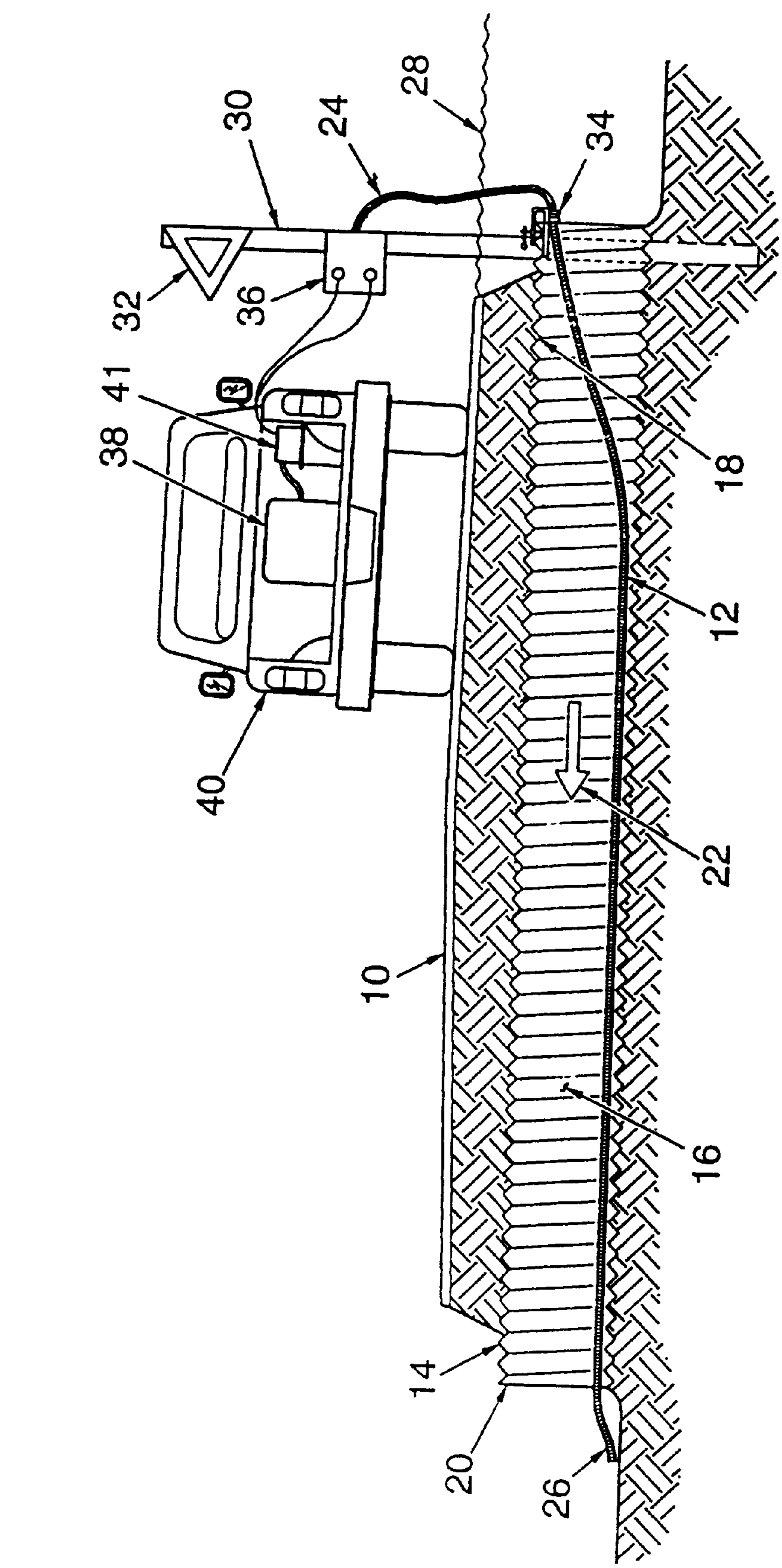


FIGURE 1

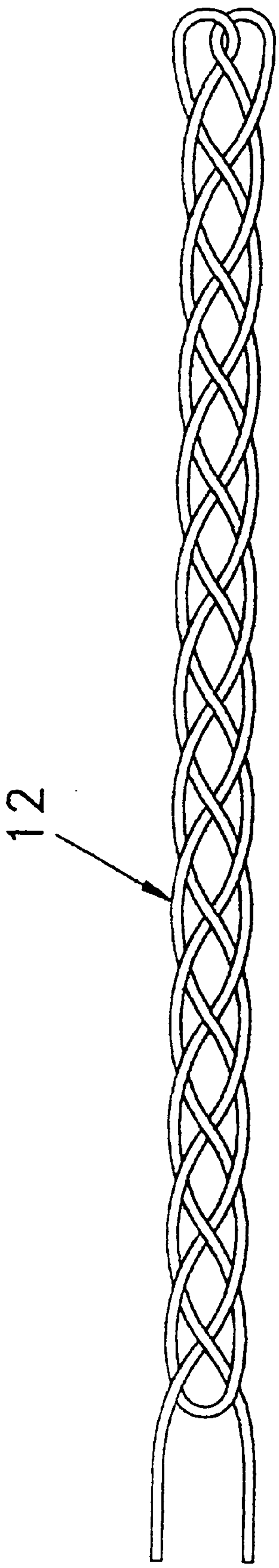


FIGURE 2

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.

* * * * *

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

[21] Appl. No.: **931,722**

[22] PCT Filed: **Feb. 24, 1986**

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

§ 371 Date: **Oct. 24, 1986**

§ 102(e) Date: **Oct. 24, 1986**

[87] PCT Pub. No.: **WO86/04939**

PCT Pub. Date: **Aug. 28, 1986**

[30] **Foreign Application Priority Data**

Feb. 25, 1985 [SE] Sweden 8500914

[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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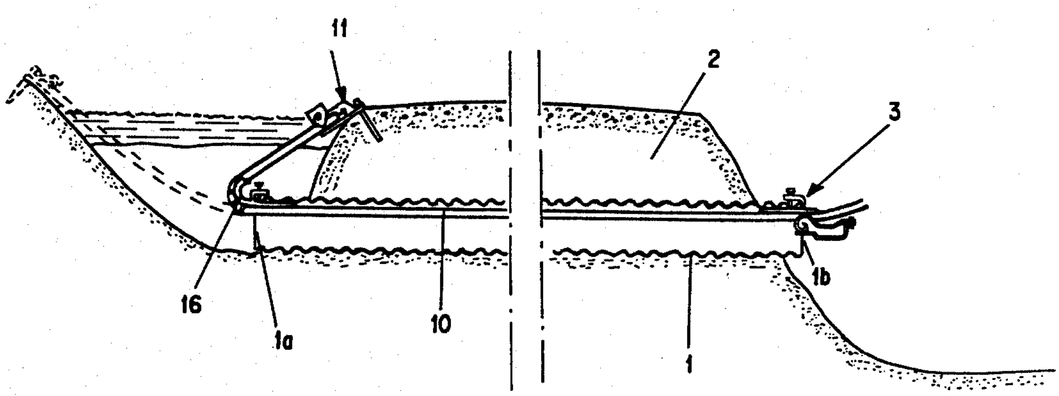
Primary Examiner—James E. Bryant, III

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



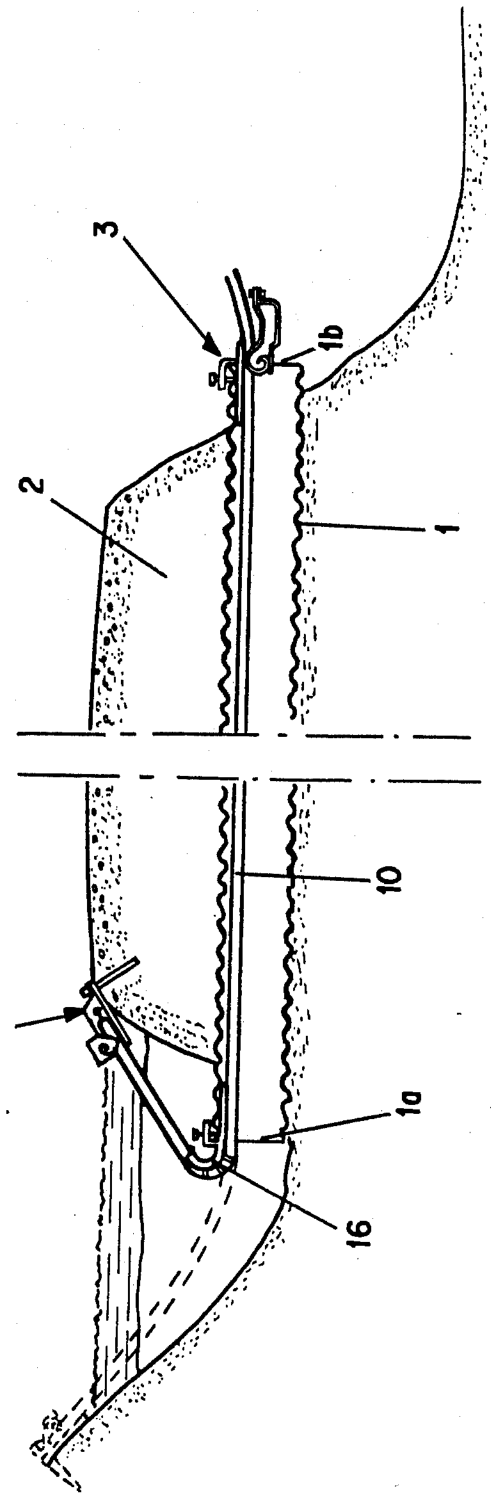


Fig. 1

Fig. 5

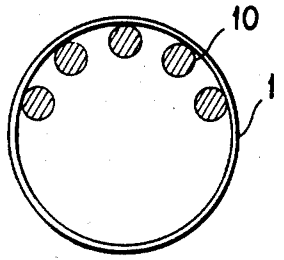
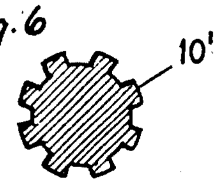


Fig. 6



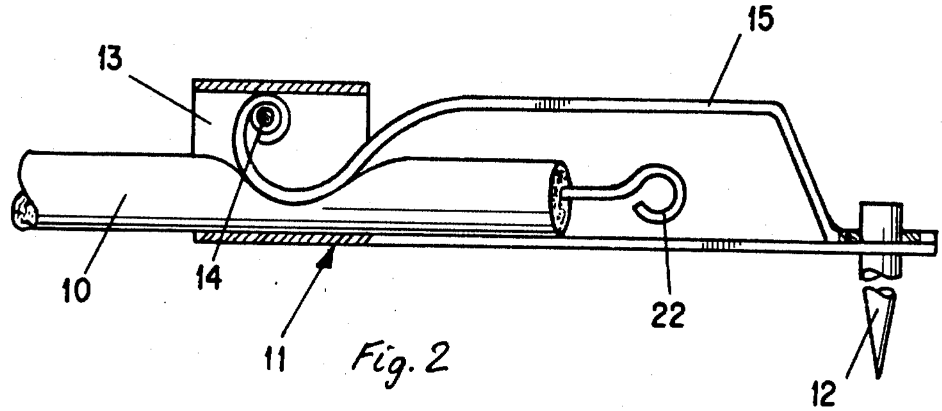


Fig. 2

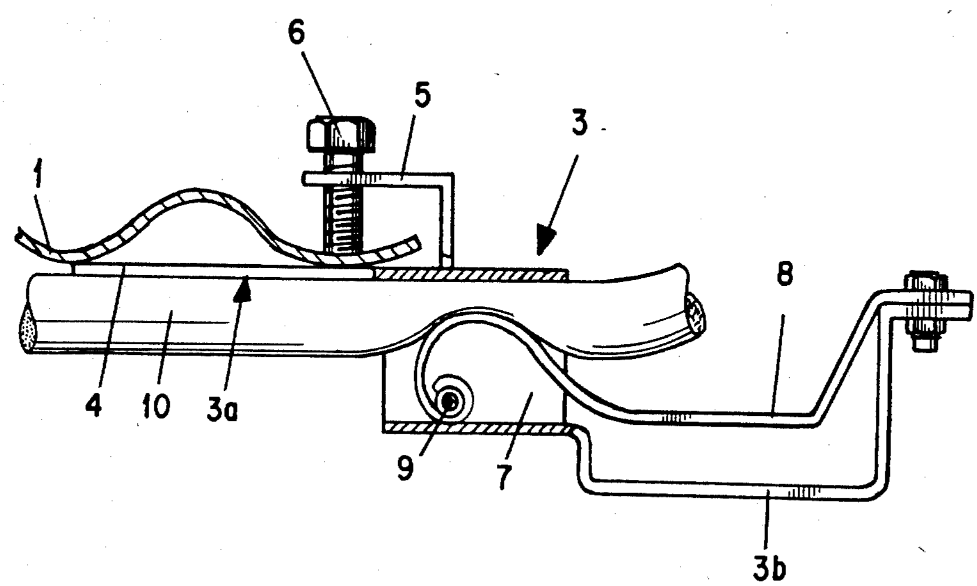
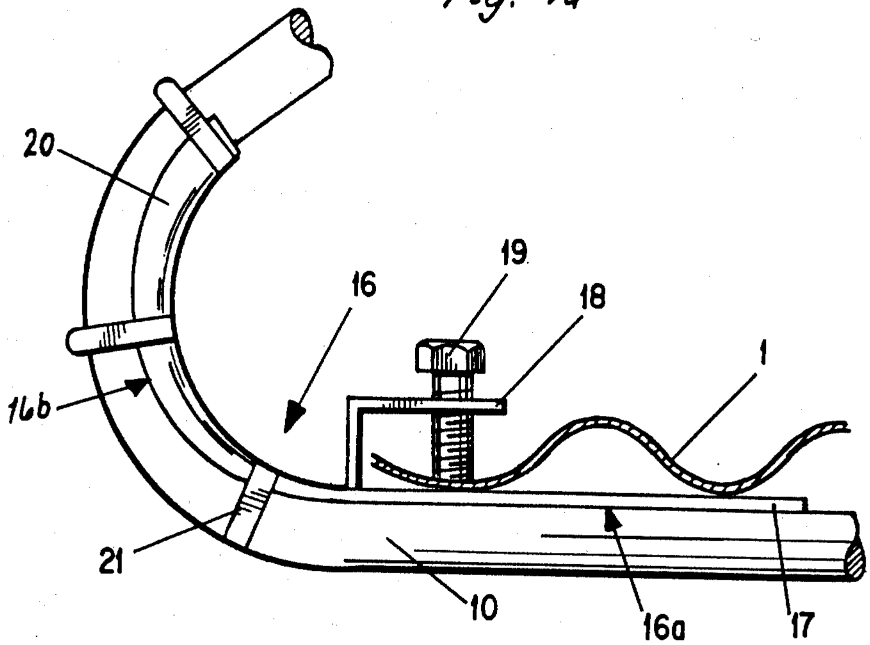


Fig. 3

Fig. 4a



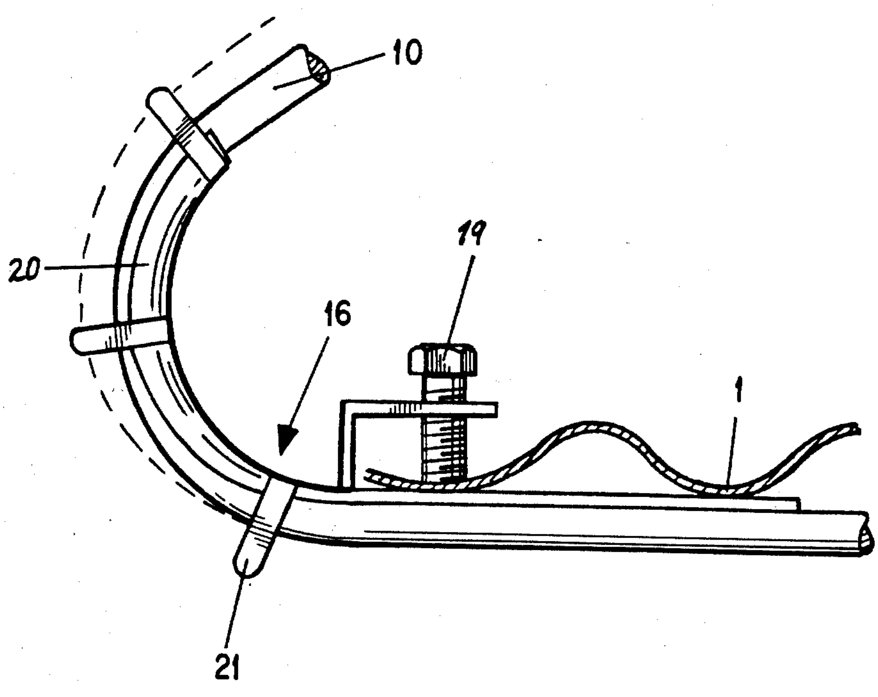


Fig. 4b

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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