Community drainage system planning, design, and maintenance in northern communities
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Preface

This is the first edition of CAN/CSA-S503, Community drainage system planning, design, and maintenance in northern communities.

Although this Standard is intended to be comprehensive, specific agencies may need to refine procedures as appropriate for their own usage.

The Standard was developed through the collaboration from many knowledgeable experts and representatives from Canada's territorial governments and the private sector.

CSA Group received funding for the development of this standard from Standards Council of Canada, as part of the Northern Infrastructure Standardization Initiative, supported by the Government of Canada's Clean Air Agenda.

In addition to the members of the Working Group and Technical Committee, CSA Group acknowledges the contributions made by Dennis Althouse, Chad Cowan, and Megan McGarrity.

This Standard was developed by the Working Group on Community Drainage System Planning, Design and Maintenance, under the jurisdiction of the Technical Committee on Northern Built Infrastructure and the Strategic Steering Committee on Construction and Civil Infrastructure, and has been formally approved by the Technical Committee. This Standard has been approved as a National Standard of Canada by the Standards Council of Canada.

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0 Introduction

0.1 What is unique about the north and northern surface drainage systems

The north of Canada is very unique due to its climate, geography, geology, demography, and culture. The north is a region with long periods of extremely low temperatures; it is a region that is exceptionally large and remote; it is a region with permafrost and other ground-related engineering challenges; it is a region of small, isolated communities with low population density; and it is a region with a large indigenous population. As much as these different attributes contribute to a diversity of communities in the north, a commonality between northern communities across the country is the challenges around surface drainage systems.

While the north may be regarded as a region of perpetual ice and snow because of the long and cold winter season, it is the short warm summers and brief shoulder seasons of spring and fall that create the perpetual surface drainage issues that are catastrophic in the extreme case, and a constant challenge year after year.

Figures 1, 2, and 3 show some typical drainage problems in the north.
Figure 1
Example of road washout after extreme rain event in Kugluktuk, Nunavut
(See Clause 0.1.)

Figure 2
Example of drainage ponding in Old Crow, Yukon Territory
(See Clause 0.1.)
0.2 Challenges for drainage systems in the north

There are no simple, quick fix permanent solutions to surface drainage issues in northern communities. Short construction seasons, remote locations, limited community capacity, and challenging ground conditions amongst other factors create a complex web in which the persistent issues of northern drainage must be addressed. As an example, the logistics involved in the installation or replacement of a simple culvert can be challenging. First, the correct size of pipe must be purchased well in advance of when it is needed. It may need to be delivered by winter road or ship, both of which operate in a narrow seasonal window. Availability of manpower and equipment cannot be assumed, as these resources might have already been committed to other projects during the summer construction season.

Even if all of the resources are available when required, the location, local ground conditions such as the presence of permafrost, and material available will influence how the culvert is installed and how long it might remain functional. The effects of climate change create challenges for the design of drainage systems in the north where there is often limited climate data available, adding to the risk and uncertainty. The situation described above is a common scenario. It assumes the predictability of the need for regular annual maintenance. It does not anticipate or address the risks, challenges, and impacts of unpredictable catastrophic events where immediate response is required and options are limited.
In most northern communities, drainage system planning, design, and maintenance are often described as ad hoc processes. Community planners, engineers, and asset managers from across Canada’s three territories, as well as Newfoundland and Labrador and Nunavik have emphasized that conventional drainage planning, approaches to design, and maintenance practices are inadequately defined and often poorly understood. The result is routine and chronic degradation of community infrastructure across the north. Proper drainage planning, design, and maintenance practices are essential for the protection of community infrastructure.

The effects of a changing climate bring additional challenges to the process of planning, designing, and maintaining northern drainage systems. Irregular and, in some cases, extreme events appear to set aside what might have been considered normal in the past. Many professionals agree that the changing climate has and will continue to alter northern weather conditions. Observed impacts in the north include:

- An increase in the frequency of extreme weather events resulting in greater snow accumulation, winter rain, icing, and higher winds;
- Rapid spring melting;
- More sudden, intense precipitation events; and
- Greater weather instability in general.

All of these weather factors in the north influence how drainage planning, design, operation, and maintenance now need to be done. New tools and adaptation strategies are needed to manage the effects of climate change on community surface drainage systems. The preparation of community surface drainage plans is only a first step.

Climate change assessment and adaptation tools are only now beginning to be developed and applied to infrastructure projects. One such tool, vulnerability assessments, is still in its infancy and is not routinely conducted in northern communities. Adaptation plans have been developed for selected northern communities, including Whitehorse and Yellowknife, as well as hamlets as small as Clyde River in Nunavut. Vulnerability assessments have also been carried out at the territorial and regional levels, albeit in much less detail. In most cases, the impacts of snowmelt- and precipitation-driven runoff have been identified as significant risks to a community.

The results of vulnerability assessment studies that have been undertaken in the north are confirming that existing drainage plans and infrastructure are often inadequate to accommodate the effects of a changing climate. In many instances, service levels are insufficient, and repairs to drainage infrastructure are infrequently and non-routinely conducted resulting in ultimately more expensive repairs in the future. Other conditions often associated with climate change, such as warming and degrading permafrost conditions and pronounced local shifts in hydrogeology, are creating new drainage problems within communities and making existing problems worse. Furthermore, human activities which cause changes to the ground surface can have an impact on the ground thermal regime with subsequent impacts on drainage conditions.

All regions of Canada are experiencing environmental, social, and economic impacts that might be attributed to a changing climate. In Canada’s north, the climate appears to be changing at a much faster rate than the rest of Canada, creating increasing challenges for northern communities. Reducing the vulnerability of infrastructure to climate change is of critical importance for several reasons including cost and intervention capacity. Traditionally, there is limited redundancy built into northern infrastructure in part due to the associated high costs and the complexities that exist in remote communities. This is especially true when it comes to high-value community assets such as schools, medical buildings, community centres, and any building identified as key infrastructure (per the National Building Code of Canada). As problems associated with the changing climate worsen, northern
governments and other stakeholders are recognizing that hard choices can no longer be put off and better tools are needed now to make decisions for infrastructure adaptation.

### 0.3 Overview of community drainage systems

Community drainage systems collect runoff water from snowmelt, ice melt, precipitation, and storm events. These systems convey surface drainage away from community sites, whether an individual lot, a community block, a community neighbourhood, or the entire community to a point down gradient where it no longer impacts the site.

The community's drainage system needs to be planned, designed, constructed, and maintained with the capacity to handle the aggregate flow of water from all catchment areas within the community as well as surface water that originates from outside the community that must flow through the community because of topography or other factors.

### 0.4 Purpose of this Standard

This Standard specifies the minimum planning, design, and maintenance requirements for community drainage systems in Canada's northern communities. The purpose of this Standard is to increase the capacity of communities and individuals to prepare and implement effective community drainage plans. These plans address both existing and anticipated drainage management challenges arising from deficiencies in past practices, as well as the need to adapt to future changes in climate.

Drainage systems in small, remote northern communities have historically been poorly developed and managed. This Standard provides guidance to practitioners who are involved in the planning, design, construction, rehabilitation, and maintenance of drainage systems in northern communities.

The provisions of this Standard are derived from existing best practices and may be incorporated directly into community land use plans. Additionally, this Standard is intended to:

- specify techniques to plan for and implement community drainage systems to account for the effects of a changing climate and changing permafrost regime;
- describe practices for site and community planning that help to conserve community infrastructure, or at least avoid actively contributing to its degradation;
- provide solutions that are low cost and implementable given local constraints on capacity and resources;
- help northern communities protect community assets; and
- promote public health and safety in northern communities.

### 0.5 Guidance to users

This Standard is designed to appeal to the needs of three audiences. The first group are the community administrators, building and land owners, and asset managers, including regulators and inspectors who are involved in selecting the drainage system used and ensuring it is constructed and operated properly. The second group includes those involved in the planning, design, construction, operation, and maintenance of the surface drainage infrastructure. The third group includes those who need to understand how incorporation of best drainage practices can mitigate the impacts of a changing climate (e.g., policy makers).

Users should be aware of the requirements of the authorities having jurisdiction for the design, construction, and maintenance of drainage systems and their associated components in northern regions. This includes all federal and territorial acts and regulations and municipal bylaws applicable to land and water use management, community infrastructure development, and building construction.
This Standard is organized to help the user proceed sequentially through the three key steps in the implementation of a community surface drainage system. These steps are planning, design and construction, and maintenance and repair. The plan should identify

- surface water management challenges specific to a community's needs and circumstances;
- the vulnerabilities of the community and the management of identified risks;
- the implications of any risks from a health, safety, and system asset management perspective; and;
- guidance on best management practices to mitigate risks through community planning, land use management, and system design, construction, and maintenance.

To prepare a new or updated drainage plan, begin with Clause 4, Community drainage system planning. Community drainage system planning should be integrated into community plans, policies, and existing zoning by-laws where they exist. Information inputs such as site characterization, hydrology, topography, surficial geology, climate data, and maps are required to develop drainage plans as well as overall community plans. However, a lack of a community plan should not preclude the development of a drainage plan, as one can be developed in the absence of a community plan.

Community drainage system design requirements are given in Clause 5. The basic requirements of community drainage system design may be sufficient to service some communities, while for others the requirements serve as a foundation upon which additional system design elements will be layered and can be tailored to meet local needs and circumstances.

Communities with fully or partially developed drainage systems should review their drainage system plans against the requirements in Clause 4 and their system designs against the requirements in Clause 5 before beginning to modify an existing system.

Requirements for the long term care of community drainage systems are described in Clause 6. They are discussed in the context of life cycle asset management, level of service standards, and subsequent operational decision making. Implementation can be in phases taking into account existing drainage infrastructure conditions, anticipated community growth, as well as best practices for system planning, design, construction, maintenance, and repair. A community with a partially or fully established drainage system may opt to adopt only the maintenance requirements.

1 Scope and application

1.1 Scope

This Standard specifies provisions for the planning, design, and maintenance of surface drainage systems within northern community boundaries. Provisions for drainage outside the community boundary are not covered by this Standard.

Note: Specific resources and expertise are required to address drainage provisions outside the community boundary. These resources and expertise might be beyond the capacity of an individual community.

1.2 Application

This Standard specifies provisions for site-level and community-wide drainage system planning, development, and operations. The provisions apply to drainage systems used for the collection, conveyance, detention, and discharge of excess surface water in the form of overland flow, originating from precipitation, snowmelt, or ice melt.

Note: Excess surface water is net of precipitation, soil infiltration, and evaporation.
1.3 Exclusions

This Standard does not cover
a) drainage systems associated with facilities that might inherently produce contaminated drainage, such as
   i) solid waste management systems and components; and
   ii) sewage treatment systems and components;
b) drainage directly from storm surges in lakes or oceans;
c) drainage directly from riverine flooding;
d) subsurface drainage; and
e) watershed level drainage planning.

Note: Certain drainage circumstances are not considered in this Standard because they have requirements that are beyond the resources and expertise of many northern communities.

1.4 Terminology

In this Standard, “shall” is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the standard; “should” is used to express a recommendation or that which is advised but not required; and “may” is used to express an option or that which is permissible within the limits of the standard.

Notes accompanying clauses do not include requirements or alternative requirements; the purpose of a note accompanying a clause is to separate normative clauses from explanatory or informative material. Notes to tables and figures are considered part of the table or figure and may be written as requirements.

Annexes are designated normative (mandatory) or informative (non-mandatory) to define their application.

2 Reference publications

This Standard refers to the following publications, and where such reference is made, it shall be to the edition listed below, including all amendments published thereto.

CSA Group
CAN/CSA-S501-14
Moderating the effects of permafrost degradation on building foundations

CAN/CSA-S502-14
Managing changing snow load risks for buildings in Canada’s North

Plus 4011-10
Technical Guide — Infrastructure in permafrost: A guideline for climate change adaptation

Plus 4013-12

The City of Whitehorse
City of Whitehorse Servicing Standards Manual, January 2007
3 Definitions and abbreviations

3.1 Definitions
The following definitions shall apply in this Standard:

Active layer — the top layer of ground that is subject to annual freezing and thawing in areas underlain by permafrost.

Community plan — a document typically consisting of text and maps, formally adopted into bylaw, that sets out the future development and planned use of community land.

Note: The community plan typically accounts for patterns of human activity within a municipality and establishes goals, objectives, and policies for the safe, healthy, and orderly development of land. The community plan typically supports the protection of the natural environment, the efficient provision of municipal services, the establishment of utilities and transportation systems, and such other matters that can influence the quality and sustainability of community life.

Crossfall — the slope from the high point in a road cross-section to the edge of the road, generally in the range of 2 to 3%.

Channel — the space above the bed and between the banks of a stream or ditch.

Competent individual — a person who through training, qualification, and experience has acquired the knowledge and skills necessary for undertaking tasks assigned to him or her.

Culvert — a pipe or box structure intended to carry runoff beneath a road or other structure for relatively short distances.

Note: Culverts are mainly made of concrete or metal (corrugated steel or aluminum), but other materials such as ribbed-wall HDPE pipe, wood, and masonry is occasionally used. The type of material used depends on cost and availability of the materials. However, corrugated metal pipe (CMP) and concrete pipe are generally more durable than plastic pipe. It is important that culverts are corrosion resistant.

Detention — to hold the water for a short-term period with the intention of release (period of time could be hours or days).
Ditch — an intentionally designed and constructed channel that intercepts, collects, diverts, directs, and drains a specific amount of area within a certain amount of time. Standing water is discouraged.

Ditch block — a surface drainage feature used to block and redirect the flow in a ditch.

Engineer — a Professional Engineer experienced with the design of community drainage systems and registered with the association of Professional Engineers in the jurisdiction where the project is located.

Excess ice — the volume of ice in the ground that exceeds the total volume that the ground would have under natural unfrozen conditions.

French drain — a buried drainage collection feature consisting of coarse granular material usually wrapped in a geotextile to minimize the migration of fine material into the system.

Frost heave — the upward or outward movement of the ground surface (or objects on, or in, the ground) caused by the formation of ice in the soil.

Flood event period — the anticipated cycle frequency of a recurring flood event based on an analysis of weather data or theoretical modelling, usually cited in terms of 5, 10, 20, 25, 50, 100 and 200 year cycles.

Note: Also known as “flood return period” or “flood recurrence interval”.

Ice lens — a predominantly horizontal, lens-shaped body of ice.

Ice-rich permafrost — permafrost containing ice in excess of 20% by volume.

Icing — applies to a surface ice mass formed by a freezing of successive sheets of water that originate from drainage flows; as one layer of water freezes, another flows over it and the icing builds layer by layer to a point where it could completely block a culvert, or other drainage conveyance feature.

IDF curve — the “intensity, duration and frequency” of extreme rainfall events.

Note: IDF information is meant to describe the frequency (in terms of probability of occurrence) of extreme rainfall events of various rates and durations. An IDF curve for a specific location shows the return level rainfall amounts for durations from 5 min to 24 h, and for return periods from 2 to 100 years, and is expressed as a rate (mm/h). The IDF curve is created with rainfall records collected at a specific monitoring location.

Local knowledge — historical information available in a community.

Minor system — the network of local and trunk sewers, ditch inlets, and street gutters which rapidly carry away storm runoff from surfaces.

Note: Minor systems are generally designed with capacity to remove runoff from minor rainfall events.

Permafrost — ground (soil or rock and included ice and organic material) that remains at or below 0 °C for at least two consecutive years.

Notes:
1) Permafrost occurring everywhere beneath the exposed land surface throughout a geographic region is considered “continuous” whereas it is considered “discontinuous” if some areas within the geographic region are free of permafrost.

2) Cold permafrost is generally considered to have a ground temperature at or below -5 °C. Warm temperature is generally considered to have a ground temperature at or above -2 °C. The ground temperature refers to that measured at a depth where it is constant year around.
Rational method — a simplified storm runoff calculation using the rational formula. It is best suited to small (< 60 ha) urban areas with drainage facilities of fixed dimensions and hydraulic characteristics.

Planner — a person in the land use planning profession with formal training and expertise in community planning, development, and management.

Pond — a smaller, shallower body of water than a lake where water temperature is fairly uniform from top to bottom. Plants root in the bottom mud and might grow completely across or around its shoreline, minimizing the open water surface area; wave action is minimal.

Retention — to hold water for a long term period with the intention of eventual release (period of time might be months).

Recurrence interval — the anticipated cycle frequency of a weather event based on an analysis of weather data or theoretical modelling, usually cited in terms of 5, 10, 20, 25, 50, 100 and 200 year cycles.

Note: Also known as “return period” or “event period”.

Riprap — rock or other material used to armour shorelines, streambeds, bridge abutments, pilings and other shoreline structures against scour and water or ice erosion. It is made from a variety of rock types, commonly granite or limestone, and occasionally concrete rubble from building and paving demolition. It can be used on any waterway or water containment structure where there is potential for erosion.

Note: Also known as “rip rap”, “rip-rap”, “shot rock”, “rock armour”, and “rubble”.

Road crown — a high point in a road cross section, usually the centre of the road.

Rock pit — a surface drainage feature consisting of rocks filling in a small shallow excavation to accommodate storage and percolation of surface water into the ground.

Sediment — material that arises from erosion in areas where the velocity of the water exceeds the static strength of the soil in situ.

Note: If erosion occurs it can be controlled by reducing the velocity of the water. There are many methods to do this, including the use of silt curtains; installing riprap, reducing the slope of the grade to slow the velocity of the water, and/or constructing energy break barriers with riprap or concrete.

Snow traps — in situ snow banked up to trap snow that could blow into the community.

Swale — a shallow, natural or man-made vegetated depression that collects and dissipates the flow of localized runoff, encouraging infiltration.

Time of concentration — time required for storm run off to flow from the most remote point of the drainage area to the point under consideration.

Watershed — the boundary of a drainage basin in which all precipitation naturally falls and flows to a single exit point.

Wetland — an ecosystem having its water table near the surface of the main root system of plants growing with it.

3.2 Abbreviations
The following abbreviations shall apply in this Standard:

ATV — All-terrain vehicle
4 Community drainage system planning

4.1 Introduction
Community drainage system planning in the north should influence where buildings, roads, and municipal infrastructure are located as well as how sites are cleared, graded, and shaped. The drainage plan outlines how runoff is managed throughout the community and specifies the placement and routing of drainage channels, ditches, berms, and culverts to collect and direct surface drainage safely through a community to the point of discharge. Community drainage plans are intended to minimize the impacts associated with flooding, washouts, slides, and any other surface drainage problems that could arise. The intent is to make drainage planning a routine and necessary element of overall community planning. The results of drainage planning should be incorporated into community plans that set out which lands can be developed and which lands should be left in a natural state. Drainage planning may also be used as the basis for making improvements to existing systems to minimize future problems.

Community drainage system plans also help communities anticipate, manage, and mitigate risks associated with excess surface water. Community drainage plans provide reference information to high-level governments, local governments, local staff, consultants, and any other parties with a stake in risk evaluation, infrastructure design, environmental assessment, and drainage system management and maintenance. Drainage plans also contain technical information to support community planning, engineering, and maintenance of related community infrastructure. The information collected and contained in community drainage plans should address issues associated with risk assessment, infrastructure, design, and drainage system management and maintenance. Good drainage plans help ensure the efficient, cost effective operation of surface drainage measures in the community.

Figures 4 and 5 show examples of systems that can be part of a drainage plan.
Figure 4
Plan view of driveways, drainage ditches, and culverts
(See Clause 4.1.)

Ditches and culverts should be located within road rights-of-way and be properly maintained to avoid flooding and the creation of stagnant pools of water.
4.2 Planning logistics

4.2.1 Timeframes and planning process
Timing and seasonality influence drainage planning in northern Canada. Planners of community drainage systems shall account for factors that can impact the timing of activities. For example, the timeframes required:

a) for capital budget approval of plans and projects;
b) to obtain the appropriate permits;
c) to research and collect necessary background information and conduct field investigation to resolve issues and concerns;

4.2.2 Existing plans and community development policies

Where they exist, community and infrastructure development planning processes should directly specify the development of drainage plans and incorporate this requirement at the earliest possible update to these documents. Annex E contains an example of a community land use plan.

Note: Policies and procedures that influence the location of roads, selection of development areas, and protection of green spaces help establish land use priorities and become an integral part of drainage system planning, design, and operation.

4.2.3 Communities with a community plan

Where a community plan exists but drainage plans do not, drainage plans shall be prepared and incorporated into the subsequent update of the community plan.

4.2.4 Communities without a community plan

In communities where a community plan does not exist, community drainage policies shall be stated in the community plan when available.

4.3 Starting a drainage plan

4.3.1 Drainage planning flow chart

A typical process for preparing a drainage plan is illustrated in Figure 6. Refer to the flowchart for Clauses 4.3.2 to 4.3.6.
Figure 6
Drainage planning flow chart
(See Clause 4.3.1.)

Collect background information on:
- Existing drainage/soils, surficial geology
- Weather records (wind, precipitation, temperature)
- Historical surface water levels
- Local permafrost conditions and areas where erosion, thaw subsidence, and other permafrost thaw related issues have been observed

Develop a base-line drainage map showing:
- Watershed boundary and drainage sub-basins
- Topography (min 1 m) and natural flow direction
- Effects of man-made interventions on flow (e.g., culverts and ditches, outlets)

Collection should start during winter months (preferably 8 months before spring melt)

Classify local terrain conditions as:
- Suitable for development: Ground conditions known, permafrost stable if present, well drained soils, slopes <5°, existing information good
- Possibly suitable for development: Area generally suitable but requires field inspection and further study as some constraints/data gaps present
- Marginally suitable for development: All data indicates significant constraints present but may contain pockets of useable land subject to detailed study
- Unsuitable for development: Rugged terrain, presence of geo-hazards or subsidence indicating permafrost instability, floodplain.
- Unknown suitability: Data non-existent or unsuitable for terrain analysis to determine land development suitability (e.g., inadequate coverage, scale, accuracy etc.)

Develop conceptual subdivision plan layouts for future development areas

Analyse amount, location, and relationships between land suitability, present and emerging community needs for lands suitable for development for different purposes (e.g., residential commercial, industrial, open space, environmental protection).

Complete development opportunities and constraint map indicating land use development priorities and growth direction, as well as implications for surface drainage management and watershed protection.

Note: This flow chart acknowledges that the spring runoff and summer drainage issues must be observed before the drainage plan can be fully developed and, therefore, funding to support drainage system development might need to span two fiscal years. This ensures that the background research is complete the previous winter and the
logistics are in place to ensure the consultant can visit the community first during the spring runoff period and then later in the summer to observe subsequent effects and maintenance procedures.

4.3.2 Compilation of information on existing surface drainage systems
Information of the existing surface drainage systems within or adjacent to the area to be developed shall be collected and summarized, as drainage planning might occur in pristine areas or within or adjacent to an area with existing drainage infrastructure. The information compiled can include
a) planning reports (which may contain drawings of current or planned infrastructure locations);
b) engineering reports (which may contain engineering drawings or calculations for drainage engineering, and/or plan and profile information for the drainage system);
c) legal survey plans; and
d) other relevant documents.

Where possible, the information collected should be summarized in text, picture, map, and chart form.
Notes:
1) The information compiled should be sufficient to show how surface water currently flows through the community and is influenced by, for example, topography, ground conditions, vegetation, and natural watercourses. In map form it should show where water originates from and how any drainage patterns have been altered by, for example, local land use, placement of roads, ditches, and channels that have been installed to collect, control, and direct surface water flow.
2) The documents listed in items (a), (b), (c), and (d) might be available from the community administration or higher level government.
3) The unique geography and topographical features of a community can affect the nature of land uses.
4) A variety of other factors relevant to drainage planning need to be considered including elevation, slope and aspect, location and latitude, climate and local weather, and ground conditions.

4.3.3 Compilation of climate data for surface drainage system planning
A variety of climate conditions can influence surface drainage planning and design. Appropriate climate and weather data, when available, shall be collected and summarized, including data on
a) air temperature;
b) precipitation types and amounts by season;
c) prevailing wind speed and direction;
d) heat/degree days;
e) sunshine and cloudiness; and
f) various other factors such as topography, geography, and proximity to large bodies of water.

Notes:
1) Proximity to large bodies of water can influence local weather conditions and in turn moderate or complicate local surficial drainage conditions.
2) Climate data should include, when available, local and traditional knowledge in order to fill in gaps and assist in the identification of information specific to the affected community.
3) Climate data are particularly important because many observable changes in the climate appear to be happening faster in northern Canada than in most other regions.

4.3.4 Existing drainage system inventory, condition, and effectiveness

4.3.4.1 Inventory of existing drainage system
The location of existing drainage infrastructure shall be mapped. An inventory of the system shall be taken and the condition of equipment shall be documented. The inventory should consist of specific drawings, tables, and photographs compiled into a complete single document that can be periodically and easily revised. Drainage problem areas shall be identified with particular attention given where
drainage problems and infrastructure failures are most common and repairs are likely needed. Where possible, indication should be made of the types of climate and related environmental conditions or events associated with the occurrence of drainage problems and infrastructure failures.

**Note:** Typical drainage system issues include culvert freeze-ups during spring melt, damaged culvert ends, eroded drainage courses and ditches, and pooling of water due to poor grading or underlying frozen ground preventing infiltration.

### 4.3.4.2 Site inspections

Site inspections shall be carried out around the time of spring melt, during the summer, and at freeze-up time to identify surface runoff management issues and causes. Site inspections should be carried out visually and make use of photography for documentation purposes. During the winter, it shall be noted where snow naturally accumulates or is piled during snow clearing operations and is affected by road and building placement.

**Note:** The existing drainage system includes all manufactured features intended to collect, direct, and convey surface water through the community. These features can include channels, ditches, swales, culverts, ponds, and pools.

#### 4.3.5 Identification of key infrastructure

Key infrastructure should be identified from the inventory and identified on a single figure of the area. Key infrastructure determination shall be based on the list of buildings set out in the *National Building Code of Canada* (NBCC) post-disaster building requirements. The drainage planning process should consider a higher degree of risk abatement to protect against inundation of buildings classified in the NBCC as having “post-disaster” status.

**Note:** Key infrastructure refers to facilities and municipal works that are essential to maintaining public health and safety. Key infrastructure can include roads, paths, culverts, bridges, ditches, swales, and natural drainage courses that collectively capture, direct, and convey surface drainage away from or through the community to prevent, erosion, flooding, the creation of standing water that might affect the structural integrity of buildings, roads and other associated infrastructure, the protection of natural water quality, and the mitigation of potential public health and safety risks.

### 4.3.6 Integration with natural features

#### 4.3.6.1 Opportunity and constraint map

An opportunity and constraint map should be developed that takes into consideration the catchment areas, drainage patterns, and permafrost conditions.

**Note:** Designing a drainage plan for future developments should begin in the early planning stages of developing an official community plan.

#### 4.3.6.2 Future development areas

Future development areas should be designed to take advantage of opportunities and avoid severe constraints. It is at this stage that the drainage plan should be developed and the primary drainage elements of conveyance systems (e.g., channels, ditches, and berms) and detention systems (e.g., ponds and pools) identified.
4.4 Data sources

4.4.1 General

4.4.1.1 Data sources
Data sources shall be used during the planning of community drainage systems in accordance with Clauses 4.4.1.2 to 4.4.6.

4.4.1.2 Alternative data sources
Where the necessary drainage-related data do not exist or cannot be collected, alternative data sources should be used, including
a) observations by community members;
b) local knowledge from community staff or other persons on the observed flow in ditches or through culverts during particular drainage events; and
c) informal measurements of precipitation and snow fall by community members.

4.4.2 Hydrologic data
Where available, hydrologic data shall be developed and used for community drainage system planning. Hydrologic data can include historical rainfall and snowfall records. In the absence of sufficient information, reasoned estimations and reasonable assumptions may be made.

Notes:
1) Hydrologic data inputs have some limitations because the period of record can be very limited. This is usually the case, with the exception of larger northern communities such as Whitehorse, Yellowknife, and Iqaluit.
2) Typically only the larger communities in the north have records that date back long enough to be statistically valid. For smaller communities, records from neighbouring communities may need to be referenced instead. These communities might be a great distance away and therefore the data might not be statistically valid in the area of interest.
3) In the complete absence of any hydrologic records, information from the nearest community with sufficiently complete data a great distance away will provide a starting point for developing hydrologic data and may provide the impetus for future data collection.
4) Where incomplete or uncertain data is used, it is very important to state the information assumptions upfront and then conservatively factor those accuracy limits into the planning methodology.

4.4.3 Topographic data
Where available, topographic data shall be used for drainage planning. This data may be obtained from various sources including the following:
a) National Topographic System (NTS) mapping, which is available for the entire north of Canada at a scale of 1:50,000 and a contour interval of 3 to 6 m;
b) aerial photographs, which are available for most northern communities at a scale in the range of 1:5000 to 1:10,000 and a contour interval of 0.5 to 1 m;
c) satellite mapping, which is becoming more readily available for most northern communities at a variety of scales and contour intervals down to 0.25 m; and
d) field survey mapping, which may be obtained by a qualified topographic surveyor and is available at a variety of scales and contour intervals less than 0.25 m. The accuracy of individual points may be within 1 cm.

Notes:
1) The conveyance of drainage generated by rainfall and snowmelt is ultimately influenced by community topography. Flat topography translates into no or slow flow and steep topography translates into fast flow; neither situation is generally desirable for drainage system planning.
2) The territorial governments generally have access to the information sources in Items (a), (b) and (c) listed above.

3) When officials are evaluating community mapping needs and considering costs, it is recommended to budget for an orthophoto product which has the ability to toggle contour information on or off. For mapping, it is important to include the immediate watershed and not just the municipal boundary.

4) Aerial photography scales have improved over the years. The most recent photographs available should be used to catalogue existing land use. Older photographs can be consulted to identify the nature of changes that have occurred over time.

5) Another useful technology for creating high-resolution maps is LIDAR (remote sensing equipment that uses laser light to measure distance).

4.4.4 Field survey mapping
Where available, field survey mapping shall be used for the design and construction of community drainage systems. The most recent information available should be used. The following maps can be used (in ordered preference):

a) accurate field survey; or
b) air photo and satellite-based mapping with topographic field survey for ground control undertaken by a qualified surveyor.

Notes:
1) Field survey mapping is ordinarily obtained during the preliminary engineering phase of a project rather than the drainage planning phase where the precision may be 1 m or more.
2) When air photo and satellite-based mapping are used (due to a lack of availability of accurate field mapping), a greater level of accuracy is still required for the design of drainage systems. A topographic field survey by a qualified surveyor provides a greater accuracy and higher precision of topographic information for existing features (e.g., roads, building, culverts, ditches, etc.) which is needed for the design of a drainage system.

4.4.5 Bedrock, surficial geology, vegetation, and permafrost data
Where available, terrain analysis maps, which may include surficial geology, vegetation, and permafrost data, shall be considered when developing community drainage plans. Where site-specific maps are not available, they should be developed for planning purposes.

Notes:
1) Surficial geology includes surface and near-surface soil and rock. Depth and type of bedrock, and the nature of soils should influence drainage planning. Understanding the nature and composition of the surficial geology of the community is important in determining the effects on runoff. During the summer months, when the ground is thawed, infiltration rates into the soil will provide a mitigating factor for surface runoff. When the ground is frozen, or if the surficial material is bedrock, there will be very limited surface runoff mitigation.
2) The vegetation associated with the surficial geology is also a factor in surface runoff. Generally, vegetation provides a stabilizing factor for surficial geology and a velocity reduction factor for the surface runoff.

4.4.6 Climatologic data
The most accurate local climate data shall be considered when developing a community drainage plan. The following data sources can be used:

a) available local data recorded at sites in close proximity to the community;
b) data kept by Environment Canada; or
c) other available data (e.g., from sites operated by the territory or community).

Notes:
1) Some observations suggest that extreme weather events will occur more frequently in the future; rainfall and snowfall amounts are expected to be greater and precipitation events more intense. This will directly affect the required size of drainage infrastructure (e.g., capacity of ditches and culverts). It also means there is greater risk of catastrophic events resulting in, for example, the washing away of roads.
2) The changing northern climate is anticipated to significantly influence the natural environment in the north resulting in changes to weather patterns, vegetation, surface and groundwater, and permafrost, which will ultimately impact northern community drainage planning.

3) Most of Canada’s north has a semi-arid climate in which the rate of evaporation exceeds the rate of precipitation.

4.5 Level of acceptable risk

The level of acceptable risk associated with the design of drainage infrastructure for runoff events should be explicitly addressed in community plans, including any and all assumptions upon which they are based. The protection of key infrastructure and transportation routes (e.g., critical link roads to infrastructure such as hospitals, nursing stations, or airports) should be prioritized by constructing larger drainage conveyance systems (e.g., ditches and culverts) in these areas.

Note: Acceptable level of risk should take into account community safety, the consequences associated with unexpected catastrophic events, the cost of protecting key community infrastructure assets, and the capacity of the community to manage, mitigate, and/or repair surface drainage damage. In an isolated community, protecting the airport runway and adjoining access road might be classified as a higher priority than protecting a local road and therefore more resources may be devoted to its initial construction and subsequent maintenance. Typically, priority assets include key public infrastructure such as schools, nursing stations, power and water treatment plants, and community supply stores.

4.6 Key factors for northern community drainage system planning

4.6.1 General requirements

Components of the community drainage system shall be planned such that they can be designed, constructed, maintained, and rehabilitated to have adequate capacity to safely handle design flows. Drainage systems should be serviceable, practical, and economical with the capability to last the design life. Where feasible, drainage systems should employ materials that are available locally and can be maintained by local personnel.

Note: It is recognized that there are differences between the various regions in northern Canada and that any drainage solution should be evaluated for its suitability based on the location of the community.

4.6.2 Geotechnical investigation

The drainage system planning process shall include a geotechnical investigation. In suspected or known areas of permafrost, the subsurface ground conditions, including ground temperature and ice content, shall be established. Geotechnical investigations should be undertaken in accordance with Annex A. In undertaking a geotechnical investigation, care shall be taken to carry out the investigation with minimal impact on the surface and underlying soil conditions.

Notes:
1) Geotechnical investigations are especially critical in areas underlain by permafrost.
2) In general, the investigation of permafrost conditions should be carried out through minimally destructive means, such as drilling. While drilling is preferred, the appropriate drilling equipment is typically unavailable in remote communities and alternative methods must be used. Annex A contains more information on sampling.

4.6.3 Disturbance of permafrost terrain

The drainage system planning process should not disturb terrain where permafrost is present. Berms shall be preferred over ditches in permafrost terrain. Particular care shall be taken to minimize erosion of the surficial soils. Where ditches are used, ditch liners should be specified.

Additional care shall be taken in permafrost areas known to be ice-rich.
Notes:
1) Permafrost, which is prevalent in many northern communities, is highly sensitive to the presence of water and will readily thaw or erode. Permafrost can be continuous or discontinuous. The latter situation is more difficult to manage because it usually occurs sporadically in pockets that are harder to define.
2) Ground disturbance in permafrost areas can ultimately increase maintenance costs.

4.6.4 Utilizing natural features
Drainage plans should specify that systems utilize natural features over manufactured structures wherever practicable.

4.6.5 Ground stability
To maintain ground stability, drainage plans shall ensure that no ponding of water occurs, with special care taken in permafrost areas. Drainage plans shall ensure that where flow could occur down a slope, the area is armoured with the appropriate constructed materials to mitigate erosion and subsidence. Figure 7 provides an example of unstable ground conditions.

Notes:
1) Ground stability is a function of the native soil materials, the slope of the soil materials, plant cover, and the presence of permafrost.
2) Standing water can thaw permafrost and, where ice-rich, result in subsidence or depressions leading to further collection of water and accelerated thawing.
3) Examples of appropriate construction materials include natural materials such as riprap and artificial materials such as geotextiles and geomembranes.

Figure 7
Unstable ground conditions within drainage discharge
(See Clause 4.6.5.)
4.6.6 Freezing and thawing

Community drainage plans shall account for seasonal freezing and thawing events as well as long term or ongoing subsidence that can hinder drainage and/or damage drainage infrastructure, such as freezing culverts and road surfaces.

Note: The freeze-thaw cycle is affected by latitude, geography, vegetation, and soil conditions as well as slope, gradient, and aspect orientation of the terrain. Thawing and refreezing events in the north are increasing in frequency as a result of the changing climate. This is creating additional challenges for drainage infrastructure, as it means systems must cope with more dynamic flow scenarios.

4.6.7 Precipitation events and patterns

Community drainage system planning shall consider climatic variability, including the intensity, duration, and frequency (IDF) of extreme precipitation events. IDF curves, if not readily available, should be developed if the data is available.

Notes:
1) CSA PLUS 4013 can be used to develop IDF curves for a community, though considerable expertise is required. Uncertainties in selecting IDF information are described in Notes (2) to (4).
2) Strictly speaking, IDF curves are site specific and generally not directly transferable to other sites even though in practice IDF data are often transposed spatially, using simple correction factors, without a full understanding of the implications and limitations.
3) Point data can be highly influenced by either the absence or inclusion of a particular outlier, especially in areas where thunderstorms tend to influence the critical design criteria and when available precipitation series are short.
4) Confidence intervals are rarely directly accounted for when applying IDF data, though uncertainty can be substantial, particularly for longer return period events and where data records are short.

4.7 Additional design considerations for the north

4.7.1 Snow management

4.7.1.1

Winter snow accumulation, blowing snow, and storage of snow can affect the performance of community drainage systems, particularly during the spring melt (freshet). Drainage plans shall account for the effects of snow on the drainage system. The following key locations within the community shall be identified:

a) areas with historically heavy snow accumulation;
b) areas historically affected by blowing snow; and
c) large community buildings with significant roof areas.

4.7.1.2

Community drainage plans should ensure that

a) ditches have adequate capacity to accommodate the piling of snow;
b) specific areas within the drainage system are designated for snow piling and snow storage, if required, and that these areas
   i) are located an appropriate distance from the nearest body of water;
   ii) are located so they do not adversely affect nearby buildings;
   iii) have positive drainage away from the piling location;
   iv) are located on soil with a sufficiently high percolation rate;
   v) are constructed to allow for the recovery of debris; and
   vi) are located so they do not block drainage courses; and
c) snow fences and snow traps are used to strategically manage snow accumulation and reduce drifting snow and the associated spring runoff within the community by creating snow accumulation in areas away from the centre of the community.

4.7.2 Seasonal planning and design considerations

4.7.2.1 General
Community drainage plans shall account for specific seasonal factors given in Clauses 4.7.2.2 to 4.7.2.6.

4.7.2.2 Spring
Freshet, or spring thaw and runoff, can comprise the majority of a community's runoff for the entire year. During this time of year, icings might be more likely.

Notes:
1) The flow rate during freshet will depend on the speed of the thaw and how saturated the ground was when it froze, as well as the rate of thawing.
2) Precipitation events during snowmelt can create exceptionally high runoff rates. This can cause overloading of the drainage system, which can be exacerbated by icing.
3) Icing can reduce the capacity of the drainage system.

4.7.2.3 Summer
Summer precipitation is primarily in the form of rainfall.

Note: Summer rainfall events can be severe and can occasionally lead to flooding. The changing climate is contributing to changes in the intensity, duration, and frequency of precipitation events.

4.7.2.4 Fall
Fall precipitation events can be in the form of rain or snow. During this time of year, icings might be more likely.

Note: Icing can reduce the capacity of the drainage system.

4.7.2.5 Winter
Winter precipitation is usually in the form of snowfall. In northern climates this usually has no immediate effect on the drainage system as it remains frozen until spring. However, partly due to climate change in recent years, freezing rain events and drastic short-term temperature fluctuations are becoming more common.

The location of snow features can impact drainage through the system when freshet begins.

4.7.2.6 Thaw season and freezing season
The length and timing of the transitional periods is influenced by the location, latitude, underlying soil conditions, terrain, and local weather patterns from year to year.
5 Northern community drainage system design

5.1 General

5.1.1 Designing to the acceptable level of risk
The community drainage system should be designed in accordance with the level of risk that is established during the planning process in accordance with Clause 4.5.

Notes:
1) It is recognized that the capacity of any drainage system might be exceeded at some point.
2) The design will be impacted by physical constraints present within the communities.
3) 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.
4) The acceptable level of risk established might be impacted by the changing 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.

5.1.2 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. Figures 8 and 9 depict catchment areas.

Note: The directions of the sloping ground will naturally indicate areas that surficial flow will meet at a common point.
Figure 8
Map of Gjoa Haven, Nunavut illustrating catchment areas (watershed and sub-basins)
(See Clause 5.1.2.)
Figure 9
Map of Gjoa Haven, Nunavut showing catchment areas that have not yet been disturbed
(See Clause 5.1.2.)
5.1.3 Cataloguing existing drainage patterns and drainage infrastructure

Existing drainage patterns and drainage infrastructure shall be catalogued and mapped in accordance with Clause 4.3.4. Existing buildings, road surfaces, ditches, culverts, and other relevant features shall be shown.

**Note:** This information is marked on the drainage catchment area map to determine where the drainage is currently being conveyed and will provide the basis for planning and possibly improving the conveyance system. If the drainage planning is being done for a new development, then the proposed roads and building sites need to be developed in conjunction with the catchment area information so as to reduce the risk of future drainage issues.

5.1.4 Positioning of the drainage conveyance system

Community drainage systems shall mimic the natural drainage system wherever practicable.

**Note:** The drainage conveyance system is the connecting system that would otherwise naturally occur in the streams that are present before the development of roads and structures. Roads and structures intercept the natural conveyance system and as such an engineered (i.e., artificial) conveyance system is created using ditches and culverts. How ditches are graded can compensate for the natural conveyance system.

5.1.5 Permafrost

5.1.5.1 Surface disturbance

Drainage systems should be designed to minimize surface disturbance in permafrost areas. Where surface disturbance (the removal of the organic insulating layer) is unavoidable, designs shall include steps to replace the insulation. It is preferable, in general, to convey surface water in ice rich permafrost areas using armoured berms or shallow swales rather than ditches.

5.1.5.2

When construction of drainage systems cannot be avoided in areas underlain by ice-rich permafrost, appropriate materials shall be selected in order to minimize permafrost degradation.

**Note:** The use of asphalt in permafrost areas will lead to heat absorption. An alternative road surfacing material lighter in colour should be selected.

5.1.6 Allowances for utilities

Community drainage systems shall be designed to avoid impact to buried utilities (e.g., telecommunications, electricity, gas, oil, water, steam, and waste collection). The lowest point of a ditch should be at least 1.5 m from buried lines.

**Notes:**

1) *It is recognized that spatial constraints in communities might not be able to achieve the required setbacks dictated by various planning requirements.*

2) *It is industry practice to leave a safe buffer from the bottom of a ditch so that lines are not damaged during construction and maintenance of the ditch.*

5.1.7 Allowances for water and sewer trucks

Where practicable, drainage system designs should incorporate shallow ditches that allow water and sewer trucks to cross safely.

**Note:** This will facilitate, for example, the delivery of water and removal of sewage from residences by allowing for adequately wide roadways (driveways) for service vehicles to access residential lots. Otherwise, if service vehicles must routinely pass over swales, this will lead to increased wear and hence maintenance costs for the vehicles. *Figure 10 shows an example of shallow swales that facilitate the crossing of vehicles.*
5.1.8 Accommodating ATV and snowmobile movement

Where trail networks exist, drainage systems should incorporate appropriate crossings. Existing drainage infrastructure should be marked so that it is visible during all seasons. Where practicable, drainage system designs should incorporate shallow ditches which allow ATV and snowmobile equipment to cross the trail network safely. When ditches deeper than 1 m are required, a crossing for ATV and snowmobiles should be placed every 25 m.

Culvert ends shall be marked in accordance with Clause 5.5.4.6.

Note: In many northern communities ATV and snowmobiles are a main mode of transportation.

5.2 Specific design considerations

5.2.1 General

5.2.1.1

Most small northern communities do not have buried storm sewers. Drainage is generally conveyed in roadside ditches. Where drainage must cross roads, culverts are typically used.
Some larger northern communities might have buried storm sewer systems. Roads usually drain to concrete or asphalt curbs. Water is collected in catch basins at low points and conveyed through buried pipe to the storm sewer.

5.2.1.2 Drainage system designs shall account for, at a minimum,

a) proposed land use of the drainage area;

b) anticipated precipitation events based on an appropriately selected recurrence interval;

c) characteristics of the drainage area;

d) infiltration zones;

e) topography of the drainage area;

f) nature of permafrost in the drainage area (if present);

g) inflows to the drainage area other than precipitation; and

h) available ground slope and grades within the drainage area.

5.2.2 Drainage estimation

5.2.2.1 Time of concentration

The time of concentration is the time required for runoff to flow from the most remote part of the drainage area (catchment) to the outlet of the drainage area. It consists of two parts:

a) the first part is the time for overland flow to travel from the perimeter of the catchment area to the drainage channel or conduit; and

b) the second part is the travel time in the conveyance system (channel or conduit) to the outlet of the drainage area.

The first part is calculated based on the overland flow length, the surface slope, the surface roughness and the depth of flow. This value is generally between 5 and 20 minutes.

The second component is calculated for each conveyance system segment based on slope, flow, and conveyance characteristics. The time of concentration can only be modified by changing pipe or channel velocities.

5.2.2.2 Flow estimation

Drainage flow shall be determined by estimating the quantity of water that moves across different land forms. It shall be calculated based on rainfall and snowmelt that is converted to equivalent rainfall.

5.2.2.3 Determining drainage demand

The surface drainage demand shall be calculated by considering the following inputs:

a) an approximation of the quantity of flow generated by rainfall or snowmelt, including but not limited to inputs from surfaces such as roadways, parking areas, building sites, building roofs, and undeveloped open spaces;

b) the permeability of the surface; and

c) the presence of frozen ground.

Notes:

1) Drainage estimate amounts from rainfall and snowmelt often require complicated mathematical models because of the size and complexity of the drainage circumstances. In northern communities, which are generally smaller and less complex, a simpler, more practical approach is needed. First, the necessary climatic information and time series might not exist or be too expensive to collect. Second, in smaller and more
remote communities, there are less external factors to consider because there is little if any sprawl beyond community boundaries that needs to be taken into account.

2) In northern Canada, the length of time that the surface is frozen, unfrozen, melting, or freezing is a key consideration for drainage systems.

3) The natural drainage system is influenced by how the natural landscape is altered through land development, including site grading, roads, parking lots, and buildings that alters the direction, volume, and infiltration of flowing water. For example, the surface of a roof is an impervious surface, and therefore a considerable amount of drainage will be generated in comparison to a grassy area of the same size, which allows for infiltration. The frozen or unfrozen state of the surface also influences drainage generation because frozen ground is relatively impervious compared to unfrozen ground.

4) For communities in the discontinuous permafrost zone, the permafrost distribution is an important factor as this will influence infiltration.

5.2.2.4 Drainage estimation across different land uses

Drainage estimates shall take into account the nature of the local geography and existing natural drainage features, and shall consider different land uses including, but not limited to:

a) developed land with buildings and pre-graded lots;
b) roads;
c) the location and nature of undeveloped land, including land that is marked for future development; and
d) whether the ground is underlain by permafrost.

Notes:

1) Different land uses have different effects on runoff. For example, infiltration in a park will be greater than in a gravel parking lot. Residential, commercial, institutional, industrial, and park land use have different characteristics. These different characteristics all affect the time of concentration of the drainage basin.

2) Roof drainage from buildings is typically discharged to the ground surrounding the building or to an underground drainage system. Roofs are impermeable, however, flat roofs may provide temporary storage for stormwater.

3) Roads usually drain from the centre to shoulders or curbs on the roadside. Occasionally, roads will drain from the sides to the centre. This is more common for lanes rather than streets. Drainage is collected by catch basins or ditches on the sides of the road.

5.2.2.5 Calculating drainage generation

Calculation of the drainage flow rate can make use of the rational method formula in accordance with Clause 5.2.2.6 with reasoned estimations and reasonable assumptions for each catchment area.

Note: The calculation is expanded downstream as smaller catchment areas combine.

5.2.2.6 The rational method for calculating drainage flow rate

The rational method can be used to calculate the potential flow contributions from the community watershed. The rational method, which relates the runoff rate to rainfall intensity and drainage area is given by the equation

\[ Q = \frac{c i a}{360} \]

where
\[ Q = \text{peak runoff rate (m}^3/\text{s)} \]
\[ c = \text{runoff coefficient} \]
\[ i = \text{rainfall intensity (mm/hr)} \]
\[ a = \text{drainage area (ha)} \]
The user of the rational method formula should exercise a considerable amount of judgement in selecting an appropriate value for the runoff coefficient $c$ as runoff is directly proportional to the value selected for $c$. Table 1 provides some typical values of $c$ for various unfrozen surface conditions in southern areas for storms in the 5 to 10 year return period. These values should be increased for more severe storms to reflect saturated ground conditions.

These values are also applicable in portions of Canada’s north, but can result in understating runoff in permafrost areas with shallow saturated active layers.

The runoff coefficients in Table 1 are also not appropriate for spring runoff conditions where runoff can approach 100% when the ground is frozen, particularly when the ground is saturated and cannot accept any infiltration. Designers shall determine which condition provides the most severe runoff (e.g., a storm event or spring runoff) and design the conveyance items accordingly.

Notes:
1) The rational method is based upon an empirical equation which relates the peak flow rate to the drainage area, the rainfall intensity, the time of concentration and the runoff coefficient.
2) More complex computer-aided methods may need to be used for larger drainage areas (e.g., greater than 10 hectares as stated in the City of Whitehorse Servicing Standard Manual).
3) The snowmelt estimation may be applied using an estimated equivalent intensity measured in millimetres per hour and the rational method of calculation.
4) More sophisticated mathematical methods for drainage estimation may be applied if the baseline data exists.
5) Lower values can be used in short return period storms, but larger values are required in longer return period storms which saturate the ground. Values should be increased for storms of >10 years return.

### Table 1

**Recommended values of relative imperviousness for use in rational formula**

(See Clause 5.2.2.6.)

<table>
<thead>
<tr>
<th>Type of unfrozen surface</th>
<th>Coefficient $c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy soil, flat, 2%</td>
<td>0.05-0.10</td>
</tr>
<tr>
<td>Sandy soil, average, 2-7%</td>
<td>0.10-0.15</td>
</tr>
<tr>
<td>Sandy soil, steep, 7%</td>
<td>0.15-0.20</td>
</tr>
<tr>
<td>Fine-grained soil, flat, 2%</td>
<td>0.13-0.22</td>
</tr>
<tr>
<td>Fine-grained soil, average, 2-7%</td>
<td>0.18-0.22</td>
</tr>
<tr>
<td>Fine-grained soil, steep, 7%</td>
<td>0.25-0.35</td>
</tr>
<tr>
<td>Bituminous surface treatment</td>
<td>0.60-0.70</td>
</tr>
<tr>
<td>Asphaltic pavements</td>
<td>0.80-0.95</td>
</tr>
<tr>
<td>Concrete pavements</td>
<td>0.70-0.95</td>
</tr>
<tr>
<td>Gravel or macadam pavements</td>
<td>0.35-0.70</td>
</tr>
</tbody>
</table>

(Source: American Iron and Steel Institute)
5.3 Designing drainage conveyance

5.3.1 General
Designing drainage conveyance refers to the approach and features used to intercept, collect, and direct the drainage flow by gravity in the desired direction down slope. 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).

Notes:
1) The Manning formula can be used to calculate the estimated velocity of water flowing through a conduit.
2) The topography may be the natural slope of the land or the constructed slope of a development such as a parking lot.
3) Natural drainage pools generally consist of wetlands, ponds (small), and lakes (large). Natural channels consist of streams (small) and rivers (large).

5.3.2 Designing to maintain natural drainage conveyance processes
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.

Note: Drainage conveyance in northern communities generally consists of constructed, exposed surface channels which collect and redirect drainage in a preconceived manner. These ditches are generally constructed to direct the drainage to collection and barrier-defined crossing points within the road network consisting of culverts. Culvert size and placement is influenced by ground conditions, the water volume to be carried, local climate conditions, and the nature of the flow.

5.3.3 Rate of runoff control detention
Drainage plans shall be developed with consideration of the rate of flow control. This can be undertaken in accordance with Clause 5.7.3.

5.3.4 Incorporating storage into drainage designs

5.3.4.1 General
Drainage storage may be incorporated into the drainage system design as an area within the conveyance system. Drainage storage should only be used in conjunction with natural or constructed (i.e., excavated) ponds or pools or where ground conditions create natural wetlands. Wherever practicable, natural wetlands shall be used over detention ponds. Drainage detention shall take place in a location where it will not adversely impact the residents within the community.

Notes:
1) Natural wetlands are preferred over detention ponds because they are low (zero) cost to build, have natural filtration for sediment control (to improve downstream water quality), do not promote breeding of mosquitoes, and moderate flow which helps to reduce bank erosion.
2) Drainage storage is most easily incorporated in natural areas of the conveyance system such as ponds, however engineered storage areas (i.e., excavated ponds) may also be constructed.
3) Naturally occurring pools of accumulated rainfall or snowmelt (ponds or lakes) provide drainage storage.

5.3.4.2 Wetlands
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.
5.3.4.3 Drainage storage by constructed pond or pool

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).

Notes:
1) In northern communities, drainage storage is generally not desirable because it promotes permafrost degradation in the immediate area, provides breeding areas for insects, and creates potential water hazards for children.
2) Surface water contamination in northern communities is a longstanding concern.

5.3.4.4 Emptying of detention ponds

Drainage system detention ponds should be built to be empty within 72 h in order to mitigate the breeding of pests (e.g., mosquitoes) and to minimize the adverse impact on surrounding permafrost.

5.4 Drainage discharge

5.4.1 Discharge location

5.4.1.1 General

The drainage discharge point shall take into account the size and characteristics of the receiving body (e.g., stream, river, lake, or ocean), the volume and velocity of the discharge, the nature of adjacent land uses, the terrain at the discharge point, as well as the need for mitigation measures to prevent erosion and ensure public safety. Figure 11 provides an example of a culvert discharge area with extensive riprap.

Notes:
1) Drainage discharges might require the use of structural elements such as riprap, gabions, concrete structures, or wood cribbing in order to reduce velocities and mitigate erosion.
2) Establishing the discharge point and method is influenced by a variety of factors including volume and rate of flow, method of conveyance, and nature of the discharge body.
5.4.1.2 Discharge location and surface water intake
Drainage discharge locations shall be positioned so that they do not impact surface water intake, and so that water samples can be easily taken.

Note: Some drainage discharge points might require a permit or licence from the authority having jurisdiction.

5.4.1.3 Riparian zone
The location of the riparian zone shall be considered when locating outfalls according to the requirements of the authority having jurisdiction.

5.4.2 Drainage discharge development
Drainage discharge shall be designed and constructed to manage large flows, avoid erosion of soil, and provide a hydraulic transition from the drainage conveyance system to the receiving body of water.

Notes:
1) The erosion of soil into the lake or ocean creates sediment loads which might damage the environment.
2) The drainage generated by rainfall or snowmelt flows by gravity through the conveyance system, which might include storage, to a drainage discharge, which is usually a lake or river, or the ocean in northern coastal communities. The drainage flow can be quite large by the time it reaches the drainage discharge point depending upon the drainage generation circumstances.
5.4.3 Drainage discharge erosion control
Designs shall mitigate erosion caused by drainage discharges. The following features can be used to manage erosion:

a) sediment traps (geotextile elements);

b) structural elements placed in the way of the flow, including
   i) riprap;
   ii) gabions;
   iii) concrete structures; and
   iv) wood cribbing; and

c) vegetation.

5.5 Design of drainage system components
Note: Additional examples of drainage component designs are contained in Annex D.

5.5.1 General
Surface drainage systems should be constructed by grading and shaping the surface to create swales, ditches, berms, and channels that drain by gravity. Other structures, such as culverts and bridges, can be installed to convey drainage through or under features such as roads. Figure 12 shows an example of drainage system components.

Figure 12
Example of ditches and culverts in Old Crow, Yukon Territory
(See Clause 5.5.1.)
5.5.2 Swales, ditches, and channels
Drainage system designs should include a network of swales, ditches, and/or channels to safely and efficiently collect, convey, and discharge surface drainage. The system design shall consider the major flow path that the runoff will take when the capacity of the drainage system is exceeded.

Note: The delineation between the drainage structures is not exact, however swales are generally shallower than ditches, with flatter side slopes, and can be associated with drainage conveyance along the property limits. Ditches are often constructed along roads to convey drainage from the road. Channels are generally larger structures that stand alone and convey drainage independently from the road system.

5.5.3 Ditches
Ditches shall be constructed to a depth that ensures the road structure is adequately drained.

Note: If the ditch is not deep enough, there is a risk that the road structure will be saturated and soft.

5.5.4 Culverts
Notes:
1) Clause 6.3 should be consulted for requirements for culvert mapping.
2) Culverts are inherently dangerous pieces of equipment, especially for children (e.g., falling into a culvert with water running through it).

5.5.4.1 Culvert sizing
Culverts shall be sized to reflect the potential flow requirement, facilitate maintenance activities, and avoid ponding during storm events. The minimum size culvert in a community drainage system should be 0.45 m (18 in) to facilitate access by maintenance personnel to thaw the culvert during spring runoff.

Notes:
1) A minimum size also allows some icing to occur without complete blockage, minimizing intervention by thawing devices.
2) When sizing culverts in new construction, it may be prudent to outfit the community with only a select few sizes of culverts while over sizing some installations so that the community’s culvert inventory can be more easily managed.

5.5.4.2 Culvert icing
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.

5.5.4.3 Culvert installation

5.5.4.3.1 General
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 13 provides an example of a culvert apron.
Figure 13
Example of a culvert apron
(See Clause 5.5.4.3.1.)

Notes:
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.

5.5.4.3.2 Culvert installation and permafrost
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.

5.5.4.4 Provisions for fish passage in fish-bearing streams
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.

Note: In the case of fish passage, the authority having jurisdiction can be any level of government (from federal to local).

5.5.4.5 Culvert end treatments
Culvert inlets and outlets shall be designed to mitigate erosion of the surrounding area. Where culverts are installed in fish-bearing streams, culvert inlets and outlets shall be designed to facilitate the passage of fish. Design documents should identify if, when, and which end treatments are to be used.
Notes:

1) Types of culvert inlet improvements include bevel-edged inlets, side-tapered inlets, or slope-tapered inlets. These can be used in conjunction with erosion control measures such as riprap armouring, gabion baskets, wing walls, and head walls.

2) Examples of erosion mitigation measures include the addition of baffles within the culvert to reduce stream velocity or the addition of riprap at the base of the plunge pool downstream of the culvert outlet to mitigate scour.

5.5.4.6 Culvert marking
Culverts should be marked with a post painted in a bright colour (e.g., red or yellow). The post should be installed at the precise location of the culvert end. Marking posts should be installed with the following convention: when looking at the marker post from the road centre line, the culvert will be on the left (or right) side at the base of the post.

Note: A marking post system improves the efficiency of maintenance activities and helps to reduce the risk of inadvertent damage to the culvert ends, which can restrict flow. A marking post system also helps prevent an ATV, snowmobile, or other vehicle from hitting the culvert end, causing damage to the culvert and/or personal injury to the vehicle operator.

5.5.5 Dykes and berms
Dykes or berms, constructed of earth, should be constructed where there is a need to divert or slow drainage.

5.5.6 Road crown and crossfall
Roads shall be crowned (i.e., higher in the centre than on the shoulders) or shall have crossfall to aid drainage from the road surface. Reverse crowns should only be done on hard surfaced road ways. Figure 14 shows an example of a road embankment.

Note: Crowns can also be lower in the centre and function as shallow swales if the road centre line has a grade.

Figure 14
Typical embankment for level ground free of ice-rich permafrost
(See Clause 5.5.6.)
Note: Refer to the Transportation Association of Canada’s Guidelines for Development and Management of Transportation Infrastructure in Permafrost Regions for additional guidance on the design of roadway infrastructure.

5.6 Erosion, sedimentation, and soils

5.6.1 Erosion control
Erosion control shall be provided where there is evidence and/or risk of erosion to the drainage structure. Erosion control can be in the form of geotextile materials, rock materials, ditch blocks, concrete structures, vegetation, or combinations of these materials.

5.6.2 Sediment control
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.
Note: Siltation traps are generally temporary until vegetation can be re-established or other erosion protection can be installed. The most common would be filter fabric supported on vertical stakes but other means such as straw bales have been used across drainage courses.

5.6.3 Soils
The type of soil can determine the acceptable velocities and potential for erosion in drainage swales. Soil types should be identified to aid in the evaluation of infiltration mechanisms including French drains, rock pits, infiltration galleries, and perforated culverts.

5.7 Overflow and flow control

5.7.1 Protection against system overflow in conveyance system
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.

5.7.2 Design of overflow culverts
The need for overflow culverts and their capacity shall be determined on a case by case basis.

5.7.3 Flow control
Natural wetlands, detention ponds, and restricted outfalls may be used to reduce the rate of discharge to protect the integrity of the downstream water course.

5.8 Pest control
Drainage detention should be selected over retention to reduce water ponding since ponded water can serve as a mosquito breeding habitat. If retention used, it shall be accommodated with a pest control plan.

Beavers shall be controlled humanely and according to the authority having jurisdiction.
5.9 Design for maintenance equipment
Drainage systems shall be designed with consideration for maintenance equipment.
Note: Drainage systems may be built with equipment that is brought in from outside the community and will be brought out once the construction is complete.

5.10 Periodic review
Drainage plans shall be updated periodically, preferably in conjunction with community plans, to account for changes in the nature of drainage and to identify deficiencies in the system.

6 Inspection and maintenance of community drainage systems

6.1 General

6.1.1 General
A properly maintained and monitored community drainage system supports a safe, clean, and well managed community. The original designs of the drainage system shall be maintained where practicable to ensure that the system operates as intended. Figure 15 shows an example of a blocked culvert where drainage would be compromised.
6.1.2 Maintenance and monitoring program

In order to ensure proper functioning of the drainage system, a program to maintain and monitor the community drainage system shall be established, implemented, and operated.

Notes:

1) Specific benefits can include a reduction in stagnant water and associated waterborne vectors and odours, reduction in seasonal impacts to infrastructure caused by damage from overland water flow and flooding, and the upholding of community aesthetics.

2) It is often the responsibility of the community chief administrative officer (CAO) or senior administrative officer (SAO) to ensure that the infrastructure goals of the community council are met. The community council and CAO or SAO should support the community foreman by including provisions in the community’s annual operations and maintenance budget to maintain the drainage system. Community councils can enable the CAO or SAO, and foreman to maintain drainage areas by implementing and enforcing bylaws for construction and litter control that help reduce the incidence of unnaturally occurring obstacles to drainage.
3) Proper functioning of the drainage system is critical for ensuring safety and economic security for community residents.

6.2 Inspection and maintenance personnel
Inspection and maintenance activities shall be carried out by a competent individual.

Note: In northern communities, competent individuals can include the town foreman or equipment and utility operators. The town foreman is often tasked with providing hands-on solutions for both day-to-day and seasonal drainage problems.

6.3 Culvert mapping
A map which indicates the location of culverts throughout the community shall be developed and maintained. The size of each culvert and the direction of flow through the culvert should be indicated on the map.

Note: When possible, the coordinates of culverts should be obtained and mapped using a GPS, recognizing that the accuracy of a hand-held GPS unit can be limited.

6.4 Maintaining culvert marking posts
Culverts marking posts, when lost or damaged, shall be replaced. Culvert markings shall be installed in accordance with Clause 5.5.4.6.

6.5 Culvert maintenance
Spare culverts shall be kept on hand to facilitate the repair and replacement of all sizes of culverts within the community. Where culvert ends are damaged and replaced, the useable section may be cut off for reuse.

Headwall and endwall protection should be used to prevent the culvert ends from being crushed. Typically, the culvert manufacturer can supply this equipment.

The corrugated steel pipe (CSP) manufacturer's recommendation for proper installation shall be followed.

Notes:
1) Typical culvert end protection devices are made of galvanized steel, concrete, or HDPE plastic.
2) If sufficient cover over a culvert cannot be maintained, the ends can be crushed or flattened. Some communities have opted to use schedule 20 steel piping for shallow buried driveway culvert installations with success.

6.6 Seasonal inspection and maintenance

6.6.1 Maintenance schedule

6.6.1.1 A drainage system maintenance schedule shall be developed and should include season-specific activities. The schedule shall consider the possible consequences of failure of the system with respect to personal safety, economic loss, environmental damage, and social disruption. The schedule should also indicate the estimated cost and effort to maintain these risks at a reasonable level.

The consequences of a drainage system failure can be grouped under the following risk classifications:

a) low — consequences of failure are minor;

b) medium — consequences of failure are considerable; and
c) high — consequences of failure are grave. This could apply to key infrastructure that would be needed following a disaster.

6.6.1.2
The maintenance schedule shall
a) cover a period of one calendar year at minimum;
b) allow for the identification of any maintenance items a year prior to the expected start of the maintenance work; and
c) assign adequate resources to allow for the completion of repairs during the period following the spring melt and before the next snow cycle begins.

If repairs cannot be completed during the prevailing season, they should be prioritized in the subsequent maintenance cycle, depending on the nature of other required maintenance at that time.

Note: Due to the short construction season in the northern latitudes, maintenance issues that are identified in the spring should be fixed in the summer and fall to ensure that improvements are complete for the following spring. Construction seasons in the north are usually from mid-May to the end of September. The community’s management personnel and administrators should assign a high priority to drainage issues when it comes to funding allocation for materials and labour so that appreciable improvements can be made.

6.6.2 Spring season

6.6.2.1
Culverts shall be inspected to determine if backed-up melt water is present. The cause of any backed-up melt water shall be identified (e.g., frozen snow and water, ice, debris etc.) and removed.

6.6.2.2
Culverts ends shall be cleared when blocked with snow or ice. A back hoe, excavator, or hand tool may be used. Blocked culverts shall be cleared to allow melt water to flow freely. An oil-fired steamer or pressure hot washer can be used to melt frozen blockage from the downstream end of the culvert. This method will help the operator to stay dry and see when the water is flowing. Equipment-specific operating procedures should be developed. Figure 16 shows a culvert blocked by snow.
6.6.2.3
A priority system shall be used to thaw and unblock culverts. Maintenance personnel should begin at the end of the drainage system and work upstream. Frozen culverts might need to be reopened over periods where temperatures are below freezing at night and above zero during the day. Melt water overflowing a road or driveway approach can erode the structure if left unchecked.

Note: Maintenance personnel should beware of thawing out a culvert only to have that water trapped at another frozen culvert downstream.

6.6.2.4
After a rain event and during spring runoff, the outlets of the drainage system closest to the discharge location should be inspected for litter and other debris from the community that has been carried by drainage water. If litter and debris are present, it shall be collected and disposed of in accordance with local regulations.

6.6.2.5
The drainage system shall be inspected at some point during runoff and rain events to identify deficiencies for repair over the spring and summer.
Note: Many buried stormwater culverts or piping will build up gravel over time which reduces their effectiveness. Use of a flusher truck or similar equipment works well to unblock the culverts. Smaller communities may consider using a fire truck’s hose.

6.6.3 Summer season

6.6.3.1 Following the spring runoff, at the beginning of the summer season, the complete drainage system shall be inspected by a competent person and any deficiencies shall be identified.
Note: A competent person can include the community foreman, an equipment operator, or other qualified person as assigned by the authority having jurisdiction.

6.6.3.2 Any deficiencies that are identified shall be investigated and a corrective action plan shall be developed. The following activities shall be included in the corrective action plan as a minimum:
   a) ponding in ditches shall be identified and corrective action taken. This can include re-sloping the ditch bottom or lowering a downstream culvert;
      Note: Ponded water left in the ditch will eventually undermine the nearby road base, possibly causing frost heaving or subsidence.
   b) in areas where overgrown vegetation is prevalent around culverts and other drainage channels, the vegetation shall be mowed or cut back;
   c) blocked culverts should be flushed to remove sediment, rocks, and other debris. A water pump attached to a water tanker can be used;
   d) where practicable, damaged culvert ends shall be cut back, replaced, or else collapsed ends bent open; and
   e) culverts that have shifted or moved shall be replaced or re-installed on a priority basis.

6.6.4 Fall season

6.6.4.1 Maintenance and repair of saturated areas of the drainage system should be carried out in the fall when water levels in the north are typically lowest.
Note: It is not recommended to repair or replace culverts when water is running through them.

6.6.4.2 Culvert marking posts shall be inspected and replaced if damaged.

6.6.4.3 Maintenance personnel should have completed all work that was identified during the spring inspection in accordance with Clause 6.6.2.

6.6.5 Winter season

6.6.5.1 An inspection shall be undertaken to ensure that the drainage system elements are not damaged or blocked during the snow removal and storage process.
6.6.5.2
The following components of the community drainage system shall be clearly marked and identifiable before the first snow fall to inform snow removal equipment operators of their location:
   a) outfalls;
   b) drainage ditches;
   c) culvert ends; and
   d) culvert marking posts.

6.7 Requirements for erosion and sediment control
Community drainage system maintenance activities should include as a minimum the following erosion and sediment control measures:
   a) maintaining vegetation in ditches to prevent erosion;
   b) mowing ditches to reduce the growth of trees;
   c) using silt curtains in areas where the community runoff barring silt can enter a fish-bearing body of water; and
   d) where discharge water velocity requires it, placing riprap or large rocks at the outlet of culverts to prevent washouts at the culvert exit.

6.8 Snow removal management

6.8.1 General
A snow removal management plan should be developed to remove snow from roads, sidewalks, and parking lots to control melting in the spring. Snow left in place can be a safety issue for pedestrians and vehicular traffic. Figure 17 shows an example of snow piled adjacent to a roadway.
6.8.2 Snow removal management plan

The snow removal management plan should consider as a minimum the following:

a) snowmelt from removed snow should be prevented from re-entering the drainage system;
   
   **Note:** Snow piles that melt and re-enter the drainage system as runoff can overwhelm the system and cause damage or flooding.

b) identification of the most critical culverts and their priority level for maintenance;
   
   **Note:** Because snow can melt so quickly, a plan must be in place to thaw critical culverts first. There needs to be a priority system in place so workers know the order to thaw culverts to effectively drain the snowmelt from the community. Snowmelt can cause a great deal of damage to road surfaces if the melt water overruns a road surface as a result of a clogged culvert.

c) if the terrain allows, snow berms or snow fences should be used to trap wind-blown snow outside of the community to reduce the amount of snow that enters the community to become additional runoff during spring melt; and
   
   **Note:** Open countryside can be susceptible to wind-blown snow.

d) if snow berms are used, they should be maintained throughout the winter and should be pushed up when the snow trap becomes full and is no longer effective.
6.9 Community drainage system monitoring and inspection

6.9.1 General
Systematic monitoring of drainage systems shall be part of the overall community asset management program. The community foreman should patrol the drainage areas while snowmelt and precipitation events are occurring in order to identify deficiencies that might require repair.

6.9.2 Warning signs of a degraded system
Maintenance personnel shall inspect drainage systems for the following warning signs of a degraded system.

a) flooding;
b) standing water;
c) poor or slow drainage;
d) damming;
e) ground subsidence;
f) erosion;
g) overgrown culvert ends;
h) blockages or excessive debris (e.g., leaves, litter, grass, rocks and silt, and other debris);
i) excessive vegetation impeding flow; and
j) abandoned cars or other vehicles, or construction material blocking the drainage area.

Deficiencies that are identified shall be remediated in accordance with Clause 6. Figures 18, 19, and 20 show drainage systems requiring maintenance.
Figure 18
Example of blocked culvert
(See Clause 6.9.2.)
Figure 19
Example of debris in drainage channel
(See Clause 6.9.2.)
6.9.3 Key areas to monitor

As a minimum, the following features and drainage components shall be inspected for proper operation as part of the community drainage maintenance program:

a) hillsides;
b) streams;
c) gullies;
d) road crowns;
e) ditches;
f) swales;
g) culverts;
h) channels;
i) dykes; and
j) infiltration areas.
6.9.4 Inspection checklists

6.9.4.1 Checklists
Inspection and maintenance checklists should be used when inspecting the community drainage system. The drainage system maintenance checklist should cover the following items at minimum:

a) location of culverts;
b) size of culverts, including the diameter and length;
c) condition of culverts:
   i) shifting;
   ii) internal damage;
   iii) culvert end damage;
   iv) plugging of culvert ends;
   v) rocks; and
   vi) silting;
d) ditch problems:
   i) damming (leading to ponding);
   ii) presence of standing water;
   iii) erosion;
   iv) soil settlement (leading to ponding); and
   v) excess vegetation or overgrowth; and

e) identification of any unnatural obstacles that could impede or block the free flow of water through the ditch or culvert.

Note: Annex C contains a checklist for areas of poor surface water drainage.

6.9.5 Record keeping
A record of inspection and maintenance performed on the drainage system shall be kept on file with the authority having jurisdiction.

Note: The community can be held legally accountable for private property damage due to flooding.

6.9.6 Reporting
Drainage system reporting documentation shall be maintained and should include the following at minimum:

a) checklist form;
b) inventory list;
c) asset management report;
d) state of culverts (e.g., overgrown, clogged etc.); and

e) details of affected drainage components (e.g., culvert diameter, type of material etc.).

Reports should provide information on any events known to have led to drainage issues that resulted in damage to elements of the drainage system or other community assets. This can assist with forensic analyses and help practitioners learn to better design or maintain assets in the future.

Results of inspections shall be reported in accordance with local requirements and made available upon request. A sample inspection and reporting form is shown in Annex C.
6.10 Repair and replacement of damaged culverts

6.10.1 General
Maintenance personnel repairing culverts that are damaged as a result of frost heaving or vehicular traffic shall ensure that the repair also addresses the cause of the damage. Culverts with crushed ends may be cut back and repaired by adding a short section of the same size and thickness culvert and connecting it with the appropriate coupling. Care should be taken to coat cut culvert pipe ends with a zinc-rich primer paint as supplied by the pipe manufacturer, or similar approved product.

6.10.2 Minor repair
Where culvert ends have been damaged, maintenance personnel should replace the damaged end in accordance with Clause 6.10.1 and incorporate either a head wall or end wall protection constructed with sand bags, wood, or steel.

Note: The sudden drop off over the culvert end will often cause a vehicle operator to take extra care when crossing or turning at an intersection with an end wall-protected culvert.

Maintenance personnel may use hydraulic jacks to open the culvert end and thereby restore flow to near the design capacity.

Note: This is usually just a temporary measure. Best practice calls for replacement of the damaged culvert end.

6.10.3 Replacement

6.10.3.1 Culverts that fail along their length because of lack of cover shall be replaced. A culvert shall be considered to have failed when the vertical deflection exceeds 10% of the original pipe diameter. Where existing conditions do not allow for the pipe manufacturer’s recommended soil bridging material cover, the user should consider using a thicker wall pipe capable of withstanding the road load conditions.

6.10.3.2 Culverts that are damaged or fail either at their centre or at their ends as a result of ongoing subsidence due to permafrost degradation or frost heaving shall be replaced. Culvert replacement should be carried out according to the manufacturer’s specifications.

Note: Typically, the underlying soil is first replaced using either geotechnical fabric and/or compacted aggregate or drain rock. Ridged insulation is sometimes used under the soil to prevent recurring failure at the culvert base.

6.10.4 Repairing a washout
Where the ground is still saturated following a washout, or water is flowing through the washed out section, drain rock or pea sized gravel should be used to eliminate the amount of fines that could be washed out and lost. Riprap rock shall then be used to armour the affected area to prevent recurrence of washout.

Note: Repair of a road washout is often is carried out with pressure on the maintenance personnel to complete work quickly in order to minimize any disruption to traffic.

6.10.5 Critical spares
Spare couplers, CSP pipe, and repair clamps should be kept on hand. At least 5% of CSP materials used throughout the drainage system should be kept in inventory as critical spares. Maintenance personnel should be careful not to mix metric and imperial sized culvert repair clamps. Universal couplers can be
used for repairs provided a gasket rubber or coating is used between the joints to ensure a good seal is created.
Annex A (informative)

Geotechnical site characterization for community drainage system planning, design, construction, and maintenance

Note: This Annex is an informative (non-mandatory) part of this Standard. It has been written in mandatory language to facilitate its adoption into regulation.

A.1 General
This Annex provides recommendations and requirements for geotechnical site characterization.

Note: There are no specific codes or standards for the geotechnical investigation. Holubec (2010) provides one perspective on the types and extent of geotechnical investigation for any structure founded on permafrost.

A.2 Requirement for a geotechnical site characterization
Geotechnical site characterization shall be undertaken before the final design process begins. This shall involve sourcing and assessing all available information on site surface and subsurface conditions as a component of project planning. The following parameters should be assessed as part of the geotechnical site characterization:

a) confirmation that the site is underlain by permafrost or not;
   Note: Typically, if no permafrost is present, no further site investigation is necessary.
b) determination of ground temperature at or near the depth of zero annual amplitude, as well as natural water or ice content;
c) identification of deep seasonal thawing or potential presence of a talik;
d) potential surface and groundwater flow within the active layer; and
e) an assessment of any extreme short-term weather events, and long-term climate change effects such as outlined in CSA PLUS 4011.

A.3 Requirements for a subsurface investigation
A subsurface investigation shall be undertaken to determine site-specific conditions appropriate for a drainage system design. In some cases, where there is significant appropriate geotechnical and geothermal data for sites in close proximity, the scope of the investigation can be reduced.

Note: Planning and executing the geotechnical investigation is important for the design of a drainage system because the drainage system performance is contingent on several important factors, including

a) confirmation of the depth and variability of the active layer soils;
b) determination of ground temperature and ice or water content;
c) identification of deep seasonal thawing;
d) identification of surface and groundwater flow within the active layer across the site; and
e) erosion potential of the soils.

A.4 Phased approach to geotechnical investigation

A.4.1 General
The geotechnical investigation should comprise several phases, even if some are undertaken in a cursory manner.
A.4.2 Information review
A desktop study should be performed to review the available general project area data, including
a) maps;
b) stereo air photo pairs;
c) aerial or satellite imagery;
d) previous site-specific geotechnical reports;
e) geotechnical/environmental reports from the community;
f) site observations, including local/traditional knowledge;
g) interpretation of surficial geology from aerial or satellite imagery;
h) identify from historic records the mean annual air temperature (MAAT) representative of the site;
i) observed changes in adjacent development, vegetation, or similar conditions around the site;
j) monitoring of any in-situ instrumentation present on the site; and
k) technical literature.

A.4.3 Site specific geotechnical investigation
If considered necessary based on the available data and initial data review, a site specific geotechnical
investigation should be performed comprising
a) borehole drilling with appropriate sampling;
b) installation of ground temperature monitoring instruments; and
c) associated laboratory testing.

A.4.4 Data analysis and reporting
A.4.4.1 Use of test pits
The use of test pits to provide geotechnical data for drainage system design should be discouraged since
they disturb more area both vertically and horizontally in permafrost and are hard on equipment. Once
the insulating material layer is disturbed, it is difficult to compact and stabilize the removed material
making the permafrost more vulnerable to temperature variation and further melting.
Note: Test pits will, at best, only reach the top of the permafrost and thus will provide very little meaningful
subsurface data. The use of test pits for design does not represent prudent or sufficient engineering practice.

A.4.4.2 Number of boreholes
Borehole locations should be chosen based on observed surface features and topography.
Note: As the project site area increases, the number of boreholes per unit area necessary to adequately
characterize the site generally decreases, unless the subsurface conditions are found to be complex.

A.4.4.3 Depth of boreholes
The recommendations and requirements for the depth of boreholes are as follows:
a) the depth of boreholes should be in the order of 10 m;
b) at least one borehole should be drilled to a minimum depth of 15 m;
c) there must be flexibility to adjust borehole depth and spacing in the field based on stratigraphy
that is encountered;
d) in the deepest borehole, a multi-bead ground temperature cable should be installed following good
practice that will ensure its survival for several years;
e) where bedrock is encountered, boreholes may be terminated at shallower depths provided at least
one borehole is advanced into bedrock deep enough to prove its existence; and
f) boreholes that remain dry and open should be inspected by looking down the hole with a strong
light or mirror.
Note: Ground temperatures typically experience seasonal changes to depths up to 15 m, and so one borehole to this depth with ground temperature measurements will provide a more complete understanding of the geothermal character of the ground.

A.4.4.4 Collection of cores and other samples
The recommendations and requirements for the collection of cores and other samples are as follows:

a) undisturbed cores or samples from a split spoon sampler, if practical, should be collected every one metre of hole depth or every stratigraphic unit, whichever is less;

Note: This provides the best data for soil and permafrost classification. If there is only a rotary percussion (air-track) drill available, bulk samples of cuttings should be collected at minimum one metre intervals or every stratigraphic unit, whichever is less.

b) core and other samples shall be logged and photographed as they are received; and

c) permafrost and ground ice shall be described using terminology in NRC Technical Memorandum 79 – Guide to a Field Description of Permafrost for Engineering Purposes.

A.4.4.5 Geotechnical laboratory testing
Representative samples should be preserved and transported to a geotechnical laboratory for testing and analyses. Samples should be protected against moisture loss, and thawing if frozen strength or creep testing is required. At a minimum, the laboratory tests should include

a) natural moisture content;

b) particle size distribution;

c) porewater salinity; and

d) Atterberg Limits (where applicable).

A.4.4.6 Preparation of an investigation report
A report should be prepared that describes and documents the following:

a) all work completed as part of the initial site investigation; and

b) the existing conditions based upon the results of the initial site investigation.
# Annex B (informative)

## Surface drainage design checklist

*Note: This Annex is an informative (non-mandatory) part of this Standard.*

<table>
<thead>
<tr>
<th>Process step</th>
<th>Activity</th>
</tr>
</thead>
</table>
| 1) Define drainage areas              | □ Obtain contour mapping.  
□ Superimpose post development contours (if different from original).  
□ Develop contours if unavailable, site surveys.                                                                                              |
| 2) Define risks and appropriate storm events | □ Obtain level of risk from the planning process (Clause 4.5).  
□ Define acceptable freeboard on ditches and at culvert entrances.                                                                               |
| 3) Define flow paths through drainage areas | □ Paths will dictate where culverts and ditches are required.  
□ Define major flow path — where will the water go if the culverts or ditches cannot accept the flow? Or if they are blocked?                |
| 4) Rainfall data                       | □ Obtain rainfall intensity versus time of concentration for rational method.  
□ Derive synthetic or historical rainfall distribution curves for storage calculations.  
*Note: The Chicago or Huff distributions can be used to derive synthetic graphical representations of the distribution of rainfall over time during a storm event (synthetic hyetographs).* |
| 5) Obtain geotechnical data            | □ Define erosion potential of local soils and safe velocity in ditches.  
□ Determine long term impacts of permafrost degradation, if applicable.  
□ Determine pipe bedding requirements.                                                                                                          |
| 6) Undertake rational method design for drainage course | □ Define runoff co-efficient for surface types in the drainage area.  
□ Work through drainage area from upper to lower, sizing ditches & culverts as you go.                                                        |

*(Continued)*
(Concluded)

<table>
<thead>
<tr>
<th>Process step</th>
<th>Activity</th>
</tr>
</thead>
</table>
| 7) Ditch design | □ Ditches to convey required water without erosion, where velocities cannot be lowered to acceptable limits provide erosion protection.  
□ Avoid very low slopes, this encourages ponding and weed growth.  
□ Ensure acceptable freeboards are not exceeded. |
| 8) Culvert design capacity | □ Size culverts to accept design flow at 80% capacity under free flow condition (1:10 year event).  
□ Size culverts to accept 1:100 design flow at 80% of available head at entrance.  
□ Determine whether culverts are operating under inlet or outlet control during 1:100 rain event. |
| 9) Culvert structural design | □ Select culvert wall thickness and corrugation suitable for the soil loads and vehicle loads. |
| 10) Exit velocities | □ Define exit velocities at each culvert.  
□ Modify slope and size or provide erosion protection if velocity is higher than erosion velocity. |
Annex C (informative)

Checklist for areas of poor surface water drainage

Note: This Annex is an informative (non-mandatory) part of this Standard.

Date: __________________, 20___________. Town, Village or Hamlet: ______________________________

Street address: __________________________________________________________________________

Existing conditions (circle all that apply):

Flooding; standing water; poor drainage; damming; ground subsidence;
Erosion; brush clearing required; excavation required; fill required
Other: __________________________________________________________________________________

Source of water (if other than precipitation) _________________________________________________

Draw sketch of location. Include direction of flow and culvert sizes:

Give estimates of distances and depths.

Culverts:

Size of culvert: __________ material: CSP; HDPE; steel other: __________ condition: good/repair/replace

Size of next upstream culvert: _____ material: CSP; HDPE; steel other: _____ condition: good/repair/replace

Size of next downstream Culvert: ____material: CSP; HDPE; steel other: ____ condition: good/repair/replace

Suggested repair:
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

Schedule repair date: ______________, 20____.

Estimated cost: $________________________

Inspector(s): __________________________________________________________________________

QA/QC (including photographs)
Annex D (informative)
Drainage related standard drawings

Note: This Annex is an informative (non-mandatory) part of this Standard.

Figure D.1
Sloped ground road embankment
(See Clause 5.5.)

Figure D.2
Road embankment in a road cut
(See Clause 5.5.)
**Figure D.3**
Pipe culvert in an embankment
(See Clause 5.5.)

![Diagram of pipe culvert in an embankment](image)

**Notes:**
1) *Minimum cover to be 450 mm in roads and 300 mm in driveways.*
2) *Invert of culvert to be 0.1 D below existing ground.*

**Figure D.4**
Pipe culvert in a trench
(See Clause 5.5.)

![Diagram of pipe culvert in a trench](image)

**Notes:**
1) *Minimum cover to be 450 mm in roads and 300 mm in driveways.*
2) *Invert of culvert to be 0.1 D below existing ground.*
Notes:
1) Snow poles to be spaced at 30 m on both sides of the road.
2) Snow poles to have three 150 x 300 reflectors mounted on each side; green reflectors for one side of the road, and orange for the other.

Figure D.6
Road embankment level ground — “False ditch”
(See Clause 5.5.)
Annex E (informative)

Land use plan from Dettah, NT

Note: This Annex is an informative (non-mandatory) part of this Standard.

Figure E.1
Dettah land use plan
(See Clause 4.2.2.)
**Figure E.2**

**Land use chart**

*(See Clause 4.2.2.)*

<table>
<thead>
<tr>
<th>Zone</th>
<th>Uses</th>
<th>Restrictions</th>
</tr>
</thead>
</table>
| **Urban Residential** | Residential use includes single unit dwellings, multiple unit dwellings, home businesses, and accessory buildings and uses. | - The minimum lot size for new development once will be 24 metres (frontage) by 30 metres.  
- The minimum width for a new development area will be 18 metres.  
- A fire separation of 15 metres will be enforced for all new buildings.  
- Water and sewer connections for truck services will be on the front side of the building, facing the main access road.  
- New buildings will be situated more than 450 metres from the waste management area.  
- New building setbacks from the property lines will be 5 metres from the front, side and back.  
- Buildings should maintain a 10 metre setback to vegetation as a protection from wildfires.  
- Buildings should be constructed in compliance with the latest edition of all codes and standards and buildings should be reviewed and inspected by the appropriate authority before occupation.  
- Placing of Urban Residential area U2 should proceed as shown on the Community Core Plan.  
- Placing of Urban Residential area U3 should proceed with the area closest to the Detachment Road. |
| **Rural Residential** | Residential use includes single unit dwellings, multiple unit dwellings, home businesses and accessory building and uses. | - The minimum lot size will be 0.5 hectares.  
- Only one single detached dwelling unit or multiple dwelling units will be permitted on any lot.  
- The lot will have a minimum 15 metre frontage (vecu profond) on an existing road right-of-way to accommodate vehicle access.  
- A fire separation of 12 metres will be enforced for all buildings on the lot.  
- Buildings will be situated more than 450 metres from existing or unreconstructed waste management areas.  
- Buildings should maintain a minimum setback from the property lines that will be 5 metres from the front, side and back.  
- Buildings and waste management system setback from the Ordinary High Water Mark of less than 30 metres.  
- Buildings should maintain a 10 metre setback to vegetation as a protection from wildfires.  
- Buildings should be constructed in compliance with the latest edition of all codes and standards, and buildings should be reviewed and inspected by the appropriate authority before occupation. |
| **Community** | Community use includes government buildings (school, offices, garages, fire hall, and ice arena), community centres, historic sites, cemeteries, churches, seasonal use buildings, boat storage within beach areas, and other uses supported by the Band Council. | - The minimum lot size for a new government building, or church will be 24 metres (frontage) by 30 metres.  
- Plans for new government buildings or churches will be forwarded to the Fire Protection Authority for review and approval.  
- Building setbacks from the property lines, for new buildings, will be 6 metres from the front, side and back.  
- Water and sewer connections for truck services will be on the front side facing the main access road.  
- Access to new buildings will avoid entrances on the south side, to reduce problems associated with snow drifting.  
- Buildings should maintain a 10 metre setback to vegetation as a protection from wildfires.  
- Buildings should be constructed in compliance with the latest edition of all codes and standards, and buildings should be reviewed and inspected by the appropriate authority before occupation. |
| **Commercial/Light Industrial I** | Commercial use includes stores, accommodation, restaurants, garages or shops and related activities. | - The minimum lot size for a new commercial building will be 24 metres (frontage) by 30 metres.  
- Plans for new buildings will be forwarded to the Fire Protection Authority for review and approval.  
- Building setbacks from the property lines will be 6 metres from the front, side and back.  
- Water and sewer connections for truck services will be on the front side facing the main access road.  
- Access to new buildings will avoid entrances on the south side, to reduce problems associated with snow drifting.  
- New buildings will be situated more than 450 metres from the waste management area.  
- Buildings should maintain a 10 metre setback to vegetation as a protection from wildfires.  
- Buildings should be constructed in compliance with the latest edition of all codes and standards, and buildings should be reviewed and inspected by the appropriate authority before occupation.  
- Placing of Commercial/Light Industrial area CL should proceed with the area closest to Section.  
- Placing of Commercial/Light Industrial area CL2 should proceed with the area closest to the Fire Protection Test. |
| **Communication/Telecommunication** | Communication use includes the RCMC Radio Tower | - No development shall occur within 150 metres of the RCMC Radio Tower |
| **Open Space Buffer** | Open space includes areas not otherwise marked on the land use plans, and will be maintained in an undeveloped state, except for uses that support the traditional lifestyle within the community. | - Development in open space areas will be limited to seasonal use buildings less than 1.0 metres by 3.0 metres.  
- Hunting and trapping or other activities that could affect Public Health and Safety will not be permitted.  
- the distances from the community before hunting and trapping will be permitted will be determined by the Band Council, and the Hunters and Trappers Association. In consultation with the Regional Wildlife and Fisheries Officer.  
- A fuel break may be constructed as a barrier to fire and so that those burning into them can be more readily controlled. |
| **Waste Management** | Waste management includes the sanitary sewage disposal area and the landfill. | - All residential and commercial development should be a minimum of 450 metres away from the waste management use area. |
Figure E.3
Dettah — Air photo
(See Clause 4.2.2.)
Figure E.4
Land use statements — Proposed Akaitcho Boundary
(See Clause 4.2.2.)

Land use statements

- Community land within the community of Dettah should be put to its highest and best use within restrictions of terrain, geology, existing infrastructure, soil, and community interests.
- The Land Use Plan will provide means for the community of Dettah to develop in an orderly fashion creating a healthy, safe, and beautiful community for the people who live and work there.
- In pursuing goals stated above, the community of Dettah has the following land use objectives:
  1. Support future rural residential development along the Dettah Road in an organized and phased manner.
  2. Maintain 450-metre development setbacks from sewage lagoons and landfill.
  3. Maintain undisturbed areas of archaeological or historical significance.
  4. Improve and design roads to minimize snow drifting.
  5. Build or improve the drainage systems to handle spring runoff, and reduce erosion damage to roads and building sites.
  6. Maintain open space along water fronts.
  7. Build residential housing that suits the needs of the community residents, for such things as hunting and trapping, and follow the restrictions in the Land Use Chart.
  8. Locate community use sites near the centre of the community.
  9. Encourage the development of commercial enterprises in the designated areas along the Dettah Road.
  10. Support the implementation of the Akaitcho Boundary.
  11. Support the identification and commissioning of a new landfill site within the waste management reserve along the Dettah Road.
  12. Support the decommissioning and remediation of the existing landfill site along the Dettah Road.
  13. Support the development and implementation of a Community Forest Management Plan in co-operation with relevant government agencies.
Figure E.5
Land use map
(See Clause 4.2.2.)
Figure E.6
Land use map
(See Clause 4.2.2.)
Figure E.7
Land use map
(See Clause 4.2.2.)