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CSA W203:19
National Standard of Canada

Planning, design, operation, and maintenance of wastewater treatment in northern communities using lagoon and wetland systems

Standards Council of Canada
Conseil canadien des normes

REVISED OCTOBER 2019

Revision History

CSA W203:19, Planning, design, operation, and maintenance of wastewater treatment in northern communities using lagoon and wetland systems

Errata — October 2019	**Revision symbol (in margin)**
Technical Committee Subcommittee	Δ

Standards Update Service

CSA W203:19
June 2019

Title: *Planning, design, operation, and maintenance of wastewater treatment in northern communities using lagoon and wetland systems*

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Published in June 2019 by CSA Group
A not-for-profit private sector organization
178 Rexdale Boulevard, Toronto, Ontario, Canada M9W 1R3

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ICS 13.030.20
ISBN 978-1-4883-2224-2

Contents

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Preface

This is the first edition of CSA W203, *Planning, design, operation, and maintenance of wastewater treatment in northern communities using lagoon and wetland systems.*

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 Guideline from the Standards Council of Canada, as part of the Northern Infrastructure Standardization Initiative with input from the Northern Advisory Committee (NAC).

This Standard was developed by the Subcommittee on Wastewater Treatment in Northern Communities Using Lagoon and Wetland Systems, under the jurisdiction of the Technical Committee on Northern Water, Wastewater and Stormwater and the Strategic Steering Committee on Natural Resources, and has been formally approved by the Technical Committee.

This Standard has been developed in compliance with Standards Council of Canada requirements for National Standards of Canada. It has been published as a National Standard of Canada by CSA Group.

Notes:

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0 Introduction

0.1 What is unique about the North and northern wastewater treatment

The North of Canada is very unique due to its climate, geography, geology, demography, and social aspects. 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; and it is a region of small, isolated communities with low population density. These unique attributes of northern communities can create challenges associated with municipal wastewater management.

0.2 Challenges for wetlands and lagoons wastewater treatment systems in the North

The treatment of domestic wastewaters in Canada's North has historically been accomplished primarily through the use of long-term detention in wastewater stabilization ponds (WSPs), commonly known as sewage lagoons.

Treated effluent from these ponds or lagoons is typically discharged to the receiving environment. Some lagoon systems discharge treated effluent directly to receiving water bodies; however, it is common practice to discharge to a natural land or to a wetland area. These wetlands vary greatly among northern communities, but are typically shallow lowlands that eventually drain into either a freshwater or marine receiving environment. These lowlands receiving treated effluent from sewage lagoons are referred to in this Standard as wetland treatment areas (WTAs). The function of a WTA is to provide ancillary treatment (polishing) beyond what can typically be accomplished by lagoon systems alone.

Many of the northern communities served by treatment lagoons and WTAs are isolated and are accessible only by air, by ice-road during a narrow period of time, or by ship during the brief summer. The remoteness of these communities, combined with the extreme climate, the logistical challenges of bedrock and/or permafrost, high utility costs, together with the lack of financial and human resources, represent significant impediments to the development and operation of mechanized wastewater treatment infrastructure commonly used in more southern locations of Canada (Hayward *et al*., 2014; Chouinard *et al*., 2014a).

It is due to these challenges that the majority of communities rely on centralized lagoon and WTA systems, as they are passive wastewater treatment technologies requiring relatively low maintenance. In some larger communities, sewage is conveyed via in-ground or above-ground pipe systems, but in most communities, vacuum trucks haul wastewater to the sewage lagoons.

In the majority of communities in the North, wastewater is stored in lagoons for a significant portion of the year with discharges occurring during the ice-free season. Ideally, lagoon discharges occur during late summer/early fall. This is to maximize the summer treatment potential, and to lower the water levels in the lagoons to increase the winter storage capacity (Ragush *et al*., 2015).

The WTAs are different from constructed wetlands, as they are non-engineered, and in most cases, not intentionally created (Hayward *et al*., 2014; Chouinard *et al*., 2014a). Most WTAs have simply been created as lagoon effluent has been discharged to those areas, prior to eventual discharge in the receiving freshwater or marine environment. As such, they are open and diffuse systems, often with poorly defined boundaries and flow patterns (Kadlec and Wallace 2009); however, non-engineered WTAs can still provide some of the same wastewater treatment processes of engineered systems. Despite the similarity to natural wetlands, the WTAs are distinctly different from natural wetlands in their hydrology, vegetation, nutrient availability, and organic loading (Chouinard *et al*., 2014b; Hayward *et al*., 2014). They are also different from constructed wetlands which are designed or engineered to meet defined treatment targets.

These differences make the prediction of treatment efficiencies challenging, but despite these challenges, WTAs have been shown in multiple studies (Yates *et al*., 2012; Hayward *et al*., 2014; Doku and Heinke 1993, 1995; Dubuc 1986) to provide a significant ancillary treatment benefit without requiring a large investment in capital or operating costs. The major challenges in the operation of a hybrid lagoon/WTA treatment system is to ensure that the WTA is suitably sized to be able to accommodate the effluent decanted from lagoon systems and to be able to detain these effluents long enough to ensure adequate treatment.

0.3 Overview of wetlands and lagoons wastewater treatment systems

0.3.1 Overview of wastewater lagoon systems

Lagoons are impoundments (e.g., natural or constructed) that can be used to both store and treat municipal wastewater. They are common throughout Northern Canada because they are simple and inexpensive to construct, operate, and maintain, as compared to mechanical treatment plants. There are several different types of wastewater lagoons used within municipal wastewater treatment, which are generally characterized according to

a) discharge regime; and
b) level of oxygenation.

With respect to discharge regime, lagoons can be designed and operated as storage systems with seasonal discharge, or as flow-through systems that discharge effluent on a continuous basis throughout the year. In intermittent or seasonal discharge systems, wastewater is stored and treated in a lagoon for an entire year for optimum treatment, or only a portion of the year. Once the effluent has achieved pre-determined treatment objectives [effluent quality criteria (EQC) or else], discharge to the environment is approved. Typically, seasonal discharge will occur in the fall, but can also occur earlier during the open water season, depending on effluent quality and/or receiving environment conditions. Alternatively, lagoons may also be designed and operated as flow-through systems that discharge effluent on a continuous basis throughout the year. However, during the winter, treatment performance will be challenged by ice cover and lower temperatures.

With respect to level of oxygenation, lagoons have been conventionally classified as either aerobic, facultative, aerated, or anaerobic (see Table 1). Although aerobic treatment is used in Northern Québec, aerobic and aerated lagoons have not been widely employed in the Canadian North. Most northern lagoon systems would be classified as either anaerobic or facultative.

Table 1
Type of lagoon based on level of oxygenation
(See Clauses 0.3.1 and D.3.3.)

Types of lagoon	Characteristics
Aerobic lagoons	a) 0.3–0.6 m operating water depth b) receive lower organic loading rates (< 22 kg BOD_5/ha-d), allowing complete oxygenation of water column
Facultative lagoons (also named waste stabilization ponds, or WSPs)	a) 1–2 m operating water depth b) receive lower organic loading rates (< 22 kg BOD_5/ha-d) c) upper water column is aerobic, via atmospheric reaeration and algae d) lower water column is anaerobic
Mechanically aerated lagoons	a) produces oxygenated conditions throughout the water column
Anaerobic lagoons	a) 2–5 m operating water depth b) receive higher organic loading rates (> 150 kg BOD_5/1000 m^3-d) c) negligible amount of oxygen in water column

Source: *Adapted from EPA 1983.*

Other types of lagoon systems are natural lake lagoons [pre-existing natural lakes used as lagoons under previous guidelines in the Northwest Territories (NWT), with or without engineering modifications] and exfiltration lagoons. These types of lagoon systems are still used in several communities in the North, but should not be considered for a new treatment system.

0.3.2 Overview of wetland treatment areas

Wetland treatment areas are wetlands that receive wastewater effluent from lagoons for supplemental treatment. Many areas functioning as WTAs in the North were either historically low-lying areas that supported natural communities of wetland plant species, or tundra landscapes that developed wetland vegetation communities after receiving wastewater effluent for several years. Most northern WTAs are characterized by the natural landscape, meaning that the size, configuration, flow paths, vegetation types, and presence or absence of surface water are all dictated by the physical and biological attributes of the area. In some cases, the physical and hydrological attributes of these natural systems have been altered (engineered) to enhance treatment performance.

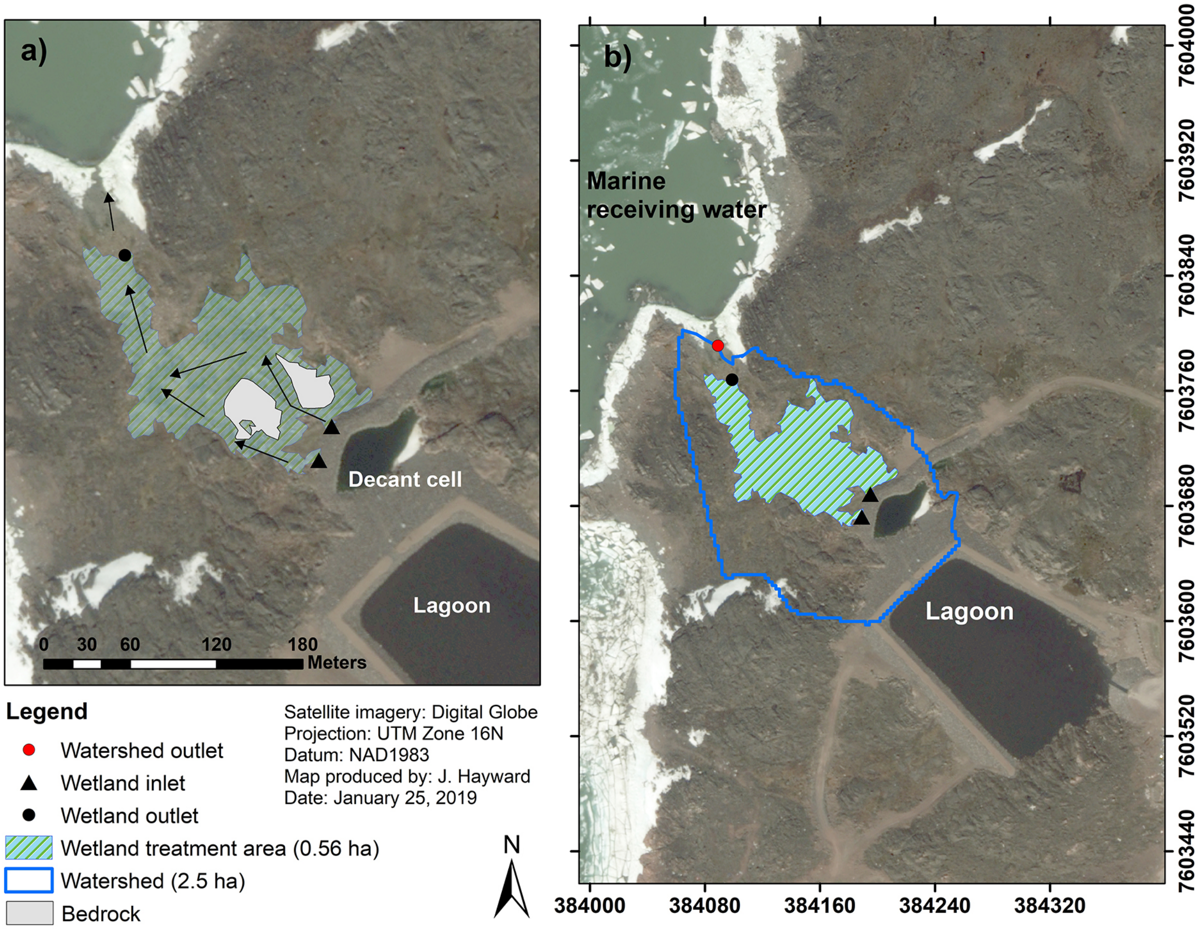
WTAs utilize natural biological, physical and chemical processes to treat municipal wastewater effluents. Treatment mechanisms include microbial degradation, plant uptake, sorption to soils and sediments, mechanical filtration and sedimentation, and microbial predation and competition. These treatment processes are often influenced by the rate the effluent flows through the wetland (slower flow rates often enhance treatment), temperature (higher temperatures favor increased microbial activity), and plant growth, which can aid in the uptake of certain nutrients.

Multiple studies have shown that northern WTAs can provide ancillary treatment needed to achieve effluent treatment objectives (Yates *et al*., 2012, 2013; Hayward *et al*., 2014; Chouinard *et al*., 2014a). Wetlands present a low cost and low maintenance option for secondary and tertiary levels of treatment in Northern Canada. However, no two WTAs perform identically and each site needs to be individually characterized for the primary features that influence treatment performance.

The use of constructed (engineered) wetlands might be an option in some regions of the North where climate, topography, permafrost conditions, and financial resources permit their use. Constructed wetlands, by design, are more defined in terms of boundaries, hydraulics, and retention times. Therefore, treatment outcomes are more predictable and potentially more controllable than WTAs. Construction and operational costs, however, can be greater than WTAs due to the land requirements (footprint) needed to accommodate the larger flows generated during lagoon decants while maintaining adequate hydraulic retention times needed for adequate treatment. Figures 1 and 2 present examples of actual WTAs.

Figure 1
Wetland treatment area in Kugluktuk, Nunavut
(See Clause 0.3.2.)

Figure 2
Plan view of a wetland treatment area which receives effluent from a decant cell in Kugaaruk, Nunavut
(See Clause 0.3.2.)



Note: *The black arrows denote effluent flow direction.*
Source: *Adapted from Balch et al. (2018).*

0.4 Purpose of this Standard

The purpose of this Standard is to address the following:

a) procedures, protocols, or methods for collecting information and evaluating the conditions of a potential site for the purpose of planning, designing, and constructing municipal wastewater lagoon facilities and wetlands for wastewater treatment in northern communities;

b) all lifecycle phases, from planning, designing, construction, operation, maintenance, and closure/remediation of municipal wastewater lagoon facilities and wetlands for wastewater treatment that incorporates climate change considerations. Such climate change considerations will include, but not be limited to,

   i) potential effects of permafrost warming and active layer depth changes on effluent containment and stability of surrounding soil; and

   ii) changes in precipitation characteristics affecting local hydrology and surface water balance from seasonal snowfall totals, warm-season precipitation changes, and spring snowmelt (e.g., high-intensity short duration events);

c) piped continuous or truck collection inflow of effluent into municipal wastewater lagoons;
d) description of monitoring practices specific to municipal wastewater lagoons and wetlands for wastewater treatment;
e) best practices and accompanying guidance for periodic inspection and remedial procedures for existing and legacy systems;
f) best practices and accompanying guidance for operations and maintenance activities that optimize treatment in a natural system;
g) best practices for the management of sludge;
h) field test methods, sampling protocols, and laboratory requirements; and
i) closure and remediation considerations.

0.5 Users

The intended users of this Standard include the following:
a) owners and operators of community infrastructures that may either contribute to, be affected by, or be relied upon for the treatment of effluent through the use of wastewater facilities;
b) engineering practitioners, reviewers, and inspectors (e.g., consulting engineers, architects, and territorial or regional technical services staff), who are engaged to
    i) design, assess, and sign off on plans and specifications for wastewater facilities in northern communities, and oversee the design, commissioning, and construction of those facilities; and
    ii) assess and/or participate in the deliberation of decision to maintain, expand, remediate, or close existing municipal wastewater lagoons; and
c) contractors who are engaged in order to prepare sites for wastewater facilities in northern communities and construct community infrastructures that either contribute to or play a role in managing those facilities.

1 Scope and application

1.1 Scope

This Standard specifically addresses the planning, design, operation, and maintenance of intermittent/seasonal discharge lagoon and wetland systems that are most appropriate for use in Northern regions, where effluent discharge is either difficult or not possible in colder months.

1.2 Application

In this Standard, the North is considered above the 54th parallel. It can also apply in communities where the same challenges, such as extreme climatic conditions and remoteness, appear.

This Standard applies across Northern Canada to all municipal wastewater lagoons and wetlands used for the treatment of municipal wastewater from
a) cities, towns, villages, hamlets, settlements, community governments, and unorganized communities; and
b) any site deemed in the public's interest by a regulatory authority.

WTAs should only be considered in remote northern environments where costs and feasibility are prohibitive for the use of constructed wetlands.