REPORT

Guidance Document for Closure of Small Domestic Waste Disposal Sites on Remote First Nation Land

Submitted to:

Taylor Ambler, Environment Management Officer
Lands and Environmental Management Branch
Indigenous Services Canada
Terrasses de la Chaudière
10 Wellington St, North Tower
Gatineau, QC K1A 0H4

Ananthan Suppiah, Senior Environmental Engineer
Indigenous Services Canada
Specialist Services, Community Infrastructure Directorate BC Region
138 Melville Street, Suite 600
Vancouver, BC V6E 4S3

Submitted by:

Golder Associates Ltd.
GHD Limited

1782027-001-R-RevC

24 July 2020

PREFACE

This document was jointly prepared by Golder Associates Ltd. (Golder) and GHD Limited (GHD). Authorship and specific responsibility for the technical information provided herein was based on the respective specialist experience of the project team, as follows:

Golder

Section 1.0, Section 4.0, Section 5.0, and Section 7.0

Appendix B

GHD

Section 1.0, Section 2.0, Section 3.0, Section 6.0, Section 7.0, and Section 8.0

Appendix A

Third party review provided by GeoEnviroLogic and TAM Environmental for contributions/section prepared by Golder.

Senior peer review provided by GHD for contributions/sections prepared by GHD.

TABLE OF CONTENTS

FIGURES

APPENDICES

LIST OF ACRONYMS

CCME	Canadian Council of Ministers of the Environment
CSM	Conceptual Site Model
COPC	Contaminant of Potential Concern
ESA	Environmental Site Assessment
GCL	Geosynthetic Clay Liner
HDPE	High Density Polyethylene
ISC	Indigenous Services Canada
LLDPE	Linear Low Density Polyethylene
PAH	Polycyclic Aromatic Hydrocarbon
PHC	Petroleum Hydrocarbon
PCDD/F	Polychlorinated Dibenzo-p-Dioxin and Furan
PFAS	Perfluoroalkyl Substance
QA/QC	Quality Assurance/Quality Control
SDWDS	Small Domestic Waste Disposal Site
SWANA	Solid Waste Association of North America
VOC	Volatile Organic Compound

1.0 INTRODUCTION

1.1 Overview

This document has been prepared at the request of Indigenous Services Canada (ISC) to provide guidance for the closure of small domestic waste disposal sites (SDWDS or Sites) on remote First Nation land.

Remote First Nation communities are considered to be those with long travel times or with limited or no road access from neighbouring communities having municipal infrastructure.

This guidance describes a process that can be used to:

- work in partnership with communities
- design for in-place SDWDS closure as an alternative to default engineered cover systems and/or remedial excavations of Sites
- assess the potential human health and environmental risks following closure
- plan for post-closure follow-up activities

The overall intent of the process described herein is to serve as a framework that can be further adapted for SDWDS by qualified professionals.

Figure 1: SDWDS pre-closure, located near Lillooet, British Columbia

1.2 Background

Remote First Nation communities throughout Canada have previously designated areas, often ravines, for uncontrolled disposal of domestic waste. These Sites were used prior to the implementation of engineered landfills (e.g., with lined landfilling cells). Further, in these communities, the lack of access to engineered landfills and programs for recycling, composting and/or waste reduction, has resulted in longer term reliance on SDWDS. As these Sites are often situated out of convenience near communities, they present potential risks to both human and environmental health.

Early environmental investigation work into the potential risks of these Sites relied on the standard contaminated sites investigation process (e.g., Canadian Council of Ministers of the Environment [CCME] *Guidance for Environmental Site Characterization, Volumes 1-4,* CCME 2016). Although standard procedures for investigation components such as sampling and quality assurance/quality control (QA/QC) remain applicable for SDWDS, the need has been recognized for a risk-based approach to investigation and related closure of these Sites. This approach is suitable because the area of potential contamination is defined by the topography and the remediation plan includes an engineered cover system over domestic waste.

Using the standard approach (e.g., CCME, 2016), certain early investigations attempting to characterize and delineate contamination resulting from the domestic waste have resulted in recommendations to excavate the waste for transport to and disposal in an engineered landfill. The costs associated with this approach are high and are neither justified by scoring per the National Classification System for Contaminated Sites (NCSCS) nor by the risks to human and environmental health. Without justification for the costs for excavation and relocation of the waste, these Sites have remained uncontrolled.

With the more recent emphasis on sustainable remediation and waste management, closure in-place with an engineered cover system has gained greater acceptance by First Nations, ISC, and other stakeholders.

Figure 2: SDWDS pre-closure, located near Lillooet, British Columbia.

Further, waste streams in many First Nation communities are now integrated into regional solid waste management programs, that include sorting, recycling, and composting. This allows for long term sustainability in waste management for First Nation communities. With a modern waste management system in-place, these SDWDS can be closed and another land use may be adopted. Future land uses are generally limited and include, though are not necessarily limited to, passive use by integrating the Sites into the natural surrounding environment or potentially active use by repurposing the Sites, such as for a transfer station facility or public works storage yard.

1.3 Intended Audience

This document is intended to be referenced by:

- First Nation community leaders (e.g., Chief and Council, Administrators, Land Managers, and Public Works)
- ISC Program Officers and Managers
- Qualified solid waste management planning and policy making professionals
- Qualified engineering professionals in landfill design, management, and closure
- Qualified environmental professionals (e.g., geoscientists, biologists, and agronomists)

In all cases where a SDWDS is being assessed, qualified professionals should be engaged to ensure the appropriate use, application, and potential adaptation of this guidance on a case-by-case basis per SDWDS.

Qualified Professional: A qualified professional is considered to be an experienced practitioner (e.g., Geoscientist, Biologist, Agronomist, or Engineer) who is registered and in good standing with an appropriate professional organization. They will only be considered a qualified professional for that portion of the assessment that is within their specialist area of practice.

As this document includes investigation processes generally in line with the CCME guidelines (2016), it should be considered as a companion document to the CCME guidelines (2016).

For the purposes of this document, remote First Nation communities are those with long travel times or with limited or no road access from communities with municipal infrastructure.

This guidance is not specifically intended for all SDWDS as there are a number of precluding conditions that require evaluation to determine whether the process described herein is appropriate for the SDWDS (refer below Section 1.4).

1.4 Precluding Conditions

The process described in this guidance document for risk-based approach to Site closure is intended for SDWDS containing primarily domestic waste as this material presents a potentially low level of contamination.

The most significant factor for the application of this guidance is that the waste stream is primarily domestic waste.

This risk-based approach is not intended to be used for Sites having one or more of the following precluding conditions:

1) Where there is a significant quantity of landfilled industrial waste.
2) Where sites are located within the 1:200-year flood zone.
3) Where there are residential properties located within 100 metres (m) of the landfilled waste material.
4) Where there are confined spaces or enclosed buildings including pumphouses or sheds within 30 m of the landfilled waste material.
5) Where there are drinking water wells, regardless of distance from the Site, and as a result of assessment or in the opinion of suitably qualified professionals, has the potential to be detrimentally affected by the Site.
6) Where measured leachate concentrations are more than 10 times those of typical SDWDS (refer Section 4.5.2 for discussion of typical conditions).
7) Where soil vapour attenuated for outdoor air, or outdoor ambient air concentrations exceed British Columbia air standards for residential land use[1,2] or other available standards/guidelines.
8) Where methane concentrations in soil vapour probes exceed 30%[3].
9) Where there are preferential pathways for groundwater or soil vapour migration.
10) Where biomagnifying substances from the Site are measured above risk-based guidelines in surface soil, groundwater, or surface water.

While the source of drinking water, size of the Site, the population of the First Nation community, the climate, and other factors are important, the most significant factor for the success of this risk-based Site closure process is that the waste stream is primarily domestic waste.

If any one of these precluding conditions exist, or other unacceptable conditions identified by the suitably qualified professionals exist, then there is the potential for unacceptable exposure and a site-specific assessment is warranted to evaluate conditions for the SDWDS.

Precluding Conditions: The composition of the waste material (primarily domestic) and the physical setting are critical factors when determining the potential suitability of closure in-place. Should any of the precluding conditions exist, additional assessment by a qualified professional is needed.

[1] http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/375_96_09#Schedule3.3

[2] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/site-remediation/docs/protocols/protocol_22.pdf

[3] Based on guidance provided in ASTM E2993 – 16 *Standard Guide for Evaluating Potential Hazard as a Result of Methane in the Vadose Zone.*

1.5 Process for Risk-Based Site Closure

This guidance describes a process for community engagement, in-place SDWDS closure design, assessment of potential risks to human and environmental health following closure, and post-closure follow-up activities. As such, the key processes throughout a SDWDS closure project include forming a project working group and building community support during project initiation, identifying and developing alternative solid waste management systems, environmental investigation, and post-closure follow-up activities.

The term alternative solid waste management system is used in this document to describe an improved process for managing waste that better aligns with applicable provincial and territorial regulations, standards, and best practices for solid waste management.

The process for transitioning communities to modern solid waste management practices and closure of Sites is outlined in Figure 3 and briefly described below.

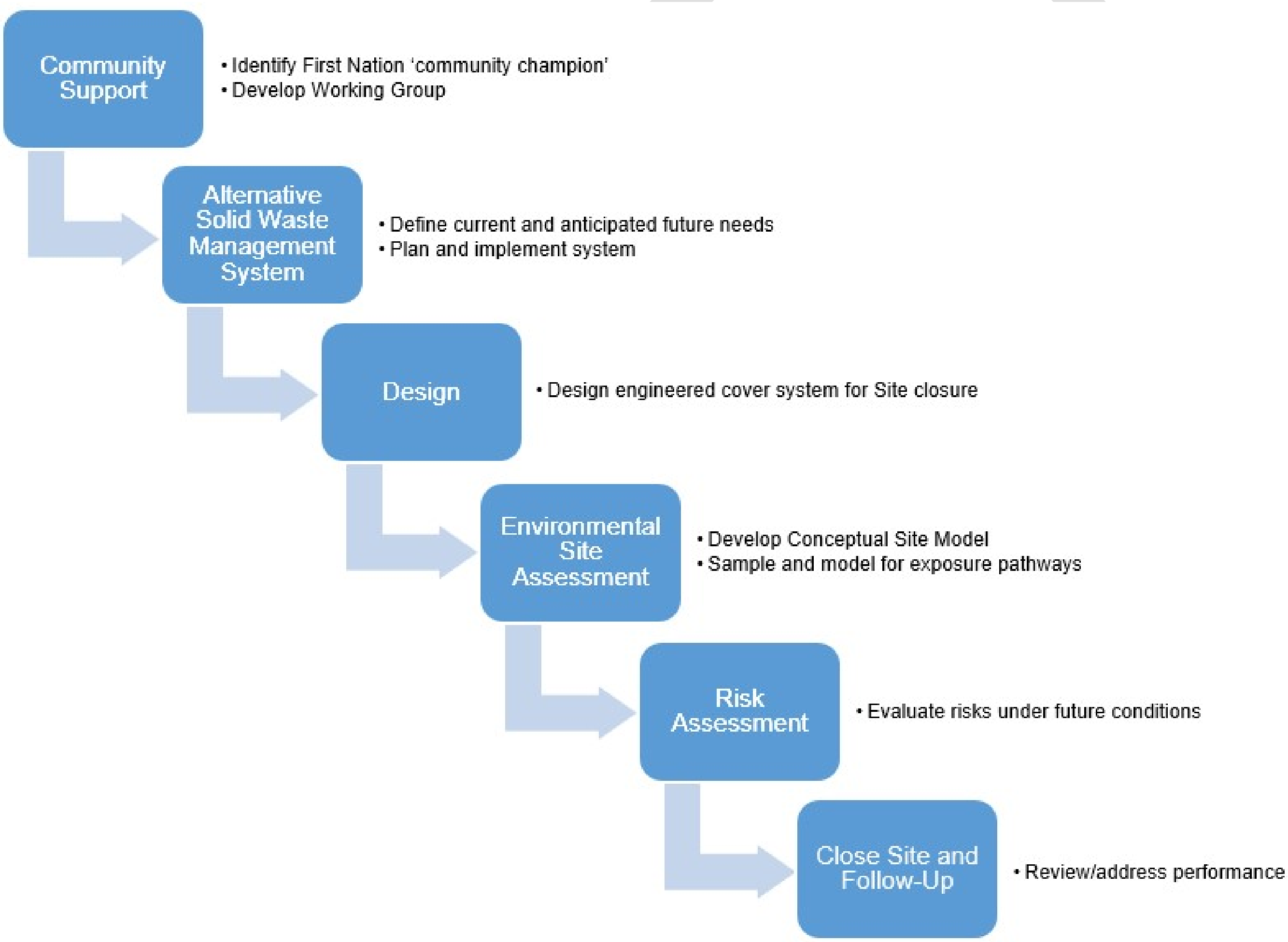

Figure 3: SDWDS closure process

Instrumental in the evolution of a successful process to SDWDS closure are two key elements:

1) Funding to communities for developing an alternative solid waste management system and Site closure
2) Collaboration among project representatives (i.e., First Nation community, ISC, and qualified professionals)

To close the SDWDS the community must have an alternative solid waste management system in operation, such that the Site may be closed. Information regarding best practices for solid waste management and closure of the SDWDS is shared and discussed with the First Nation community to determine whether there is interest in moving forward. An interested First Nation community 'self-identifies' and nominates a representative of the community to act as 'community champion' and collaborate with ISC and the qualified professionals. The 'community champion' works with the First Nation community to define current and anticipated future solid waste management needs with the assistance of ISC and qualified professionals where appropriate. Together, these representatives form a project working group that develops an alternative solid waste management system that may be suitable and defines future land use and design considerations to enable SDWDS closure. The project working group meets regularly throughout project planning, implementation, and follow-up activities.

Figure 4: Pre- (top) & Post-closure (bottom) SDWDS on Penelakut Island, BC

The identification of future land use for the Site is conducted early in the process and considered in conjunction with community needs and the design of the engineered cover system such that the system accommodates for the future land use. Further, this design considers local sources of potentially suitable engineered cover system materials and native vegetation. For Sites where integration into the natural surrounding environment is the desired future land use, the final grades of the engineered cover system can be blended into the landscape and native vegetation used for stabilization. As the landfilled waste will settle over time and in a manner that may be difficult to define (given age, type, and manner of waste landfilled), active uses are typically limited to those not requiring substantial loads or building foundations. Two examples of Site closure for passive and active land use are provided below as Figures 5 and 6.

Figure 5: SDWDS closure for passive land use, located near Ahousaht, British Columbia

Figure 6: SDWDS closure for active land use (public works storage yard), located near Metlakatla, British Columbia

An Environmental Site Assessment (ESA) is conducted with a focus on future conditions when the waste material is covered and as such, evaluates contaminant fate and transport away from the source waste material rather than characterizing the waste material. This approach is taken because the engineered cover system to be designed will prevent direct exposure to possible contaminants by incidental ingestion, dermal contact, or inhalation of dust. The remaining exposure pathways to be assessed are potential indirect exposure.

A human health and ecological risk assessment is conducted to assess the significance of the potential indirect exposure pathways under future conditions (i.e., waste material is covered). The potentially low level of contamination associated with these Sites containing primarily domestic waste means a risk-based approach to closure is suitable.

Once indirect exposure pathways are assessed/confirmed to be of low risk, the engineered cover system is finalised for construction. Follow-up work in the first year or two following closure can generally include, though is not limited to the following, as determined to be appropriate to the project:

- First Nation community outreach support to assist in informing community members of the alternative solid waste management system and potentially needed modifications (e.g., transfer station facility hours).
- Inspection of the Site to assess the integrity of the engineered cover system and erosion management (e.g., vegetation establishment and any indication of erosion).

Figure 7: SDWDS post-closure, located in Seton Lake, British Columbia and re-purposed as transfer station facility

1.6 Organization of Document

In line with the risk-based Site closure process described in Section 1.5, this guidance document is organized as follows:

Section 1.0 Discusses the purpose of this document, provides a background and context for its development and the intended audience, outlines precluding conditions for its use and overviews the process for risk-based Site closure.

Section 2.0 Discusses the importance of, and approach to obtaining community support and building a project working group that will see the project through to a successful completion.

Section 3.0 Discusses alternative solid waste management systems and potential staging of interim and longer-term solutions such that the SDWDS may be closed.

Section 4.0 Discusses typical conditions at SDWDS and the modified risk-based approach to undertaking an ESA for these typical conditions.

Section 5.0 Discusses the risk assessment process for future conditions at SDWDS.

Section 6.0 Discusses design and considerations for permeable and low-permeable engineered cover systems.

Section 7.0 Discusses potentially appropriate follow-up activities for closed SDWDS.

Section 8.0 Discusses case studies outlining historical use of SDWDS, development and implementation of an alternative solid waste management system, Site risk assessment, and closure for future land use.

2.0 COMMUNITY SUPPORT

2.1 Overview

The support and involvement of the First Nation community are critical to a successful process to SDWDS closure, for a variety of reasons that may include:

- Finances and infrastructure investments
- Interest and commitment to an alternative solid waste management system
- Knowledge of Site conditions and historical landfilling activities
- Knowledge of local sources of potentially suitable engineered cover system materials and native vegetation
- Land use planning and bylaws and future land use determination such as passive or active
- Risk awareness and acceptance

A demonstrated method of developing community support is for the First Nation community to be represented by an interested 'community champion'. This 'community champion' may be one or more members with an interest in First Nation community aspects such as solid waste management, the environment, land use, education, and/or community health. This may typically include, though is not necessarily limited to, a First Nation community leader, solid waste collection worker, or planning/finance/health/education/youth/elder representative(s).

The 'community champion' works with the First Nation community to define current and anticipated future solid waste management needs, with the assistance of the qualified professionals and ISC where appropriate. Together, the 'community champion', ISC, and the qualified professionals form a project working group that develops an alternative solid waste management system that may be suitable and defines future land use and design considerations to enable SDWDS closure. The project working group meets regularly throughout project planning, implementation, and follow-up activities. This level of collaboration provides an important communication and feedback loop for the project.

2.2 Project Working Group Objectives

The general objectives of the project working group are as follows:

- Liaise with the First Nation community leaders throughout project planning, implementation, and follow-up.
- Identify suitable alternative solid waste management system.
- Define future land use and design considerations for SDWDS closure.

2.3 Project Working Group Responsibilities

The responsibilities of the project working group and its relevant members are generally as follows:

- Seeking First Nation community input and approval on key project activities.
- Submitting monthly project progress reports and land use designations to First Nation community leaders.
- Obtaining a letter of support from the appropriate First Nation community leaders for funding applications as appropriate and needed for the nature, amount, and requirements of the funding.
- Participating collaboratively and actively throughout the project including, though not necessarily being limited to, attending meetings, reviewing project documentation to develop informed opinions and decision making, providing input, feedback, and recommendations, and maintaining open communication.

An example terms of reference for a project working group is provided as Appendix A.

3.0 ALTERNATIVE SOLID WASTE MANAGEMENT SYSTEM

3.1 Overview

Implementation of an effective alternative solid waste management system will provide the First Nation community with access to improved waste management options and eliminate the need for further disposal at the Site. An alternative solid waste management system may therefore be needed if not already in place to allow for SDWS closure. Components of such a system may include:

- Recycling program to manage recyclables
- Composting program to manage organics
- Waste reduction program to reduce waste generation
- Transfer station facility to collect, combine, and transport waste to an approved facility
- Engineered waste management/disposal facility to manage residual waste

The components listed above have varying levels of complexity and may require relatively substantial considerations such as the potential need for changes to collection and transportation of solid waste materials (i.e., recyclables, organics, and/or residual waste) and alternative disposal methods for managing residual waste. Further, the development and operation of a relatively complex approved facility requires longer term planning, investment, and monitoring to manage and mitigate potential impacts associated with such a facility.

As such, the development of an alternative solid waste management system may need to be staged with interim and longer-term solutions. Where it may be useful, staging of the system with interim and longer-term solutions can also allow for the trial and adaptation of the collection and transport approach, waste management programs, and/or waste management equipment. In addition, it may be suitable to enter into service agreements with neighbouring local municipalities for collaborative waste management.

With the focus of this document being on remote Sites, this section provides guidance on securing access to an alternative disposal method and staged interim and longer term alternative solid waste management systems that may be suitable to the First Nation community. Key considerations for the planning, staging, and implementation of an alternative solid waste management system are provided, along with examples of systems that may be suitable for the First Nation community.

Further provincial and federal guidance on solid waste management planning and developing service agreements is available in other documentation[4].

3.2 Alternative Disposal Method

Alternative disposal methods to the use of the SDWDS that are suitable to the First Nation community will vary based on financial requirements and other factors, generally including:

- Current and anticipated future waste management needs (e.g., rates of waste generation)
- Proximity of and acceptability at an approved facility
- Availability and condition of the transportation network to the approved facility

[4] Example documentation including: Environment and Climate Change Canada. 2017. Solid Waste Management for Northern and Remote Communities, Planning and Technical Guidance Document. (March 2017); BC Ministry of Environment. 2016. A Guide to Solid Waste Management Planning, Version 1.0 (September 2016); and Federation of Canadian Municipalities (FCM). 2011. First Nation – Municipal Community Infrastructure Partnership Program, Service Agreement Toolkit.

Suitable alternative disposal methods may typically include the following and/or a combination of:

1) Direct Hauling
   a. Waste is collected at each dwelling and loaded into a waste collection vehicle. Waste is then directly hauled within these collection vehicles to the nearest approved facility. Waste may also potentially be hauled directly by individuals to the nearest approved facility.
   b. Generally, this method can work well where: the First Nation community has a population of less than 2,000 people; a recycling program is in place to manage recyclables; and the approved facility is located within 200 kilometres (km) of the community.
2) Transfer Station Facility
   a. The collected or individually hauled waste is unloaded at a transfer station facility operated by the First Nation community. Waste may be segregated or combined for consolidation in bulk containers or trailers designed for longer hauling transportation. The appropriate type of transfer vehicles (e.g., roll-off and walking floor) will vary based on factors generally including the size of the community, transport distance, and available unloading area.
   b. This method can assist in preparing waste for further hauling via transportation network including road, railway, water (by barge), and air (by plane) or a combination thereof.

The availability and economic feasibility of using an approved facility outside the First Nation community may also be affected by factors including, though not necessarily being limited to:

- Higher tipping fees for waste materials hauled from outside the approved facility's applicable region. This may be because taxes levied within the region include an amount for solid waste management services.
- Municipalities may include conditions that outside users similarly implement recycling and composting programs for access to landfilling at the municipal disposal facility.

Given the above factors, the development of recycling, composting, and waste reduction programs is recommended to be undertaken as an important part of the alternative solid waste management system. Suitable waste reduction options may include the following:

Landfill Bans: Municipalities across Canada have initiated landfill bans to reduce the amount of waste being landfilled (e.g., ban on cardboard or food waste). Implementing recycling and composting programs is becoming a prerequisite for access to landfilling at municipal disposal facilities and/or higher tipping fees may be required for loads containing banned materials.

- The collected or individually hauled waste is unloaded at an engineered waste management/disposal facility developed by the First Nation community. Waste is further managed via segregation or combined for incineration and/or waste is directly landfilled. Segregation of materials (e.g., recyclables and/or organics) and/or incineration will reduce the volume of waste to be landfilled.
- With regard to small-scale incineration, this is generally limited by the type and size of material that can be processed (e.g., bulky waste such as furniture and construction debris is too large for these systems), the rate of incineration, the fuel required for operation, the needed supervision, and the associated impacts (e.g., air emissions, odours, potential need to manage residual ash as hazardous waste). Shorter term rental units may be available to trial this alternative method. A visit to other communities operating an incinerator may also provide useful hands on knowledge/experience.
- With regard to composting of organics, this is generally limited by the type and size of material that can be processed (e.g., easily compostable or otherwise), the climate and related suitability and performance, the needed supervision,

Figure 8: Example of an incinerator in disrepair

and the associated impacts (e.g., air emissions, odours, potential need to manage generated and receiving waters).

Developing and operating an approved facility requires longer term planning, investment, and monitoring to manage and mitigate potential impacts associated with such a facility. The development is also to adhere to the applicable provincial or territorial regulations and design standards. Given the extent of related requirements, it is typically not economically feasible for remote First Nation communities to develop such a facility.

Drivers for developing a facility may include a larger community with elevated rates of waste generation, where the nearest approved facility is greater than 200 km of the community, and/or where year-round access to an approved facility is not possible. A feasibility study of the alternative disposal methods is recommended to be undertaken.

A key component of the feasibility study is siting the facility. The aim is to assess potential locations that provide suitable land and access, and that minimize potential impacts to sensitive receptors (e.g., dwellings, schools, water bodies, and groundwater).

3.3 Development and Implementation of Solution

There are multiple considerations, varying levels of complexity, and substantial investments needed to implement a particular solution for providing an alternative solid waste management system for the First Nation community.

Transitioning in a timely manner from disposal at the SDWDS to closure may be staged with interim and longer-term solutions. A staged approach can also allow for the trial and adaptation of the collection and transport approach, waste management programs, and/or waste management equipment.

A description for the development and implementation of potentially suitable interim and longer-term solutions is provided herein. It may be appropriate for these solutions to consider entering into service agreements with neighbouring local municipalities for collaborative waste management.

3.3.1 Interim Alternative Solid Waste Management System

An effective interim alternative solid waste management system can comprise a transfer station facility with complexity ranging from a relatively basic installation to a more comprehensive installation. It can be beneficial to align this interim solution with the planning and development of the longer-term solution.

Implementation of an interim transfer station facility typically comprises the following components:

- Waste collection arrangement
  - This includes waste collection at dwellings, individual drop off, and/or area-based depots/bins.
- Transfer station facility
  - This includes a dedicated area for collecting and consolidating as combined or segregated waste for efficient longer haul transportation.
- Transportation network
  - This includes an available transportation network of road, railway, water (by barge), and air (by plane) or a combination thereof and can assist in establishing an agreement with a licensed contractor.

3.3.2 Longer Term Alternative Solid Waste Management System

The implementation of a longer term alternative solid waste management system typically comprises the following components in addition to the interim solution:

- Recycling program, composting program, and/or waste reduction program
  - This includes material separation at the source or segregation at the approved facility along with waste management education and waste generation reduction initiatives.
- Comprehensive transfer station facility
  - This includes development of a facility potentially by adaptation of an existing system following trial and performance review. With waste management programs in place, more comprehensive services will align to manage the source separated or segregated materials.
- Engineered waste management/disposal facility
  - This includes a small-scale incineration system, composting system, and/or approved disposal facility for landfilling of residual waste.

3.4 Considerations for Community Support, Funding, and Installation

The success of the alternative solid waste management system will be in part determined by community support throughout the project and upon implementation of the solution. Each First Nation community is unique and the approach taken by the project working group should be appropriately tailored to the needs of the community. A vital step is to proactively engage, listen, and consider the community's current and anticipated future waste management needs. As such, the project working group aims to ensure the participation of the First Nation community members in developing and actively contributing to their waste management programs and suitable use and operation of their facility. Community members are typically responsible for sorting waste materials. Education linked to the waste management programs is available through a variety of means and may include involving local municipal or non-profit waste management educators to deliver training specific to the community's selected solution.

As part of the SDWDS closure process, funding is required and this may be obtained potentially through First Nation community revenue and/or funding application to ISC. Typically, a funding application will outline key project details including anticipated capital and/or operating costs for the project phases (e.g., planning, design, construction, commissioning, and operation of the alternative solid waste management system).

An open tender process is typically used to collect competitive bids and engage the services of a suitable contractor for construction including procurement of specified equipment and/or service agreements. Where staging of a solution may be appropriate given project related preferences or financing requirements, the open tender process may also be staged to deliver interim and longer-term solutions or portions thereof.

Commissioning of the facility will typically include testing, training, and handover of the constructed works to the appropriate representatives (e.g., the planned facility operator) of the First Nation community. Operator training is a key part of commissioning and can be conducted in a variety of means, such as through formal training (e.g., 'Eco-Depot Operators' course provided by Solid Waste Association of North America [SWANA]) or through informal training (e.g., role shadowing at a similar facility). Neighbouring local municipalities are generally supportive of role shadowing and this approach can work well for building useful relationships between the First Nation community and a receiving approved facility for the community's waste. Relationships such as these are important to the longer-term sustainability of the alternative solid waste management system.

4.0 ESA TO SUPPORT RISK-BASED APPROACH FOR SDWDS CLOSURE

4.1 Overview

The CCME (2016) presents a “Guidance Manual for Environmental Site Characterization in Support of Environmental and Human Health Risk Assessment”. The goal of this four-volume Environmental Site Assessment manual is to assist qualified professionals in providing Canadians with a consistent approach to sampling and analyzing complex environmental matrices (e.g., soil, groundwater, surface water, soil vapour, sediment, ambient air) so that the data are representative and sufficient to support a human health and/or ecological risk assessment.

Using this standard approach some early investigations attempting to characterize and delineate contamination resulting from domestic waste have resulted in recommendations to excavate the waste for transport to and disposal in an engineered landfill. The costs associated with this approach are high and are neither justified by scoring per the National Classification System for Contaminated Sites (NCSCS) nor by the risks to human and environmental health. Without justification for the costs for excavation and relocation of the waste, these Sites have remained uncontrolled.

The fundamentals of the CCME guidance including the development of a conceptual site model (CSM), planning, strategy, sampling techniques, handling and storage, QA/QC, and analytical methods also apply to the site characterization for risk-based closure of SDWDS.

A description of the considerations for the ESA to support risk-based approach for SDWDS closure is provided herein. Select examples of Site-specific Contaminants of Potential Concern (COPCs), sampling considerations, and assessments are also provided. The examples referred to herein were not evaluated using a numerical groundwater flow model. It is inferred that the CSM/analytical approach will be suitable for SDWDS, with the qualified professionals confirming the Site-specific requirements for investigation and closure.

4.2 Risk-Based Considerations for Site Characterization

The need has been recognized for a risk-based approach to investigation and related closure of SDWDS given that the characterization differs in two important ways from most contaminated site investigations. These two key factors are the extent of contamination and potential migration pathways as well as the non-iterative approach to investigation of these Sites.

4.2.1 Extent of Contamination and Potential Migration Pathways for SDWDS

The site characterization process described in CCME (2016) is designed to identify the potential locations and types of contamination on a site and then, where contamination is confirmed, to delineate the vertical and lateral extents of contamination at the identified locations. For the majority of SDWDS, the location of the source of contamination, and the type of contamination is known (i.e., the landfilled waste). The extent of landfilled waste can often be estimated based on local topography, as these Sites are often infilled gullies, valleys, and ravines located near communities. With the nature and extent of the source of contamination being generally known, an investigation of the source is not needed. The challenge for the ESA is the characterization and delineation of potential contaminant migration. Contaminant migration pathways include:

1) waste to leachate to groundwater to surface water
2) waste to leachate to groundwater to drinking water wells (this pathway is less likely to be present for SDWDS as they are remote)

3) waste to soil vapour to outdoor air (this pathway has not yet been an environmental concern based on information collected to date at SDWDS)
4) particulate/aqueous transport to downslope soil (this pathway may indicate the need to extend the engineered cover system)

Of these pathways, the leachate to groundwater pathways tend to be the most challenging to investigate, particularly at SDWDS where access for drill rigs is not always possible. The approach and considerations for sampling at these Sites are discussed in Section 4.5.

4.2.2 Non-iterative Approach to Investigation for SDWDS

The second way that ESAs for SDWDS differ from most contaminated sites investigations is that the common approach to site characterization is usually iterative. Initial sampling is conducted to evaluate potential contaminant sources with subsequent field programs designed to delineate the contamination. Additional field programs to fill data gaps for risk assessment are sometimes also necessary.

An iterative approach is often not practical for these SDWDS where access is often limited and repeat field programs cost-prohibitive. Therefore, it is important to anticipate potential exposure pathways for future conditions in the field program and include samples necessary to evaluate these pathways in the risk assessment should contamination be found.

Ideally, there will be no contaminant exposure pathways warranting quantitative evaluation for the risk assessment. Where downslope soil is found to be contaminated, the engineered cover system can be extended to cap the landfilled waste as well as the contaminated downslope soil[5]. Aside from eliminating a possible future exposure pathway to contaminated soil, capping contaminated downslope soil with the engineered cover system also eliminates possible secondary contaminant exposure pathways related to uptake of contaminants in flora/fauna. If contaminated soil is left uncovered, the ESA may need to include sampling of vegetation in the area of soil contamination and a background location, particularly if area plants, including berries, may be consumed.

Leachate generated from a SDWDS is typically weak. Furthermore, concentrations of contaminants are typically assessed as having been attenuated prior to reaching the receptors. Concentrations of volatile contaminants in soil vapour have also generally been low and have met guidelines/standards. As such, the scope of the risk assessment conducted for a SDWDS may be limited to a Problem Formulation showing no potentially significant exposure pathways.

4.3 Contaminants of Potential Concern

The COPCs for SDWDS reflect the nature of the landfilled waste and the timeframe in which the SDWDS operated. Domestic waste may contain minor quantities of common contaminants including:

- Relating to soil
  - Petroleum hydrocarbons (F1-F4), polycyclic aromatic hydrocarbons (PAHs), metals, volatile organic chemicals (VOCs) and chemicals associated with these
- Relating to groundwater
  - Petroleum hydrocarbons (F1-F4), polycyclic aromatic hydrocarbons (PAHs), metals, volatile organic chemicals (VOCs) and chemicals associated with these.

[5] As determined through confirmatory soil sampling.

- Relating to soil vapour
  - Fuel-related volatile chemicals, solvents, and refrigerants.

The extent of sampling and analysis of additional COPCs specific to the Site should be evaluated by a qualified professional in consultation with the project working group.

Example of Site Specific COPCs

Where the SDWDS had including burning of domestic waste in open vessels or incinerators to reduce the volume of waste being landfilled, this can generate additional COPCs within the burned material and residual ash. Related investigations of polychlorinated dibenzo-p-dioxins and furans (PCDD/F) in soil or residual ash at SDWDS has indicated that PCDD/F are produced at low concentrations below risk-based standards as depicted below on Figure 9.

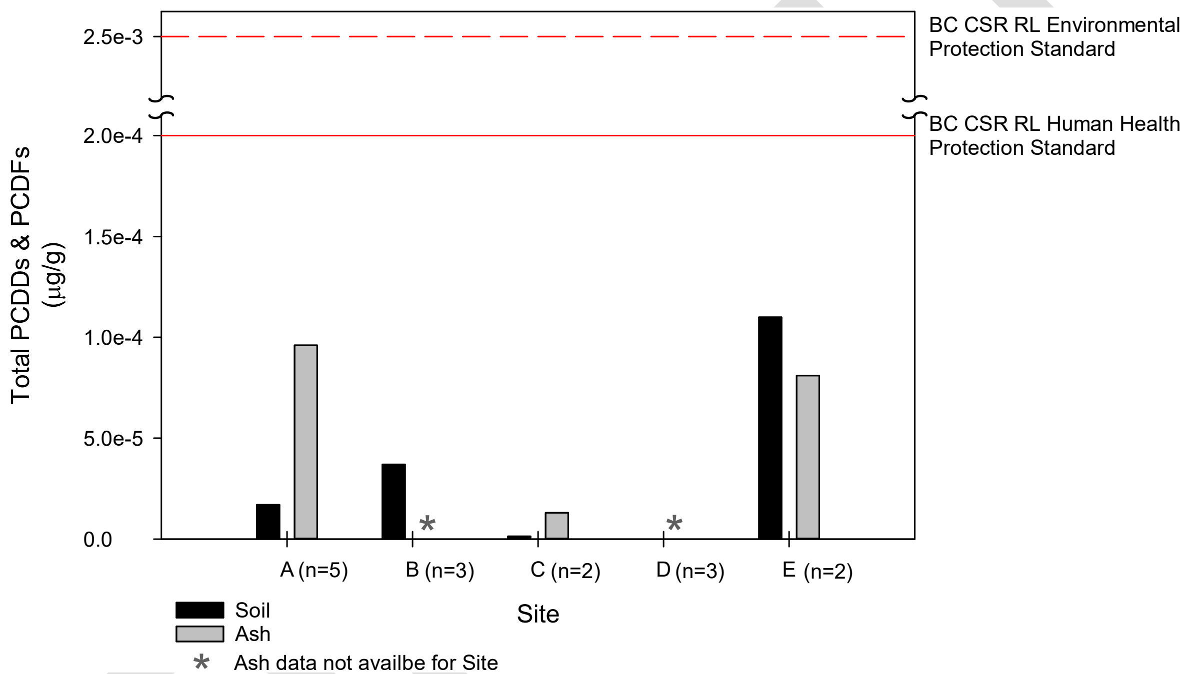

Figure 9: Maximum total PCDDs & PCDFs concentrations in soil and ash at a SDWDS located in British Columbia

Similarly, where pesticides have been employed for household use in communities, concentrations in soil and groundwater have been less than regulatory standards. If there are reports of disposal of larger volumes of pesticides or other contaminants, they should be tested in the appropriate media as part of the ESA.

As noted above, a qualified professional should evaluate the COPCs that are appropriate for the Site. Consideration should be given to the nature, quantity, and timeframe of landfilling and whether it is appropriate to conduct analysis for newly regulated chemicals in Canada (e.g., perfluoroalkyl substances [PFASs]).

4.4 Conceptual Site Model

The proposed approach to the development of the investigation of contaminated sites (CCME 2016) includes the development of a preliminary CSM prior to undertaking the Site activities. The extent of contamination is not known at this point, though readily available information from the project working group and other resources (e.g., aerial imagery and geological/topographic maps) can be used to depict on a CSM what is known and what information is needed. For instance, the exact location of a SDWDS may not be known if the Site has already been capped with locally sourced materials. In this case, review of historic aerial photographs or other records may be undertaken. If that review is fruitless, light weight and portable geophysics equipment (e.g., Geonics Limited EM61) operated by an experienced technician can be used to locate the waste material.

The preliminary CSM is updated following the Site investigation and as data becomes available. The CSM is used as a communication tool for the project working group to discuss with all stakeholders (i.e., the First Nation community, ISC, the qualified professionals). The information listed on the CSM development checklist depicted below as Figure 10 will assist in the development of a CSM for the Site. Examples of CSMs and ESA designs are provided as Appendix B and development of a CSM is detailed in CCME (2016).

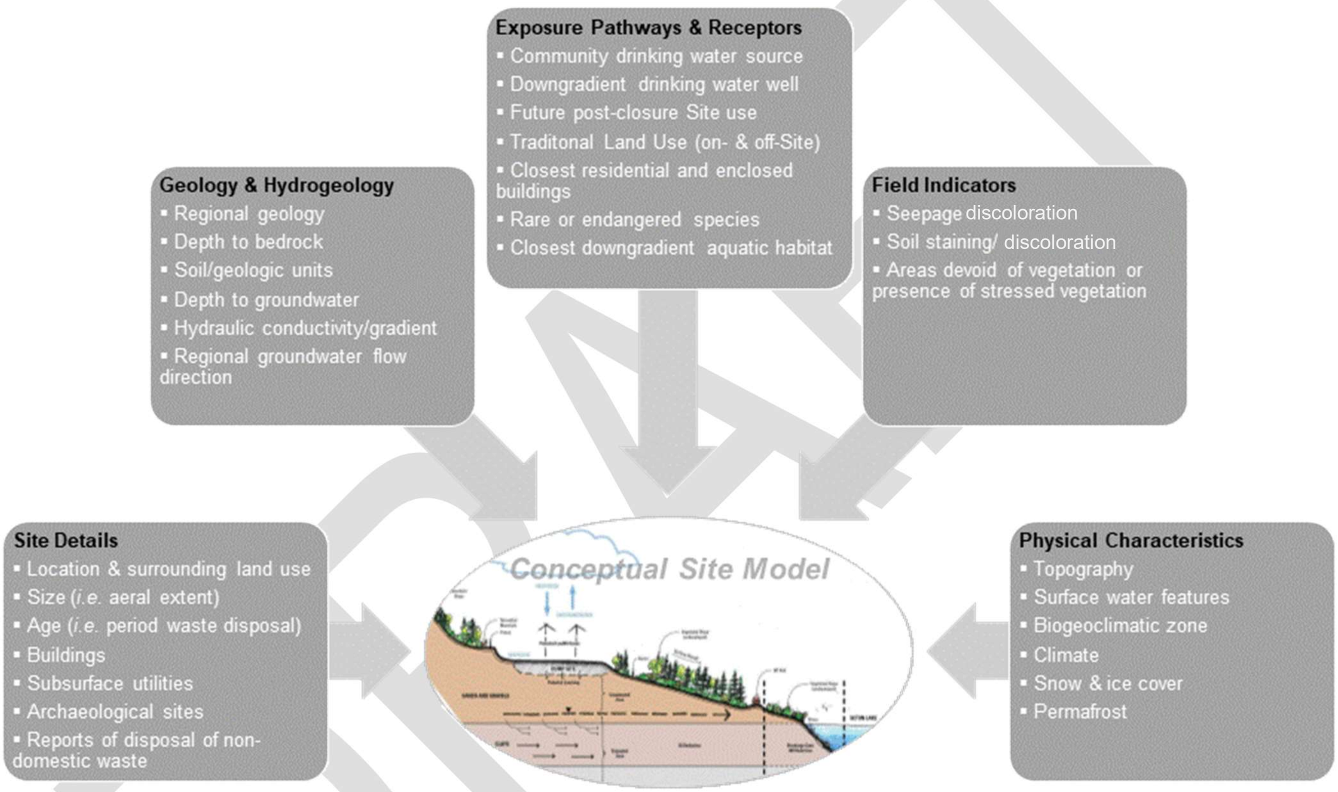

Figure 10: Checklist for Conceptual Site Model Development

4.5 Investigation of SDWDS

A primary challenge with SDWDS is that they are remote and it is not always possible to bring in standard equipment, such as drill rigs, for investigation of the Site. As such, there is a need to use portable and innovative means to obtain quality samples. The approach and considerations to undertaking soil quality, groundwater quality, surface water quality, and soil vapour quality sampling for SDWDS is discussed below and may assist in avoiding challenges associated with the Site investigation.

The qualified professionals should assess whether conditions at a project site are typical of SDWDS or if a more detailed investigation is warranted.

4.5.1 Approach and Considerations for Soil Quality Sampling

The focus of soil sampling for SDWDS is both the surficial soil located downslope from the landfilled waste that may have become contaminated via surface water runoff or erosion and upslope surficial soils selected as being representative of background soil quality. As such, soil sampling is not typically challenging at SDWDS.

Soil quality samples should be collected from the surface to a depth of 10-15 cm, as representative of surficial soil where potential exposure can occur.

The sampling approach should take into consideration the topography, where depressions or gullies may be expected to have higher concentrations than up-slope locations. Samples should be taken across the depressions to provide worst case sample results for the area; however, areas with lower, or effectively no risk of contamination should also be sampled to delineate contaminated soil. Sufficient sample numbers (nominally 12 and a field duplicate) should be taken to allow for statistical interpretation of the data.

Site-specific soil sampling to establish local background concentrations of COPCs may be undertaken. This can be particularly important for metals concentrations as mineralized areas may have naturally higher concentrations of metals in soil.

Remedial and management activities including risk assessment and capping with an engineered cover system are only required for COPCs that exceed background concentrations. The Federal Contaminated Sites Action Plan (FCSAP), as part of its ecological risk assessment guidance series, has developed guidance on defining background conditions and using background concentrations (FCSAP 2020). Alternatively, published regional background concentrations or technical guidance may be used where they are available from provincial agencies (e.g., BC Ministry of Environment and Climate Change Strategy [BC ENV] Technical Guidance Document #16 [BC ENV 2017a] and Protocol #4 [BC ENV 2017b]).

4.5.2 Approach and Considerations for Groundwater Quality Sampling

The leachate to groundwater migration pathway tends to be the potential exposure pathway of greatest concern for SDWDS. The CCME guidance (2016) outlines in detail methods recommended for investigations of groundwater quality and where warranted these methods should be employed.

As leachate from SDWDS tends to be weak, it is often possible to use a CSM/analytical approach to assessment of groundwater and unsaturated zone pathways associated with these Sites. In this instance, the CCME (2016) approach may justifiably be avoided.

The CSM should, as far as the data set allows, include use of published references or other interpretations and investigations available to the qualified professional, be rigorous and quantitatively identify ranges for important parameters such as:

- Infiltration rates.
- Saturated and unsaturated thicknesses particularly below the SDWDS and the thickness, nature and influence of any perched water tables.
- The spatial geometry of hydrostratigraphic units particularly as they relate to forming a pathway between the SDWDS and any receptors.
- The pertinent hydraulic conductivities of those hydrostratigraphic units.

The parameter ranges identified in the CSM are then used in a deterministic or stochastic analytical approach, to assess the fate and transport of contaminants along the unsaturated and groundwater pathway emanating from the SDWDS and to determine whether conditions are typical of SDWDS. This information will help qualified professionals assess if the proposed CSM/analytical approach is adequate or whether a more detailed approach such as intrusive investigation is required.

For arid regions or Sites with deep water tables, modelling of infiltration rates in the unsaturated zone can be used to determine if contamination associated with leachate has had sufficient time to reach the water table. Modelling attenuation, dilution and dispersion in the saturated zone using worst case assumptions provides a conservative estimate of dilution along the pathway from the SDWDS to the receptors and the general leachate quality at the receptors.

For SDWDS, the leachate to groundwater migration pathway is typically the pathway of greatest concern. For remote sites, bringing a drill rig to the site to install groundwater monitoring wells is not always possible. For sites with a deep groundwater table, travel time from the SDWDS to the nearest receptor may indicate that there has not been sufficient time for contaminants from the waste to reach the water table. Installation of groundwater monitoring wells would not be useful for site characterization under these conditions.

In these cases, leachate quality can be sampled, and the groundwater concentrations at receptors, such as a surface water body or a drinking water well can be modelled to provide input to the risk assessment. Simple methods of leachate sample collection include:

- Installation of lysimeters immediately below the landfilled waste
- Sample collection from seeps from the downslope sides of the Site
- Where the groundwater table is in range and subsurface materials are amenable, installation of hand, or portable power driven piezometers (mini-piezometers) at the toe of the SDWDS

Lysimeters usually require a rainfall event in order for there to be sufficient volume for sample analysis. Installation at the beginning of the field program or a return trip to obtain a sufficient sample volume may be necessary. Certain times of the year may be better for sample collection as a result of potentially increased seepage or the water table rising closer to ground surface due to seasonal climate variation.

Figure 11: Lysimeter location selection (left), placement (middle), and cover (right) at a SDWDS located on Penelakut Island, British Columbia

Consideration should also be given to the distance to the closest receptor. In some instances, receptors that are remote from the Site have the potential to be indistinguishable from background. The qualified professionals should evaluate whether preferential pathways for groundwater flow exist that could lead to potential impact at receptors.

Example of Site-Specific Leachate Quality

A number of Sites have been assessed for closure using a permeable cover. These Sites were located along the coast of British Columbia where precipitation is high and water tables are near to the surface. Other Sites within the British Columbia interior were also assessed where precipitation is low and the water table is deep. The leachate quality from these Sites tended to be relatively weak in comparison to larger municipal waste landfills. A comparison of leachate quality from nine SDWDS and typical municipal landfill leachate in that province[6] is depicted below as Figure 12.

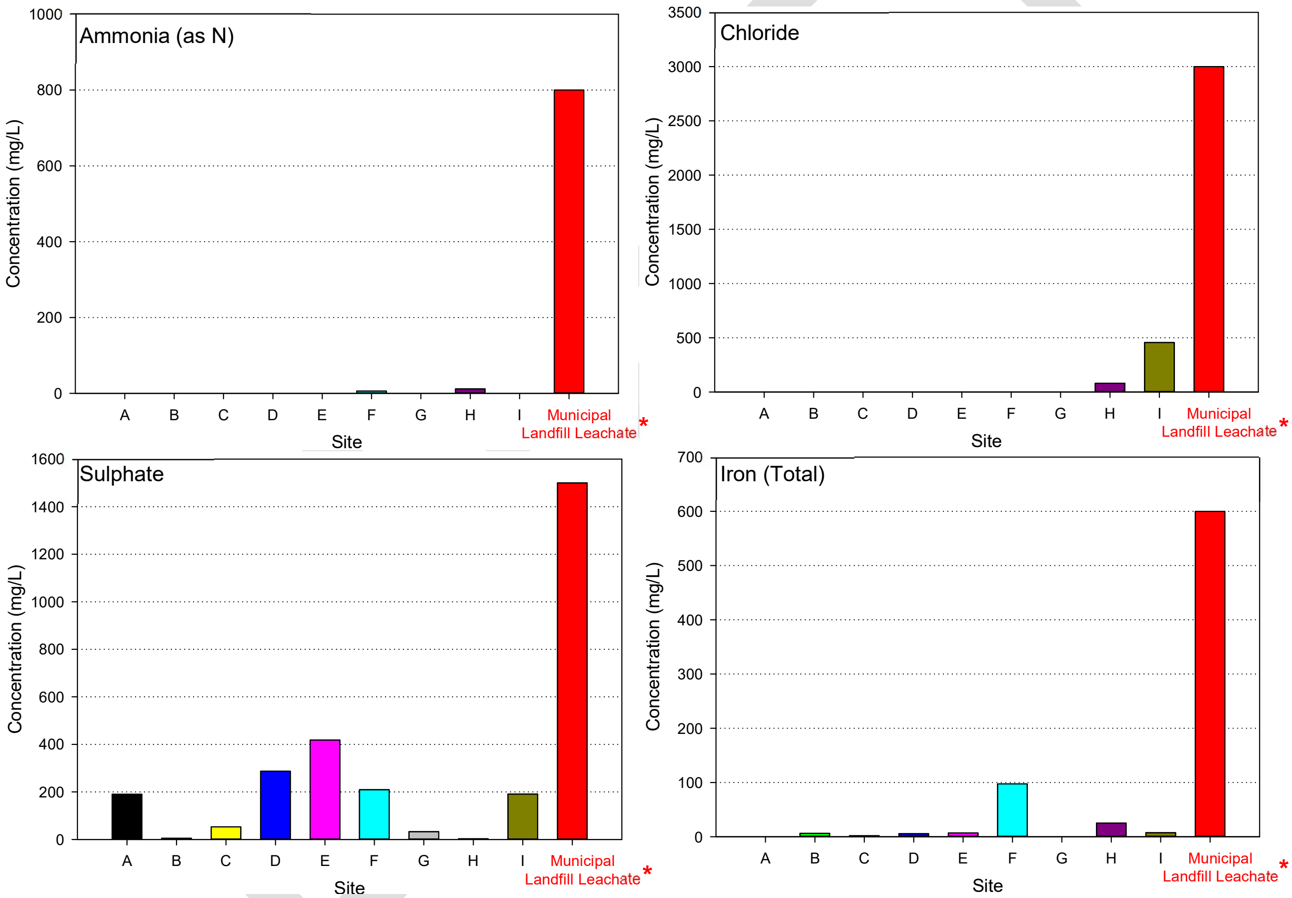

Figure 12: Maximum concentrations of leachate indicator parameters at nine SDWDS located in British Columbia

[6] *Municipal landfill leachate concentrations from BC ENV *Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills (from SWANA 1991)*

4.5.3 Approach and Considerations for Soil Vapour Quality Sampling

The soil vapour investigation should focus on worst case conditions within the landfilled waste. The CCME guidance (2016) provides detailed guidance for conducting soil vapour sampling.

Soil vapour probes are reasonably portable for installation at remote locations. Portable methods of installation include use of a slide hammer or hand-drilling methods to obtain sufficient depth. Methods for QA/QC outlined in CCME (2016) including leak testing are important when installing soil vapour within the landfilled waste, as there is increased potential for short circuiting in the probes due to the heterogeneous terrain as compared with natural soils.

Figure 13: Leak testing drive-point soil vapour probe at a SDWDS near Lillooet, British Columbia

The outdoor air breathing zone concentrations are predicted by applying standard attenuation factors to the soil vapour analytical results. The predicted concentrations are compared to criteria protective of human health. Details regarding attenuation factors and health criteria can be obtained from CCME (2014). Attenuation factors and breathing zone air standards can also be obtained from BC ENV Protocol #22 (BC ENV 2017c) and BC Contaminated Site Regulation (CSR) Schedule 3.3 (BC ENV 2018) respectively. Typical conditions at a SDWDS include low concentrations of organic vapours within the landfilled waste with the predicted outdoor air concentration well below air quality standards.

Example of Site-Specific Soil Vapour Quality

Depending on the size of the Site, investigations have typically included installation of 3 to 5 vapour probes within the landfilled waste. The soil vapour probes were screened for organic vapours in the field and a subset of the probes having the highest readings were sampled for detailed lab analysis. Typically, there have been very low or no vapours detected in the field. Under these circumstances, the probe locations selected for detailed lab analysis were based on qualified professional judgement. Concentrations of chemicals in soil vapour samples attenuated for outdoor air have been assessed as being very low at a number of sites (for instance, being less than 10% of the BC CSR vapour standards, [BC ENV, 2018]). As such, the vapour exposure pathway has not required evaluation beyond the Problem Formulation step of the risk assessment at any sites to date.

Figure 14: Soil vapour quality sampling locations within landfilled waste at a SDWDS located in Lax Kw'alaams (Left) and Opitsaht (Right), British Columbia

4.5.4 Approach and Considerations for Surface Water Quality Sampling

Surface water and sediment sampling should be undertaken where there is reason to suspect that the landfilled material may have affected surface water or sediment quality in a downgradient aquatic habitat.

The qualified professionals should assess the habitat quality where surface water drainage becomes aquatic habitat. Samples should be taken upgradient of potential impact from SDWDS leachate, immediately downgradient of the point of impact, and/or where surface water becomes aquatic habitat and further downgradient to discern a zone of impact, where applicable.

Figure 15: Surface water quality sampling plan for a SDWDS in Ahousaht, British Columbia (left) and surface water quality sampling at depicted Site location SW11-02 (right)

5.0 RISK ASSESSMENT OF FUTURE CONDITIONS AT CLOSED SDWDS

5.1 Overview

A risk assessment is conducted to evaluate human health and ecological risks associated with contaminants in the SDWDS. The SDWDS risk assessment evaluates potentially significant exposure pathways under future conditions when an engineered cover system is installed over the landfilled waste. With a cover system in place there will be no direct contact exposure pathways with the landfilled waste.

The risk-based approach for assessment of future conditions at closed SDWDS is described herein.

5.2 Risk Assessment Process

With the focus on future conditions at closed SDWDS, the risk assessment process should follow existing guidance provided by Health Canada and FCSAP.

A general outline of the risk assessment process used in Canada and elsewhere is depicted below as Figure 16. The process is generally iterative, with conservative assumptions used in the initial iteration and more refined and site-specific assumptions then used where the initial assessment indicates an unacceptable level of risk. The risk assessment process can be the same for both human and ecological receptors, although more detailed ecological risk assessment often include bioassays and *in situ* evaluations of contaminated media which incorporate both exposure and toxicity in one step.

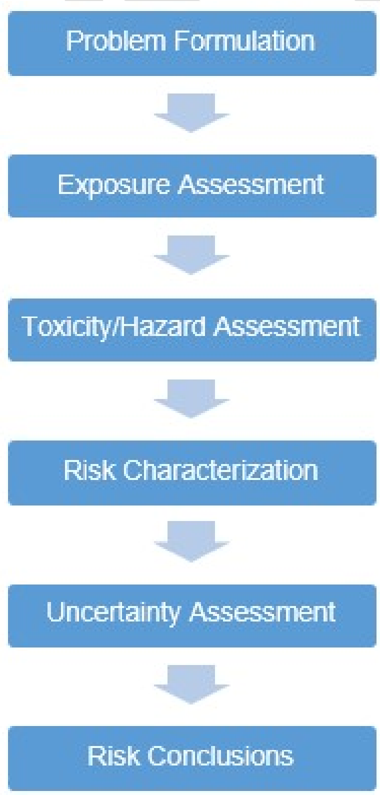

Figure 16: Risk Assessment Process

The Problem Formulation is the initial step in the risk assessment process and focuses on identifying COPCs, receptors, and contaminant exposure pathways. The process for identification of COPCs and receptors is the same as that outlined in *Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment, Version 2.0* (Health Canada, 2010) and *FCSAP Ecological Risk Assessment Guidance* (FCSAP, 2012). From an exposure pathway perspective, the remaining potentially significant contaminant exposure pathways are the indirect pathways associated with potential contaminant migration. These include:

1) Waste to leachate to groundwater to surface water used by people or aquatic life.
2) Waste to leachate to groundwater to drinking water wells.
3) Waste to vapour to outdoor air.
4) Particulate/aqueous transport to downslope surficial soil.

The significance of these potential exposure pathways is evaluated by sampling these media or a combination of sampling and modelling fate and transport of contaminants to receptor locations, as discussed in Section 4.

Soil contamination downslope of the landfilled waste, if present, can be included as part of the risk assessment or removed as a potential exposure pathway where it is to be capped under the engineered cover system. If contaminated soil is left in place for quantitative evaluation in the risk assessment, it may be necessary to evaluate pathways related to uptake in flora/fauna. The need for evaluation of plant and animal-related exposure pathways should be based on the extent of contamination of soil, the fate and transport of the contaminant, and input from the project working group concerning harvesting of plants and berries at or in the vicinity of the site.

When concentrations of contaminants in groundwater are not acceptable for a water use, risk assessments for contaminated groundwater should rely on measured or predicted concentrations at the receptor location (e.g., measured or predicted at surface water discharge location and predicted at groundwater well locations). For the waste to groundwater to surface water pathway, the data from the ESA should provide surface water concentrations that can be evaluated directly for human or ecological use. Similarly, data from the ESA should provide measured or predicted concentrations in groundwater at the receptor location for comparison to drinking water guidelines/standards.

Where potentially significant exposure pathways are identified as part of the Problem Formulation (i.e., if there is a contaminated media that could contact a receptor), the risk assessment proceeds through the subsequent steps through to Risk Characterization.

There are key assumptions used in the risk assessment for SDWDS that become risk controls for future land use. These include:

1) No residential properties located within 100 m of the landfilled waste.
2) No confined spaces or enclosed buildings including pumphouses or sheds will be situated within 30 m of the landfilled waste.
3) A groundwater use exclusion zone may be required for the Site.
4) Future land use within the Site footprint will not include growing or harvesting food such as planted crops, medicinal plants, and wild berries.

It is important that the project working group understand these risk controls and that they be communicated with all project stakeholders such that limitations on future land use are understood and a suitable engineered cover system can be designed to meet the needs the community. Implementation of these risk controls may include community resolutions and/or restrictions in community land use plans.

6.0 DESIGN CONSIDERATIONS FOR ENGINEERED COVER SYSTEM

6.1 Overview

A suitably designed engineered cover system will allow for Site closure for future land use. The general intent of the engineered cover system is to:

- Provide a cap over the landfilled waste that acts as a barrier to direct exposure
- Reduce infiltration of precipitation, leachate generation, and impacted surface water runoff
- Control emissions of odour, dust, and landfill gas (LFG)
- Mitigate waste related activity from vectors or pests such as rodents and birds

Along with consideration of the future land use, cover system materials and native vegetation, the design for the engineered cover system should also consider the information gathered from the ESA and risk assessment (refer to Sections 4 and 5). These activities will identify any potentially significant contaminant exposure pathways, guide a targeted investigation of the Site to assess the suitability of a potential engineered cover system, and define the level of risk associated with the Site closure under future conditions.

The two types of engineered cover systems for Site closure are permeable and low-permeable. These systems meet the capping objectives and generally align with provincial and territorial design guidelines/standards across Canada. The level of risk identified for the Site (refer to Section 5) will assist in defining whether a permeable (given a low risk level) or low-permeable (given a high risk level) engineered cover system is appropriate for the Site.

Additional evaluation criteria not discussed herein for the design of an engineered cover system include surface water management, Site constraints, First Nation community acceptance, energy use and related greenhouse gas (GHG) emissions, and post-closure monitoring and maintenance requirements.

6.2 Permeable System

Permeable engineered cover systems are commonly used in remote locations, in part given the relative ease of sourcing suitable local materials as compared with low-permeable alternatives. Benefits of a permeable system as compared with a low-permeable system can also include:

- Lower supply, installation, repair, and maintenance costs/requirements
- Potential suitability for steeper slopes (e.g., greater than 1 vertical:3 horizontal [1V:3H]) upon review by a qualified professional of the material characteristics

A permeable system includes the following layers from top to bottom:

- Growth Media/Vegetation Layer
  - Provides stabilization of slopes, reduces surface erosion, and can blend with surrounding environment.
  - Typically a minimum 150 millimetre (mm) of topsoil suitable for native vegetation growth and additional depth of topsoil as needed to accommodate for anticipated root depth.
- Barrier Layer
  - Provides a permeable physical barrier between the landfilled waste and humans or wildlife that prevents future direct exposure, reduces leachate generation, assists in controlling emissions, and minimizes the presence of vectors.
  - Typically a minimum 600 mm well-graded sand or soil

- This layer may be required to be installed above a separation geotextile.

A typical permeable engineered cover system depicting the material layers is provided below as Figure 17.

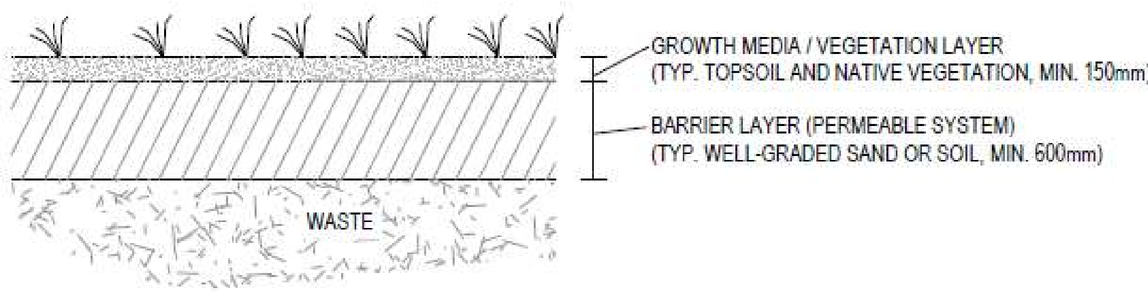

Figure 17: Drawing detail for typical permeable engineered cover system.

6.3 Low-Permeable System

Low-permeable engineered cover systems provide for an enhanced barrier to further reduce leachate generation and control emissions where this improved mitigation may be appropriate. Necessary considerations of a low-permeable system as compared with a permeable system can also include:

- Augmenting surface water management network to manage increased runoff.
- Controlling the migration and venting/management of LFG under the confining layer of the low-permeability barrier.

A low-permeable system includes the following layers from top to bottom:

- Growth Media/Vegetation Layer
  - Provides stabilization of slopes, reduces surface erosion, and can blend with surrounding environment.
  - Typically a minimum 150 millimetre (mm) of topsoil suitable for native vegetation growth and additional depth of topsoil as needed to accommodate for anticipated root depth.
- Protective Cover/Drainage Layer:
  - Provides protection and further depth to the barrier layer.
  - Typically a minimum 450 mm of well-graded sand or soil.
  - Drainage is typically accommodated via use of drainage aggregate at 300 mm or geocomposite drain at 7-10 mm to provide suitable hydraulic conductivity (k) equal or greater than 1×10^{-4} centimetres/second (cm/s).
- Barrier Layer
  - Provides a low-permeable physical barrier between the landfilled waste and humans or wildlife that prevents future direct exposure, reduces leachate generation, assists in controlling emissions, and minimizes the presence of vectors.
  - In arid or semi-arid regions (areas with less than 500 mm of annual precipitation), suitable hydraulic conductivity may be equal to or less than 1×10^{-5} cm/s and in non-arid regions, suitable hydraulic conductivity may be equal to or less than 1×10^{-7} cm/s.
  - Typically a low-permeability soil (e.g, compacted clay at 600-1,000 mm) or a geosynthetic material (e.g., geosynthetic clay liner [GCL] at 5-12 mm or geomembrane at 1-2 mm [40-80 mils]).
  - This layer may require to be installed above and/or below a protection geotextile.

- Cushion/LFG Control Layer
  - Provides a suitable subgrade for installation of the barrier layer and where needed it can also provide a preferential pathway for control of LFG migration through to passive venting or active management. Given the Sites are relatively small, passive venting of LFG is typically suitable, but this should be confirmed and considered during the ESA, risk assessment, and design. Provision should be made for installation of passive/active components through geosynthetics where these are part of the design.
  - Typically a minimum 300 mm of well-graded sand.

Design considerations specific to the various low-permeable barrier types include the following:

- Compacted Clay
  - Consists of a well-graded clay material placed and compacted in lifts to provide a low-permeability barrier layer.
  - Viable option primarily where the suitable clay material may be locally sourced.
  - Locally sourced clay deposits often require screening to remove rock and debris that otherwise degrade the performance of the barrier layer.
  - Installation may be undertaken by a general earthworks contractor. Installation must be completed during favourable weather conditions within minimum temperature requirements. Construction should include QA/QC measures such as source testing data, moisture content, and compaction testing to ensure the integrity of the barrier layer. Prompt placement of the surficial layer is required to prevent erosion.

- Geosynthetic Clay Liner (GCL)
  - Consists of manufactured sodium bentonite layer supported by non-woven geotextiles.
  - Compatibility of GCL with adjacent materials should be reviewed by a qualified professional.
  - Inherent capacity to self-repair minor punctures/tears.
  - Installation may be undertaken by a general earthworks contractor with suitable experience but typically the manufacturer’s field services are required. Installation must be completed during favourable weather conditions within minimum temperature requirements. Construction should include QA/QC measures such as source testing data and field sampling/testing to ensure the integrity of the barrier layer. Prompt placement of the surficial layer is required to prevent damage.

- Geomembrane
  - Consists of manufactured linear low density polyethylene (LDPE) or high density polyethylene (HDPE).
  - Additional geotextile layers above or below the geomembrane may be required for protection.
  - Installation requires specialist installer services and requires the manufacturer’s field services. Installation must be completed during favourable weather conditions within minimum temperature requirements. Construction should include QA/QC measures such as source testing data and field sampling/testing to ensure the integrity of the barrier layer. Prompt placement of the surficial layer is required to prevent damage.

Typical low-permeable systems depicting the material layers are provided below as Figures 18 and 19 with compacted clay and GCL or geomembrane for the barrier layer.

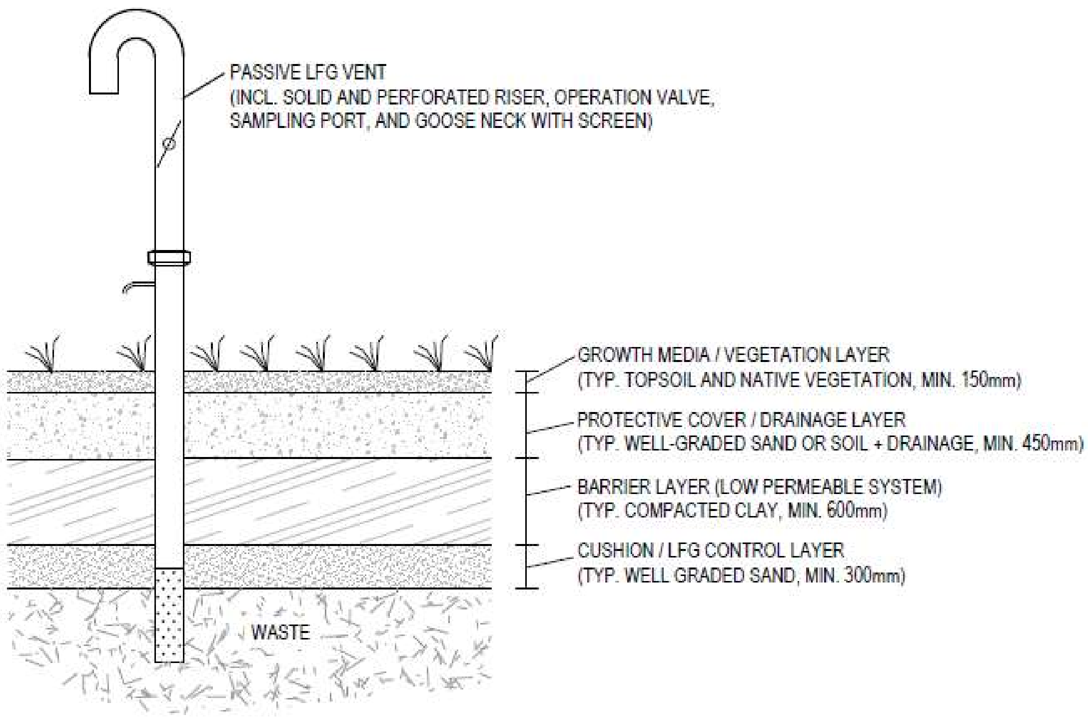

Figure 18: Drawing detail for typical low-permeable system with compacted clay.

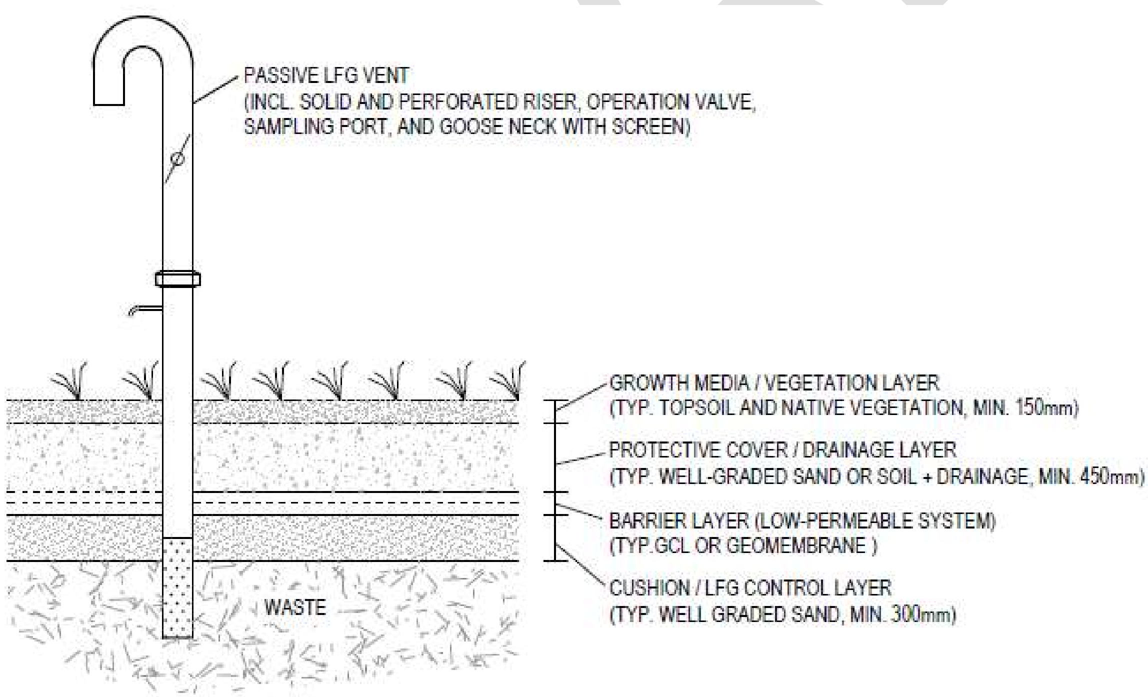

Figure 19: Drawing detail for typical low-permeable system with GCL or geomembrane.

7.0 FOLLOW-UP ON CLOSED SDWDS

Upon Site closure and within one to two years after closure, it is recommended that follow-up activities be conducted. The appropriate activities will vary by Site and may include the following:

- First Nation community outreach
  - This may include the project working group and education/support to assist in informing community members of the alternative solid waste management system to ensure active participation in the selected solution.
- Performance review/modifications
  - This may include review/adjusting transfer station facility hours to suit community needs and the frequency of collection and transport to optimize hauling.
- Vegetation care and management
  - This may include watering, fertilizing, removing invasive species or weeds as needed, and/or additional planting of selected native species for suitable establishment of vegetation.
- Inspection of the engineered cover system and potential impacts
  - This may include a Site inspection by a qualified engineering professional to assess the engineered cover system integrity, stability, and potential damage as well as to identify potential impacts to applicable receptors.
- Longer term environmental monitoring
  - The monitoring and assessment of closed Site performance may be required to manage and mitigate potential impacts. Monitoring may be undertaken to identify and assess the quality of groundwater, surface water, and soil vapour (e.g., subsurface LFG) as well as potential surface emissions of LFG. The monitoring program could be undertaken in conjunction with periodic vegetation care and management and general inspections of the Site. The need for and extent of longer-term environmental monitoring should be determined as part of the ESA and risk assessment based on future conditions with consideration for the selected engineered cover system design. The assessment of monitoring data should be used to determine the ongoing need for and extent of the program.

8.0 CASE STUDIES

8.1 Overview

This section provides three case studies outlining historical use of SDWDS, development and implementation of an alternative solid waste management system. The Case Studies 1 and 2 also discuss Site risk assessment and closure for future land use. A unique difference between case studies is the available transportation network.

8.2 Case Study 1 – System including water access/transportation

Metlakatla is a coastal village with a population of approximately 980 residents located on an island approximately 10 km from Prince Rupert, British Columbia.

The community is accessible via water (by boat or seaplane).

Historically, the community landfilled waste in three SDWDS located near the village with Site footprints ranging from approximately 0.12 to 0.37 hectares (ha). In 2009, the community commenced working toward SDWDS closure including developing an alternative solid waste management system. Funding was available from ISC as part of a multi-community coastal First Nations solid waste management program.

The developed alternative solid waste management system includes a recycling program. Source separated materials (recyclables) and domestic waste are collected weekly at dwellings for drop off at a developed transfer station facility. This facility (Metlakatla solid waste management centre) assists in sorting, storing, and consolidating materials for transfer by barge to approved facilities off-island.

The facility consists of a grade-separated wall with three bays for domestic waste drop off into roll-off bins, a fabric shelter used for sorting, baling, and storing recyclables, and a household hazardous waste shelter. The roll-off bins are transferred by barge on a monthly basis and recyclables are transferred by barge on a periodic basis. The facility includes stockpile areas for metals, white goods, and bulky waste, which are removed periodically via transfer by barge.

Leading to Site closure, an ESA was undertaken with development of CSM and Site investigative sampling in support of a risk assessment. Sampling was undertaken in soil, soil vapour, sediment, surface water, coastal porewater, groundwater, and ambient air. With consideration for the assessed low level of risk and based on the project needs, one of the SDWDS was excavated and consolidated with another Site, and the two remaining Sites were contained with a permeable engineered cover system making use of locally sourced materials.

The land uses for the closed Sites include a passive use (walking trail) and an active use (public works storage yard).

8.3 Case Study 2 – System including road access/transportation

The Tache and Binche communities are home to the Tl'azt'en & Binche Keyoh First Nations. Tache and Binche are located in the Regional District of Bulkley-Nechako on the North Shore of Stuart Lake at the Tache River, British Columbia.

These communities are accessible via road.

Historically, the communities of Tache and Binche landfilled waste at a SDWDS in Tache. Bulky waste such as scrap metal and white goods were also stockpiled at the SDWDS for periodic removal. The Site had an approximate footprint of less than one hectare. In 2015, the communities commenced working toward SDWDS closure including developing an alternative solid waste management system. Funding was available from ISC as part of a Zero Waste Program.

The developed alternative solid waste management system includes a recycling program. Source separated materials (recyclables) and domestic waste are collected weekly on separate days at dwellings for direct haul in the collection vehicle to approved facilities. The recyclables are directly hauled to the Fort St. James recycling depot located 45 minutes travel from the communities. The domestic waste is directly hauled to the Clearview Landfill located near Vanderhoof, British Columbia, which is approximately 1 hour away from the communities.

Prior to Site closure, an ESA was undertaken including development of a CSM and investigative sampling to support a risk assessment. Sampling was undertaken in soil, soil vapour, and surface water. Groundwater was evaluated through desktop assessment due to project needs and because monitoring wells were not available at the Site. In consideration of the assessed low level of risk, the landfilled waste was contained with a permeable engineered cover system made from locally sourced materials. The cover system was graded to promote run-off of surface water.

The land use for the closed Site includes passive use and the access road was decommissioned.

8.4 Case Study 3 – System including air/ice road access/transportation

Old Crow is a small town in northern Yukon with a population of approximately 300 residents, located at the confluence of the Crow and Porcupine Rivers, Yukon.

The community is accessible via air (by plane) and biannually by ice-road.

The community landfills waste at a SDWDS located in the town. At the SDWDS, the combustible fraction of select waste materials was burned in an open burning vessel. In 2013, the community commenced developing an alternative solid waste management system and partial closure of the SDWDS.

The developed alternative solid waste management system includes a gasification system to convert select organics and carbonaceous based materials into synthetic gas that is then flared, producing carbon dioxide and residual ash. A relatively substantial amount of diesel fuel is required to operate the system and this is flown into the town. During periods of time where the system requires repair or is not operating, the materials are instead burned in an open burning vessel as was done historically.

The developed alternative solid waste management system also includes a recycling program, a waste reduction program, and diversion of waste to be landfilled to an approved facility. The recycling program consists of container deposit items (e.g., beverage cans and bottles) that are collected and transported by plane to an approved facility as well as non-deposit items (e.g., paper, cardboard, cartons, and other plastics) that are burned within controlled burning systems. The waste reduction program consists of reducing packaging on incoming products and completing a waste audit on materials processed via gasification/burning vessel to assess whether there is additional opportunity for waste diversion.

A portion of the SDWDS was closed for implementation of the alternative solid waste management system. The landfilled waste was contained with a permeable engineered cover system made from locally sourced materials. A longer-term environmental monitoring plan was implemented to monitor groundwater and surface water at the Site.

The land use for the operational Site includes active use for the gasification system.

9.0 REFERENCES

British Columbia Ministry of Environment and Climate Change Strategy (BC ENV). 2017a. Technical Guidance on Contaminated Sites No. 16: Soil Sampling Guide for local Background Reference Sites (Version 1 November 1, 2017). Available Online: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/site-remediation/docs/technical-guidance/tg16.pdf

BC Ministry of Environment. 2016. Landfill Criteria for Municipal Solid Waste, Second Edition (June 2016). Available Online: https://www2.gov.bc.ca/assets/gov/environment/waste-management/garbage/landfill_criteria.pdf

BC Ministry of Environment. 2016. A Guide to Solid Waste Management Planning, Version 1.0 (September 2016). Available Online: https://www2.gov.bc.ca/assets/gov/environment/waste-management/garbage/swmp.pdf

BC ENV. 2017b. Protocol 4 for Contaminated Sites: Establishing Background Concentrations in Soil (Version 9 November 1, 2017). Available Online: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/site-remediation/docs/protocols/protocol_4.pdf

BC ENV. 2017c. Protocol 22 for Contaminated Sites: Application of Vapour Attenuation Factors to Characterize Vapour Contamination (Version 1 November 1, 2017). Available Online: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/site-remediation/docs/protocols/protocol_22.pdf

BC ENV. 2018. Environmental Management Act: Contaminated Sites Regulations (CSR) (includes amendments up to BC Reg. 116/2018, June 14, 2018). Available Online: http://www.bclaws.ca/Recon/document/ID/freeside/375_96_00

Canadian Council of Ministers of the Environment (CCME). 2014. A Protocol for the Derivation of Soil Vapour Quality Guidelines for Protection of Human Exposures via Inhalation of Vapours (PN 1531 ISBN 978-1-77202-013-7). Available Online: http://ceqg-rcqe.ccme.ca/download/en/347

CCME. 2016. Guidance Manual for Environmental Site Characterization in Support of Environmental and Human Health Risk Assessment: Volume 1 - Guidance Manual (PN 1551 ISBN 978-1-77202-026-7 PDF), Volume 2 – Checklists (PN 1553 ISBN 978-1-77202-028-1), Volume 3 – Suggested Operating Procedures (PN 1553 ISBN 978-1-77202-030-4) and Volume 4 – Analytical Methods (PN 1557 ISBN 978-1-77202-032-8). Available Online: https://www.ccme.ca/en/resources/contaminated_site_management/assessment.html

Environment and Climate Change Canada. 2017. Solid Waste Management for Northern and Remote Communities, Planning and Technical Guidance Document. (March 2017). Available Online: http://publications.gc.ca/collections/collection_2017/eccc/En14-263-2016-eng.pdf

Federal Contaminated Sites Action Plan (FCSAP). 2012. Ecological Risk Assessment Guidance (ISBN 978-1-100-22282-0 & Cat no. En14-19/1-2013E) (March 2012). Available Online: http://publications.gc.ca/collections/collection_2014/ec/En14-19-1-2013-eng.pdf.

FCSAP. 2020. Ecological Risk Assessment Guidance – Module 5: Defining Background Conditions and Using Background Concentrations. Version 1.0, March 2020.

Federation of Canadian Municipalities (FCM). 2011. First Nation – Municipal Community Infrastructure Partnership Program, Service Agreement Toolkit, Second Edition. (September 2011). Available Online: https://fcm.ca/sites/default/files/documents/resources/tool/solid-waste-management-toolkit-cipp.pdf

Federation of Canadian Municipalities (FCM). 2017. First Nation – Municipal Community Infrastructure Partnership Project, Solid Waste Management Toolkit. (October 2017). Available Online: https://fcm.ca/sites/default/files/documents/resources/tool/solid-waste-management-toolkit-cipp.pdf

Government of Alberta. 2010. Standards for Landfills in Alberta (ISBN 978-0-7785-8826-9 or 978-0-7785-8825-2) (February 2010). Available Online: http://aep.alberta.ca/waste/waste-facilities/documents/StandardsLandfillsAlberta-Feb2010.pdf

Government of Manitoba Department of Sustainable Development. 2016. Standards for Landfills in Manitoba Available Online: https://www.gov.mb.ca/sd/envprograms/swm/pdf/standards_for_landfills.pdf

Government of Ontario. 2012. Landfill Standards: A Guideline on the Regulatory and Approval Requirements for New or Expanding Landfilling Sites (Latest Revision January 2012). Available Online: https://www.ontario.ca/page/landfill-standards-guideline-regulatory-and-approval-requirements-newexpanding-land

Government of Prince Edward Island. 2014. Environmental Protection Act Waste Resource Management Regulations (Latest Revision August 30, 2014). Available Online: https://www.princeedwardisland.ca/sites/default/files/legislation/E%2609-15-Environmental%20Protection%20Act%20Waste%20Resource%20Management%20Regulations.pdf

Government of Quebec. 2018. Environment Quality Act Regulation Respecting the Landfilling and Incineration of Residual Materials (Latest Revision September 12, 2018). Available Online: http://legisquebec.gouv.qc.ca/en/pdf/cr/Q-2,%20R.%2019.pdf

Government of the Northwest Territories Department of Municipal and Community Affairs. 2003. Guidelines for the Planning, Design, Operations and Maintenance of Modified Solid Waste Sites in the Northwest Territories (April 21, 2003) Available Online: https://www.enr.gov.nt.ca/sites/enr/files/guidelines/solidwaste_guidelines.pdf

Government of Yukon, Yukon Environment. 2014. Closure Requirements for Solid Waste Disposal Facilities (May 2014). Available Online: http://www.env.gov.yk.ca/air-water-waste/documents/SOLW7FacilityClosureRequirements2014.pdf

Government of Yukon, Yukon Environment. 2014. Environment Act Solid Waste Regulations, (September 30, 2014) Available Online: http://www.gov.yk.ca/legislation/regs/oic2000_011.pdf

Health Canada. 2010. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0 (Revised 2012) (ISBN 975-1-100-17671-0 & Cat no. H128-1/11-632E). Available by Request at: https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/contaminated-sites/federal-contaminated-site-risk-assessment-canada-part-guidance-human-health-preliminary-quantitative-risk-assessment-pqra-version-2-0.html

Ministry of Forests and Range Forest Analysis and Inventory Branch. 2007. Vegetation Resources Inventory Ground Sampling Procedures, Version 4.7 (July 10, 2007). Available Online: https://www.for.gov.bc.ca/hfd/library/documents/bib46612_2007.pdf

Newfoundland Labrador Department of Environment and Conservation Pollution Prevention Division. 2009. Guidelines for the Closure of Non-Containment Municipal Solid Waste Landfill Sites (GD-PPD-062) (December 2009). Available Online: https://www.mae.gov.nl.ca/env_protection/waste/closureguidance.pdf

Nova Scotia Environment and Labour. 1997. Municipal Solid Waste Landfill Guidelines, (Latest Revision November 10, 2004). Available Online: https://novascotia.ca/nse/dept/docs.policy/Guidelines-Municipal.Solid.Waste.Landfill.pdf

Saskatchewan Environment and Resource Management. 1998. Draft Guideline for the Closure and Reclamation of Municipal Waste Disposal Grounds (October 1998). Available Online: http://www.saskh2o.ca/PDF/EPB178.pdf

Solid Waste Management for Northern and Remote Communities. 2017. Planning and Technical Guidance Document (ISBN 978-0-660-06691-2) (March 2017) Available Online: http://publications.gc.ca/collections/collection_2017/eccc/En14-263-2016-eng.pdf

Appendix A

Example Terms of Reference for Project Working Group

[logo]

____________*Band/First Nation/Tribal Council*

Project Working Group Terms of Reference

(*date*) _________, 20__

Purpose

The (name)_____________'s project working group is responsible for advising Chief and Council on the planning, implementation, operation, and maintenance of solid waste management solutions that are economically, environmentally, and technically sound, and that find favor and acceptance with the community at (location)_________________.

Objectives

In response to the community support for improvements to current solid waste management and an alternative solid waste management system, the primary objectives of the project working group at this time are to oversee the design and implementation of policies and practices to:

1) Set up a reliable means of transportation of solid waste and recyclables to approved solid waste management facilities.
2) Work towards overall waste reduction through greater education in the community.
3) Initiate a sustainable recycling and composting program.
4) Execute other relevant waste management projects as the need arises.

Optional paragraph [The solid waste management implementation work plan is hereby approved by Chief and Council, and outlines the tasks and schedule for achieving these objectives.]

Structure of the Project Working Group

The project working group membership will be comprised of individuals interested in solid waste management and will primarily include representatives from:

1) Relevant departments (e.g., public works, projects, finance, and health)
2) Chief and Council
3) Community Members (e.g., elder, youth, and recycling/composting champions)
4) Other partners in an advisory non-voting role (e.g., professional consultant)

Project Working Group Members

1) Chair
2) Vice-Chair
3) Administrator
4) Public works representative
5) Projects representative
6) Finance representative
7) Health representative
8) Other department representative (e.g., education)
9) Community representative (elder)
10) Community representative (youth)
11) Community representative (recycling/composting champion)

12) Partners in advisory non-voting role (e.g., professional consultant)

Project Working Group Membership

Members will be approved by Chief and Council and must report any conflict of interest prior to decision-making.

Project Working Group's Responsibility to Chief and Council

Due to the fact that Chief and Council must approve all new members and that the Administrator or that a Councillor chair's the project working group meetings, it is not necessary to seek Council's approval on each task. Approval requirements are as follows:

1) Monthly reports must be submitted to Chief and Council on the progress of the project, unless a project is in the operation and maintenance phase, in which case only deviations from the norm need be reported.
2) All land-use designations must be submitted to Chief and Council for approval.
3) Any large funding application must include a letter of support from the Administrator or one of the Councillors, or a Band Council Resolution, depending on the nature and amount of the funding and the funder's own requirements.

Chair and Vice-Chair

A fundamental requirement of the Chair role is an open-minded and fair approach to meeting management and to providing input and advice with respect to the overall purpose of the project working group.

The Chair should either be a member of Council or the Administrator.

The Vice-Chair is responsible for coordination of meetings, taking of minutes, and contacting and keeping informed relevant officials and consultants.

Tasks of the Project Working Group

1) Attend meetings as required.
2) Review all documents, agendas, and minutes presented to make informed decisions.
3) Provide input, feedback, and recommendations, including identifying potential opportunities and strategies for consideration.
4) Operate in a consensus mode, allowing members to discuss their respective views and come to a shared conclusion on decisions.
5) Maintain two-way communication as much as possible with the community during all phases of a project.

Meetings

1) A meeting schedule, location, draft meeting agenda, and minutes of the previous meeting shall be prepared and forwarded to project working group members prior to the scheduled meetings by the Vice-Chair.
2) Any member of the project working group may propose items for the agenda.
3) Meetings shall be held as per the solid waste management implementation work plan and as needed.

Project Working Group Decision Making

If a decision cannot be reached through consensus, a vote will take place. In order for a vote to be counted, a quorum of at least half of the working group must be present. If there is not a clear majority, the Chair will break the tie. Once a conclusion has been reached, the project working group as individuals must abide by the group's decision.

Appendix B

Example Conceptual Site Models and Environmental Site Assessment Design

The conceptual site model (CSM) is a three-dimensional picture of the small domestic waste disposal sites (SDWDS) conditions illustrating contaminant distribution, release mechanisms, transport mechanisms, exposure pathways, and potential human and ecological receptors. The CSM will represent the qualified professionals understanding of the physical, chemical and biological conditions at a site. The CSM is an iterative tool that should be developed and refined as information is obtained during review of the SDWDS history and continues throughout the environmental site assessment (ESA) and closure design. Development and refinement of the CSM will help identify potential investigative data gaps in the characterization process and will ultimately support the final closure design at the site.

As discussed in Section 4.0, the modified ESA approach taken for SDWDS acknowledges that the footprint of these sites contains waste material that collectively may be considered “contaminated”. However, following placement of an engineered permeable cover over the waste material; direct contact with the waste material will be eliminated for both human and ecological receptors. The exposure pathways identified in CSMs for these SDWDS therefore focus on those pathways which will remain operable following closure. The three exposure pathways consistently identified at these sites were:

1. waste to leachate to groundwater to surface water bodies.
2. waste to soil vapour to outdoor air
3. particulate/aqueous transport to downslope soil

Other potentially operable pathways at select sites have included:

1. waste to leachate to groundwater to drinking water wells
2. waste to leachate to daylighting groundwater (as seeps)

The primary contaminant transport pathway at waste disposal sites is the generation of leachate and its migration with groundwater. With the unique hydrogeological setting of each site and variation in potential receptors, the focus of the CSMs for SDWDS has typically been on the leachate to groundwater migration pathway. A selection of the CSMs and study designs for three SDWDS are provided below.

Example 1: Skeetchestn, BC

Figure C-20: Skeetchestn General Setting - Outline of the SDWDS is red; largest outlined area is the general conceptual model area; irrigated field is also outlined

Setting

The Site is located 1,200 m south of Skeetchestn, a small (< 500 residents) First Nation community approximately 45 km northwest of Kamloops, BC. At the time of closure, the Site had been in operation for more than 30 years and occupied an approximate footprint of 0.8 hectares (ha). Waste was managed by the Nation through routine light compaction and cover using gravel and sand excavated from an adjacent hill and segregation of large appliances, vehicle parts and other metals. The regular capping of waste resulted in an estimated waste/cover soil volume of approximately 24,000 m^3, of which 60% was estimated to be waste.

The Site is surrounded to the north, east and west by undeveloped shrub and forestland. An agricultural pasture to the south is used for cattle grazing. Deadman River is the nearest year-round surface water body which supports freshwater aquatic life, located approximately 600 m to the west. The nearest residences to the Site are located approximately 550 m to the northwest and southwest, on the west side of Deadman Vidette Road. Drinking water for residences of Skeetchestn is obtained through two groundwater supply wells located approximately 1,600 m northwest, upgradient, of the Site. However, private domestic supply wells exist at the two residences closest to the Site.

The Skeetchestn First Nation had no plans to develop or designate a specific use to the Site or adjacent lands in the future and requested it be reintegrated back into the natural surroundings following closure in-place using a permeable engineered cover and locally sourced rock/soil.

Conceptual Site Model and Environmental Site Assessment Design

Five contaminant exposure pathways were identified for the Site as being potentially operable following closure:

1. waste to leachate to groundwater to Deadman River
2. waste to leachate to groundwater to domestic wells on Deadman Vidette Road
3. waste to leachate to groundwater used for irrigation or livestock watering
4. waste to soil vapour to outdoor air
5. particulate/aqueous transport to downslope soil outside the proposed cover footprint

Groundwater wells (11 – 17 m below ground surface [m bgs]) had been installed at the site by a previous consultant. Based on our experience in the region, sampling of groundwater from beneath the Site was determined unlikely to provide any information on the potential for groundwater contamination from the waste material. This conclusion was based on the low rate of precipitation at the Site and a review of regional geology that indicated groundwater at the site is expected to be deep (>30 m bgs) and the travel time from surface to groundwater sufficiently long that contaminants generated from the waste material could not have reached the groundwater. In semi-arid climates in which the depth to groundwater is significant and potentially within the underlying bedrock, obtaining site-specific groundwater samples is difficult and often unsuccessful. Given these limitations in obtaining groundwater samples at the Site, Golder completed a hydrogeological assessment, including contaminant transport modelling, to evaluate the fate of leachate originating from waste material at the Site.

To assess the potential presence of contaminants in soil vapour, four soil vapour probes were installed in the footprint of the Site within the waste material. Probes were screened with a Landtec GEM™ 2000 for indicators of landfill gas (i.e., methane and carbon dioxide) and a photoionization detector for indicators of volatile contaminants (e.g., petroleum hydrocarbons). The three probes with the highest measured landfill gas and/or volatile contaminants during the field screening were selected for sampling.

Figure C-21: Sample Locations – Skeetchestn, BC

To assess the potential migration of contaminants via erosion or surficial run-off, surficial soil samples were collected in areas which migrating contaminants were most likely to have been deposited (i.e., areas downslope of the main disposal footprint). A select number of surficial soil samples were also collected from within the footprint of the site to provide potential information on "source area" contaminants, in the event downslope soils were found to contain exceedances.

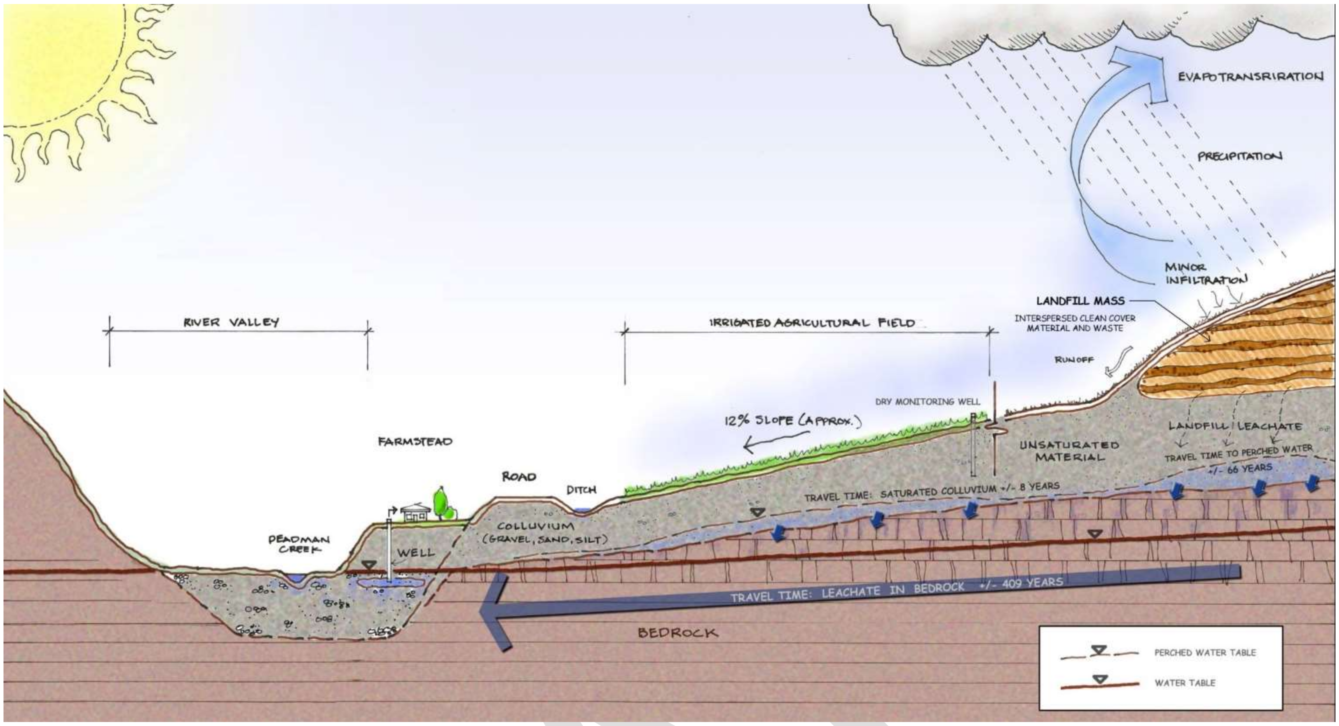

Figure C-22: Conceptual Site Model – Skeetchestn, BC
Note: Contaminants in media other than groundwater (i.e., soil and soil vapour) although considered and assessed during the ESA, were not included for illustrative purposes in the CSM.

As illustrated in Figure C-3, as precipitation percolates through the waste material, it is expected to pick up some contamination which is carried vertically downwards to the underlying perched water table and bedrock interface. Once this leachate reaches the bedrock it is expected to continue to move both vertically through the bedrock to the regional aquifer and horizontally to the west and south. The hydrogeological assessment used stochastic methods to calculate leachate travel times and found leachate originating from the Site would take over 500 years to reach the Deadman River or domestic drinking water wells. The evaluation of potential leachate impacts was assessed using chloride ion as a tracer. Chloride ions are conservative natural tracers, which means they do not degrade in the environment and tend to remain in solution, once dissolved providing a very conservative approach to modelling other potential contaminants, which undergo natural attenuation during travel. Using an improbably high estimate of chloride concentration in leachate, the resulting concentrations reaching the downgradient drinking water wells and the Deadman River were predicted to be indistinguishable from background concentrations. An evaluation of groundwater usage for irrigation and livestock watering in the agricultural field also did not predict contaminants at concentrations exceeding the applicable provincial standards or federal guidelines.

No parameters in soil or soil vapour exceeded the CCME guidelines and/or provincial CSR standards at the Site.

Therefore, the results of the ESA ultimately supported the placement of a permeable engineered cover over the footprint waste disposal area in order to bring about closure to the Site.

Example 2: Metlakatla, BC

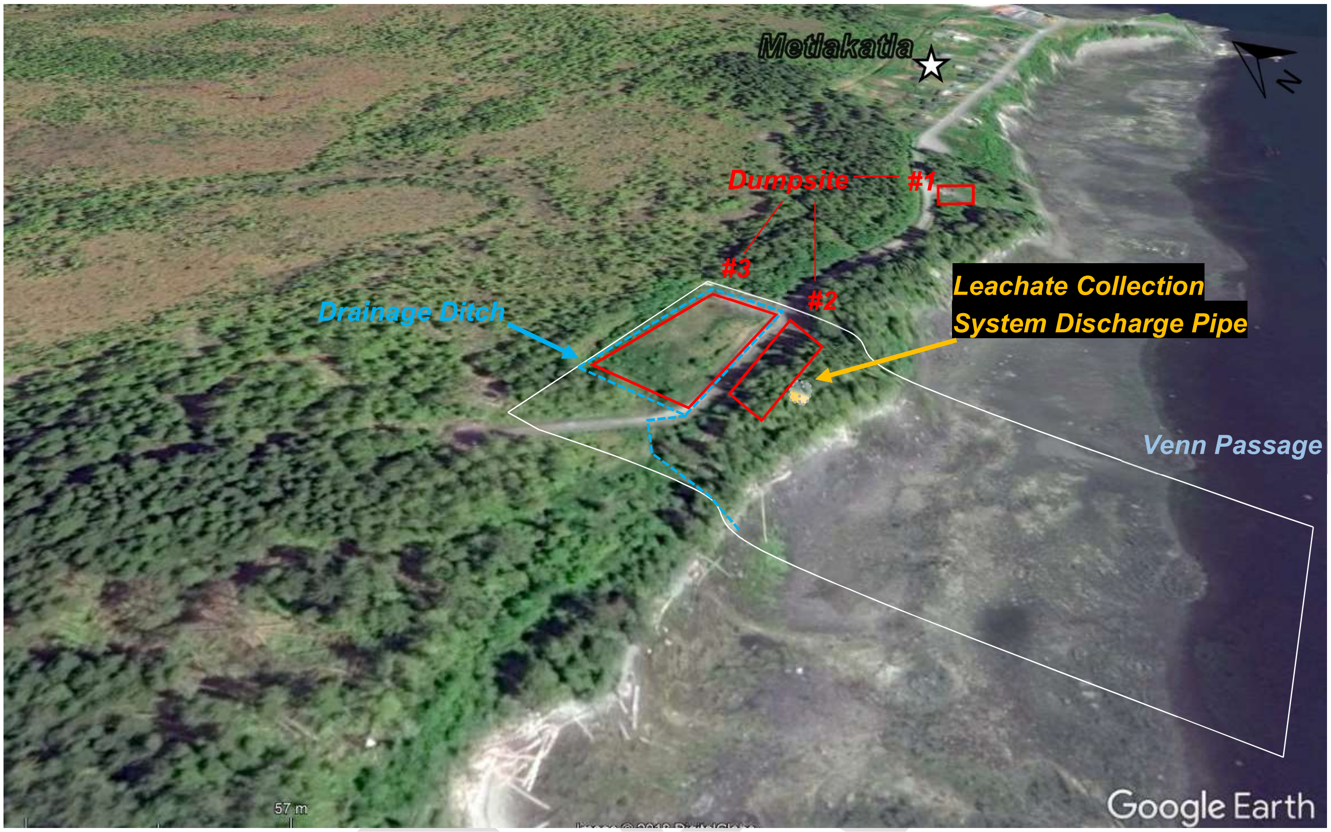

Figure C-23: Metlakatla General Setting - Outline of SDWDSs in red; largest outlined area is the general conceptual model area.

Setting

The three sites are located 600 – 800 m west of Metlakatla, a small (< 100 residents) First Nation community approximately 8 km northwest of Prince Rupert. At the time of the closure, the sites had been operational 20 – 35 years and occupied approximate footprints of 0.21 (Dumpsite #1), 0.12 (Dumpsite #2) and 0.37 (Dumpsite #3) hectares. Waste was managed by the community through a combination of routine burning and light compaction & cover using sand and gravel. The sites were estimated to contain 2,100 m^3 (Dumpsite #1), 1,620 m^3 (Dumpsite #2) and 15,000 m^3 (Dumpsite #3) of waste/soil.

The sites are surrounded by undeveloped forestland. Venn Passage (marine environment) is located to the south of the sites. Dumpsite #3 is surrounded by drainage ditches which connect to a culvert southwest of the site, allowing surface water to flow through the forest and discharge in the foreshore. Leachate from Dumpsite #2 and #3 is suspected to be partially drained by a collection system (design/constriction details were not available) that discharges from a PVC pipe in the forested embankment south of Dumpsite #2. The nearest residence is located approximately 120 m to the east of Dumpsite #2. Drinking water for Metlakatla is obtained from a supply well located 500 m northeast of the community

The Metlakatla First Nation requested that Dumpsite #1 be redeveloped into recreation/picnic area. Waste from Dumpsite #1 was excavated and consolidated with waste in Dumpsite #3. Dumpsite #2 and #3 were closed in-place using permeable engineered covers of locally sourced rock/soil. Dumpsite #3 was selected to be the site of the new public works yard and Dumpsite #2 was requested to be allowed to reintegrate back into the natural surroundings. The remaining discussion on the CSM and environmental study design will focus on Dumpsites #2 & #3 (the Sites).

Conceptual Site Model and Environmental Site Assessment Design

The Sites had, prior to Golders involvement, been subject to a serious of phased ESAs (Phase II ESA, Detailed Site Investigation and Supplemental Site Investigation), following the typical CCME paradigm, in which delineation of contamination is attempted through iterative field programs. Soil contamination was effectively delineated to within the footprint of each of the Sites through a series of drilling and surficial soil sampling programs during these investigations.

Based on the results of the historical assessments, four contaminant exposure pathways were identified for Dumpsite #2 & #3 as being potentially operable following closure:

1. waste to leachate to groundwater to porewater in the marine foreshore
2. waste to leachate to surface water to the marine foreshore
3. waste to leachate to surface water used by terrestrial wildlife
4. waste to soil vapour to outdoor air

The Golder site investigation and subsequent results interpretation, which included the historical data, focused on identifying linkages between the dumpsite footprints and these potential exposure pathways. To achieve this, groundwater, surface water, leachate and co-located porewater/sediment samples were collected between the Sites and the marine foreshore. This quantitative assessment was paired with a qualitative aquatic habitat assessment of the drainage ditches surrounding the site, surface water flow path through the forest and the downgradient marine foreshore by an experienced biologist.

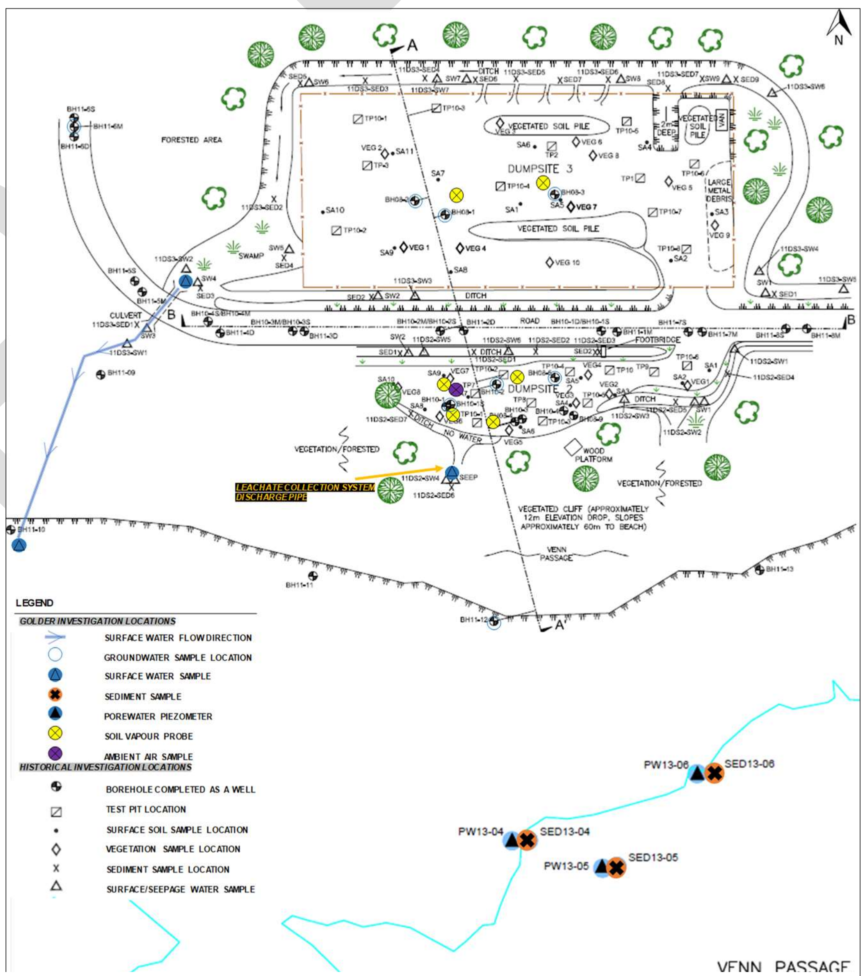

Figure C-24: Sample Locations Dumpsite #2 & #3 – Metlakatla, BC

To assess the potential presence of contaminants in soil vapour, probes were installed in the footprint of the Sites within the waste material. Saturated soils within Dumpsite #3 precluded the collection of soil vapour samples. Three probes were installed within Dumpsite #2 during August

2013. Probes were screened with a Landtec GEM™ 2000 for indicators of landfill gas (i.e., methane and carbon dioxide) and a photoionization detector for indicators of volatile contaminants (e.g., petroleum hydrocarbons). The two probes with the highest measured landfill gas and/or volatile contaminants during the field screening were selected for sampling and detailed analysis. A follow-up soil vapour investigation, including installation of two soil vapour probes as well as ambient air sampling, was completed at Dumpsite #2 during October 2013. The second sampling event was necessary to aid in the interpretation of an anomalous[7] trichlorofluoromethane result during the initial soil vapour investigation.

As illustrated in Figure C-6, topography of the area surrounding the dumpsites, which slopes towards Venn Passage, made the marine foreshore the primary receiving environment for potential contaminants in leachate being transported by surface water and/or groundwater[8]. The evaluation of potential leachate impacts included both quantitative (groundwater/surface water and porewater sampling) and qualitative (aquatic habitat assessment) components. Previous assessments had considered freshwater aquatic receptors at the Sites based on the surface water drainage channels. The aquatic habitat assessment of these constructed watercourses and associated drainage channels leading to the foreshore concluded they were of limited use as freshwater aquatic habitat and unlikely to be utilized by fish; therefore, freshwater aquatic receptors were not considered further in the drainage ditches. Surface water (including samples from the leachate drainage system outfall pipe), groundwater and porewater samples exceeded relevant guidelines for selected metals, anions and polycyclic aromatic hydrocarbons (PAHs) in the Golder (2013) and historical (2008 and 2010) investigations. Parameters, for which no observable linkage existed between the Sites and the location of downgradient exceedance, were considered unrelated to the dumpsites and not retained for further assessment. Sulphide was the only retained potential contaminant of concern for the quantitative risk assessment following this evaluation. Risks presented by sulphide to marine receptors were concluded to be acceptable after consideration of (a) the predominance of different sulphide forms (i.e., H_2S and HS^-) under different water condition's (b) toxicological impact of these forms and their relevance to applicable guidelines (c) predicted fate of sulphide discharging to a marine intertidal zone and (d) the overestimation inherent to the methodology employed to calculate hazard quotients. This conclusion was supported by the aquatic habitat assessment which found the marine shoreline habitat productive and free of any visually observable evidence of adverse effects.

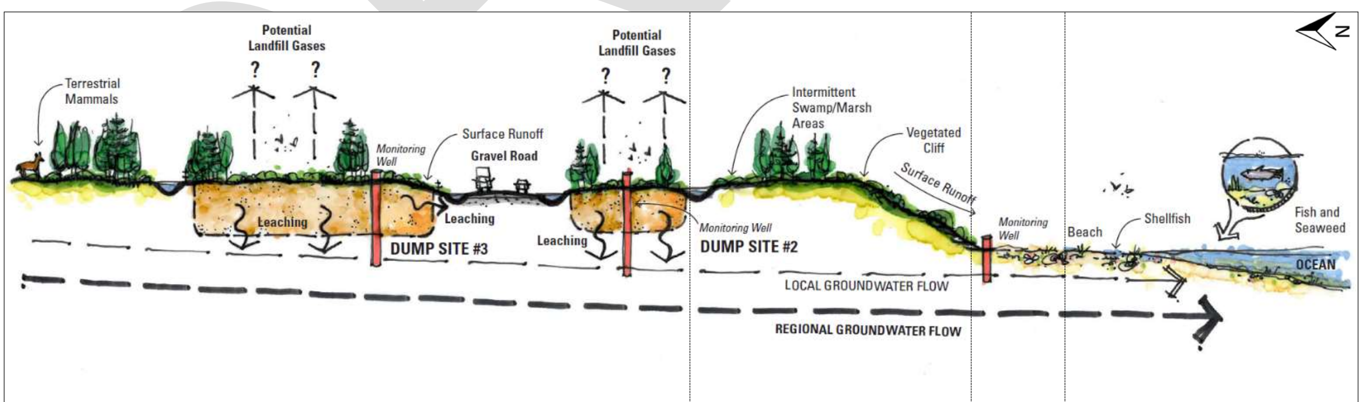

Figure C-25: Conceptual Site Model – Metlakatla, BC

N*ote: Leachate collection system design was not known and therefore not illustrated within the CSM*.

---

[7] Reported concentration in one sample had no upper limit bounding (i.e., > X μg/m³)

[8] Consistent with the groundwater gradient observed during historical groundwater monitoring events.

To evaluate surface water potentially used by terrestrial wildlife, CCME water quality guidelines protective of livestock were employed for screening. No exceedances of these criteria were identified in surface water, including in the water discharging from the leachate drainage system outfall pipe. No parameters in soil vapour or ambient air exceeded the provincial CSR standards at the Sites.

Therefore, the results of the ESA and risk assessment ultimately supported the placement of a permeable engineered cover over the waste disposal area footprints, in order to bring about closure and re-use of the former waste disposal Sites.

DRAFT

GOLDER

golder.com