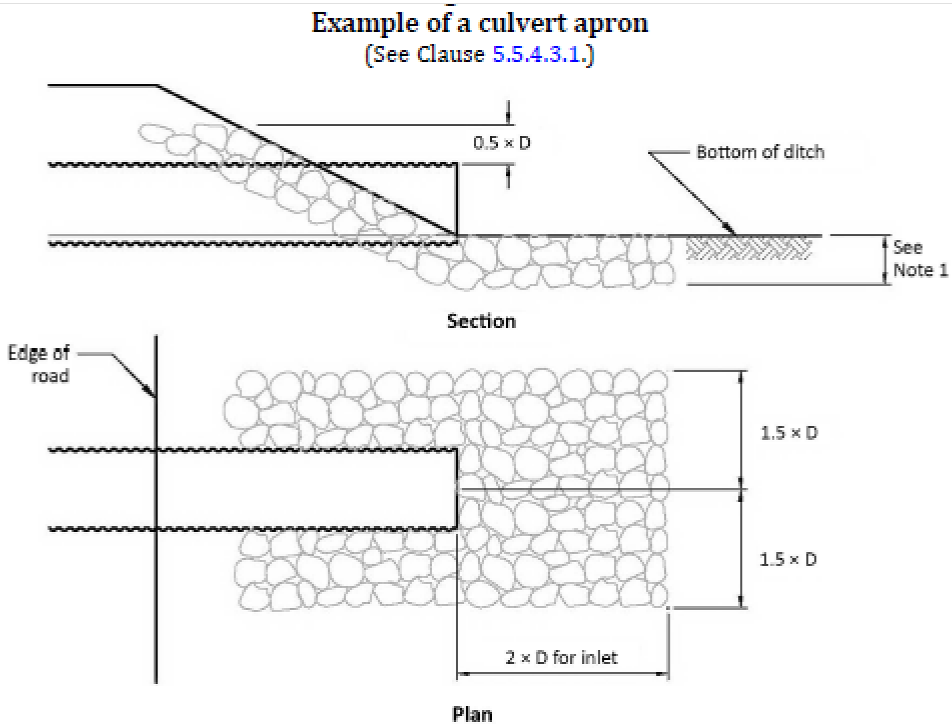
4. Material for temporary signs, such as subdivision layout signs, shall be approved by the City prior to installation.

E-9 DRAINAGE AND CULVERTS

1. Drainage systems shall meet the flow requirements outlined in Section H for both local and collector cross sections.
2. Ditches for roadways shall have back slopes no steeper than 3H:IV, and no flatter than 2H:1V.
3. Swale and ditch grades shall match the road grades wherever possible.
4. Swale and ditch grades shall have a minimum grade of 0.5% wherever possible. Grades less than 0.5% shall be subject to review and approval by the City Engineer.
5. Drainage channels shall be provided with ditch checks and/or other means of erosion control as necessary.
6. Ditches shall have a flat bottom, width as per applicable design standard and shall be designed to accommodate 1:5 year rainfall event.
7. The minimum inside diameter of cross road culverts is 18 inches. Smaller diameter culverts may be allowed if it can be demonstrated that glaciation will not be a problem, the pipe will handle peak flows, pipe cover is adequate and the ditch depths are sufficient. Actual culvert sizing shall be based on IDF curves shown on Figure H.3.1 and icing potential. Ditches shall be allowed to back up during such an event to the height of the subgrade.
8. Culverts shall be new galvanized corrugated steel pipe with a minimum wall thickness of 1.6mm or as required to meet the design loading criteria.
9. All culverts shall have appropriate end treatments depending on application. Inverts shall be extended to the toe of the side slope.
10. The culvert grade shall not be less than the ditch grades at the inlet and outlet.
11. Culverts shall have a sufficient amount of cover to protect against damage from the expected traffic loading. Minimum cover shall be 300mm or one-half the diameter of the culvert, whichever is greater as measured from the finished shoulder grade tot he top of the culvert.
12. Where multiple culverts are needed at a single location, the upstream inverts shall be designed to reduce the risk of icing of the culverts. To reduce the risk of culvert icing, the culverts can be placed at slightly different elevations to prevent blockage of all the culverts at the same time.
13. Culverts shall be installed according to the manufacturer's recommendations and industry accepted practices. Care shall be taken to avoid damage to culverts during installation. Where applicable, culverts shall have adequate soil cover to maintain their structural strength. Culverts shall be clearly marked to avoid damage from road maintenance equipment. Figure E-9-1 provides an example of a culvert apron.



1) *Riprap should be 300 mm for diameters less than 1400 mm, and 600 mm for diameters greater than 1400 mm.*
2) *Riprap should be hand placed.*
3) *The minimum culvert diameter should be 400 mm.*
4) *The minimum size of riprap should be 0.3 m thickness.*
5) *Filter cloth should be installed under the entire riprap apron.*

Figure E-9-1: Example of Culvert Apron

14. Care shall be taken to avoid damage to permafrost during the installation of culverts. Where disturbance to the permafrost is unavoidable, designs shall incorporate a means to re-establish and reinsulate the permafrost.
15. Culvert inlets should be placed at the same elevation of the natural stream bed to facilitate the passage of fish. Where culverts are to allow for the passage of fish, designs shall take into account the requirements of the authority having jurisdiction.
16. Where there is a risk of drainage overflow causing washout of critical infrastructure such as a roadway, the drainage system design shall include a means to prevent overflow of the system (e.g., overflow culverts). The level of risk, as determined during the planning process in accordance with Clause 4.5, can be used to determine whether or not protection against system overflow is required and what should be.

E-10 QUALITY ASSURANCE

Quality control testing related to the roadway construction shall include but not necessarily limited to sieve analysis, densities, mix design, core sampling and concrete testing. Quality control shall be performed by an independent party and certified by a professional engineer licensed to practice in the Territory of Nunavut.

H STORMWATER MANAGEMENT SYSTEM

H-1 GENERAL

These guidelines are intended as a guide only. The Design Engineer is responsible to ensure that the water system is designed and constructed according to accepted engineering practice.

These Guidelines shall not be considered as a substitute for a detailed material and construction specification prepared by the Design Engineer.

The stormwater management system should be designed with major and minor drainage systems. In general, a minor system consists of swales, ditches and culverts that have been designed in order to avoid property damage and flooding due to runoff generated by a 1 in 5 year rainfall event. When the capacity of the minor system is exceeded, the major system must provide a continuous overland flow route allowing the excess runoff to reach the designated ponding areas or water body.

The drainage conveyance should follow the natural starting point of flow on a surface (e.g., natural ground, roof, road, or parking lot) and sequentially follow the flow to a collection point (natural or constructed), such as a swale or ditch, and ultimately into a channel (natural or constructed).

Drainage systems shall be designed to maintain natural drainage conveyance patterns wherever practicable. Drainage systems shall be designed with a preference for detention over retention when directing drainage.

Where available, natural wetlands should be utilized to provide storage and thus slow the flow to the drainage area outlet. Wetlands can also be used to provide a degree of treatment by settling suspended solids out of the runoff.

Drainage storage by a constructed pond or pool should only be considered where

a) there is a need to slow the velocity of the flow in order to prevent erosion in areas where the soil is particularly vulnerable to erosion or the use of riprap, baffles, or vegetated ditches is not possible; or

b) there is an opportunity to use the retained water for other purposes as deemed appropriate by the authority having jurisdiction (e.g., fire fighting).

H.1.1 Identifying Drainage Catchment Areas

Drainage catchment areas and drainage patterns shall be identified. Available topographic mapping shall be used in order to identify the directions of sloping ground throughout the community.

H.1.2 Erosion Controls

Erosion stability and channel design shall at minimum calculate, tabulate and report for representative sections and lining characteristics at peak flow of the design storm for the following items:

1. Maximum shear stress;

2. Shear stress in critical bends;
3. Side slope stability for channels with side slopes steeper than 3:1;
4. Permissible or critical shear stress for proposed channel lining or armor;
5. General shape of rock substrate (e.g. rounded rock tends to be more easily mobilized than angular rock.)
6. Gradation of the rock substrate; and
7. Effective Manning's "n" and transitional lining characteristics for composite channel linings, particularly where low flow channels are required (e.g., for low base-flow streams and other perennial flows subject to icing).

Designs shall mitigate erosion caused by drainage discharges. The following features can be used to manage erosion:

1. Sediment traps (geotextile elements) / Silt Fencing: These are installed to reduce the velocity of flow and allow for the deposition of sediments doe the deposition of sediments before they can enter a fish bearing body of water. These are made from filter fabric that is buried at the bottom, stretched and supported by posts. Silt fences shall not be designed to withstand high heads.

   Silt fences are appropriate for the majority of construction sites that are not more than moderately sloped. The design life a silt fence is 6 months or less. The maximum contributory sheet flow drainage area should not exceed 0.1 hectares per 30 metres of silt fence. Use of a silt fence is usually more complex, expensive, and maintenance-prone than other sediment control measures.

   Silt fence might not be the most appropriate control measure for uneven terrain or when vegetative mat contains high density of roots that preclude keying in the fabric.

   Silt fences should be installed at right angles to the slope and along contours. Silt fences should be installed at the bottom of a slope or on a bench on a slope. Because of the difficulty of installing silt fence on frozen ground, installation should take place, where possible, before the ground freezes. Posts should be securely installed with the fabric attached to the uphill side of the post. The filter fabric should be securely attached to the posts. The filter fabric should be keyed into the surrounding earth. Silt fences should not be used in locations with concentrated flow, including streams or other storm water conveyances. Silt fence should only be used to contain sediment on-site.

2. Structural elements placed in the way of the flow, including
   a. Riprap: Large stone placed on embankments or slopes to provide stability to that slope. This keeps the embankment material in place and does not allow it to erode and potentially enter the Stormwater system. Deisgn guidelines for rip rap are listed in section H.3.3.
   b. Gabions;

   c. Concrete structures; and
   d. Wood cribbing;

3. Vegetation;
4. Surface Roughening: The practice of creating horizontal depressions on slopes, this reduces runoff velocities and increases infiltration which helps to prevent erosion of the slope. Roughening methods include stair-step grading, grooving, and tracking. Equipment such as bulldozers with rippers or tractors with disks may be used.
5. General Surfacing: Once an area has been developed, there are several methods of erosion control in the form of resurfacing an area. This can be done by seeding, sodding, the placement of rock, concrete and asphalt.
6. Rolled Erosion Control Products: Long sheets, or coverings that can unrolled onto unvegetated cut of fill slopes where erosion control or stabilization is needed. Designer shall ensure that RECP's are anchored, spacing depends on type of material and slope steepness. In addition, a firm continuous contact between RECP and soil must be maintained to prevent erosion below RECP.

   RECPs function best in providing a protective cover on slopes and channels where the erosion hazard is high and plant growth is likely to be slow, generally on slopes steeper than 3H:1V and greater than 10 feet of vertical relief.

7. Rock Flume: A rock flume is a riprap-lined channel to convey water down a relatively steep slope without causing erosion problems on or below the slope.

   Drainage area should not exceed 10 acres per rock flume.

   Remove all unsuitable material, such as trees, brush, roots, or other obstructions before installation. Shape the channel to proper grade and cross-section as shown in the plans, with no abrupt deviations from design grade or horizontal alignment. Compact all fills to prevent unequal settlement. Design the rock flume for the local conditions and have the hydraulic capacity for rain storms and break-up. Consider placing geotextile under the riprap where appropriate.

H.1.3 Sediment Controls

Sediment control shall be incorporated into designs to ensure proper functioning of the drainage components. Sediment control can be accomplished through the use of natural features such as ponds and wetlands or through constructed features such as siltation traps and re-vegetation of ditches. The choice of re-vegetation seed mixes should mimic, to the extent possible, native local vegetation.

H-2 ORGANIZATIONS ISSUING STANDARDS:

ASTM – American Society for Testing and Materials

CSA – Canadian Standards Association

H-3 MINOR SYSTEM

H.3.1 Flow Rates

1. The stormwater management system shall be designed as a separate system. Effluent from sanitary sewers or any potentially contaminated drainage shall not be discharged in the ditches or swales.
2. The five-year rainfall intensity table for the City shall be used for minor storm sewers. Duration time shall equal inlet time plus flow time.
3. The Rational Method shall be used in estimating flows for the design of storm ditches and swales for areas less than 10 hectares.

$$Q = \frac{CIA}{360}$$

where Q = the design peak flow rate in cubic metres per second

I = the intensity of rainfall in millimetres per Hour

A = the contributing area in hectares

C = the runoff coefficient

4. Minimum runoff coefficients shall be according to the following table:

Land Use/Surface Characteristics	Runoff Coefficient, C
Open Space	0.15
Residential Lots	0.35
Industrial	0.70
Commercial	0.70
Multiple Family	0.70
Undeveloped Land	0.1
Pavement, concrete, buildings	0.95
Gravel Roadways	0.3

5. Due to the large variation in lot sizes for commercial and industrial areas, a weighted runoff coefficient for these types of developments can be calculated using the following formula:

$$C = \frac{(0.9 \text{ X Impervious Area}) + (0.15 \text{ X Pervious Area})}{\text{Total Area}}$$

6. The intensity for the rational formula is selected from the Intensity Duration Frequency (IDF) curve, with a duration chosen to coincide with the time of concentration (tc). The time concentration for runoff flow is the time required for runoff flow to become established and reach the design location from the furthest point within the contributing catchment area.

7. Determination of tc requires estimation of two components, the inlet time and travel time. The inlet time is the time for flow from the extreme limits of the catchment to reach the point of inflow into the defined conveyance system. It is dependent upon the imperviousness and the size of catchment. The travel time is the length of time required for flow to travel within the conveyance system from the point of inflow to the design location.

8. Rainfall IDF curves for City of Iqaluit for selected return frequency events are presented in the tabular form in **Tables H.3.1 and H.3.2**, visual representation of which can be seen on **Figure H.3.1**. The IDF curves are based on data collected at 3 station between 1950 and 2017.

9. IDF curves for the future climate change scenarios are presented in **Figure H.3.2** along with the two-parameter equation for curve fitting. Designers shall use the non-climate change IDF curves from **Table H.3.1** and **H.3.2** for design purposes and Climate Change IDF Curves from **Figure H.3.2** for a “stress test” to determine future climate change impacts on infrastructure.

10. In areas, where snow is piled intentionally or accumulates naturally, a design check should also be done for peak daily melt rate using a conversion of 1cm of snow = 1 mm of runoff. This is to ensure that the runoff from snow piles during the melt period is also accounted for, in the design.

11. Minimum velocity shall be 1m/s. Where velocities in excess of 3 m/s are attained, special provisions shall be made to protect against displacement by erosion or impact.
12. Pipe sizing shall be determined by using Manning's Formula. A maximum manning's "n" of 0.013 for smooth walled storm pipe and "n" of 0.016 for concrete gutters and paved roads is to be used.
13. For areas larger than 10 hectares, acceptable computer modeling of the area must be submitted for review.

Table H.3.1 - IDF Curves - Intensity Table
3 Rain Gauges, Period 1946 - 2017
Maximum Years of Record = 71
IDF Intensity (mm/hr)

Time		Return Frequency						
Minutes	Hours	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
5		12.85	19.57	24.11	29.89	34.19	38.45	42.71
6		12.41	19.03	23.49	29.14	33.35	37.52	41.68
7		12.00	18.54	22.91	28.44	32.55	36.64	40.70
8		11.64	18.08	22.36	27.77	31.80	35.79	39.78
9		11.31	17.64	21.84	27.14	31.08	35.00	38.89
10		11.01	17.23	21.34	26.54	30.40	34.23	38.05
11		10.73	16.85	20.88	25.97	29.76	33.51	37.25
12		10.47	16.48	20.44	25.43	29.14	32.82	36.48
13		10.23	16.14	20.02	24.91	28.55	32.15	35.75
14		10.00	15.81	19.62	24.42	27.99	31.52	35.04
15		9.79	15.50	19.24	23.95	27.45	30.91	34.37
16		9.60	15.21	18.88	23.50	26.93	30.33	33.72
17		9.41	14.93	18.53	23.07	26.44	29.78	33.10
18		9.24	14.66	18.20	22.65	25.96	29.24	32.51
19		9.08	14.40	17.88	22.26	25.50	28.73	31.93
20		8.92	14.16	17.57	21.87	25.07	28.23	31.38
21		8.77	13.93	17.28	21.51	24.64	27.75	30.85
22		8.63	13.70	17.00	21.16	24.24	27.29	30.34
23		8.50	13.49	16.73	20.82	23.85	26.85	29.84
24		8.37	13.28	16.47	20.49	23.47	26.42	29.36
25		8.25	13.08	16.22	20.17	23.10	26.01	28.90
26		8.14	12.89	15.98	19.87	22.75	25.61	28.46
27		8.03	12.70	15.75	19.57	22.41	25.22	28.03
28		7.92	12.53	15.52	19.29	22.08	24.85	27.61
29		7.82	12.36	15.31	19.01	21.76	24.49	27.20
30		7.72	12.19	15.10	18.75	21.46	24.14	26.81

Time		Return Frequency						
Minutes	Hours	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
31		7.63	12.03	14.89	18.49	21.16	23.80	26.43
32		7.53	11.88	14.70	18.24	20.87	23.47	26.07
33		7.45	11.73	14.51	18.00	20.59	23.15	25.71
34		7.36	11.58	14.32	17.76	20.32	22.84	25.36
35		7.28	11.44	14.14	17.54	20.05	22.54	25.02
36		7.20	11.31	13.97	17.31	19.79	22.25	24.70
37		7.13	11.17	13.80	17.10	19.55	21.97	24.38
38		7.05	11.05	13.64	16.89	19.30	21.69	24.07
39		6.98	10.92	13.48	16.69	19.07	21.42	23.77
40		6.91	10.80	13.32	16.49	18.84	21.16	23.48
41		6.84	10.68	13.17	16.30	18.61	20.91	23.19
42		6.78	10.57	13.03	16.11	18.40	20.66	22.91
43		6.72	10.46	12.88	15.93	18.19	20.42	22.64
44		6.65	10.35	12.75	15.75	17.98	20.18	22.38
45		6.59	10.25	12.61	15.58	17.78	19.95	22.12
46		6.54	10.14	12.48	15.41	17.58	19.73	21.87
47		6.48	10.04	12.35	15.25	17.39	19.51	21.63
48		6.43	9.95	12.23	15.08	17.20	19.30	21.39
49		6.37	9.85	12.10	14.93	17.02	19.09	21.15
50		6.32	9.76	11.98	14.77	16.84	18.89	20.92
51		6.27	9.67	11.87	14.63	16.67	18.69	20.70
52		6.22	9.58	11.75	14.48	16.50	18.50	20.48
53		6.17	9.49	11.64	14.34	16.33	18.31	20.27
54		6.12	9.41	11.53	14.20	16.17	18.12	20.06
55		6.08	9.33	11.43	14.06	16.01	17.94	19.86
56		6.03	9.25	11.32	13.93	15.86	17.76	19.66
57		5.99	9.17	11.22	13.80	15.70	17.59	19.47
58		5.95	9.09	11.12	13.67	15.56	17.42	19.28
59		5.90	9.01	11.03	13.54	15.41	17.25	19.09
60		5.86	8.94	10.93	13.42	15.27	17.09	18.91
61		5.82	8.87	10.84	13.30	15.13	16.93	18.73
62		5.78	8.80	10.75	13.18	14.99	16.77	18.55
63		5.74	8.73	10.66	13.07	14.86	16.62	18.38
64		5.71	8.66	10.57	12.96	14.73	16.47	18.21
65		5.67	8.59	10.48	12.85	14.60	16.32	18.05
66		5.63	8.53	10.40	12.74	14.47	16.18	17.88
67		5.60	8.46	10.32	12.63	14.35	16.04	17.73
68		5.56	8.40	10.23	12.53	14.22	15.90	17.57

Time		Return Frequency						
Minutes	Hours	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
69		5.53	8.34	10.15	12.42	14.11	15.76	17.42
70		5.49	8.28	10.08	12.32	13.99	15.63	17.27
71		5.46	8.22	10.00	12.23	13.87	15.50	17.12
72		5.43	8.16	9.92	12.13	13.76	15.37	16.98
73		5.40	8.10	9.85	12.03	13.65	15.24	16.83
74		5.37	8.05	9.78	11.94	13.54	15.12	16.69
75		5.33	7.99	9.71	11.85	13.43	15.00	16.56
76		5.30	7.94	9.64	11.76	13.33	14.88	16.42
77		5.28	7.88	9.57	11.67	13.23	14.76	16.29
78		5.25	7.83	9.50	11.58	13.13	14.65	16.16
79		5.22	7.78	9.43	11.50	13.03	14.53	16.03
80		5.19	7.73	9.37	11.41	12.93	14.42	15.91
81		5.16	7.68	9.30	11.33	12.83	14.31	15.78
82		5.13	7.63	9.24	11.25	12.74	14.20	15.66
83		5.11	7.58	9.18	11.17	12.64	14.10	15.54
84		5.08	7.54	9.12	11.09	12.55	13.99	15.43
85		5.06	7.49	9.06	11.01	12.46	13.89	15.31
86		5.03	7.44	9.00	10.94	12.37	13.79	15.20
87		5.01	7.40	8.94	10.86	12.29	13.69	15.08
88		4.98	7.35	8.88	10.79	12.20	13.59	14.97
89		4.96	7.31	8.82	10.72	12.12	13.49	14.87
90	1.5	4.93	7.27	8.77	10.64	12.03	13.40	14.76
120	2	4.35	6.22	7.42	8.91	10.02	11.10	12.18
180	3	3.63	4.94	5.79	6.83	7.61	8.36	9.12
240	4	3.18	4.18	4.82	5.61	6.20	6.78	7.35
300	5	2.87	3.66	4.17	4.80	5.27	5.73	6.18
360	6	2.64	3.28	3.70	4.22	4.61	4.98	5.36
420	7	2.46	2.98	3.34	3.77	4.10	4.42	4.74
480	8	2.31	2.75	3.05	3.43	3.71	3.98	4.26
540	9	2.19	2.56	2.82	3.14	3.39	3.63	3.87
600	10	2.08	2.40	2.62	2.91	3.13	3.34	3.55
660	11	1.99	2.26	2.46	2.71	2.91	3.09	3.28
720	12	1.91	2.14	2.32	2.54	2.72	2.88	3.06
780	13	1.84	2.04	2.20	2.40	2.55	2.70	2.86
840	14	1.78	1.95	2.09	2.27	2.41	2.55	2.69
900	15	1.73	1.87	1.99	2.16	2.29	2.41	2.54
960	16	1.67	1.79	1.90	2.05	2.17	2.29	2.41
1020	17	1.63	1.73	1.83	1.96	2.07	2.18	2.29

Time		Return Frequency						
Minutes	Hours	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
1080	18	1.58	1.67	1.76	1.88	1.98	2.08	2.18
1140	19	1.54	1.61	1.69	1.81	1.90	1.99	2.09
1200	20	1.51	1.56	1.63	1.74	1.83	1.91	2.00
1260	21	1.47	1.51	1.58	1.68	1.76	1.83	1.92
1320	22	1.44	1.47	1.53	1.62	1.69	1.77	1.84
1380	23	1.41	1.43	1.48	1.56	1.64	1.70	1.78
1440	24	1.38	1.39	1.44	1.52	1.58	1.64	1.71

IDF Parameter

Rate = a*(b^t)*(t^c)	Return Frequency						
Parameter	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
a	5.876	8.466	10.188	12.369	13.989	15.598	17.203
b	0.988	0.985	0.983	0.981	0.980	0.979	0.979
c	-0.409	-0.428	-0.436	-0.442	-0.446	-0.448	-0.450

Where t = duration in hours

Figure H.3.1: Intensity Duration Frequency Curve – City of Iqaluit

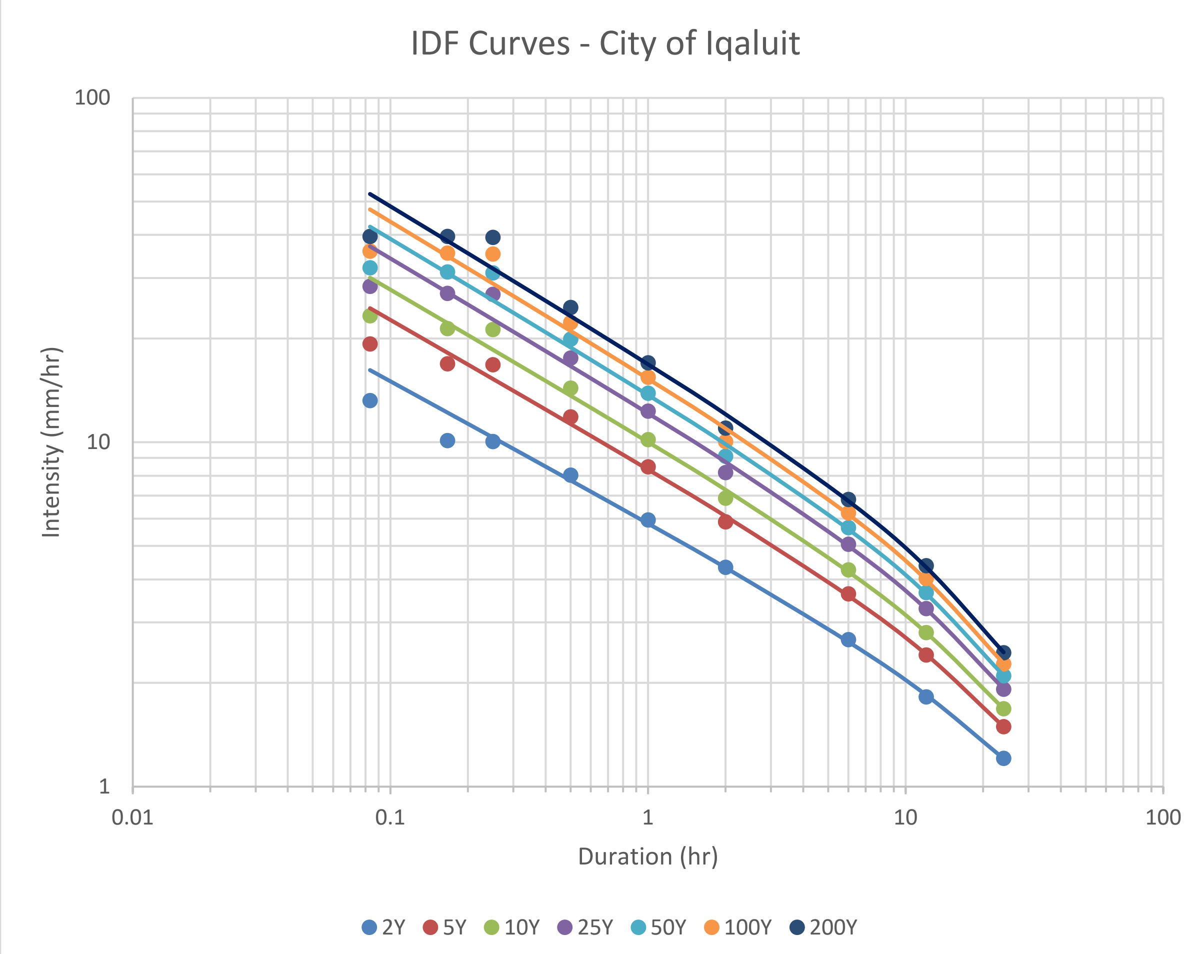


Table H.3.2 - IDF Curves - Intensity Table - Summary
3 Rain Gauges, Period 1946 - 2017
Maximum Years of Record = 71

Duration		Return Frequency						
Min	Hours	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
5	0.083	13.22	19.28	23.29	28.36	32.13	35.86	39.58
10	0.167	10.11	16.89	21.38	27.05	31.26	35.44	39.60
15	0.25	10.06	16.79	21.25	26.88	31.06	35.21	39.34
30	0.5	8.03	11.85	14.37	17.56	19.93	22.27	24.61
60	1	5.95	8.49	10.18	12.30	13.88	15.45	17.01
120	2	4.34	5.87	6.88	8.16	9.11	10.05	10.99
360	6	2.67	3.63	4.26	5.05	5.65	6.23	6.82
720	12	1.82	2.41	2.80	3.29	3.66	4.02	4.38
1440	24	1.21	1.49	1.68	1.92	2.10	2.27	2.45

Figure H.3.2: Intensity Duration Frequency Curve – Climate Change Scenario City of Iqaluit

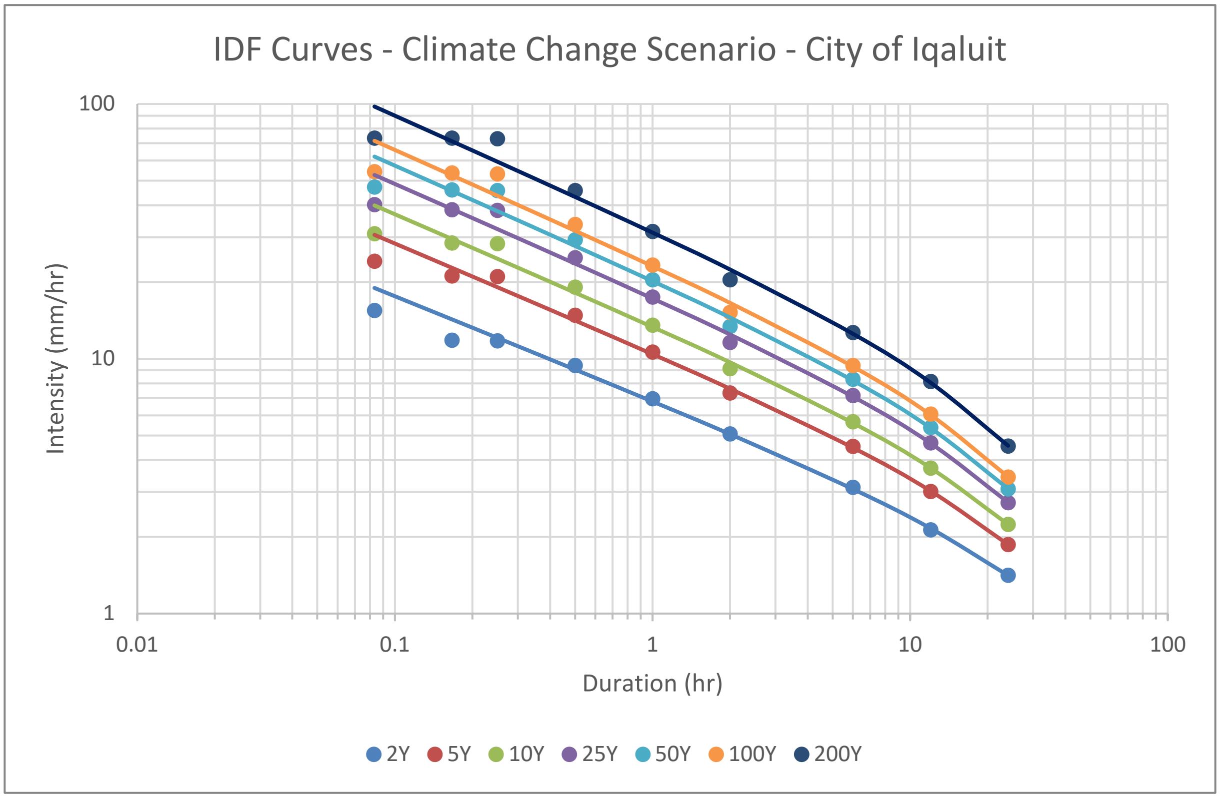


Table H.3.3
IDF Parameters – Climate Change Scenario

Rate = a*(b^t)*(t^c)	Return Frequency						
Parameter	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
a	6.875	10.583	13.550	17.564	20.564	23.553	31.940
b	0.988	0.985	0.983	0.981	0.980	0.979	0.979
c	-0.409	-0.428	-0.436	-0.442	-0.446	-0.448	-0.450

Where t = duration in hours

H.3.2 Curb and Gutter

Drainage discharge locations shall be positioned so that they do not impact surface water intake, and so that water samples can be easily taken.

H.3.3 Outfalls

1. At the end of an outfall sewer, energy dissipaters are often necessary to avoid downstream erosion and damage of creeks, ravines or river banks from high exit flow velocities. Outfall structures are required at locations where it is necessary to convert supercritical flow to subcritical, to dissipate flow energy and to establish suitably

tranquil flow conditions downstream.

2. When sewers discharge at subcritical flow, then smaller concrete structures with suitable baffles, aprons and rip-rap will be acceptable. For all outfalls, it is required that a rigorous hydraulic analysis be completed, to ensure that the exit velocities will not damage natural watercourses. The final exit velocities, where the flow passes from an apron or erosion control medium to the natural channel, shall not exceed 1.0 m/s and may be further limited depending on site specific soil and flow conditions.
3. Appropriate erosion control measures are to be provided at and downstream of the outfall to prevent erosion in the downstream channel.
4. All sewer outlets shall be constructed with provisions to prevent the entrance of children or other unauthorized persons. A grate with vertical bars spaced at no more than 150 mm shall be installed with adequate means for locking in a closed position. Provide for opening or removal of the gate for cleaning or replacing the bars. Grates should be designed to break away under extreme hydraulic loads in the case of blockage.
5. Guardrails or fences of corrosion resistant material shall be installed along concrete headwalls and wingwalls to provide protection against persons falling.
6. Outfalls, which are often located in parks, ravines, or on river banks should be made as safe and attractive as is reasonably possible. The appearance of these structures is important and cosmetic treatment or concealment is to be considered as part of the design. Concrete surface treatment is recommended to present a pleasing appearance. Bush hammered or exposed aggregate concrete is recommended. Live stakes or bioengineering is encouraged wherever applicable.
7. The location of the riparian zone shall be considered when locating outfalls according to the requirements of the authority having jurisdiction.

H-4 MAJOR SYSTEM

H.4.1 General

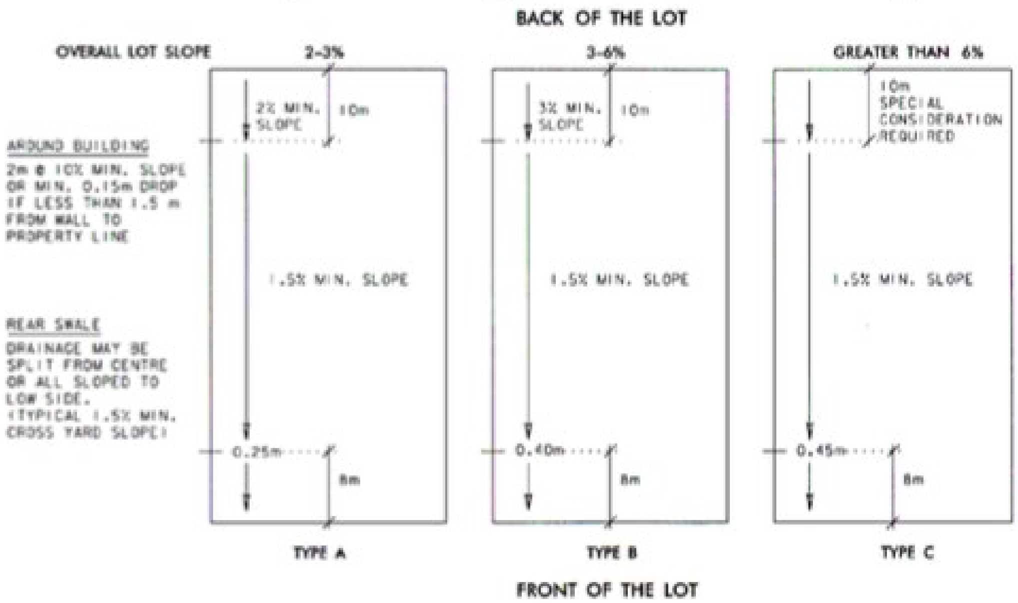
The major conveyance system accommodates flows not intercepted by or beyond the capacity of the minor drainage system through planned surface flow routes and storage facilities. The intent of the major system is to provide surface flow management in order to minimize flooding and property damage from a 1:100 year rainfall event. The design of the major drainage system must not be limited to the immediate development area but must consider overland flows that may enter the area from adjacent land as well as down stream effects on adjacent development and receiving water bodies.

H.4.2 Lot Grading

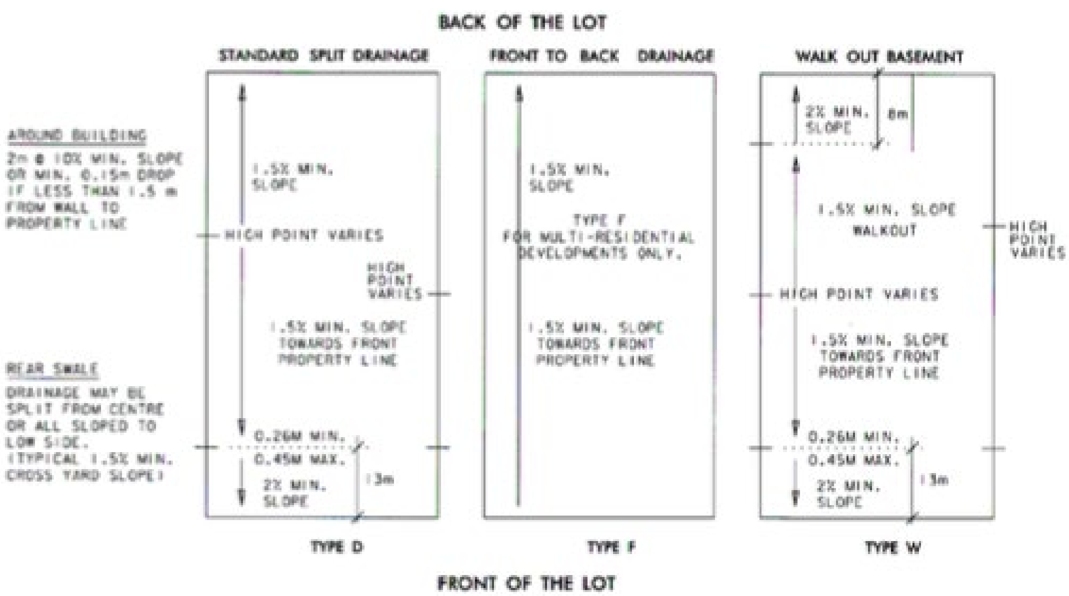
Proper lot grading is the first step towards a well-planned major drainage system. The goal of the lot grading shall be to ensure that water flows away from the building. Flow from lots shall always have an escape route to a public right-of-way. The lot-grading plan shall develop a proper balance between the road elevation, proposed building elevations, surrounding development and existing topography.

1) The level-of-service requirements for lot grading include provision of protection against surface flooding and property damage for the 1 in 100 year return frequency design storm. Through control of surface elevations, designs should be such that maximum flow or ponding surface elevations are 150 mm below the lowest anticipated finished ground elevations at buildings. An overflow route or sufficient ponding volume must be provided from or at all sags or depressions to provide for this 150 mm freeboard with the maximum depth of ponding is limited to 350 mm.
2) The establishment of a lot grading plan is one of the principal means for establishing a critical component of the major drainage system. The lot grading plan is a specific requirement within the detailed Engineering Drawings for a subdivision under the terms of a standard servicing agreement. Lot grading plans are required for most property developments involving building construction or surface improvements and may be a requirement of a development permit or pursuant to requirements of bylaws, regulations, other approvals or agreements.
3) Site grading shall ensure proper drainage of individual private properties or establish an effective surface drainage system for a whole development area. A lot grading plan will establish the drainage relationship between adjacent properties and its approval is an effective basis for the control of grading of the properties.
4) In the design of lot grading plans, the designer must achieve a proper relationship and balance between the street elevation, building grade elevation, surrounding development and existing topography.
5) The implications of required noise attenuation berms and other elevation controlling features are to be fully addressed by the designer. It is also important to ensure that the lot grading design and the anticipated house or building designs are complementary. Reverse slope driveways and other features that would be likely to capture runoff or fail to drain during major rainfall events should be discouraged.
6) The Developer must ensure that builders are informed of any potential problems or restrictions respecting building design and lot grading. The lot grading plan will be used as one of the principle means by which this information is communicated.
7) Details of grading within lots. Refer figures below for typical lot grading details for various standard drainage arrangements for detached residential developments.

Typical Lot Grading Details – Rear To Front Drainage



Typical Lot Grading Details – Split/Front to Back Drainage



8) The relative surface elevations must allow for the slope of the ground adjacent to the building to be at a minimum of 10% for a distance of 2.0 m or to the property line, on all sides of the house, with the slope directing drainage away from the building and then for reasonable slopes in the order of 1.5% to 2.0% from all points within the property to the property boundary at which the drainage may escape.

9) Property line elevations are to be established such that lots have a minimum overall slope of 2.0%, from the high point to the front or back property lines for split drainage situations, or between the higher and lower, front and rear property lines with through drainage. The

minimum grade (2%) should normally be exceeded if topography allows.

10) Split drainage or through drainage (front to rear or rear to front drainage) will be allowed when a lot is located such that there is a road, lane, or public right-of-way at both the front and back of the lot.
11) Rear to front drainage is preferred in alleyless subdivisions. Split drainage in alleyless subdivisions will be permitted only if all of the following conditions are met:

    - it is not feasible to achieve rear-to-front drainage due to extreme natural topography;
    - the receiving downstream lot has an overall grade of 3.0% or more;
    - there is no concentration of flow from upstream lots to downstream lots;
    - only one lot drains to another lot;
    - runoff from the roof of the upstream lot is directed to a storm service or the upstream lot's grading is designed with the ridge as close to the rear property line as possible.

    In situations where split drainage may be problematic due to the above conditions not being met, the use of a swale for the interception of split drainage and its conveyance to a public right of way will be permitted.

H.4.3 Swales

12) Drainage swales on municipal or private property shall be constructed prior to any development of subdivision lots. Complete swale construction shall be a prerequisite to the issuance of the Substantial Certificate of Completion.
13) Swales may be used on public rights-of-way, including easements, for the collection and conveyance of major and minor runoff to appropriate points of interception or release. Swales on public rights-of- way, except easements, should not to be provided with concrete flow channels or hard surface treatments, except where such measures are required to address flow velocity or erosion concerns. A standard swale / ditch example for driveways and public right of way (ROW) has been provided in appendix A of this design guidelines.
14) The use of swales crossing private properties for collection of runoff and drainage control is not permitted unless proper justification is produced and documented indicating that no other alternative is feasible. If the Engineer approves use of such swales they are to be covered by easements in favour of the City, to the satisfaction of the Engineer.
15) Drainage swales located on private property shall be covered by an easement in favour of the City. A minimum clearance of 200mm should be provided between the edge of the swale and the property line. Major rainfall event flows shall be contained within the easement.
16) Drainage swales crossing several properties for the collection of runoff shall not be permitted unless special circumstances warrant.
17) When swales crossing several properties cannot reasonably be avoided, then the following requirements shall be satisfied:

a) Grass swales serving lots on one side only
   i) Location**:** Rear of upstream lot in a 2.0 m easement
   ii) Cross Section: V-shape, 150 mm minimum depth and 4H:1V maximum side slope
   iii) Longitudinal slope: 1.5% minimum
b) Grass swales serving lots on both sides
   i) Location: Common rear property line as centre of a 4.0 m easement.
   ii) Cross-section: Trapezoidal with 1.0 m bottom, 150 mm minimum depth and 4H:1V maximum slope.
   iii) Longitudinal slope: 1.5% minimum
c) Grass swales with concrete gutter, serving lots on one or both sides
   i) Location: Upstream lot with the gutter preferably centred on the 2.0 meter easement.
   ii) Cross-section of gutter: V-shape, 75mm to 150mm deep, 500mm to 610mm wide with 4H:1V maximum slope. 100mm minimum thickness with 3-10 M longitudinal bars and 3.0 m spaced control joints.
   iii) Longitudinal slope: 0.75% minimum.
   iv) Note: alternate design considerations with respect to minimum slope requirements for swales will be considered when swales are located within existing developments or at locations where infill development is proposed.
d) Other parameters and requirements
   i) Capacity: Contain the 1:5 year storm flow within the concrete gutter and the 1:100 year storm major flow within the easement.
   ii) Interception: Provide a catchbasin upstream of a walkway to intercept the 1:5 year storm flow. Limit the depth of ponding to 150 mm with 5H:1V maximum side slope all around the CB cover.
   iii) No. of lots draining to swale – Depending on the concrete gutter and swale capacities, and the CB's 1:5 year storm flow inlet capacity.
   iv) Bends: Bends greater that 45 degrees shall be avoided, and no bend greater than 90 deg. shall be allowed. When 45 deg. bend is exceeded, provide a 1.0 minimum centreline radius and adequate curbing to contain the design flows within the gutter and easement.
   v) Conveyance: The grading of the boulevard and sidewalk shall be such that the major flow will not be allowed to flow down the sidewalk.
   vi) Erosion and sediment control: Grass swales preferably shall be sodded, or at the least, shall be topsoiled and seeded, Interim measures shall be provided to protect exposed surfaces from erosion until the grass cover is established.
   vii) Swales that convey flows from more than two lots must not be routed along the side yard of a single family or duplex residential lot.
   viii) Future swale extensions shall be identified and evaluated to ensure that anticipated constraints and capacities are addressed.
   ix) Details: Show on the Lot Grading Plan, the cross-section, inverts, slopes and lot grades along the swale.
   x) Calculations for the swale's minor and major flow capacities shall be submitted with the engineering drawings.

18) The minimum design slope for swales is 1%.

H.4.4 Roadways

Grading of streets comprising the major drainage system shall follow the guidelines listed below:

1. Continuity of over flow routes between adjacent developments shall be maintained.
2. Collectors shall have at least one lane that is not inundated.
3. The depth of peak flows and ponding in developed area streets, conveyance channels and swales, are to be limited so that major system flows will not constitute a significant hazard to the public, or result in significant erosion or other property damage. Where erosion is anticipated, an ESC Plan should be designed to suit site specific situations.
4. An overflow must be provided from all sags or depressions such that there will be a freeboard of at least 150 mm above the overflow elevation to the proposed ground surface elevation at adjacent buildings and maximum depth of ponding is limited to 350mm.
5. The maximum water surface level of surface flows and ponding in streets is below the lowest anticipated landscape grade or opening at any adjacent buildings, with a freeboard provision generally in the order of 350 mm with a minimum of 150 mm.
6. Depths of flow and ponding are less than 350 mm in roadways and other public rights-of-way.
7. For arterial roadways, the water depth at the crown of the road shall not exceed 150 mm.
8. The theoretical street carrying capacity can be calculated using modified Manning's formula with an "n" value applicable to the actual boundary conditions encountered. Recommended values are n = 0.013 for roadway and n = 0.05 for grassed boulevards.

I STREET LIGHTING

I-1 STANDARD AND GUIDELINES

These guidelines are intended as a guide only. The Design Engineer is responsible to ensure that the water system is designed and constructed according to accepted engineering practice.

These Guidelines shall not be considered as a substitute for a detailed material and construction specification prepared by the Design Engineer.

The street lighting design shall be in accordance with the “Guide for the Design of Roadway Lighting” published by the Transportation Association of Canada (TAC) as well as applicable standards published by the Illuminating Engineering Society of North America (IES).

All roadway lighting systems shall be installed in strict compliance with the Canadian Electrical Code.

These Guidelines only apply in areas where street lighting is specified.

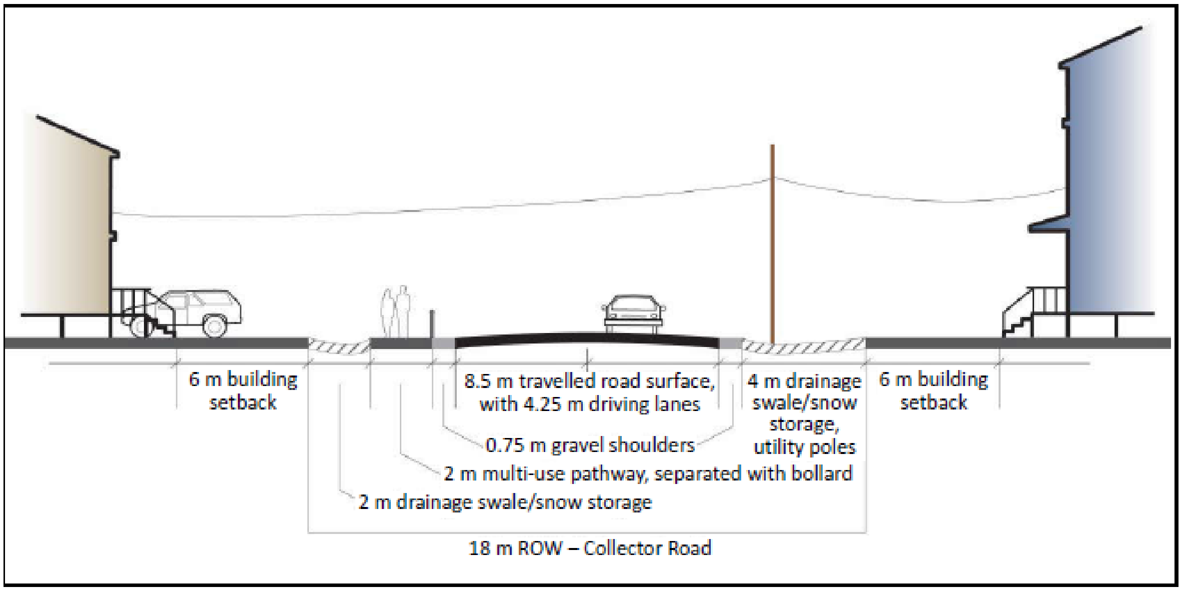
Appendix A

Excerpt taken from CAN / CSA – S503 – 15 Community drainage system planning, design and maintenance in northern communities, indicates proper width of ditch / swale for public right of way.

Profile view showing driveways and drainage ditches/swales

(See Clause 4.1.)

Collector road rights-of-way should be at least 18 m wide to allow for road lanes, shoulders, pedestrian walkways, drainage ditches, and utility poles.



Local road (two-way) rights-of-way should be at least 16 m wide to accommodate road lanes, shoulders drainage ditches, and utility poles.